STRATEGIC
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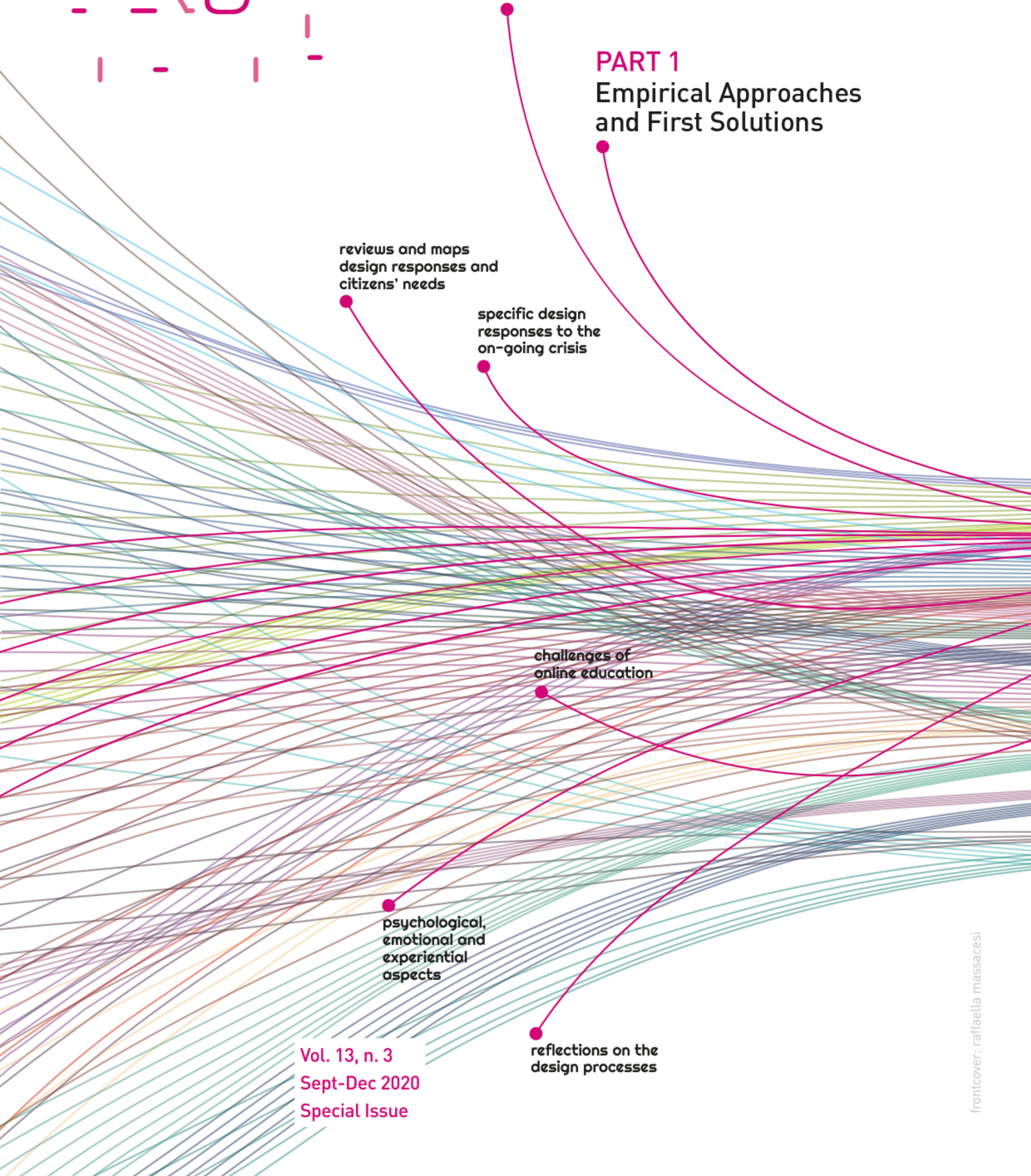
Design contributions for the COVID-19 global emergency

PART 1
Empirical Approaches and First Solutions



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STRATEGIC DESIGN RESEARCH JOURNAL

SPECIAL ISSUE EDITORIAL

Design Contributions for the COVID-19 Global Emergency (Part 1): Empirical Approaches and First Solutions

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This is a landmark publication for the field of design. It was catalysed by unprecedented circumstances, as designers around the world had to rapidly deploy their competencies in strategic problem-solving to help humanity in the fight against an invisible enemy during a global pandemic. In alliance with other disciplines, from medicine to mechanical engineering, from computing to anthropology, designers everywhere have addressed the challenges and produced remarkable results through a diversity of initiatives. This Special Issue presents a peer-reviewed sample of these initiatives.

The coronavirus pandemic can be considered as the biggest 'problem' faced by an entire generation of designers. It has produced a great many unexpected changes and demands, many of which neither governments, companies nor communities were prepared to handle. Although designers were able to gather existing knowledge and reapply it, it became clear that our ability to learn from the past was limited, considering the complexities presented by COVID-19. Hence, a wholly deductive or inductive approach was neither viable nor relevant, as, in last hundred years, humanity has never been asked to face a pandemic of such scale and gravity. The result was a rapid, earnest application of abductive reasoning, typical of the creative process inherent in design activity. In a short period of time, designers contributed, and in many instances led, innovation processes associated with products, systems, services and experiences to mitigate the impacts of the coronavirus.

The promotion of this Special Issue has brought together a coalition of the main global design institutions, which is in itself a remarkable achievement: **LeNS (Learning Network on Sustainability)**, the **DESIS Network (Design for Social Innovation and Sustainability)**, the **Cumulus Association**, and the **World Design Organization (WDO)®.** As a result of this collaboration, the number of submissions and their global geographical distribution would match a large international conference, a clear indication of the level of engagement of the design community around the world. Indeed, this Special Issue received 115 submissions by researchers from 26 countries located on 5 continents.

The Special Issue's Part 1, which contains 31 papers, is dedicated to empirical contributions, with direct accounts of the hands-on activities of designers in different contexts and from a variety of perspectives. Part 2, which will be published in early 2021, will focus on the theory underpinning the practical experiences as well methodological reflections concerning the role of design during the pandemic.

In Part 1, most papers present the knowledge generated during the process of designing specialized health-related products and equipment (e.g. isolation units, field hospitals, robots, personal protective equipment (PPE), and so on), including approaches to frame the problem, capture requirements, create and evaluate alternatives, manufacture and distribute these products during the pandemic (e.g. co-design, design of distributed networks, product-service system design, open design). It also includes propositions to alleviate the psychological aftermath of the pandemic, as well as alternative strategies to foster resilience via social innovation within communities during this worldwide crisis.

REFLECTIONS ON THEMES FOUND ACROSS PAPERS

Many have compared the COVID-19 pandemic to the one that affected the world with the Spanish Flu from 1918 to 1920. The two phenomena have in common a large number of infections and the impact they have had on the lives and economies of all nations. However, the world in 1920 was very different from the one we live in today. Traditional industry was in the midst of its expansion phase, telecommunications had just begun to develop, the United Nations and the World Health Organization did not yet exist, the world was generally much less interconnected, and each nation faced the epidemic on their own with very different strategies and consequences. Design was a tool at the service of industrial expansion, still not fully identified and with its potential impact on society limited to the sphere of the product. The Spanish Flu was a disease that hit younger people more severely and spread among a society where life expectancy was much lower than it is today.

The average age of the population has exponentially grown and the whole of humanity is ageing at an even faster rate today; the disease we are facing today, COVID-19, causes deaths especially among the elderly. The virus has diffused in a globalized scenario, in which infinite networks of relationships, both physical and immaterial, branch out and overlap; the economy of the intangible interpenetrates and dominates that of the product; and the digital revolution crosses geographical and physical boundaries continuously, changing the behaviours and identities of human communities. We live in a complex world, which we cannot fully perceive and understand with our natural abilities, which makes us more and more interdependent with the artificial environment that we are building up.

Design has taken on strategic value in strengthening the human capacity to govern this complexity and directing development in a way that can be sustainable for future generations: it is no longer considered a purely technical or artistic and independent discipline, and it is recognized as a humanizer and harmonizer of knowledge and skills in the development of all innovative processes that have an impact on society. This Special Issue was launched with the intention to report on the variety of interpretations of this role, as manifested during the pandemic emergency. Each crisis tests a community's ability to react and reveals its adaptation skills.

Resilience is the term that has been most frequently used to define the combination of these two characteristics. Far from being a measurable and intrinsic property, as in the case of

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materials science, where the term is also often utilized, in human society resilience is the result of the transformation choices that a community makes, more or less consciously. *Conscious transformation* choices are the substance of design research and practice: what is represented in the selected papers can possibly help to highlight how design has contributed to the development of social resilience during the pandemic.

The topics contained in this Part 1 range across diverse fields of design research, as evidenced by the keywords chosen by the authors: some of the topics and keywords recur, indicating which approaches were more often applied. For example, the theme of sharing and cooperation can be associated with terms such as *Open Source, Open Innovation, Clustering* which recurred in 13 papers. The awareness of the complexity of the scenario and the need for an articulated and harmonious design approach on multiple levels is well summarized by the term *Multidisciplinarity*, which is explicitly used in the keywords of 5 articles. The interdependence of new digital technologies and the possibility of exploiting virtual networks for the definition of new strategies or the proposal of new tools is a theme that crosses almost all the papers, emerging in terms such as *Distributed Manufacturing, Maker* and *Fab Lab.*

THEMATIC CLUSTERS

The papers contained in the Special Issue's Part 1 can be categorized into five thematic clusters.

The first group of papers critically **reviews and maps design responses and citizens' needs** in relation to the COVID-19 emergency.

Two papers offer a comprehensive analysis of international cases of design responses. Rodgers et al. documented over 500 design interventions that have been created by individuals, networks, amateurs, professionals, and public and private organizations and institutions. Moura et al.'s analysis resulted in 113 mapped cases, whose key features are discussed and presented through a range of infographics. With a focus on digital solutions, Cordeiro et al. offer a comparative analysis of applications that contact trace people or inform them about the disease. Xia conducted an analysis of the relationship between distributed systems and resilience, focusing on three representative cases based in the Chinese province of Wuhan. As a result, distributed system design strategies suitable for China were identified. Prado et al. map initiatives of social innovation that have promoted positive social capital in Brazil. This resulted in the analysis of 15 cases, which were categorized according to their field, coverage area and target. Fonseca Braga et al. focus on informal settlements' communities in Brazil, analyse their challenges and cluster their needs in six major themes: sources of information, prevention, diagnosis and treatment, support and change.

The second cluster of papers is the largest, and includes contributions presenting and/or reflecting on **specific design responses to the ongoing crisis,** ranging from physical artefacts (e.g. PPE, field hospitals) to digital solutions (e.g. apps to monitor the pandemic).

Three papers focus on hospitals and hospital facilities. Ribeiro et al. illustrate the requirements in the design and construction of the field hospital in Lagoa Barra (Brazil) and reflect on the lessons learned, considering a wide range of aspects including, for example, the configuration of the environments, the definition of the circulation flows and the typology of beds. Manrique et al. present the design of a portable epidemiological isolation unit: a pneumatic structure which permits the treatment of infected patients in aseptic and well ventilated spaces and allows the sanitary authorities to expand its hospital capacity when needed, as well to set up field hospitals in isolated areas. Fossati et al. present a telepresence robot designed to facilitate communication between patients isolated in COVID-19 hospital ward and their relatives.

The design, prototyping and manufacturing of innovative personal protective equipment (PPE) and prevention measures are explored in a range of papers. Pagnan et al. present a 3D printed individual protection mask combining a PLA (polylactic acid) filter mesh with Tourmaline and a triple layer with cotton fabric. Santos et al. provide insights on the need to design beyond the sole provision of physical artefacts and the importance of thinking in terms of product-service systems (PSS), with a proposal for a distributed PSS for mask provision for the state of Ceará, Brazil. Segura-Duque et al. reflect on the experience of two MSMEs (micro, small and medium enterprises) that adapted quickly to meet the demand for personal protection products, analysing the cases with a strategic design lens. Two papers, in addition to presenting PPE designs, also reflect on the importance of establishing networks of actors involving academia and public and private organizations. Rebola et al. describe how the University of Cincinnati mobilized and joined forces with local hospitals and organizations to quickly design and prototype a range of PPE, as well as developing a plan for material sourcing, production line and distribution. Dos Santos et al. describe the experience of creating an interinstitutional network, formed by universities and other organizations, to transform an academic design laboratory into a space for the production of PPE using 3D printing and laser cutting techniques, which made it possible to meet the high emergency demand for PPE in the city of Rio de Janeiro.

Three papers also focus on the role of open design and the 'maker movement' in the development and production of PPE. Tsuda and Sakuragi present a do-it-yourself face shield developed in Japan, reflecting on the benefits and challenges of personal fabrication. Li et al. illustrate a UK-China initiative on how open design and distributed manufacturing can be effective in producing PPE when there is a shortage of supply. García and Cuartielles provide insights on how the Spanish 'Coronavirus Makers' (CVM) group developed and supplied ventilators and PPE to hospitals and people in need.

More in general on prevention measures, Piccoli et al. present a hand sanitizer dispenser for public transport and other locations in the urban environment.

Finally, in terms digital solutions, Motta et al. analyse the Brazilian Ministry of Healthcare's Interactive Voice Response (IVR) system and its effectiveness in informing citizens about the pandemic.

<u>The third group of papers</u> addresses the **challenges of online education,** with a particular focus on teaching design in higher education.

Spitz et al. present a selection of educational experiences, strategies and methods to remotely teach design. Bernardo and Duarte reflect on the use of various technologies to support teaching and learning, but also the identification of positive aspects and pain points influencing the overall experience of staff and students.

<u>The fourth cluster of articles</u> focuses on the **psychological, emotional and experiential aspects of people** dealing with the pandemic's implications and consequences.

De Paulo et al. address the topic of social isolation, in particular investigating the role of social media applications in affecting people's daily emotional experiences. Delgado and Sattele explore the construction of quarantine narratives related to the design of everyday public spaces and domestic artefacts in Mexico City and propose a set of values for Mexico City's New Normal to be adopted in urban and product design. Araya et al. analyse the implications of working from home, with a focus on the impact on well-being and behaviour. This provides insights into the relationship between the domestic built environment and certain elements that shape it, and the role they play in relation to the perception, emotional state and productivity of the users. Rocco et al. focus on how a positive environment plays an important role in the well-being of individuals, with effects on both physical and psychological levels. In particular the paper presents a range of graphic interventions for Hospital de Clínicas de Porto Alegre, Brazil. Finally, Conti et al. explore the psychological and physical therapeutic effects of knitting on people in isolation or self-quarantine.

Finally, the fifth group of papers provides **reflections on the design processes** adopted for the development of various design responses.

Three papers discuss the methods and tools that can be used by design teams in emergency situations like a pandemic. Mincolelli et al. present a methodological approach that integrates Human Centred Design (HCD) with Open Innovation (OI), conceived to enable design teams to quickly develop solutions during a pandemic. Methodological challenges are presented together with tools and methods developed to overcome those challenges. Cipolla explores the limitations that design teams face during a pandemic (e.g. lack of physical or face-to-face interactions with communities and citizens) with a particular focus on social innovation, service design and design for placemaking. As a result, and building upon a case study, the article puts forward a set of strategies to support design for social innovation processes. Freire et al. present a process for design services during the COVID-19 emergency, with a particular focus on the provision of essential benefits to homeless and other vulnerable people.

Two papers shed light on the role of design platforms on the design and dissemination of solutions. Argenton Freire and Ziggiatti Monteiro explore the role that design sharing platforms have on enhancing collaboration, continuous development and dissemination of design solutions tackling the COVID-19 emergency. Finally, Colombo and Ciuccarelli present the experience of conceiving, developing and implementing a specific design sharing platform, 'Design for Emergency', which started in Italy but soon became global, expanding to 11 countries on three continents.

DATA INTERPRETATION

The papers collected in this first Special Issue portray the complex scenario concerning empirical approaches and first solutions developed by designers and researchers to tackle the pandemic. The issue clearly reflects the collective effort performed by the design community.

By comparing the concepts discussed and the geographical distribution of studies, it is possible to illustrate **dimensions of the emergency in relation to regional priorities** (Figure 1). In particular, 6 studies deal with *Design for Social Innovation,* which is the most important research topic found across all papers. A large group of studies (18) explore the following topics: *Multidisciplinarity* (5), *Emotion, Psychology and Wellbeing* (5), *Human*

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Centred Design (4) and *Open Designs and Open Processes* (4). The remaining papers face issues related to *Distributed Manufacturing* (3), *Methodological Developments* (2), *Distributed Economies* (1) and *Innovation* (1). In terms of geographical dimension, more than two-thirds of studies are addressed to Brazil (11) and to Global scales (10). The remaining studies focus on Italy (2), Colombia (2), China (1), Mexico (1), USA (1), Spain (1) and Japan (1). Accordingly, the dimensions of the emergency oscillate between social and psychodynamic issues, with interesting projections toward innovation concepts at distributed scales; on the other hand, the applications of these dimensions document the need of researchers to act in those countries where the pandemic has generated significant disruptions in people's lifestyles (e.g. Brazil and Italy). Overall, the studies outline the strong regionalism of proposed interventions, which can be interpreted as the will of the community to operate at the regional level, where the impacts of experimentations are more visible and replicable.

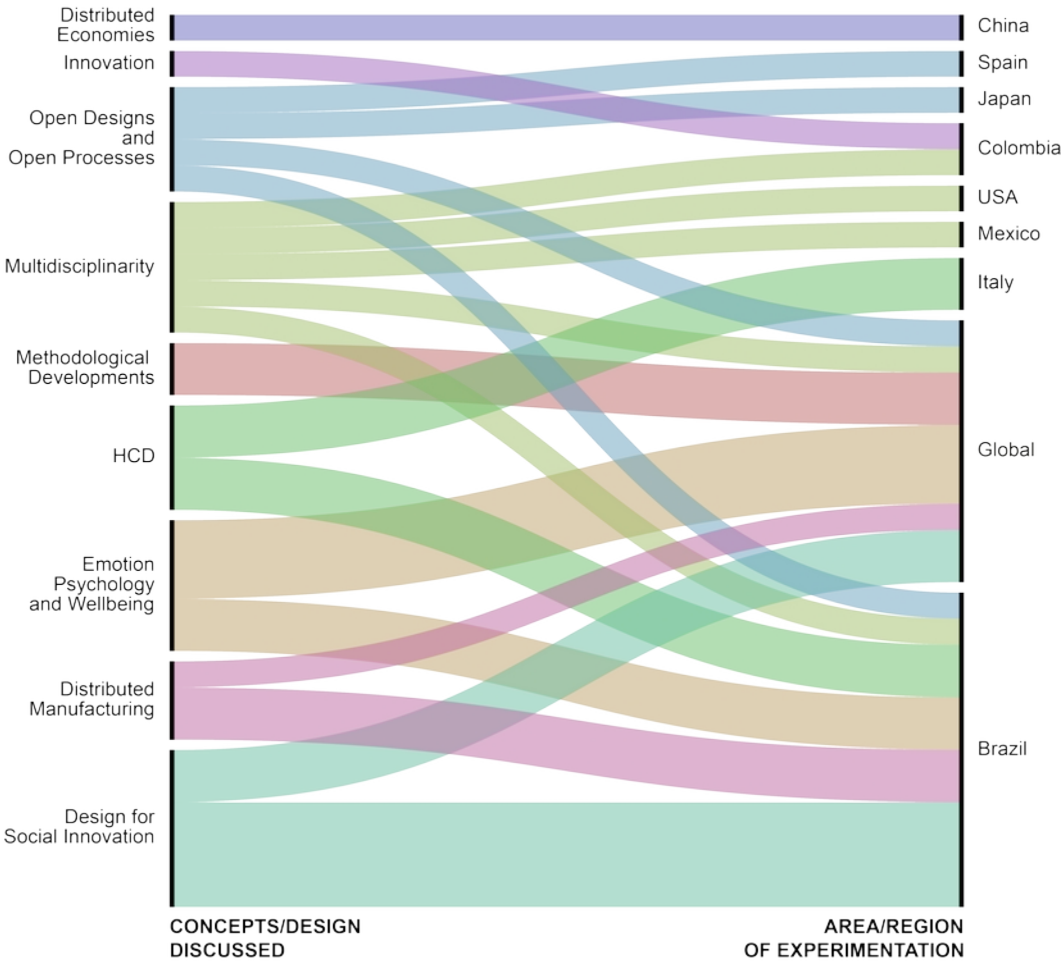

Figure 1: The dimensions of the emergency in relation to regional priorities.

Typologically examining the scales of intervention in the papers can be illustrated by linking the five clusters used to classify the papers with their domains of exploration (Figure 2). This analysis provides an overview on the scale of interventions in relation to the nature of the papers. In particular, it can be observed that the *Communities/Regions* scale covers the majority of the study presented in this Part 1 (19); only those that have worked on the *Challenges of online teaching* (2) have not considered this dimension. Therefore, clusters that have produced studies impacting on this scale are: *Specific design responses to the on-going crisis, Psychological, emotional and experiential aspects, Reflections on design processes,* and *Review and map of design responses and citizens' needs.* From the methodological point of view, this aspect seems very interesting because authors have directly and indirectly

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recognized that the medium scale is the most suitable dimension to operate effective interventions. Studies on the remaining dimensions – *Companies, Universities, Homes* and *Hospitals* – are important for the quality of design outcomes, but have a marginal relevance in terms of number of studies (altogether 10 studies). These patterns also reinforce the ones previously introduced about the regional priorities, confirming that *Design for Social Inclusion, Multidisciplinarity, Emotion, Psychology and Wellbeing* and *Open Designs and Open Processes* have a significant influence on the medium scale.

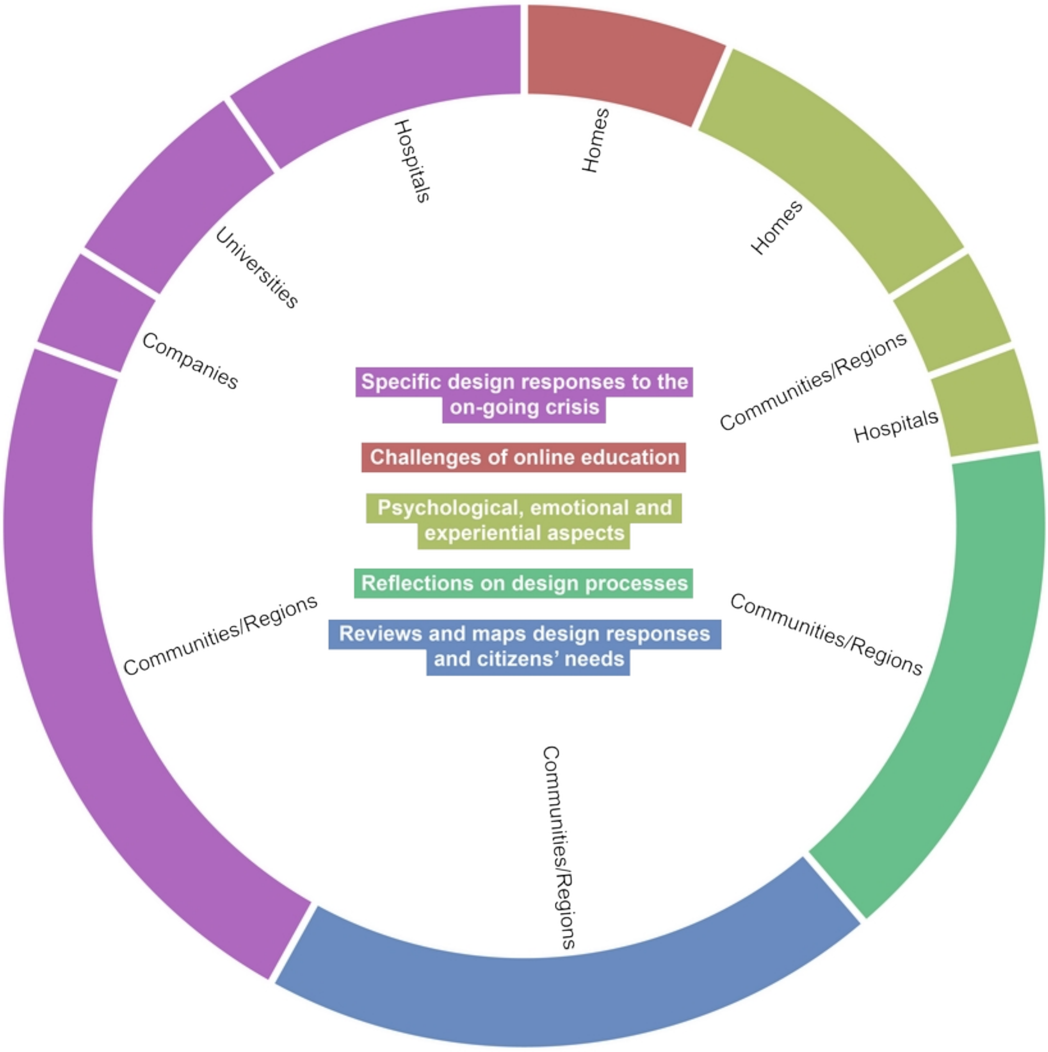

Figure 2: Typological examination of the scale of interventions.

Continuing with the investigation on intervention scales, interesting patterns concerning the **design-oriented research foci** can be identified (Figure 3). These data enrich the analysis with useful information about the design experiments carried out by authors represented in this Part 1. In general, it is possible to affirm that the nature of design outcomes follows the intervention scales. Therefore, the *Communities/Regions* dimension is the favoured testing ground for *Product Networks* (2), *Product Development* (2), *Design Platforms* (2) and *PSS* (1); on the level of processes and methodologies, this scale gathers *Maps of Design Responses* (3), *Product Analyses* (3), *Maps of Community Solutions* (2), *Methods and Tools* (2) and *Design Processes* (2). Moving toward the small intervention scales – *Companies, Universities, Homes* and *Hospitals* – it is possible to find *Specialized Products* (4+1), *Online Education* (2) *Product Networks* (1), *Environmental Design* (1), as well as a range of methodological insights (3).

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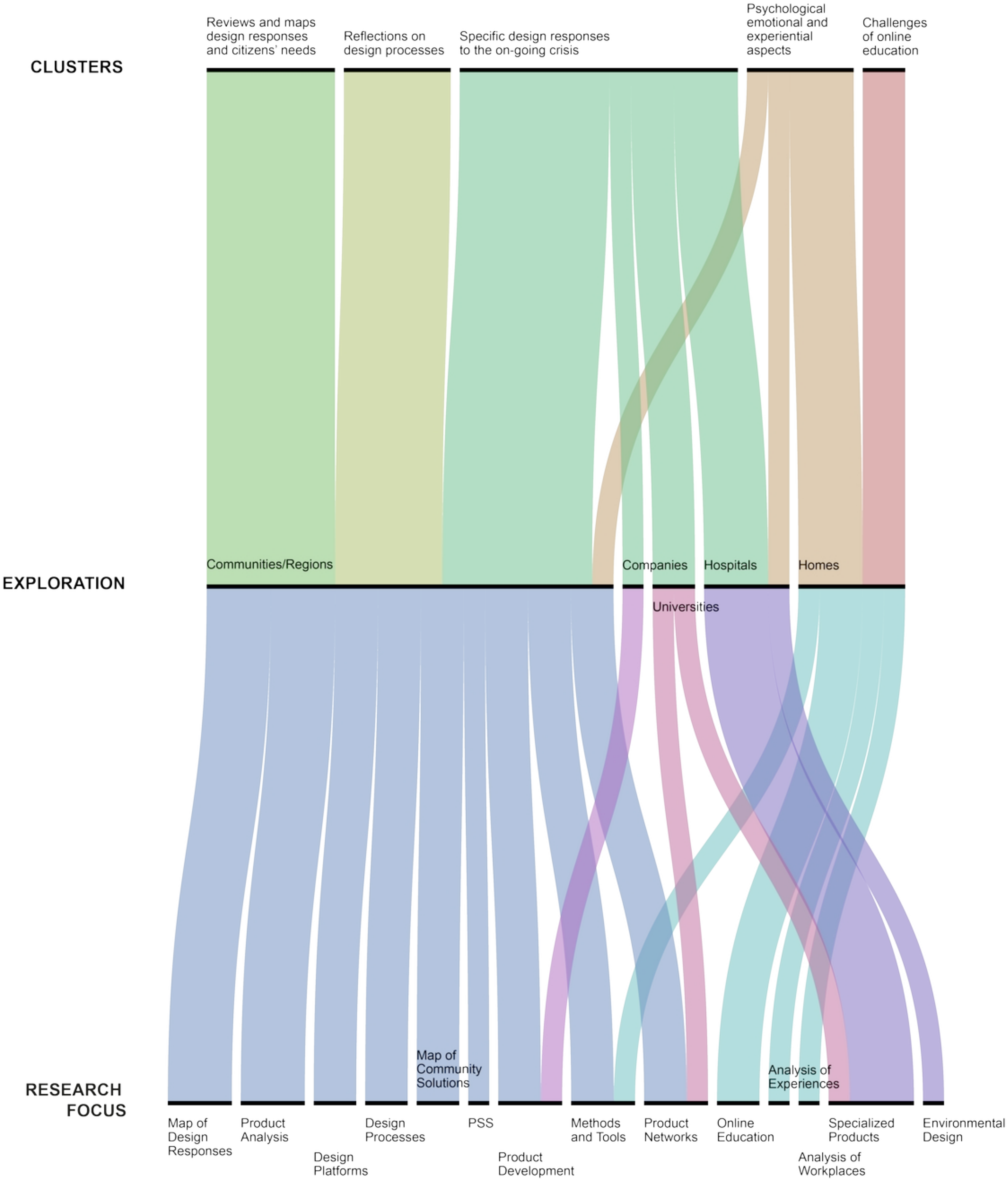

Figure 3: Correlation between the five Clusters (top), Domains of Exploration (middle) and specific Research Foci (bottom).

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The comparison between *Domains of Exploration, Clusters, Main Foci* and *Areas/Regions of Experimentations* provides a complete and holistic overview about the **explicit, implicit and hidden interrelations among papers composing the Special Issue's Part 1 and the emergency scenario of the COVID-19 pandemic.** The map (Figure 4) portraits all empirical approaches and first solutions developed in the last year to tackle the pandemic. As can be seen in the following diagram, there is not a direct and logical relationship between

Domains of Exploration, Main Foci and *Areas/Regions of Experimentations;* however, this apparently chaotic framework allows to enrich the strengths of the design discipline compared to both the scale of interventions and the geographical implications of the approaches used by researchers and designers involved in this 'collective effort'.

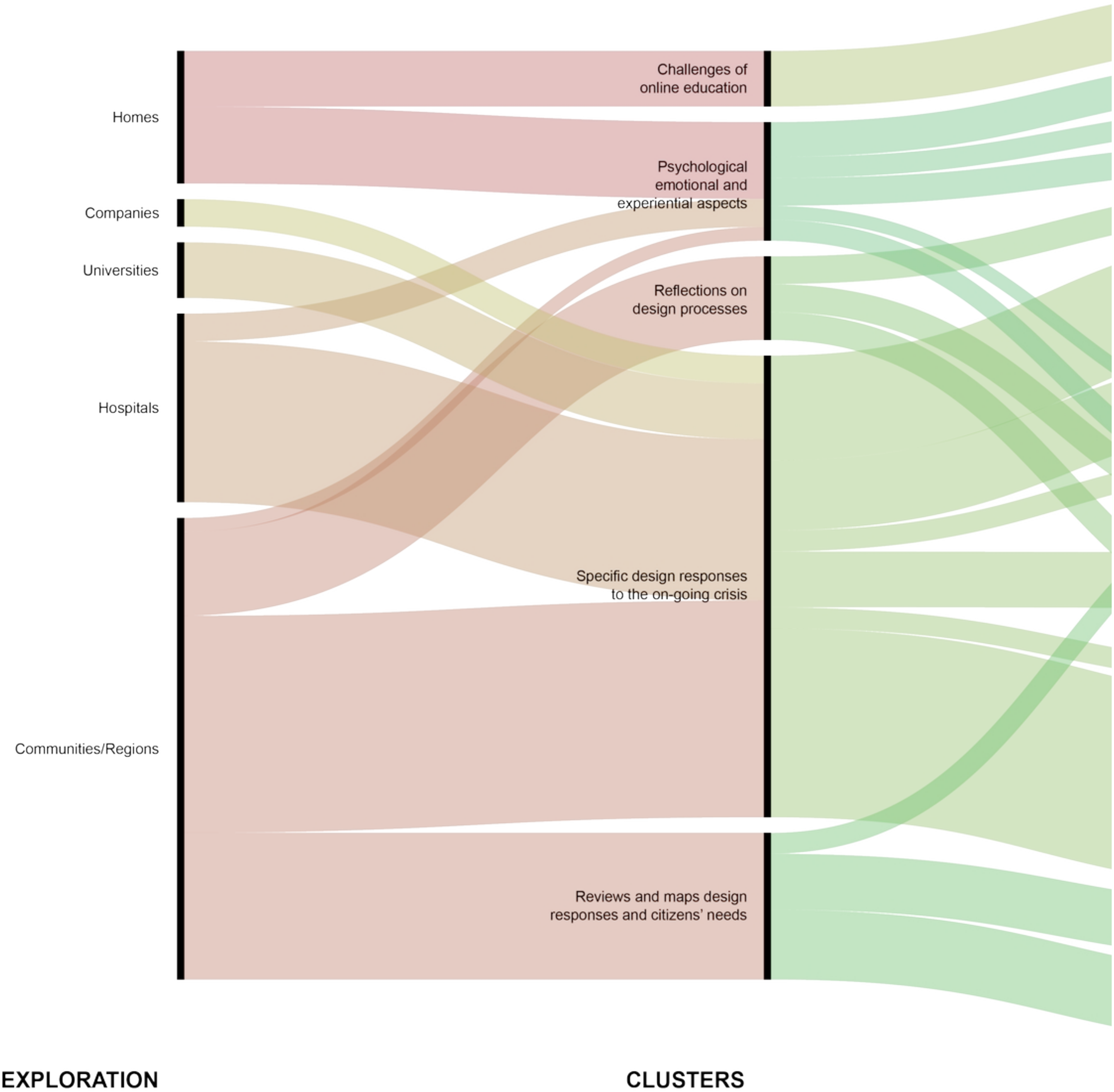

Figure 4: Map of research, design, thematic and geographical relationships composing Part 1.

This map is also useful for readers to apprehend the range of papers found in Part 1. In terms of intervention dimensions, readers will find a significant number of studies focused on *Communities/Regions,* followed by *Homes* and *Hospitals;* these papers will therefore present a comprehensive set of studies focused on the various domains of the discipline: from product design to service design, from design for social innovation to human-centred design,

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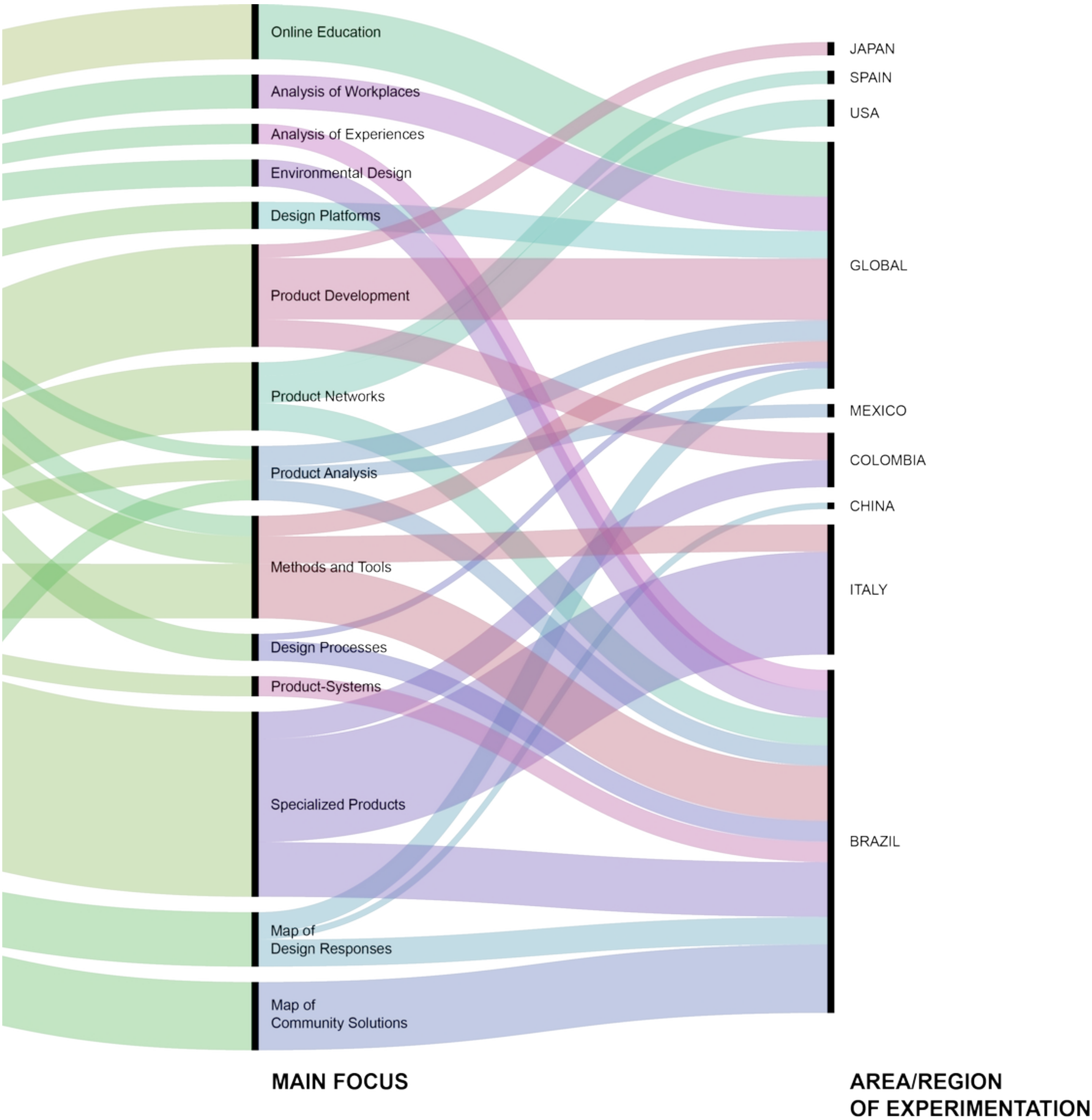
from the development of methodological tools to the development of complete sets of design-oriented analyses. Readers of this Special Issue can therefore navigate this map to find the various experimentations and understanding the specific areas of intervention considered by the design community as a first reaction to face the pandemic.



The next two maps (Figures 5 and 6) have been created with the aim to **simplify the interpretation and the comprehension of papers** contained in this Part 1 in relation to all key topics used for their classification – *Clusters, Concepts Discussed, Main Focus* and *Area/Region of Experimentation* – as well as to give readers the possibility to find and readily

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compare the papers using common interpretative lenses that could simplify the analysis of data and the understanding of field experiences.

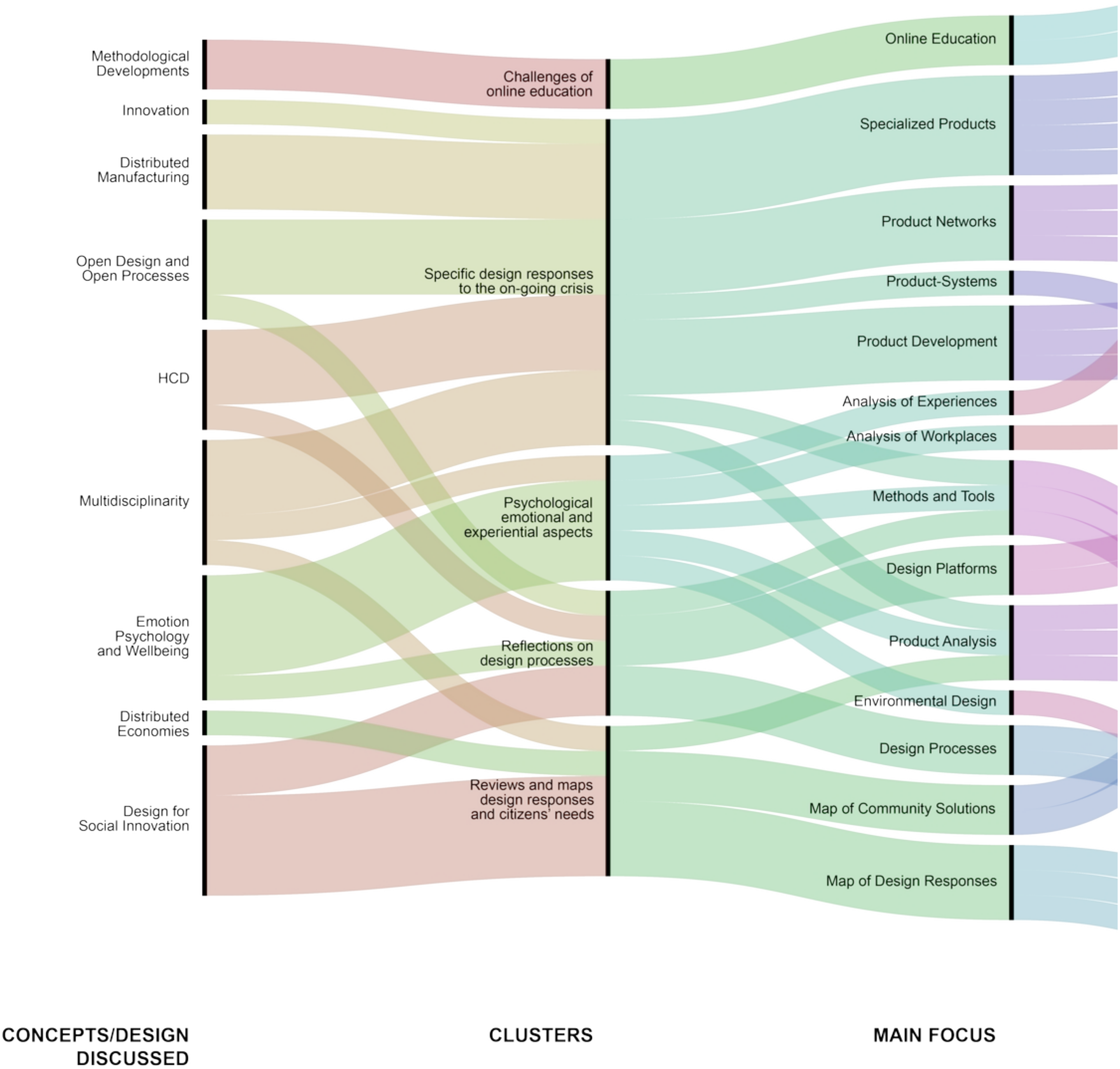

Figure 5: Map of links between papers, Concepts, Clusters and Main Foci.

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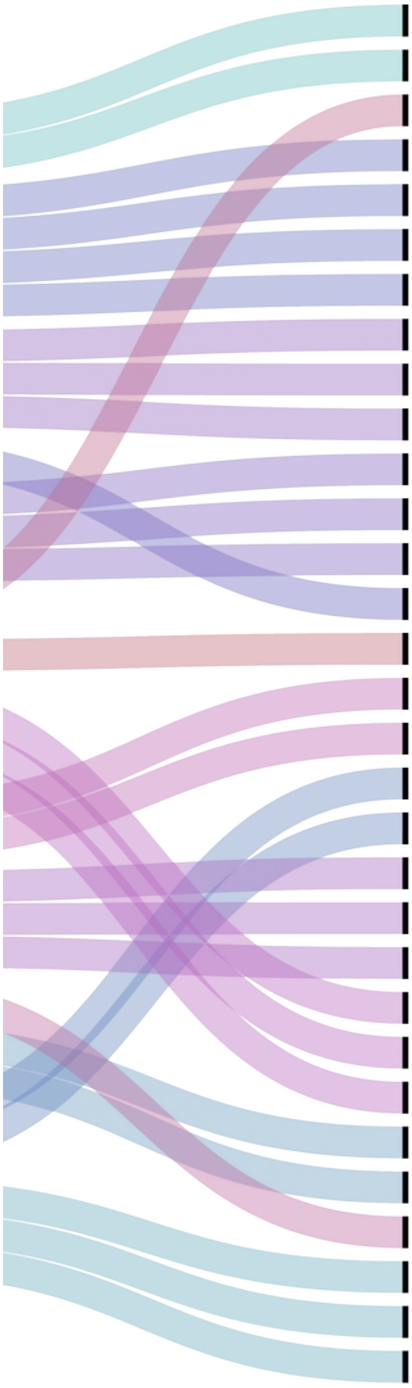

Towards a "Better Normal": Educational Experiences in Design in Latin America during the COVID-19 Pandemic

Design, Education, and the Online Tech-Pandemic

Looking Through the Window: Emotional Experiences of Instagram Users in Isolation

Portable Epidemiological Isolation Unit: Ephemeral Architecture for Covid-19 Emergency

LHF Connect: A DIY Telepresence Robot Against COVID-19

Individual protection mask with improved filtering properties: 3D printed solution guided by design materials selection

Field Hospitals to Face COVID-19: Requirements and Lessons Learned in the Design and Construction of the Lagoa Barra Hospital – Brazil

Tri-Design: Coordination Between Healthcare, Design, and Regulatory Communities

Makers Against Covid-19: Face Shields as the International Solidarity KPI

Confronting COVID-19: The Case of PPE and Medical Devices Production using Digital Fabrication at PUC-Rio

Towards Strategic Design: The Experience of two Colombian MSMEs

Open Design and 3D Printing of Face Shields: The Case Study of a UK-China Initiative

Co-Design of Do-It-Yourself Face Shield in Japan Under COVID-19 Pandemic

A Distributed Product-Service System for Mask Provision During COVID-19: An Action Design Research Study in Brazil

HETEROTOPIA WORK: Correlation Between the Domestic Built Environment and Home Offices During COVID-19 Confinement

The Impact of Sharing Platforms on Collaborative Design Development During Emergencies: The Case of COVID-19

Design for Emergency: An Open Platform to Design and Implement User-Centered Solutions in the COVID-19 Pandemic

Strategies of Design for Social Innovation and Design Activism in the Promotion of Positive Social Capital During the COVID-19 Pandemic in Brazil

Design for Resilience: Mapping the Needs of Brazilian Communities to Tackle COVID-19 Challenges

Mexico City's Quarantine Narratives and Underlying Values for Future Urban and Domestic Design

Interactive Voice Response Systems for Informing Citizens About the COVID-19 Pandemic: A Study on Brazil's Disque Saúde

Citizen Data-Driven Design for Pandemic Monitoring

Reacting to the Emergency by Opening Perspectives: Design-Driven Knit Therapy as an Adaptable Tool to Answer the Change

Design in Emergency Scenario: Project of a Hand Sanitizer Dispenser in Public Transport Using Design Sprint Method

"OPER.TEN" Transform Emergency Now! Facing Covid-19 with Open Innovation and Human Centered Design

Designing with Communities of Place: The Experience of a DESIS Lab During COVID-19 and Beyond

Design Amid Emergency

Design as a Positive Stimulus in a Brazilian Hospital environment

Design Strategy and Case Study of Distributed System Resilience in the Chinese Context

Design Research-in-the-Moment: Eliciting Evolutive Traces During the Covid-19 Crisis

Contemporary Design in Quarantine: A Critical Review of Design Responses to Covid-19 Crisis

PAPERS

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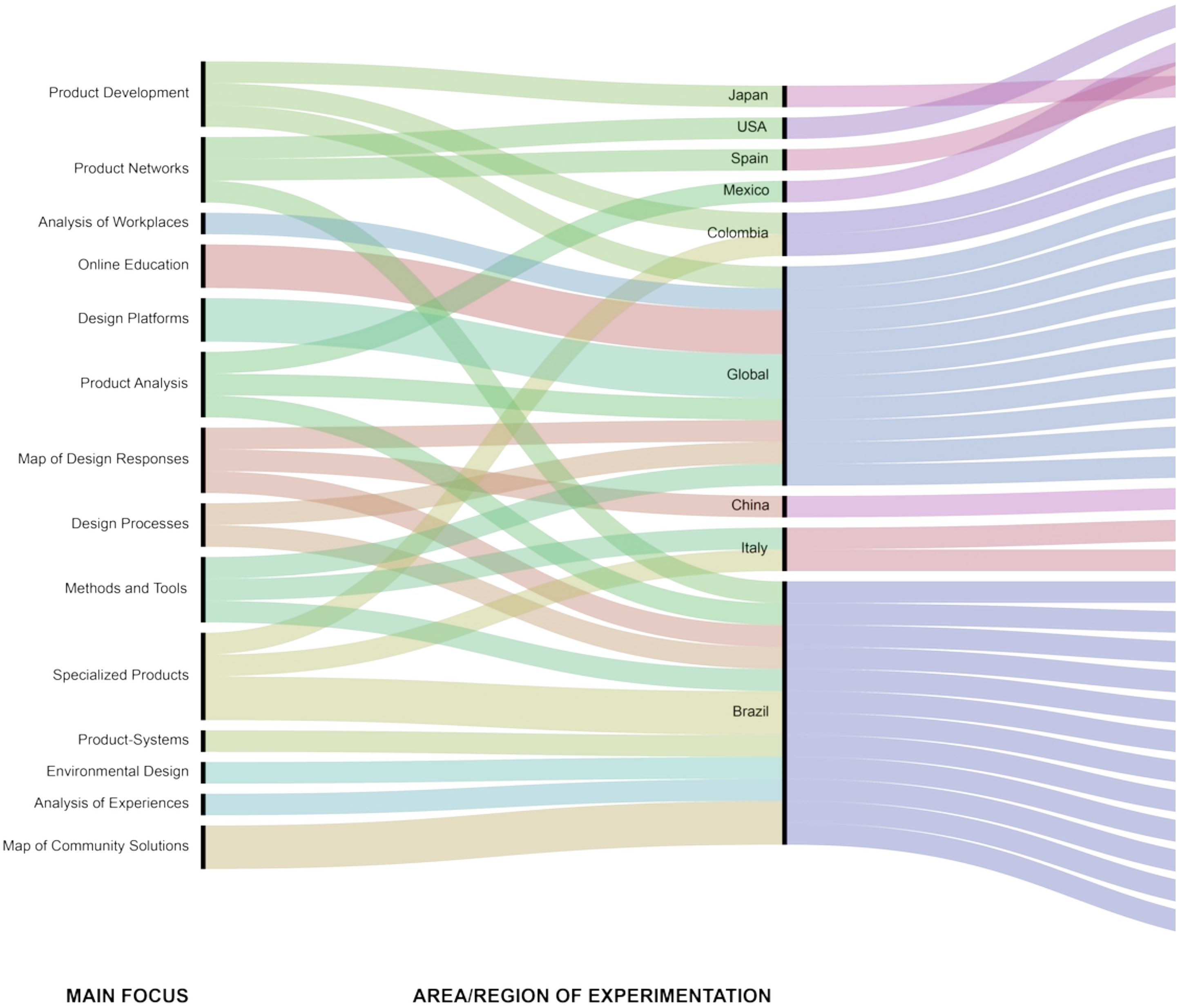

Figure 6: Map of links between papers, Main Foci and Areas/Regions of Experimentation.

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LHF Connect: A DIY Telepresence Robot Against COVID-19
"OPER.TEN" Transform Emergency Now! Facing Covid-19 with Open Innovation and Human Centered Design
Strategies of Design for Social Innovation and Design Activism in the Promotion of Positive Social Capital During the COVID-19 Pandemic in Brazil
Looking Through the Window: Emotional Experiences of Instagram Users in Isolation
Interactive Voice Response Systems for Informing Citizens About the COVID-19 Pandemic: A Study on Brazil's Disque Saúde
Individual protection mask with improved filtering properties: 3D printed solution guided by design materials selection
Field Hospitals to Face COVID-19: Requirements and Lessons Learned in the Design and Construction of the Lagoa Barra Hospital – Brazil
Design in Emergency Scenario: Project of a Hand Sanitizer Dispenser in Public Transport Using Design Sprint Method
Design for Resilience: Mapping the Needs of Brazilian Communities to Tackle COVID-19 Challenges
Design as a Positive Stimulus in a Brazilian Hospital environment
Design Amid Emergency
Contemporary Design in Quarantine: A Critical Review of Design Responses to Covid-19 Crisis
Confronting COVID-19: The Case of PPE and Medical Devices Production using Digital Fabrication at PUC-Rio
A Distributed Product-Service System for Mask Provision During COVID-19: An Action Design Research Study in Brazil

PAPERS

CONCLUDING NOTES ON ARTICLES COMPOSING PART 1

An overall view of these papers points to the conclusion that the pandemic produced a phenomenon of fast tracking various technological and societal changes that were already taking place but otherwise would have taken years to fully occur. The integration of remote working into urban lifestyles, a more intensive use of data-driven design and hybrid approaches for teaching and learning are some examples. At the same time, it shed light on new issues that were not on the radar of the design community.

Foremost, the articles show an active community working around the clock to frame new and complex problems, co-creating solutions with a variety of stakeholders, having limited time to put these ideas into the real world whilst at the same time having to deal with the limitations imposed by social isolation. The frenetic pace of design contributions during the pandemic, linked with the social isolation, provided reduced opportunities for reflection. Thus, this publication provides the necessary space for reflection by registering the lessons learnt during this period. It is a solid contribution to leverage our knowledge on how to

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engage design and designers during a global health crisis. It also provides insights for transition scenarios for the aftermath of the pandemic, with a contribution to build upon what we have learnt so far.

The design community, like any other profession, has been heavily affected by the pandemic. However, the articles presented in this Part 1 show that it was not powerless. When rapid innovation was required to deal with a global scale emergency, design was the discipline that was able to rapidly frame the problem, creatively shape ideas, and connect various fields of knowledge to deliver viable propositions. When the centralized and slow production systems demonstrated their incapacity to deliver results at the speed required by the pandemic, designers brought more distributed strategies for enabling production through digital fabrication. When collaboration and co-creation was necessary at global scale, designers put into place their know-how on open-design approaches, drastically accelerating the speed of knowledge sharing. Without doubt, design demonstrated its capacity to save human lives.

At the same time, the papers illustrate well that the pandemic has forced designers to realize that many assumptions they took for granted in the past were no longer in place: in order to reduce the spread of the virus most designers could not have direct contact with a user apart from digital channels; moving across the city to do a follow-up on the production of a prototype was not advisable; the synchronicity of people-to-people interactions become increasingly difficult if not impossible. This and so many other impossibilities were converted into new possibilities by the creative minds of the design community.

For all these reasons, the guest editors believe that this historical edition in two Parts of the Strategic Design Research Journal is a solid contribution to enrich the scientific debate regarding what we have learnt from the actions taken during the COVID-19 emergency scenario. We hope that this knowledge will contribute to develop further our collective capabilities and readiness to deal with present as well as future global emergencies.

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Design Research-in-the-Moment: Eliciting Evolutive Traces During the Covid-19 Crisis

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ABSTRACT

This paper presents a chronological account of design's response to the Covid-19 crisis as it unfolded globally. From January to May 2020, we documented over 500 design interventions that have been created by individuals, networks, amateurs, professionals, and public and private organizations and institutions. This international response witnessed the rapid design and development of products, networks and systems such as facemasks, hospitals, infographics, respirators, sanitizers, and virtual communities all created in an effort to save us. In response to the Covid-19 virus the problems that the world faced were highly complex, interdependent, and could not be addressed by conventional means. As such, this paper presents over 500 design-led responses that illustrate comprehensively that when pressed we can find new ways of designing. In short, this work outlines what we might think of as a new model for designing. This new model does not describe a new condition to come after what we currently call design. Rather, what we witness here is the revival of the practice of design – from handmaiden of Capital to one of Care – which is expressed in a new critical attitude for looking at the design world, probing its practice, its theoretical position and its product.

Keywords: Care, Covid-19, Design, Dilemmas, Preparedness, Research-in-the-Moment

INTRODUCTION

In a book we, the authors, have just published, A Design History of the Covid-19 Crisis (Rodgers et al., 2020), we have catalogued the designed interventions to the Covid-19 crisis and we prove definitively that design does care (Rodgers et al., 2017; Rodgers et al., 2019). We have documented this event as it evolved every day from the 1st of January 2020 to 31st May 2020 inclusive. We look at all of this care and caring from the point of view of design and, by the sheer volume of design interventions we have documented, illustrate that design is good in a crisis.

What the Covid-19 pandemic has illustrated is that for the first time in modern history capital was totally irrelevant. Money could not save your life. Only design could. Rapidly designed masks, shelters, hospitals, instructional posters, infographics, dashboards, respirators, sanitizers, virtual and local communities emerged to save us. From January 2020, design became king. The Covid-19 global pandemic presented an ontological reality; design is more than margins or profit. In fact, design became extremely valuable when it stopped concentrating on those things and started to care about peoples' lives. This brief episode in history is repositioning the status of design and reconfiguring its signifier from consumption to care.

In a recent interview for Design Emergency - a project that explores design's role and impact on the COVID-19 crisis and its aftermath - Alice Rawsthorn interviewed Dries Verbruggen, co-founder of Creatives tegen Corona (Creatives against Corona), "…a collaborative network in Antwerp, started in response to the urgent need for personal protective equipment by Belgian health and social care workers in the Covid-19 crisis…" (Rawsthorn, 2020). Creatives tegen Corona used volunteers and created a not-for-profit company to deal with the situation by creating garments with donations, collaborated with a multiplicity of experts, and made their designs open access. No money. No profit. No margins. Only caring for others. This is an example of how design excels and illustrates what design can be. If the inter-period between world wars repositioned economics from the margins to centre-stage, this crisis, which is not an economic crisis, but a design crisis, could reposition design from the margins to centre-stage.

However, this should not come as a surprise. Design's turn from the overtly commercial to a wider social agenda is not new. Design has long despised its profitmaking and wasteful nature articulated by key figures such as Victor Papanek (Papanek, 1971), Ken Garland (Garland et al., 1964) and, more recently, by Anthony Dunne and Fiona Raby (Dunne, 2005) who argue for design that makes us think instead of making us buy. In his critical paper, On Design and Disillusion, Silvio Lorusso highlights the recent rise in labels like "social design", "critical design", and "speculative design" and how each of these iterations contributes to a spectacle of design super-heroes versus societal problems - packaged in events like the Dutch What Design Can Do, a platform created to "…demonstrate the power of design; to show that it can do more than make things pretty. To call on designers to stand up, take responsibility and consider the beneficial contribution that designers can make to society." (Lorusso, 2019: 110).

Whilst there is mileage in Lorusso's argument that design loves a challenge such as the "refugee challenge" or the "climate change challenge" where design positions itself as "…the ultimate problem-solving discipline, superior to governments or NGOs…" where "…global tragedies become design opportunities", there can be no doubt that the 500+ design interventions documented in our book, are legitimately aiming to make things better for people.

Our book catalogues the 500+ design interventions and we consider the book to be one more of the 500+ projects we have assembled. It is a design response to the Coronavirus pandemic because we could see the need to collect all this material and assemble it as a durable record for all time because "…we need to learn to live in a world that is interconnected not only ethereally or ideally, through communication technologies, but also materially, via direct embodied contact. In short, we must learn to live in a reality that may, at any moment, go viral." (Marder, 2020).

1. DESIGN RESEARCH AND RESEARCHING DESIGN

In this context, Bruce Archer went some way in 1978 to proposing design as a third culture of thinking (Archer, 1978). This approach was deepened by Nigel Cross in his seminal paper Designerly Ways of Knowing. Building on Archer's work at the Royal College of Art, he describes this third culture as: "…the collected experience of the material culture, and the

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collected body of experience, skill and understanding embodied in the arts of planning, inventing, making and doing." (Cross, 1982: 221). This is exactly what we have done in the book and we discuss here.

While leaderships were floundering, design (together with volunteers and the general public) was at the forefront of stepping in and sorting out many of the most significant problems during the Covid-19 crisis. Very obviously, planning, preparedness, readiness, and appropriateness, which are fundamental characteristics of design, were found wanting when many countries' carefully-constructed and trialled global pandemic plans were put into action. As Lydia H. Liu asks: "…how do we end up in a state of unpreparedness in the midst of advanced preparedness?" (Liu, 2020) One answer presented endlessly by a critical media was that the Capital Project's search for maximum profit appeared to have undermined many countries' public health system's crisis capacity. The voids in pandemic plans enabled a space for potential interventions and, since there was nothing in place, design stepped up and stepped up very visibly. Our book maps this response to build preparedness and to build a case for just how important to governance design and care are. From the massive number of cases assembled in our book, governments should have no choice but to recognize design's capabilities and integrate designers into an expanding concept of lasting care.

Every project in our book attempts to fill the shameful gaps left by the Capital Project when it extracted preparedness from the balance sheets of the world's healthcare systems. In what was beginning to look like an unthinkable-world, these design projects care for people who clearly had both thinkable and previously unthinkable needs. As Joan W. Scott (2020) describes: "The pandemic has exposed yet another of the fault-lines of our moment: the difficulty of imagining ourselves beyond the current worlds in which we live." (Scott, 2020) The ability to imagine possible futures or future possibilities or what-might-become is the historic territory of design, the designer, and the act of designing. Or at least it used to be. But as Franco 'Bifo' Berardi maintains we were already living through the "slow cancellation" of the future where what-might-become is morphing into what-might-not become (Berardi, 2011).

This temporal contest – present versus future – is also a mental space occupied by administrations as Mike Davis points out: "On the same day that the president was bragging of the United States' unmatched scientific and technological superiority", the New York Times was devoting a page to "How to Sew a Mask at Home." (Davis, 2020) Again, Joan W. Scott broadens this temporal contest when she compares past and future: "Sometime in the twentieth century, we lost our belief in the redemptive power of history and so in the guarantee of a better future." Again, this resonates strongly in the world of design where many seem to ignore or are ignorant of historical accounts of design[ing] and fall into the trap of reinventing the wheel. By compiling this impressive and comprehensive response to Covid-19, we partly redeem some of design's temporal confusion – seeing no future in the past, locked in an imitative loop in the present while imagining it is designing the future. A response of this magnitude, showing what design can do, also partly redeems design's unwillingness to take responsibility for what design does. And prior to design's response to the Covid-19 crisis the state of design might best have been described as being trapped in a number of paradoxes – sustaining the unsustainable, disciplining the undisciplined, reconciling future visions with harsh realities, and others (Rodgers et al., 2017). In the case of the coronavirus pandemic, the context is paradoxical (combating an invisible enemy) and we have had to make many undesirable choices (e.g. lock down or die!). But dilemmas are

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what design confronts constantly in practice. For instance, the contradiction of designing a tracking system to help, but which implies invading somebody's privacy.

The Covid-19 design responses acknowledge our material and energy flows and environmental impact and contests the legitimization of power – to respond is to be responsible and many governments are being criticized for their irresponsible response. As we have said, and as the 500+ interventions in the book show, design has proved that in a crisis it cares.

It is possible that all of this, both the known and the unknown, must have been chronicled in non-stop media coverage. But like the contents of our book some of this can be analysed. The website Coronavirus Readings allows users to "…browse and search a wide range of analysis and commentary relevant to COVID-19 - across text, video and audio in multiple languages". On May 31st there were over 12,500 contributions. Half were produced in English and the rest in seven other languages. Journalism makes up 90% of the database. It already lists two books (to the best of our knowledge there are already 5 books). The topic 'future' makes up only 3.5% of the readings, which doesn't seem to align with the vast amount of journalism competing to predict the effect of the pandemic as the long-awaited opportunity to think and do everything anew – what is dubbed the "new normal". This output aligns with our research, where most of the work included was discovered by searching the specialist blogsphere coverage of the event. Their agility and connectivity provided an in-the-moment space for enquiry. In contrast to the relentless media speculation competing to project both evermore worse or forever better future scenarios, our book functions as a 'history' – a history of the design reaction to Covid-19.

Slavoj Žižek (2014) would classify the virus as: "…an event at its purest and minimal: something shocking that happens all of a sudden and interrupts the usual flow of things; something that appears out of nowhere, without discernible causes, and whose ontological status is unclear – an appearance without solid being as its foundation". As a "history of…", an assembly of what design did between 1st January and 31st May 2020, our book does what Žižek defines as to de-eventalize the event. That is, to explain it as an occurrence that fits the coordinates of our normal reality. Because this is what our book is - an ontology of design. It aims to understand what has happened. This typology will complement traditional epistemological models focusing on how we did it.

2. METHODOLOGY

Given the very peculiar coronavirus lockdown circumstances to assemble our book we simply collected everything as a type of diary entry form of data collection. We saw it as the best possible method to gather the collected experience of the material culture, body of experience, skill and understanding embodied in the arts of planning, inventing, making and doing related to the event. Also, the infinite array of digital tools enabled us to collect the interventions from our desks. In this context, photos, videos and text were collected using a variety of online apps and tools that allowed us to collect the design interventions dealing with an unexpected event. Here we are not investigating how people changed over time, but how practice, in this case design, adapted through time and circumstances to address readiness, appropriateness and preparedness.

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3. DATA COLLECTION

In this book we are using what could be characterized as an elicitation perspective. It consists of capturing media as soon as the phenomenon occurs to record examples of pandemic design as soon as they were found in the digital landscape. Figure 1 (below) is an example of the information we collected from each case.

TITLE	COVID-19 CORONAVIRUS MAP: GLOBAL OUTBREAKDASHBOARD
AUTHOR	THE NEW YORK TIMES
PUBLISHED	2020-01-28T22:57:20.000Z
URL	https://www.nytimes.com/interactive/2020/world/coronavirus-maps.html
KEYWORDS	days, reported, outbreak, rate, global, countries, average, jan, coronavirus, map, deaths, cases, tracking
DESCRIPTION	The virus has infected more than 2,843,000 people in at least 177 countries.
COUNTRY	USA

Figure 1. Design Intervention Data Collection Example

In order to frame the intended outcome, a progressive and systematic integrative review was conducted. It was decided to use this approach to insert flexibility into the cataloguing of the event. The search criteria were articulated based on their relevance to the subject. Design blogs, and specialist websites were searched daily. These online sources articulated the views of relevant and amateur practitioners. We also included reports from news platforms to complement and expand data collection to insert a broader and more inclusive and representative perspective. The criterion for inclusion was the relevance to the practice of design.

The selection was conditioned by our searches; therefore, it was somewhat arbitrary. The cases collected in our book represent a sample data of the event. The date represented in the cases is an estimation. Online tools such as scraping data tools were used to determine the date of publication. However, as the tool in itself claims, is just an estimation. In cases where we could not determine the date, we used the day it was encountered. We were not interested in documenting what happened with exactitude; this job belongs to sociologists and anthropologist. Rather, we were interested in documenting a sample of data to extract high patterns of knowledge to build "*knowledge for future actions*" (Glanville, 2015).

Figure 2 shows an example of one of the 500+ design interventions we have assembled as part of this ongoing work[1]. The 500+ design interventions were collected over a period of 152 days. In this process, as figure 3 illustrates, 63 different types of design intervention were collected from 54 countries. There are 6 main categories of design intervention (Figure 2 top left) – Actions, Graphics, Networks, Products, Shelters, and Systems; 24 sub-categories, and 8 enablers (i.e. who has supported the creation of the intervention – Independent, Private, Government, University, Citizens, Consortium, NGO, Professional Association). The example also shows further information – country of origin, type of intervention (e.g. mask, robot, mechanism, wearable, shield, test, etc.), author, definition, source of information, the main image, and the intervention title at the bottom of the figure.

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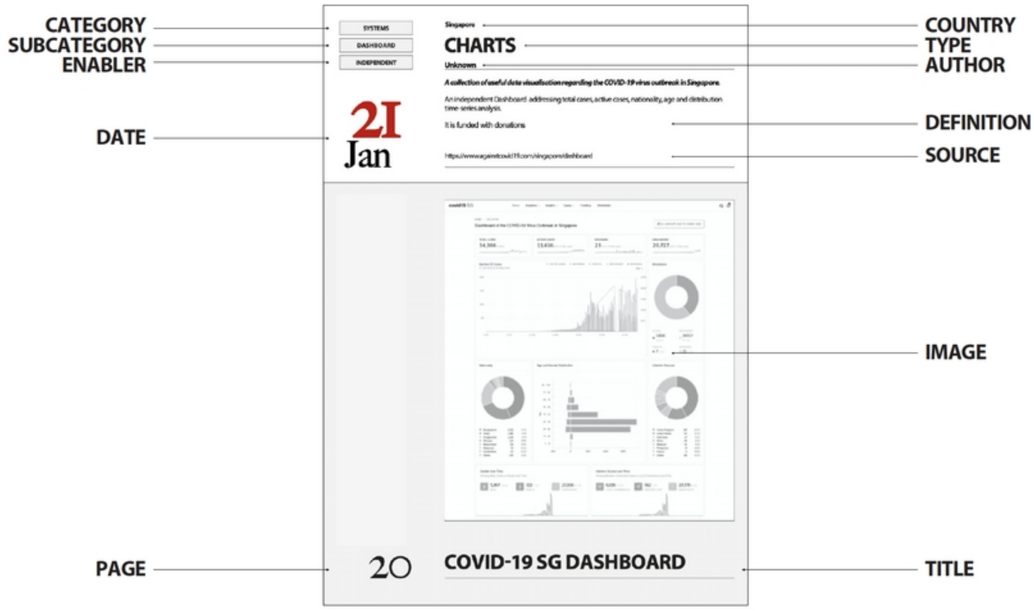

Figure 2. Design Intervention Example

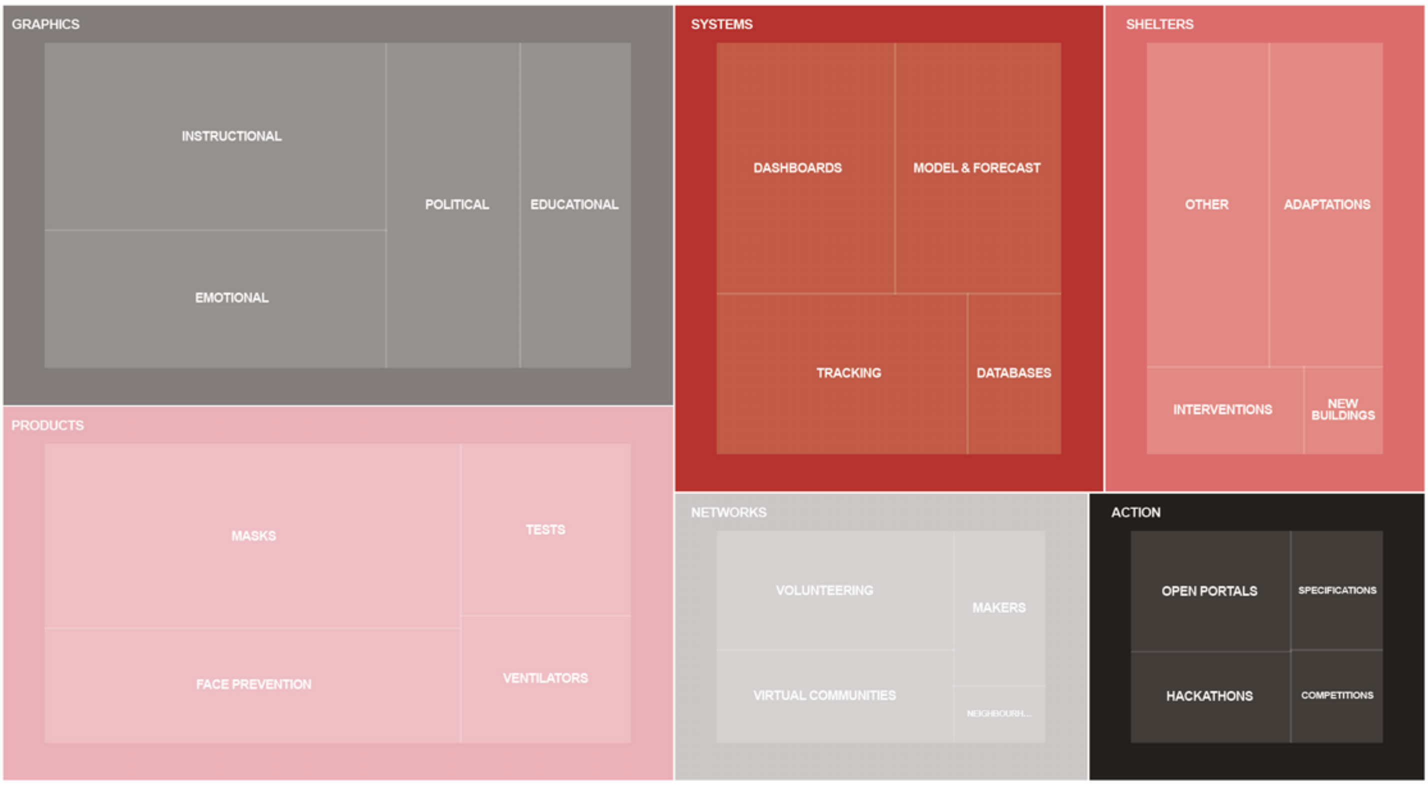

Figure 3. Design Intervention Categories and Sub-Categories Spread

Figure 3 shows the 6 main categories of design intervention and the spread of the 24 sub-categories. Here, we can see that the highest number of Graphics interventions (n=122) are *Instructional* in nature (*e.g.* stay home, what to do if you need help, raising awareness, how to stay safe when exercising outdoors, etc.), more *Masks* have been designed than any other type of Product (n=114), *Dashboards* are the highest number of Systems (n=95) produced, Shelters (n=71) encompass a broad range of *Adaptations* and *Other* interventions, most Networks (n=54) are *Voluntary* in nature, and most Actions (n=44) are *Open Portals* where

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predominately private organizations are calling on citizens to help better understand and track Covid-19 outbreaks.

4. DATA ANALYSIS

As design researchers we are concerned with extracting and identifying patterns of activity emerging from the collected experience of the material culture, and the collected body of experience, skill and understanding embodied in the arts of planning, inventing, making and doing in the artificial world, to infer knowledge for future actions in the context of appropriateness.

As we have stated, we documented this event as it evolved and we selected the cases in our book from the point of view of design. This temporal span encompasses; the outbreak; the lockdown and the reopening. Accounting for 500+ interventions in total. These interventions are a record of places, dates, embodiments and strategies and the chronological structure operated as a type of index system, which we have operationalized by articulating several graphic organizational frameworks enabling projects to be cross-referenced and compared. We have accepted all design interventions as valid and gave them the same role and status by representing each of them in a single page. No curation. No selection. No position. Just recording.

The classification of the interventions into categories emerged in the process of collecting. There was no preliminary hypothesis as nobody was expecting this event to happen. Furthermore, there was no reference in the field of design research in how to conduct or catalogue pandemic design. The classification of cases into categories and subcategories presented challenges. What is the ontological nature of a mobile test unit? Is it a product, a service, a tester, a system, a shelter, or an action? This kind of complexity led to a dynamic categorization of prospective initiative. The classification process was executed in the moment, therefore was influenced by contextual elements and personal interpretations and judgements. Different variables were assigned to each case as they were collected. This aspect may provide variability in the assessment. However, as stated earlier, we are not so much concerned with exactitude, but recollection to underpin emerging patterns for future actions.

Once we classified the cases and organized them into subsets, we could implement categorical analysis to underpin evolutive traces in specific categories or subcategories. Then, we colour coded the different variables in the subset to understand its evolution. This process enables preliminary understanding to generalize data patterns (Figure 4).

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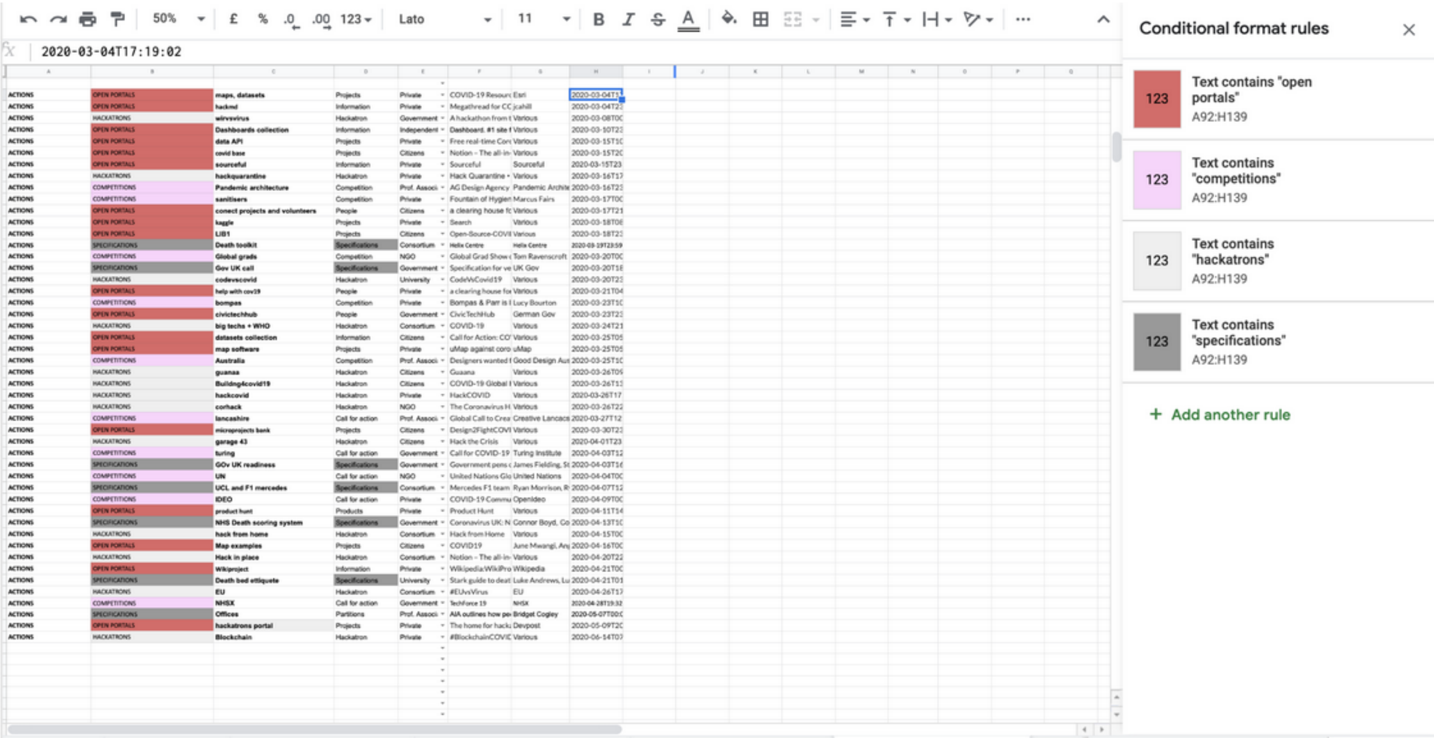

Figure 4. Classification of Design Interventions in Categories and Subcategories

The example represented above illustrates how we operated the actions category. We colour coded the four subcategories and we could then trace dominant subcategories in longitudinal trajectories. We could observe how portals dominated the first part of the event, and hackathons the upper middle part of the spectrum. Specifications emerged in the latest part of the longitudinal spectrum. Competitions are more or less evenly distributed, and are placed in the lower middle part, by dominant displacement.

From this point we were able to organize graphic material in a chronological way to further analyse its evolution. By using chronology to frame the assembly of this book we uncovered evolutive traces; for instance, posters were first instructional, then emotional, and then they became political. In terms of Personal Protective Equipment (PPE), we observed transparent masks becoming simplified over time (Figure 5). The first models were complex and 3D printed. The latest models are a sheet of plastic with 2 holes and a band, thereby removing the need for 3D printers, and enhancing production and sustainability in the process. Furthermore, we have discovered how at the beginning of this crisis, due to a shortage of products, it was a combination of professionals, individuals, groups and communities that stepped forward to fill the gaps left by errant public policy, planning and preparedness. We witnessed that once the systems of production adapted and started to produce/import those goods, the civil production of initiatives/goods decreased in cycles in different countries. This process presents a design-led alternative to pure statistical and mathematical models.

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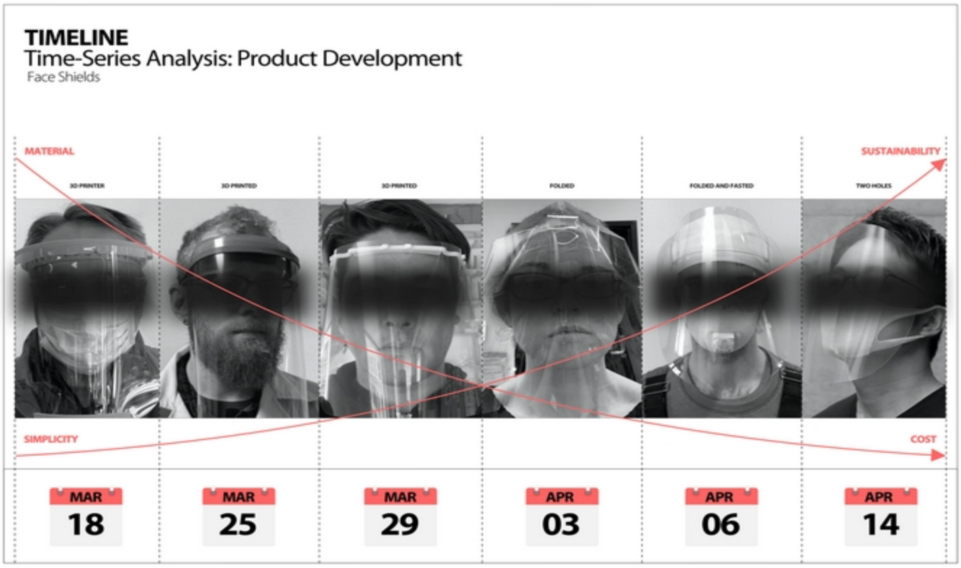

Figure 5. Evolutive traces in Personal Protective Equipment (PPE)

5. DISCUSSION

5.1. Structuring Research

The contents of our book cover the outbreak, lockdown, and the beginning of re-openings In between, the book functions as a history of pandemic crisis design interventions. As such it is a 'research-in-the-moment project' where we illustrate our thoughts and insights in tables, charts and diagrams. We have accepted all design interventions as valid and gave them the same role and status by presenting each of them on a single page. No curation. No selection. No position. The task of critical analysis must follow – perhaps by us, certainly by others. At this stage of the Coronavirus pandemic, where this book is an integral project of response/protest, any attempt to designate or distinguish or select projects will promote a notion of a "good design" and by default demote the rest. This is a typical approach applied by the museum sector concerned with the classification of types. Already some of the projects collected here are finding their way into the time capsules of museums via projects like Pandemic Objects at the V&A, London. In contrast to these archival practices, the rapid spread of the pandemic around the globe mirrors the fluid global information flows. Only when the viral chronicling ends will critical analysis of design's response to the coronavirus be applicable. Only then will we be able "…to think about these social ills, and so, about what might constitute a cure for them that the pandemic has so glaringly exposed." (Scott, 2020).

The 500+ design projects we have collected have been formatted chronologically into a range of highly informative tables, charts, timelines and images including the following:

- Chronological development, frequencies of interventions and type
- Categorical analysis, type and impact
- Relational developments among categories, embodiments and enablers
- Relationships among typologies, phases (outbreak, lockdown and reopening) and time
- Geographical developments and typologies
- Weighted hierarchical analysis of interventions and places

Rodgers, P. A., Galdon, F. & Bremner, C. (2020). Design Research-in-the-Moment: Eliciting Evolutive Traces During the Covid-19 Crisis. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 312-326. DOI: 10.4013/sdrj.2020.133.02

- Flow developments
- Product/ service/ system/ environment typologies evolution
- Development rationale and dynamics
- Aims/ needs/ worries/ concerns/ challenges

As Fred Block acknowledges: "this is not the last pandemic we will face" (Block, 2020), so in the likely event of a second wave, and/or other pandemic or emergency events, these insights lead a case to build preparedness for such circumstances. This framework identifies key categories/ needs/ worries/concerns and challenges. It also highlights the important roles that design, designing, and designers might play.

Before the projects catalogued in our book, design was certainly paradoxical (Rodgers et al., 2017) and this is the context from which design designed its way through the Covid-19 crisis. Despite this successful exit by design from a list of binding paradoxes, new dilemmas are now emerging. As a result of all the design projects assembled here, design must now make some challenging choices. Will it go back to being the handmaiden of Capital or abandon Capital to build on what it has achieved? For example, care and community, while aiming for even bigger targets such as inequality and the climate emergency, etc. That is, a new human condition? And the paradoxes inevitably also become dilemmas - after the crisis, which way will design go? If design chooses the hard route - the unknown knowns (Rodgers and Bremner, 2019; Zizek, 2006) - then what do the projects in this book indicate about how to design?

In the midst of the quarantine in Italy, Franco 'Bifo' Berardi wrote: "Use value, long expelled from the field of economics, is back, and the useful is now king." The 500+ design projects in our book add up to a history of the Covid-19 crisis and we expect much of what is illustrated will disappear - so more than likely, as a document, this book will be extremely useful forever.

6. RESULTS

6.1. Framework

In design research we trade some degree of accuracy in order to access areas that are yet-to-be or not-fully-formed. Therefore, our output is probabilistic, and research is always preliminary in its nature (Rodgers and Bremner, 2018) (Galdon and Hall, 2019). Moreover, in exchange we provide guiding knowledge for prospective developments – as Glanville proposed, "*knowledge for*" future action and possibilities rather than "*knowledge of*" past actions and events (Glanville, 2005). Design research is directional and transformational at its core. In this context, we are more concerned with how things "*ought to be*" (Simon, 1996, pp.111-167) instead of how things actually are. Consequently, output is based on potentialities, not certainties. In the same way, history is not about facts, but rather about approximations which are updated as new information emerges. In this context, as the life of the intervention is placed into the future, the time required to assess the impact of the design is extended during its lifetime. Validation is always *a posteriori*, and the proposed output becomes the main element to be assessed. In this context transferability becomes crucial (Figure 6).

Figure 6. Transferability of Design Interventions

Transferability is defined as "*The ability to apply the results of research in one context to another similar context. Also, the extent to which a study invites readers to make connections between elements of the study and their own experiences*" (Barnes *et al*., 2020). The framework presented in this book is potentially transferable to other pandemic events. This aspect is very relevant since the rate at which novel viruses are emerging means other pandemics and emergency events will occur. It is clear the world will need to build preparedness for such circumstances. However, in our book we illustrate the ingenuity, practicality and willingness of designers that also generated a range of dilemmas and paradoxes to consider. Therefore, this framework identifies key categories and needs, but also, worries, concerns and challenges.

In an earlier paper (Rodgers *et al*., 2017), the authors presented a critical examination of the current state of design by highlighting a number of paradoxes that included sustaining the unsustainable, disciplining the undisciplined, and reconciling future visions with harsh realities. In this work, the 500+ design interventions we have documented since 1st January 2020 present further dilemmas and paradoxes for designers and others to resolve. Figure 7 highlights some of these dilemmas and paradoxes that have developed as a result of the design-led interventional activities of individuals, organizations, amateurs, communities, virtual networks, and many others since the start of 2020. Given the space limitations in this paper, we will highlight a few of these dilemmas and paradoxes here.

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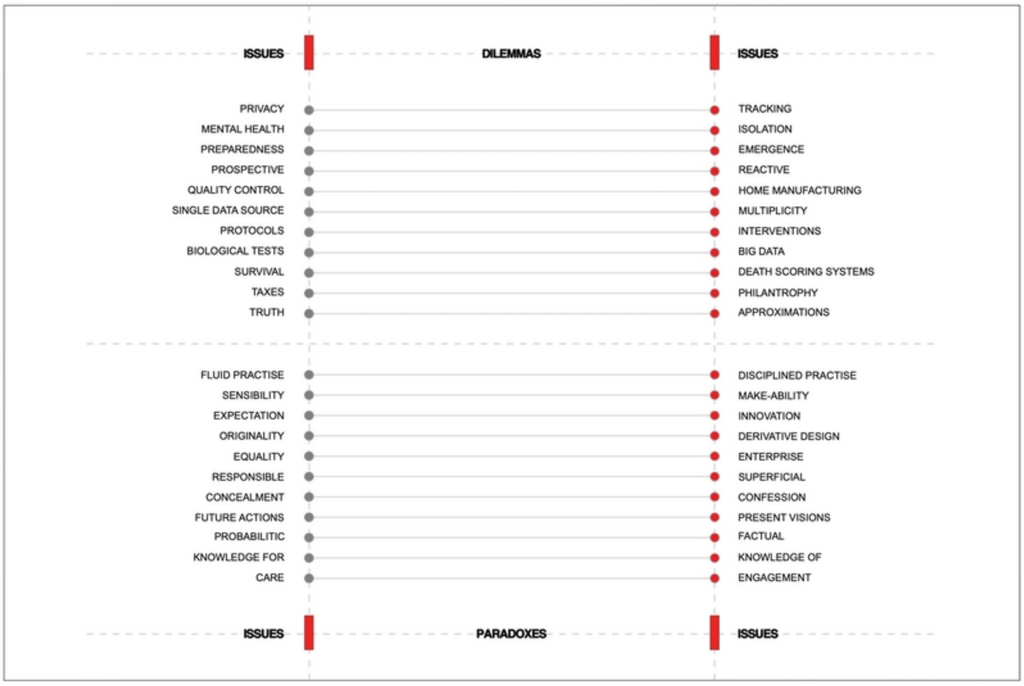

Figure 7. Dilemmas and Paradoxes Created by the 500+ Design Interventions

In terms of practice, contemporary design sees no boundaries between so called disciplines such as product, furniture, graphics, interior, and so on. Alex Coles in his study of *The Transdisciplinary Studio* (Coles, 2012) points out: "*Artists and designers are now defined not by their discipline but by the fluidity with which their practices move between the fields of architecture, art, and design.*" Rather, modern forms of design practice move seamlessly between historic and outdated disciplines.

We are constantly reminded of the ease nowadays of turning our future visions into real products. Personal fabrication and home manufacturing tools such as 3D printers, laser cutters and small CNC machines give us all the ability to design and produce our own products from the comfort of our very own homes. A number of vast technological developments in computing and manufacturing combined with low production costs and rapid execution cycles mean it is relatively simple to turn ideas into finished objects ready to be distributed all over the world. The explosion of home manufactured Personal Protective Equipment (PPE) such as facemasks, gowns, eye protection and gloves whilst well intentioned throws up quality control issues. As we have expressed in an earlier paper (Rodgers *et al.*, 2017), we need to take great care with design and heed the warning from Dieter Rams - arguably one of the greatest designers of all time – "*…that design is a serious profession, and for our future welfare we need to take the profession of design seriously….*" (Rams *et al*., 1991).

7. CONCLUSIONS

In response to the Covid-19 virus the problems that design faced were highly complex, interdependent, and could not be addressed by conventional means, structures and research. As such the response presented here illustrates comprehensively that when pressed we can find new ways of designing. What we witness in this work is what we might think of as a new model for designing. This new model does not describe a new condition to come after what we currently call design (who knows what that might be…). Unlike the structure developed in this work, a new model for design is not a chronological idea. What we witness here is the revival of the practice of design – from handmaiden of Capital to one of Care – which is expressed in a new critical attitude for looking at the design world, probing its practice, its theoretical position and its product. At this stage looking at designing with care through the lens of critical theory we can only draw temporary conclusions. Time will continuously revise this history. But from what we have seen we can also foresee some critical issues that will need careful thinking, which we summarize below:

Designing with care concerns not only how we care for the world outside, but also how we care for ourselves or, rather, how we react to the way in which the world appears to care for us.

Designing with care is a new gesture for design. It might not be immediately clear to the designer what care actually is, and how the gesture is supposed to be performed. In order to start designing with care, we need a theory that explains what designing with care is. Such a theory could give us the possibility to universalize both design and care.

Designing with care, while we live in these strange and transitional times, is not necessarily transformational. Whereas transformation implies dramatic change, transition suggests a defined future state arrived at through some form of managed change. Whether change can be managed or not it will help if we (as designers) define the future state rather than leave it to Capital or politics. In that sense a central promise of care is the possibility for transition to a better future. In transition to this possible future it must be asked whether we can continue to design with care and if so, what will we design?

Designing with care in the service enterprises economy is regulated to guarantee the delivery of care is consistent and viable. But care is like conversation theory, which maintains that conversation is constituted by the listener not the speaker. In the case of care – care is determined by the receiver not the provider. In this scenario, we must transition design from engagement to trust. The idea that trust is earned or built is a marketing project. Here we must shift orthodoxies of trust and reposition the relational gesture of care as granted by the receiver.

As this work makes very clear, designing with care turns out to be extremely useful, which could lead us to think the more care we use the better things will get. But care has become an element for both profit and pleasure and how we care for the world is constantly being conditioned in the same way marketing has conditioned consumers to consume. Clearly, designing with care will call for vigilance.

Not only will designing with care call for vigilance, it will also have to take good care of itself. Despite all the energy and effort thrown at sustaining life on the one planet we share, now all we can do is constantly recalibrate downward earth's carrying capacity. Care needs to be taken with the calibrations and the calibrations tell us how much more care we need to take.

Even with the massive and compelling design response to the Covid-19 crisis, caring for design is not very visible. Caring for design is the responsible job of stewardship and only with care is the design for the future possible…after which, we will have to steward design to take care of it. Designing with care has pitfalls. We are inevitably careless and we need to be careful about our carelessness. No matter how careful we might be, all design thought and action has consequences which raises a number of dilemmas and paradoxes that underpin the positionality of what-might-not-become.

ACKNOWLEDGMENTS

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ENDNOTES

[1] The project is ongoing and can be accessed here - https://fgedesign.wixsite.com/adesignhistoryofc19/timeline

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Contemporary Design in Quarantine: A Critical Review of Design Responses to Covid-19 Crisis

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ABSTRACT

The following article aims to analyze Brazilian and international cases of design responses to the COVID-19 pandemic related crises. It initiates with reflections about the social and political roles of design, emphasizing the importance of social innovation, design activism, and transition design to contemporary design. The methodological approach adopted is qualitative and quantitative with assessment and selection of data based on the bibliographic, desk, and documentary research methods. The result of 113 mapped cases is presented by graphic synthesis and discussed through the bibliographic research.

Keywords: Contemporary Design, Design Activism, Pandemic, Social Innovation, Transition Design.

INTRODUCTION

We are facing the major global health crisis of the past 100 years: the COVID-19 pandemic. At the same time, the contemporary scenario is the stage of multiple systemic crises - economic, political, social, and environmental -, that are aggravated by the pandemic and can be seen as its cause, as attest several contemporary thinkers (*e.g.*, Davis & Klein, 2020; Mascaro, 2020; Žižek, 2020). Around the world, the current system has been unable to prevent the pandemic and contain the socio-economic damage resulting from it.

On the one hand, some political institutions and people in power positions have responded to the current crises with actions that we can characterize as necropolitics[1], especially in Brazil, where a significant part of the population becomes complicit with the genocide agenda organized by the federal government. On the other hand, researchers and practitioners from multiple areas of knowledge have presented solutions not only to prevent or treat COVID-19 but also to face the pandemic's socio-economic consequences.

The design has made its contribution, but it is necessary to analyze the design's performance to see if it is limited to emergency responses to the COVID-19 health crisis or also consider the systemic crises that the pandemic aggravates. Furthermore, new pandemics may occur in the short or medium future, and we are already facing the first signs of a climate crisis. Therefore, this article aims to analyze Brazilian and international cases of design responses to the COVID-19 pandemic related crises, investigating if the approaches adopted convergences to social innovation, design activism, and transition design, whose importance is explained next.

1. THE SOCIAL AND POLITICAL ROLE OF CONTEMPORARY DESIGN

Contemporary design registers the expansion within humanitarian and sensitive relations. Although the design texts that predicted the future did not point health issues and the necessary strengthening of public policies related to them, the indications of activist, political, social, and transitional actions were already emerging as essential foundations facing crises. For Bomfim (1997), to present solutions to contemporary problems implies the transdisciplinary work of design based on the observation of reality and the application of inductive and experimental methods. Furthermore, contemporary emergencies demand more from design than aesthetic solutions or those that perpetuate dominant ideologies and values. Redig (1978), for example, indicates the importance of the social, environmental, political, and interdisciplinary action of design considering the human being, which was on the design agenda in the last decades (*e.g.*, Löbach, 2000; Bürdek, 2006; Margolin, 2006; Bonsiepe, 2011). With the urgency of the transition to sustainability and questioning the current models of production and consumption, the social and political role of contemporary design becomes increasingly important. The three design approaches presented next are an example of that.

1.1. Social Innovation

The social and political responsibility of designers is not a new topic. Papanek (1971) already defended the social and ecological action of designers. Later, Heller and Vienne (2003) pointed out the need to raise awareness of designers' political and social performance based on critical postures. In the current scenario, the 2030 Agenda (UN, 2015), aligned with Maslow's Theory of Human Motivation (1943), contributes to (re)thinking the contemporary ecosystem in social and environmental terms. Another essential contribution comes from social innovation - SI, which corresponds to new solutions that are more effective than the existing ones to meet social needs and increase citizens' capacity to act when dealing with complex or intractable problems (Santos et al., 2019; Manzini, 2015).

SI emerges from creative communities that work collaboratively to solve everyday problems, often establishing new lifestyles and patterns of production and consumption (Santos et al., 2019). It seeks fairer and more efficient solutions to conflicts presented in contemporary society that reflect guidelines, mindsets, projects, and products that have been inefficient for the promotion of equity and social and environmental justice.

The SI process can be top-down, bottom-up, or hybrid. The first one refers to initiatives that involve experts, decision-makers, or political activists; in the second one, solutions emerge from the community itself (Manzini, 2014). Thereby, SI does not need designers, but they can make significant contributions as professionals (expert designers) dedicated to practice, teaching, research, and extension. However, in the ecosystem of creative communities, subjects are equally important. Even without any training in design, diffuse designers manifest the human capacity of exercising creativity, applying it in a project adapted to the social actors' reality.

To make SI more likely and effective, expert designers can act as facilitators, supporting existing initiatives and participating in co-creation teams. Nevertheless, they can also start the SI process by acting as design activists. In both cases, they join in co-creation processes with diffuse designers. Therefore, designers' role is no longer to design "closed" products and services, but to expand people's capacities, collaborating in the creation and implementation of new forms of life and action to which the individuals involved attribute meaningful value (Manzini, 2014, 2015).

1.2. Design Activism

One of the first authors to ever deal with design as activism was Papanek (1971), who called on designers to take on a more revolutionary performance related to issues of political, militant, and subversive activities, which increasingly take space in contemporary discussions. Thereby, the term "design activism" was incused in 2004, when the 5th Conference of Pacific Rim Community Design Network defined one of its thematic axes as "citizen movement & design activism" (Hou, Francis, & Brightbill, 2005). Since then, design activism became an emerging narrative in the design field, parallel to the resurgence of social discussion and interest in the design practice.

Design activism indicates thought, imagination, and practice applied knowingly or unknowingly to create counter-narratives promoting changes in social, institutional, environmental, or economic spheres. There are multiple instances of design activism, ranging from cultural to social and environmental agendas, converging to social impact, public service systems design, broad proposals for social organization, and questions about consumption and aesthetics. So design activism acts as a general concept that incorporates many design approaches and other connections between actions (Thorpe, 2009; Fuad-Luke, 2009).

In short, design activism can be defined as a social movement linked to social change processes. Activism aims to challenge the dominant patterns of power in favor of social improvements, which is why it has its importance in developing design theories and practices, which can expose visions of a better and fair present and future. Contemporary design distances itself from the production of artifacts and presents increased possibilities of action, differentiating itself from practices linked to consumerism and ephemeral society. Therefore, new design initiatives are required – as the interrelation with other areas of knowledge - in the search for more sustainable scenarios through transition design.

1.3. Transition Design

Facing the current system's inability to deal with the COVID-19 emergency and the demand to restructure our way of life indefinitely, many people question the contemporary economic, political, and social system, a fact that leads to the need for changes. As Mascaro (2020) argues, it is impossible to overcome the multiple contemporary crises through the same system that created them. We need radical and systemic transformation, which will not happen spontaneously due to the pandemic since the trend of the post-pandemic natural change is the maintenance of the current system (Davis & Klein, 2020; Harari, 2020; Mascaro, 2020; Žižek, 2020).

Positive change demands organization and will not occur quickly, but gradually (Santos, 2020; Davis & Klein, 2020), as a lengthy transition process, which may have a more active contribution from the design field. More specifically, from the transition design, term incused by Irwin (2015), as attest Gaziulusoy and Houtbeckers (2018). Transition design focuses on radical and systemic changes in different levels: cultural, institutional, organizational, social, and technological. It develops and analyses place-based scenarios for sustainable futures based on theories and ideas from social sciences, humanities, and engineering that deal with social and technological change. The long-term vision is not the single focus of transition design since the scenarios developed inform and inspire the design of short and mid-term solutions (Ceschin & Gaziulusoy, 2016; Gaziulusoy & Öztekin, 2019; Gaziulusoy & Houtbeckers, 2018; Irwin, 2015).

In a post-pandemic perspective, transition design can help to build a new and more sustainable world, reinforcing the need to implement change by design and not by disaster. Of course, the design for disaster approach is vital to face the health crisis, but we highlight the need to focus more on possible transition design contributions. We are facing a dystopian scenario that we have not yet learned to deal with (Dunker, 2020). Nonetheless, experts have pointed out the possibility of a pandemic for years, and we are likely to face others in the future, besides an imminent climate and environmental crisis (Harari, 2020; Santos, 2020; Žižek, 2020). We have to act now and change by design to prevent these crises from happening and prepare ourselves to face them. Once positive changes demand organization and a clear horizon (Davis & Klein, 2020), the COVID-19 pandemic responses can teach us how (not) to deal with a crisis and inform what world we should build.

2. METHOD

To analyze design responses to the crisis triggered and aggravated by the COVID-19 pandemic, it was undertaken exploratory and inductive research adopting a mixed approach - quantitative and qualitative - with assessment and selection of data based on the bibliographic, desk, and documentary research methods. First, the narrative literature review allowed the exploration of contemporary design's social and political roles in a scenario of emergencies. The second part of the research was identifying and systematizing the design responses. The identification occurred until July 14, 2020, through desk research, as described in Figure 1. Due to the vast number of initiatives regarding the pandemic, we settled the selection criteria shown below. Because of the need for a filter, many social innovation cases were not included for not having proof of designers' participation. Moreover, similar solutions were grouped as a single case. Thereby, the collection of cases did not intend to represent the whole, but the variety of experts and diffuse designers' solutions.

DATA SOURCES
Design websites and blogs (e.g., Dezeen, AIGA Eye on Design, What Design Can Do, Design Week);
United Nations and Global Compact database;
Social media;
E-mails of an international group of design researchers.

SELECTION CRITERIA
Cases with solutions that fit into traditional design segments (e.g., product and graphic design) or into new segments relevant for the discussion proposed (e.g., transition design);
Social innovation cases with the participation of expert designers.
Solutions with significant differentiation in the artifact, its production or distribution.

Figure 1. Data sources for content and selection criteria for the research

Moura, M., Perez, I. U., Melara, L. F. & Magro Junior, J. C. (2020). Contemporary Design in Quarantine: A Critical Review of Design Responses to Covid-19 Crisis. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 327-341. DOI: 10.4013/sdrj.2020.133.03

The analysis of cases was based on Gibbs (2009). It occurred through documentary research, with consultation on websites, social media profiles, blogs, images, and documents available online of each case identified. All the data collected were registered in a spreadsheet for comparative analysis, in which we used categories and codes that emerged from the data. Figure 2 shows the correspondence between them, where it is seen that some codes do not apply to all categories. As the solutions of "analysis for post-pandemic transformation" are not physical products, they can not be manufactured. "Design contests and challenges", in their turn, are often broad, embracing different design segments, solutions types, and targeted audiences, which are difficult to account.

CATEGORIES	CODES							
	Country	Cocreation & Open Design	Digital Manufactu-ring	Design Segment	Kind of Solution/ Artifact	Expert or Diffuse Designer Solution	Universities Enterprises or Public Power Participation	Targeted Audience
Analysis for post-pandemic transformation	✖			✖	✖	✖	✖	✖
Solutions for social and economic assistance	✖	✖	✖	✖	✖	✖	✖	✖
Design contests and challenges	✖	✖	✖			✖	✖	
Prevention Solutions	✖	✖	✖	✖	✖	✖	✖	✖
Treatment Solutions	✖	✖	✖	✖	✖	✖	✖	✖

Figure 2. Correspondence between analysis categories and codes

The categories and codes allowed the quantitative analyses of the cases, while the narrative literature review grounded the qualitative approach. The next section presents the results and discussion that focused on the social and political roles that designers are taking over - or should take over - during the pandemic considering the need for systemic transformation to prevent or face future economic, environmental, health, political and social crises.

3. RESULTS AND DISCUSSION

After the desk and documentary research, we selected 113 cases. Figure 3 shows their distribution in each category. Since there are many prevention solution cases (68%), we divided them between personal protection equipment – "PPEs" (42,5%) and "others" (25,7%). There are fewer treatment solutions (12,4%), probably because of the complexity and expertise of this category and the more significant concern with preventing contagion. The smallest representation of the "social and economic assistance" category (9,7%) solutions does not mean there was no concern to face these particular pandemic consequences and the actions for social distancing. There are social innovation - SI initiatives around the world dealing with this question, but we did not find many with expert designers.

Moura, M., Perez, I. U., Melara, L. F. & Magro Junior, J. C. (2020). Contemporary Design in Quarantine: A Critical Review of Design Responses to Covid-19 Crisis. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 327-341. DOI: 10.4013/sdrj.2020.133.03

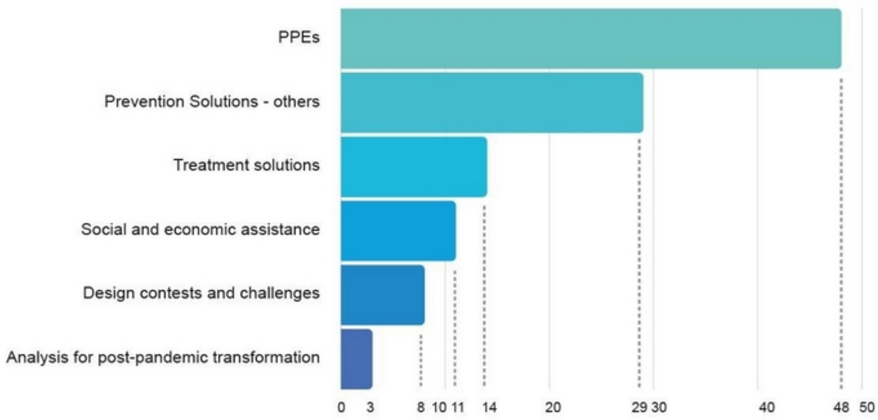

Figure 3. Number of cases per analysis category.

Figure 4 presents the global distribution of the selected cases, whose quantitative analyses are representative and not intended to be absolute. The collection of cases is not a faithful portrait of the design activities during the pandemic across the globe but reveals their variety. Therefore, Figure 2 shows most cases are from Brazil (34,5%), which does not mean the country is a leader on design responses for COVID-19, but that its article had more contact with Brazilian cases, the focus of the article's context, despite the international approach of the survey and analysis of cases.

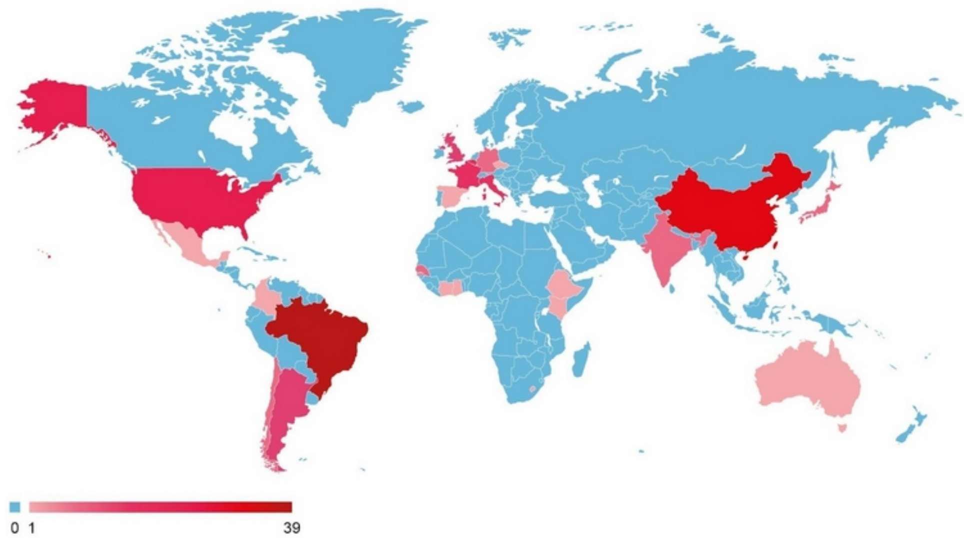

Figure 4. Global distribution of the cases

Some cases (20%) are not from a particular country but widespread solutions (*e.g.,* industrial conversion and social distancing wayfinding), global design contests and challenges, or solutions by multinational institutions (*e.g.,* WHO[2] video that pedagogically explain the coronavirus). There are many solutions from China (11,5%), which was expected considering the COVID-19 emergency initiated there. From African countries (6,2%) – Ethiopia, Ghana, Kenya, Ivory Coast, Lesotho, and Senegal -, it was identified only prevention solutions, most of them hand washing equipment (5,3%) for places without piped water. One example is the creation of a Ghanaian diffuse designer: a solar-powered hand-washing sink with a motion sensor (Awal, 2020). There are also solutions from Argentina, Australia, Belgium, Chile, Colombia, Czechia, France, Germany, India, Italy, Japan, Mexico, Spain, United Kingdom, and the USA.

Figure 5 presents the design segments associated with the solutions of each analysis category. Some cases fit in more than one, so the sum is higher than 100%. Most of them are product design results (65,5%), especially in the treatment and prevention solution categories, where there is a more significant variation of similar results (*e.g.*, masks and face shields). Visual communications (14,2%) and information design (12,4%) perceive all categories and are essential for spreading knowledge about the COVID-19 disease. Their representation is lower because their solutions are very similar and troublesome to categorize, although they are widespread like social distancing wayfinding, awareness videos and graphic images, or do-it-yourself (DIY) manuals to manufacture protection products.

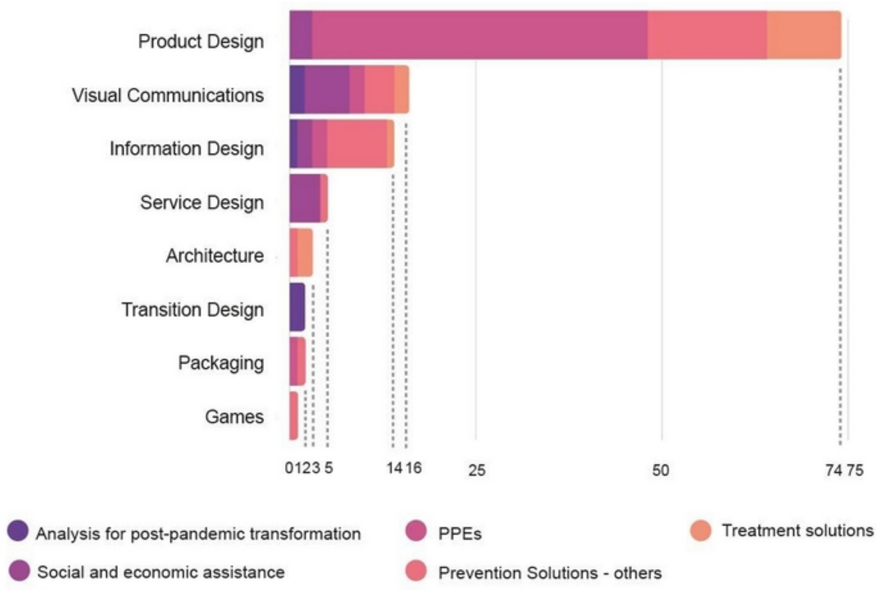

Figure 5. Design segments.

Service design solutions (4,4%) are often information design as well, like apps and platforms. One example is brochures for printing and distribution to inform about social distancing and fill in with contact details of volunteers willing to assist vulnerable people (Wong, 2020a). Architecture contributions (2,6%) are micro residences for quarantined COVID-19 patients and emergency hospital intensive care units, like the Italian project Connected Units for Respiratory Ailments – CURA[3], which uses shipping containers to deploy Intensive-Care Units in cities around the world quickly. Only two cases are transition design ones, both in the "analyses for post-pandemic transformation" category. One of them is a project led by Terry Irwin at Carnegie Mellon, in which researchers developed a systemic problem map that identifies system failures that helped the virus spread in the USA and the interconnected problems that the virus has exposed (Peters, 2020).

There are different kinds of solutions (Figure 6). The main product results are PPEs - masks (24,8%), face shields (12,4%), and hospital uniforms (7%). There would be more cases like that if one of the selection criteria did not establish the need for significant differentiation in the artifact, its production, or distribution. This high amount reflects the demand for protective equipment. Before the pandemic, few enterprises in the world centralized the production of these items and other essential to COVID-19 treatment. The increased demand forced national businesses and designers, diffuse or experts, to create ways to achieve a distributed production. Because of that, respirators or ventilators (8,8%) are also between the most designed products.

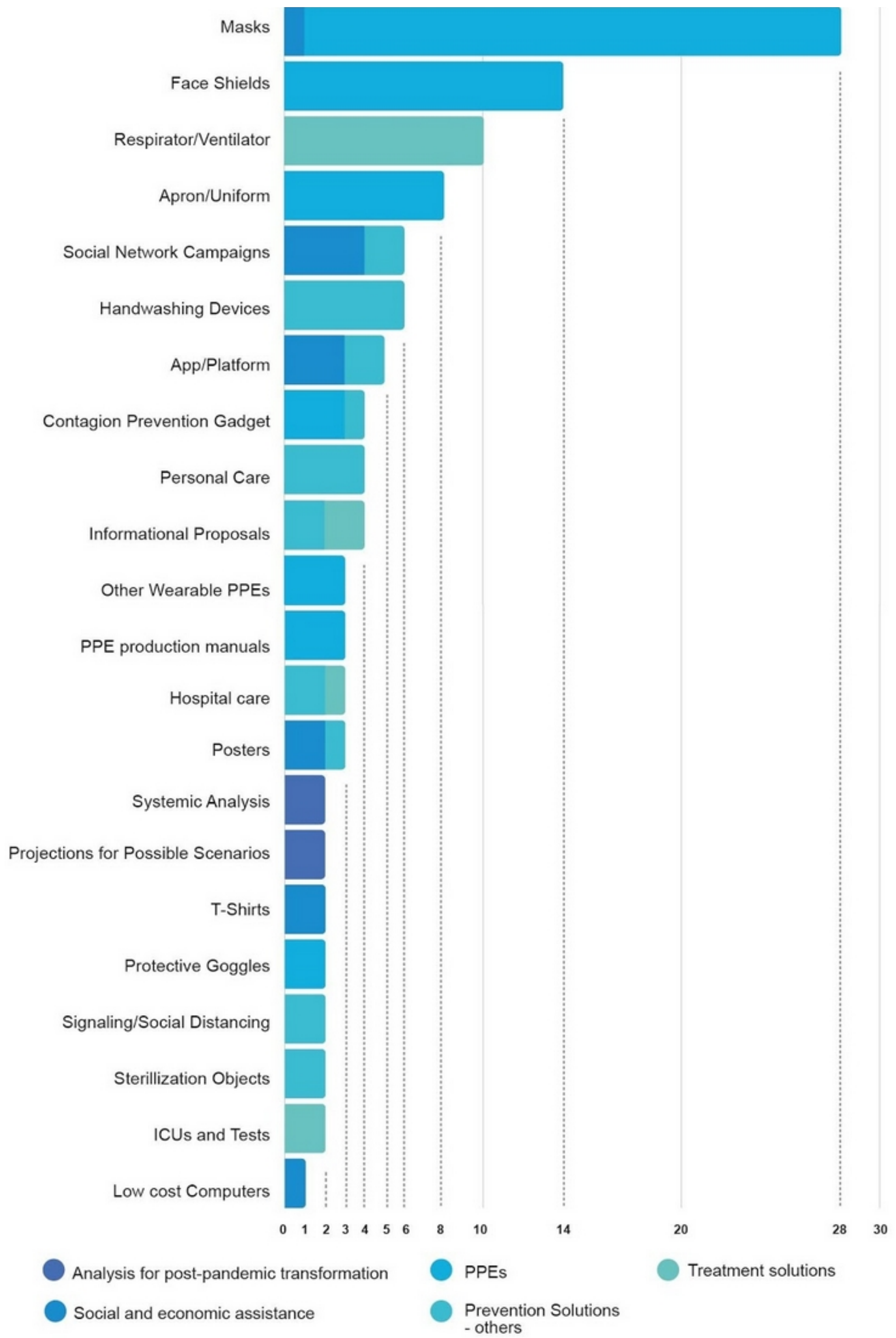

Figure 6. Different kind of design solutions.

Regarding PPEs, designers have been innovating materials (e.*g.,* antiviral technological fabrics[4]), models *(e.g.,* face shields with extra coverage on top of the head[5]), manufacturing technologies (*e.g.,* 3D printed masks[6]), and distribution (*e.g.,* SI projects to connect fashion industries and independent or amateur seamstresses for the production of masks and hospital uniforms to local health unities[7]). Besides the variety of solutions, female healthcare professionals have issues with poorly fitting PPE, according to Wong (2020b), which indicates that designers do not necessarily consider women as first responders in the fight against the COVID-19 pandemic, as affirms Santos (2020).

Social media campaigns (5,3%) are the most numerous visual communication results. They encompass prevention solutions (*e.g.,* images or videos about the coronavirus and how to prevent the contagion) and socio-economic assistance (*e.g.*, campaigns to raise money for facing the pandemic or its consequences[8]). Apps and platforms (4,4%) provide solutions for socio-economic assistance (e.g., linking local and small businesses to designers[9] or customers[10]) and for prevention (e.g., interactive map[11] showing the hospitalizations for severe acute respiratory syndrome in São Paulo, Brazil).

Other products are contagion prevention gadgets (e.g., keyring[12] to avoid the use of hands on the doors) and personal care objects (e.g., soap packaging that indicates the time of hand-washing[13]). "Informational proposals" include an infographic[14], a children's game[15], and an informational guide about COVID-19[16]. The analyses for post-pandemic transformation results are systemic analysis (information design) and scenarios projection (transition design).

Figure 7 presents the mapped cases' targeted audience. Most of them (54%) are for the public in general (e.g., post-pandemic proposals and some prevention solutions) or address more than one segment. The primary specific audience is health professionals (31,8%) and COVID-19 patients (12,4%), especially in the PPE and treatment solution categories.

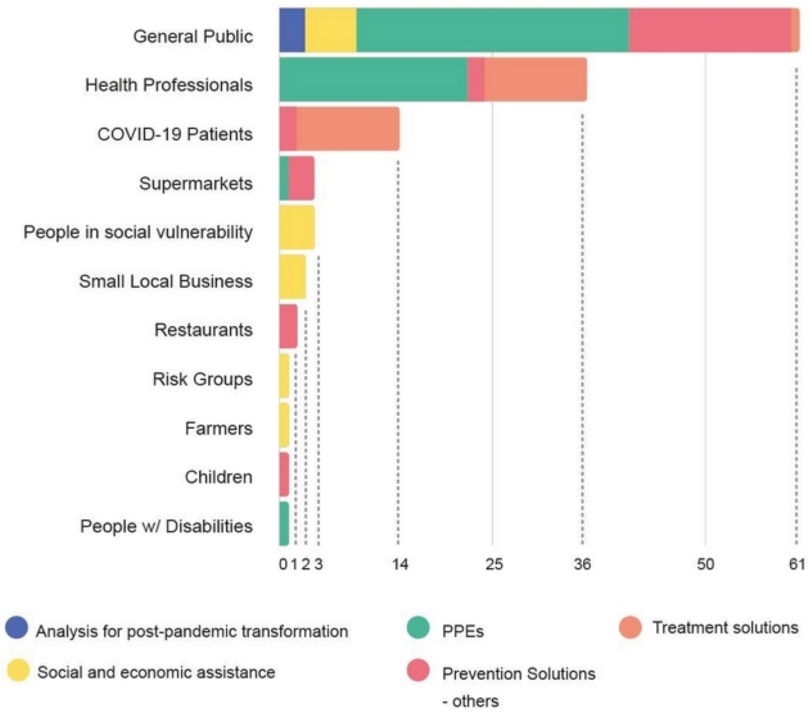

Figure 7. Targeted audience.

Figure 8 shows the involvement of universities, private companies, and government offices, which are more expressive on prevention solutions and "design contests and challenges" categories, representing respectively 81,8% and 87,5% of these cases. Solutions for social and economic assistance have less institutional collaboration (27,3%), reinforcing the need for SI, which often occurs when neither the government nor the market provides adequate solutions, as Manzini (2015) proposes.

The short participation of the government offices confirms the political inefficiency to fight the pandemic and its socio-economic consequences. Over the last decades, neoliberal politics have dismantled the State and its public health and social services, without which many governments around the world, especially in Brazil, cannot respond effectively to the present crises (Davis & Klein, 2020; Mascaro, 2020; Santos, 2020). Some Brazilian cases show the collaboration between municipal health departments, universities, and enterprises, but the only one resulting from a national public policy is the SUS app[17].

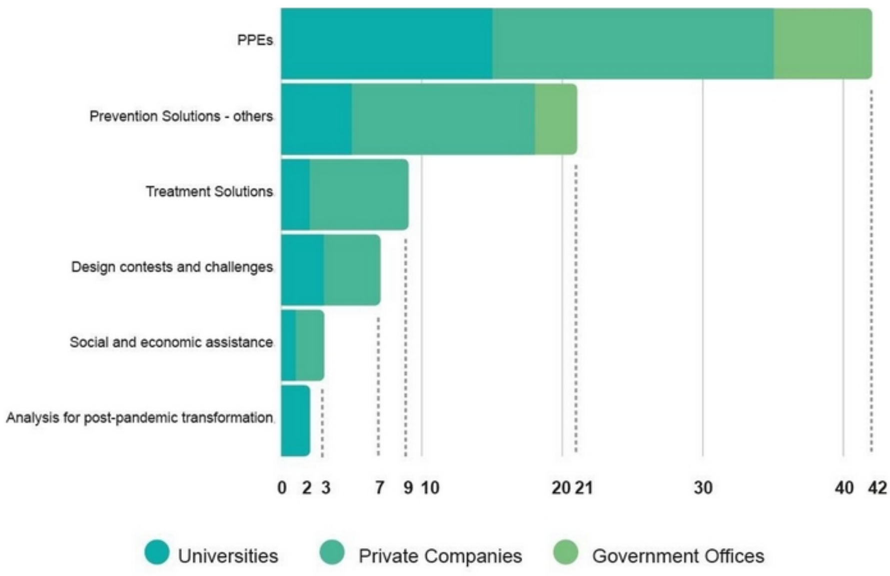

Figure 8. Universities, enterprises, and government offices involvement.

Universities lead part of the cases (24,8%), especially in Brazil, where public universities head scientific research. Design companies (23%) have also been involved, sometimes needing to adapt their design and production activities. However, most of the cases analyzed are independent, while Brazilian and international design associations have not been actively involved in the fight against the pandemic.

Expert designers are responsible for developing most solutions considered here (64,6%), as Figure 9 shows, but the selection criteria may have influenced this result, especially regarding SI cases. Nevertheless, diffuse designers play a fundamental role in facing the pandemic, either alone (14,3%) or co-creating with expert designers (19,5%). Proportionally, diffuse designers are more expressive in the “solutions for socio-economic assistance” and “design contests and challenges” categories, while expert designers are essential in the “treatment solutions” one.

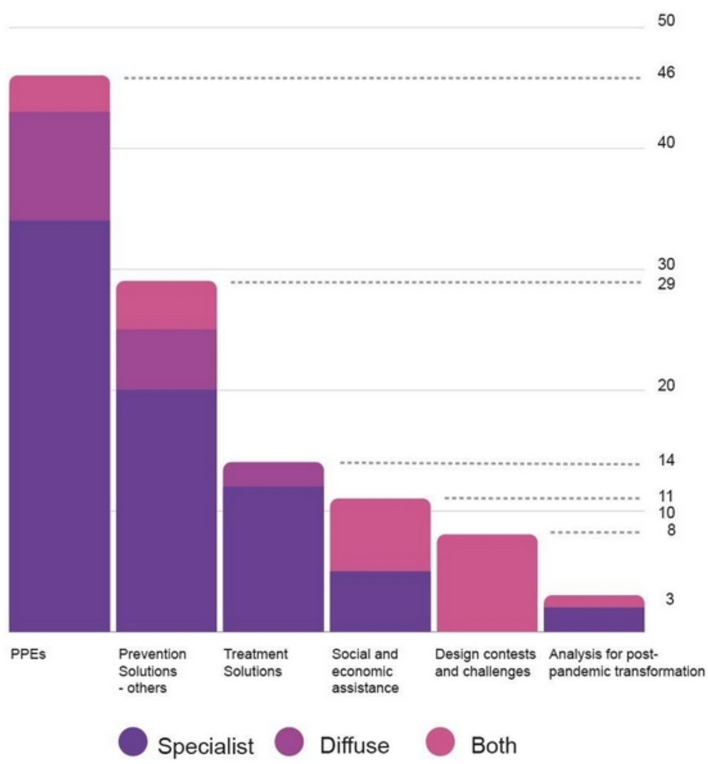

Figure 9. Expert and diffuse designer’s participation.

Moura, M., Perez, I. U., Melara, L. F. & Magro Junior, J. C. (2020). Contemporary Design in Quarantine: A Critical Review of Design Responses to Covid-19 Crisis. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 327-341. DOI: 10.4013/sdrj.2020.133.03

Diffuse designers usually solve problems not considered by experts. For example, a college student of education developed a mask with a plastic window that allows lip reading by the deaf and hard of hearing (Kopsky, 2020). Furthermore, part of the diffuse designers' responses is from the maker movement. As Figure 10 shows, digital manufacturing is essential to develop prevention and treatment solutions, representing 36,6% of them, while co-creation (37%) and open design (35,4%) rise in all the categories considered in this graph.

What defines open design is the creator's permission to freely distribute their project blueprints, allowing modifications and derivations (Abel, Evers, & Klaassen, 2011). In general, open design cases are also co-creation ones. They are essential facing the pandemic since the creator democratizes the project results, usually in the form of do-it-yourself - DIY manuals or downloadable files for digital manufacturing *(e.g.,* 3D printing).

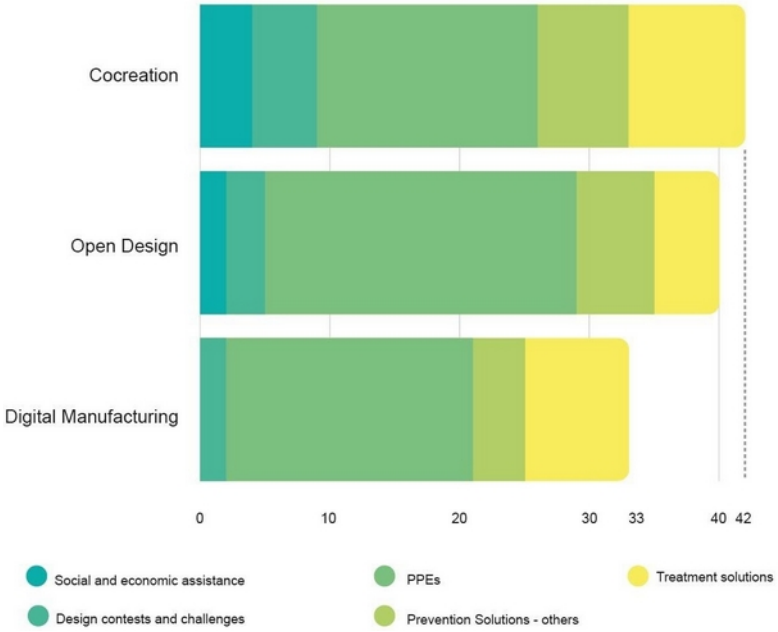

Figure 10. Co-creation, open design, and digital manufacturing solutions.

Open design combined with digital manufacturing can trigger SI, as Manzini (2015) attests, which demand new economic and productive models, like distributed economies. As indicated before, the pandemic shows failures within the current centralized economy. Now, when people need a quick supply of PPE and treatment devices, the maker movement has developed globally open source products for local production, often through digital manufacturing technologies. One example is *Diseñadores sin Fronteras*[18], an Argentinian network of designers who collaboratively developed and shared DIY manuals to locally produce masks, face shields, and hospital uniforms and beds.

A significant part of the design activism cases – 35,4% (Figure 11) are also open design and digital manufacturing. Graphic and information design also contribute to the transmission of messages and acknowledgment, in either DIY manuals or awareness and guidance pieces. Thereby, design activism reinforces its contemporaneity and designers' citizen awareness. Activism within the Organized Civil Society, public institutions, and community spaces for cultural knowledge production are of great importance for developing products, processes, and design services. The overlap of these agents creates a practical, digital, social, and technological network of a locality, enabling community articulation to prevent and fight the pandemic through SI or social design initiatives (13,3%) whose actions propose a social value to attend basic needs demanded by the community. One of these cases is the movement Free the Future[19] that proposes a post-pandemic world of social and environmental justice. It is one of the only two transition design cases identified.

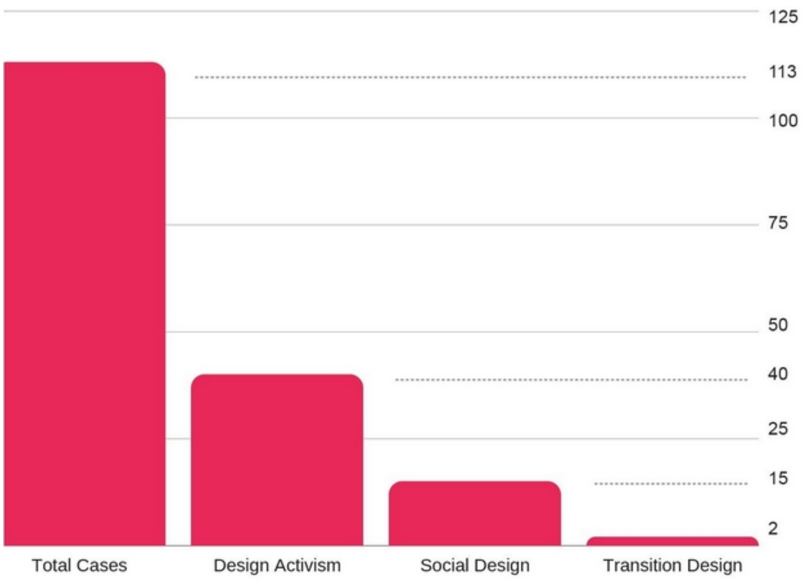

Figure 11. Social design and design activism cases proportion.

Although design has shown its relevance towards facing the health crisis, its performance could go beyond. Most of the analyzed cases (96%) focus on the period during the pandemic, not considering the future. Moreover, only three cases are solutions developed before the COVID-19 crisis. These facts suggest that the design field was not prepared to face a pandemic, acting mostly according to the design for disaster's approach. As Dunker (2020) declared, global society is a beginner facing the pandemic, evolving to create solutions and deal with unforeseen effects. It is necessary to coop with the health emergency faced now. However, it is also essential to consider the pandemic's socio-economic impacts and "the unintended consequences of the solutions and innovations that are being hastily implemented", as Terry Irwin attested to Peters (2020, para. 5).

Probably the future will bring other pandemics, environmental degradation, climate crisis, and increased social inequality. Designers need to be more prepared for this than they were to face the COVID-19 emergency, which can teach valuable lessons, such as the importance of interdisciplinarity and collaboration with professionals and researchers from other areas of knowledge. If health sciences, engineering, and technology are now essential, designers need to get closer to the social, biological, and climate sciences to prepare themselves for the next global challenges.

4. FINAL CONSIDERATIONS

This article presented a critical analysis of 113 Brazilian and international cases of design responses to the systemic crises related to the COVID-19 pandemic. First of all, it is necessary to recognize its limitations. It is not possible to collect and analyze all existing cases in which diffuse or expert designers are active, which is why it was necessary to establish sometimes restrictive selection criteria. Furthermore, due to the large number of identified cases, it was not possible to contact those responsible for each solution to collect additional information

Moura, M., Perez, I. U., Melara, L. F. & Magro Junior, J. C. (2020). Contemporary Design in Quarantine: A Critical Review of Design Responses to Covid-19 Crisis. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 327-341. DOI: 10.4013/sdrj.2020.133.03

that would benefit the analysis. Finally, the pandemic was ongoing while this article was written, so solutions continued to be developed and implemented.

Despite these limitations, the identification and analysis of cases allowed us to obtain a framed picture of design responses to the health, social, and economic crises faced. The analysis suggests that designers recognize the importance of their social and political role as citizens. However, they were little involved in SI initiatives focused on social and economic issues linked to the health crisis. They also neglected the transition design approach in favor of design for disaster's one. Immediate solutions are essential when responding to emergencies. However, this pandemic is unlikely to be an isolated case in the history of current generations, who must face many other economic, environmental, health, and social crises.

The COVID-19 crisis probably will have a profound impact on the practice and teaching of design in the upcoming years, reinforcing the social and political role of design and the importance of some approaches (e.g., interdisciplinarity, social innovation, distributed economies, open design, co-creation, and transition design). Design needs to help portray new visions of the future, starting from the difficulties of the present. New ways of thinking and acting become urgent, making it necessary to put social and environmental issues in the foreground, where they should have always been.

ACKNOWLEDGMENTS

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ENDNOTES

[1] Necropolitics, derived concept from biopolitics, limits life to the administration of populations. In practice, this policy denies or makes access difficult to the necessary conditions to maintain people's lives considered "unproductive" or less important to the current socio-economic system (Dunker, 2020).

[2] https://bit.ly/3j0lg6w

[3] https://curapods.org/

[4] https://bit.ly/3gO1WYi

[5] https://bit.ly/307TRGZ

[6] https://bit.ly/32l1ZqF

[7] https://bit.ly/32dvYk1

[8] https://bit.ly/3iZ3Qaq

[9] https://bit.ly/3gTj0vY

[10] https://bit.ly/2OlN1Iv

[11] https://bit.ly/2Wgf00S

[12] https://bit.ly/2DFU4d5

[13] https://bit.ly/32dUlhF

[14] https://bit.ly/38V9q99

[15] https://bit.ly/32f7SFN

[16] https://bit.ly/3epXttf

[17] https://bit.ly/2ATNyOK

[18] https://bit.ly/2WcSfuw

[19] https://bit.ly/2ZnYfTg

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STRATEGIC DESIGN RESEARCH JOURNAL

Citizen Data-Driven Design for Pandemic Monitoring

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ABSTRACT

In a world concerned with the coronavirus pandemic, many governments do not know how to control the disease. Although there are several technologies that generate citizen data, transparency, and privacy are very important to ensure social engagement and more effectiveness in fighting the virus. This article analyzed some applications that contact tracing people or inform them about the disease. We selected the applications based on how they captured data, privacy issues, citizen participation, and the main challenges faced. Later, we created the app journey map to compare them and discovered the most used technology is Bluetooth, and the apps often have open source. However, these initiatives bring superficial insights and need to integrate with more complex data.

Keywords: Citizen Participation, COVID-19, Data-driven Design, Data Privacy, Social Innovation, Smart City.

INTRODUCTION

The coronavirus pandemic impacted the world in 2020. Consequently, many countries developed new ways to control contamination. Unlike previous pandemics, the citizens' mobility is higher, as well as the number of sensors to monitor them. The COVID-19 disease has great epidemic potential, and it is challenging to track asymptomatic people. The only tools to avoid contamination are case isolation, quarantine and contact tracing, difficult procedures to implement.

In a critical crisis context, many protocols are ignored in order to collect citizens' data. So, it is important to evaluate what is being done. This is an urgent topic, not only for the current coronavirus crisis but for a future with more monitoring technologies. The whole world shares similar concerns, and it is trying to improve public management without affecting the citizen's experience.

As many countries do not know how to track their citizens, some governments can take advantage of the crisis to increase surveillance. Many institutions launched applications, but they may not be efficient in their purpose. This article presents a comparative study between applications that intend to contain the coronavirus contamination in ten countries. It explains the importance of citizen-driven focus, understanding their behaviour, desires, and bringing them to the discussion and design participation.

1. DATA-DRIVEN DESIGN IN A CONNECTED CITY

The implementation of smart cities, where there are technologies to connect data and manage urban decisions, could be useful for epidemic control. Kitchin (2015) says that in recent years the smart cities concept has grown among industry, government, media and, academia, referring to the use of information and communication technologies (ICTs) to stimulate economic development and augment urban management.

However, according to Consoli et al. (2017), the interaction among different actors brings heterogeneous solutions. As cities have different kinds of data, the capacity to integrate them safely is essential to the smart cities interest:

> Transforming our cities into the smart cities of the future encompasses incorporating technologies and key digital advances, and links them with machine-to-machine solutions and real-time data analytics. Collecting data and transforming them into tangible insights is crucial for modern innovative smart cities. (pp. 1-2)

The capacity to link various data is essential to data-driven design. This approach helps to understand some behaviours and to guide proper solutions. When cities use the citizens' data to increase their information, they expand their knowledge about them. According to Aguilera et al. (2017):

> All data gathered, either automatically by the city sensors or by contributing citizens, who act as mobile sensors in their daily interactions with the city, is useful to take earlier and better decisions, providing improved services to the citizens. (p. 234)

In this way, the design modality is not only for individual subjects but also for all human activities, individual or collective. As stated by Manzini (2014), in highly connected organizations, it is necessary to operate in the design modality. "That is, design has been mainly seen in its potentiality as a problem solver. This is correct. But, in my view, design is not only that. Design can also create meanings. That is, operate as a sense maker." (p. 97).

Thus, the evolution in design research from a user-centered approach to co-design is changing the roles of the designer, the researcher, and the user. According to Sanders and Stappers (2008), the implications of this shift support a transformation toward sustainable ways of living in the future.

In a connected city, citizen data could contribute to human-centered design. According to Oliveira and Campolargo (2015), urban challenges and societal transformations contribute to a new social consciousness leading to new approaches, such as citizen-driven innovation, focused on the co-design and co-creation of city services:

> Cities are smart when they take full advantage the human capital of its citizens, create innovation ecosystems where the new dynamics of wealth and jobs creation takes place and promote new forms of participatory governance. In short, when they become Human Smart Cities. (p.2336)

Besides the importance of the data, they can also reveal a lot of sensitive information about the citizen. According to Cottrill (2020), some privacy issues are critical, such as geotagged or otherwise location-enabled data, despite representing valuable inputs. Collecting location data from personal devices or aligned to identifiable individuals can be highly revealing, and someone can use them to detail traces of an individual's behaviour.

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For that reason, it is important to understand the privacy and ethics concepts. For Cavoukian (2017), privacy equals control: personal control over the uses of your personally identifiable data. It is not about secrecy; it is not about having something to hide.

1.1. Privacy

With the technology progress and new ways of data capture, some countries have created and updated their laws. Some examples are the GDPR (General Data Protection Regulation) in Europe and LGPD (*Lei Geral de Proteção de Dados*) in Brazil.

Another effort to create privacy principles is the Privacy-by-design concept, characterized by proactive measures and anticipates privacy violation events. Cavoukian (2009) developed seven principles:

1. **Proactive not Reactive; Preventative not Remedial:** Anticipates and prevents privacy-invasive events before they happen. For example, a product would provide a clear commitment, with high standards of privacy and higher than the global laws.

2. **Privacy as the Default:** No action is required by the individual to protect their privacy. The purposes for which information shall be communicated, only the data strictly necessary must be collected, with non-identifiable interactions, only as long as necessary to fulfill the stated purposes, and then safely destroyed.

3. **Privacy Embedded into Design Privacy:** A systemic approach to privacy at every step in the design and operation, with detailed privacy impact and risk assessments clearly documented.

4. **Full Functionality:** There are not dichotomies between privacy and security; it is desirable to have both. It should be done in such a way that full functionality is not impaired, and to the greatest extent possible, that all requirements are optimized; all objectives must be clearly documented.

5. **End-to-End Security:** Privacy before the first element of information being collected extends security throughout the entire lifecycle. Entities must assume responsibility for the personal information security, consistent with standards that must assure the confidentiality, integrity, and availability of personal data.

6. **Visibility and Transparency:** Its component and operations remain visible and transparent to both users and providers alike. Responsibility for all privacy-related policies, the openness of information and complaint mechanisms to access the next level of appeal.

7. **Respect for User Privacy:** Empowering user-friendly options to play an active role in managing their own data may be most effective against abuses and misuses of privacy and personal data.

With technology increasing, it is crucial to embed privacy directly into the default design process. We must have privacy and innovation, embracing a positive-sum paradigm, allowing an open society.

1.2. Ethic

Likewise, the designer who works with data capture technologies must understand their decision outcomes besides to respect users' privacy. It is important to know the ethics definition; according to Barbosa and Souza (2011), ethical virtue has different interpretations because it is the result of different situations: the action in line with general laws and the actions that address the singular cases, in which the law does not apply easily, but the virtuous man is able to act according to the fair measure.

For Frascara (1997), every situation of human communication falls within the ethics field:

> That is, it can be ethical or unethical but it cannot be a-ethical. The basic tenet of ethical communication lies on the recognition of the Other - the receiver of the communication - as a subject (a person) and not as an object. By recognizing the Other as a subject, the Other is recognized as an independent, thinking person, with a specific way of understanding, evaluating and integrating experiences and information. (p. 17)

Although communication can control behaviours, attitudes will not change unless there is a partnership between the message producer and the public about desirable objectives. For Frascara (1997), when attitudes do not change, the need for repressive communications, legislation, and enforcement grows. In a smart city, we should be conscious of the citizen's role as co-author; this notion seems essential from an ethical point of view. In pandemic circumstances, the co-operation and balance between all those involved are crucial.

1.3. Citizen Participation for Social Innovation

Social change happens when we not only understand citizens' data but also when they participate in the design process. The designer role is more about facilitating the conversations from various social actors than designing alone with citizens' data. Manzini (2015) defines design for social innovation as:

> ... is the expert design contribution to a co-design process aiming at social change. In practical terms, it is a blend of different components: original ideas and visions (from design culture), practical design tools (from different design disciplines), and creativity (which is a personal gift), within the framework of a design approach (deriving from previous reflexive design experience). (p. 63)

Citizen participation is present in a smart city environment, and this concept integrates technologies with citizen wellbeing. Mulder (2018) sees a necessary shift from city management to participatory city-making:

> Such a participatory city making process envisioning liveable and sustainable urban environments goes far beyond simple, or even complex, product-service design; it has political, organizational, and even cultural implications. It interestingly offers a variety of design opportunities to engage with citizens, to empower them, and enabling a social fabric to be increasingly reflexive and responsive. (p. 179)

In the epidemic context, citizens' data are captured, and their participation helps in getting information and transforming it in public actions more efficiently. The digital application is an unfinished product; it could be improved through user interaction and participation.

2. CASE STUDY OF APPLICATIONS FOR COVID-19 CONTROL

Given the infectiousness of COVID-19 pandemic and the high transmission from presymptomatic individuals, manual control of contact tracing is infeasible. The use of a contact-tracing app that builds a memory of proximity contacts and immediately notifies positive cases would be more efficient in reducing the epidemic, in particular when combined with physical distancing. (Ferretti et al., 2020)

When the World Health Organization (WHO) decreed the pandemic, March 11, and began to discuss ways of control, some organizations created initiatives to develop technologies to monitor and, also, respect privacy. In Europe, following the GDPR, a group called Pan European Privacy-Preserving Proximity Tracing (PEPP-PT[1]) created a platform for proximity tracing with a privacy-preserving approach. Google[2] and Apple[3] also jointly created the Exposure Notifications System, which uses Bluetooth technology to identify the contacts through encrypted keys in the device operating system.

This article reports a desk-research, during June 2020, with information about applications for mapping the coronavirus epidemic in several countries. We choose ten examples (Figure 1) from different continents that track the population or alert about possible contamination.

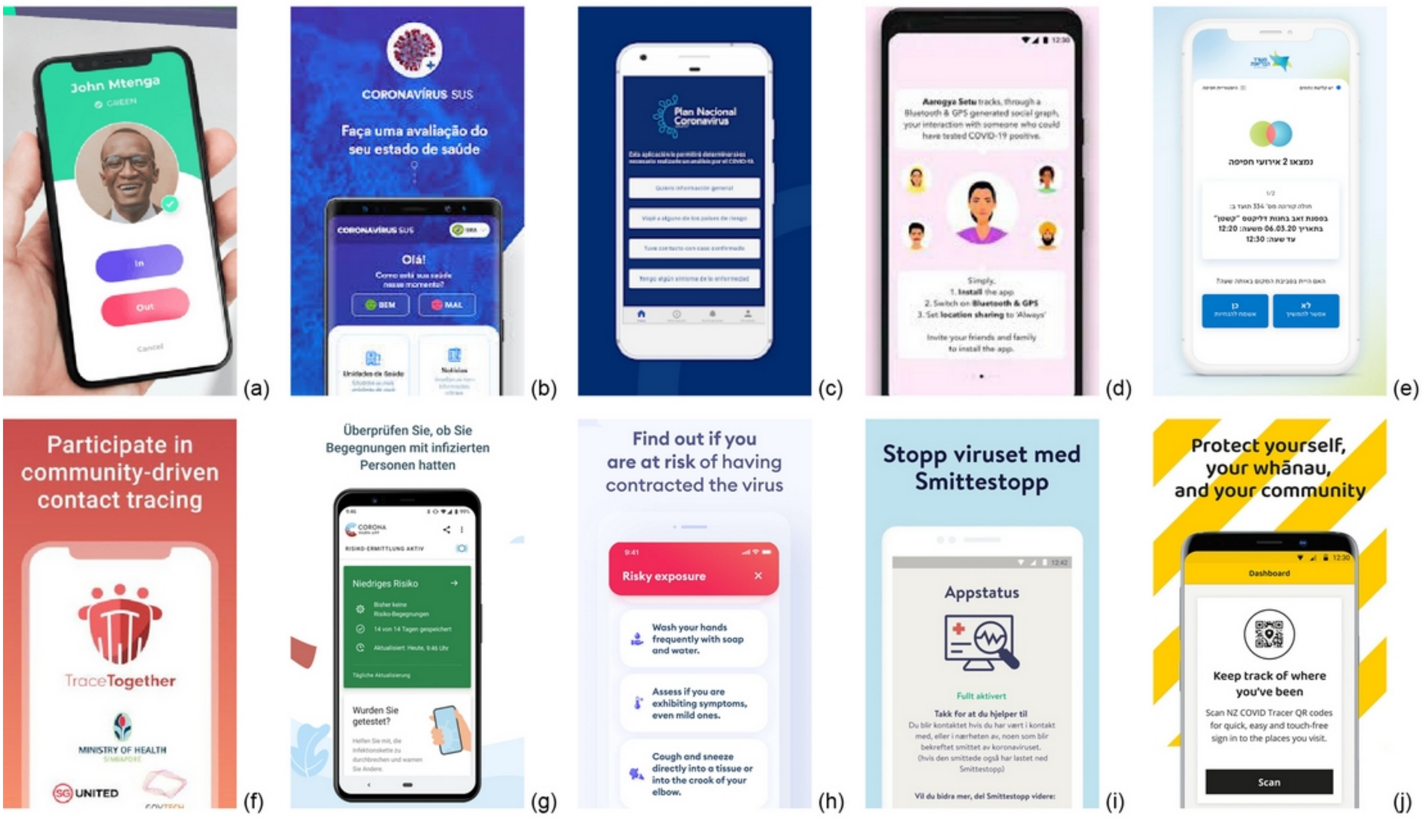

Figure 1. Applications screen: (a) South Africa - Covi-ID, (b) Brazil - Coronavirus SUS, (c) Uruguay - Coronavirus UY, (d) India - Aarogya Setu Mobile App, (e) Israel - HaMagen, (f) Singapore - TraceTogether, (g) Germany - Covid-Warn-App, (h) Italy - Immuni, (i) Norway - Smittestopp (j) New Zealand - NZ Covid Tracer app.

We chose nationwide applications, so examples from the USA were not selected because its initiatives came from each state. We researched official communication sources; therefore, applications from China and South Korea were also not selected because they did not

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provide information in English, which made analysis impossible. These sources were considered because the goal was to analyze public communication.

We analyzed how the population is using the apps during the research period, although it is not a strict experience, as the situation quickly changes and some updates could not be covered. We searched for the apps on the government official websites, in the Apple and Google stores of each country, and on the WHO website.

Table 1. The data investigated in the study.

• Application operation description;	• Who developed it;
• Source data location;	• Source data from COVID-19;
• Device permissions;	• How long personal data is stored;
• If the user can delete your data;	• Mention of citizen participation;
• The privacy policy and explanation beyond the terms of privacy;	• Transparency with the data and what will be done with it;
• Open source code;	• Date of the first confirmed case;
• Date of app release;	• Confirmed cases on the research day;
• Rating in the application stores;	• Number of reviews.

From these collected data (Table 1), we created the applications journey (Table 2) to compare the different stages. The development stage details the involved agencies, citizen participation, and if it is open-source. The usage stage highlights how the app works, the technology to capture location, and health information. Finally, the post-use stage shows when the data is deleted; and the pain points of each initiative.

We observed that there are many technologies for capturing the location: two applications use QR code, two GPS, and six Bluetooth. Of these, three use Exposure Notifications technology, five said they developed with citizen participation, and seven are open source. In Brazil's case, the application already existed before the pandemic; it was updated but still has no contact tracing.

3.RESULTS AND DISCUSSION

After comparing the applications, it is possible to make some relationships, find patterns, and highlight challenges. In the next sections, we divided the insights into four major subjects: technology and data, privacy and transparency, citizen participation and, risks and challenges.

3.1. Technology and Data

After Apple and Google announced a partnership to develop Exposure Notification technology, some countries have released their application or updated to this new technology. Despite this, Bluetooth is still an inefficient technology, as it cannot identify different floors, walls separating people, the type of establishment, or whether it is a closed or open place, for example.

For public services to work efficiently, many systems capture multiple data sources. As Cottrill (2020) summarizes, we can separate them by:

- **Public Data** held by governmental organizations, such as health information provided by the Ministry of Health in the case of Singapore, India, Israel, Uruguay, and Brazil. In New Zealand, Germany, Italy, Norway, and South Africa, the user self-notifies with test information.

Table 2. Selected applications journey

Deployment			Using			After use	
Country	**Built**	**Open Source**	**App**	**Geolocation**	**How it works**	**Stored data time**	**Pain Point**
South Africa	Research Center	✗	Covi-ID	QR code	The citizen generates an ID with QR code that has health status. Trader download an app that scans it and identifies an infected person	As long as it takes	Organizations checking who is free can be invasive and embarrassing.
Brazil	Governance	✓	Coronavirus SUS	GPS	The application does not track, it has information about the disease, symptoms check, nearby hospitals, among others	Not specified	The content is a pocket website version, with no need to download.
Uruguay	Governance, Citizen Participation	✓	Coronavirus UY	Bluetooth	With the Exposure Notifications technology, the application traces and notify contacts if someone has reported infection	15 days	With a few cases, the government needs to convince the population of the app utility.
India	Governance, Citizen Participation	✓	Aarogya Setu Mobile App	Bluetooth	The application detects other devices with Bluetooth, exchange digital signature with information about time, location, and duration.	Negative: 30 days Positive: 60 days	Data shared with many agencies, making privacy difficult.
Israel	Governance, Citizen Participation	✓	HaMagen	GPS	Crossing the smartphone GPS history with the geographic data patient history	Location: 7 years Other data: 30 days	Population confidence in government and data usage.
Singapore	Governance, Citizen Participation	✓	TraceTogether	Bluetooth	The device stores the data. It will only be shared with the government if the user tests positive	25 days	Bluetooth may not be accurate.
Germany	Governance, Citizen Participation, Research Center	✓	Covid-Warn-App	Bluetooth	Exposure Notification technology creates a temporary encrypted ID. Citizens can voluntarily report they positively tested, share their temporary key, and the app notifies other contacted devices	Negative: 14 days Positive: 21 days	Many companies involved, making privacy difficult.
Italy	Governance	✓	Immuni	Bluetooth	Exposure Notification technology, a health professional inserts the COVID-19 test voluntarily	Until December 31, 2020	Released after the epidemic peak, citizens may not engage.
Norway	Governance, Research Center	✗	Smittestopp	Bluetooth, GPS	If diagnoses COVID-19, the app identifies other users who have had contact. Everyone will receive an SMS with recommendations	30 days	They discontinued the app because of personal data usage.
New Zealand	Governance	✗	NZ Covid Tracer app	QR code	The user creates a digital diary of the visited places by scanning the official QR codes at the entrances to business premises, other organizations and public buildings.	31 days	Population and organizations engagement.

Application development participation: Governance Citizen Participation Research Center

Technologies for capture location data: Bluetooth GPS QR code

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- **Private Data** acquired by a private firm, such as mobile phone usage, data from RFID tags and QR code, as in New Zealand and South Africa.

- **Data Exhaust** often useful when combined with other data sources. Such data may include internet search histories, location traces from mobile phones, or interaction records from Bluetooth Exposure Notification technology, used by Germany, Italy, and Uruguay. Or, yet, to track cellular networks, as in Brazil and Israel.
- **Unstructured Community Data** captured as part of social interactions, such as the research groups Ghost Data and Visua in Italy, which identified several violations through Instagram photos with tagging in lockdown regions. They offered this technology to the government, but it was not used in the app.
- **Self-Quantification Data** revealed by individuals through self-monitoring or tracking. Singapore is testing to replace the Trace Together app for a device the user would carry with them. (Balakrishnan, 2020)

Some countries analyze the contagion by self-assessment, which is a reasonable alternative when there are not enough tests to verify the entire population. In the case of India, they categorize the users into four risk status, assessed by themselves or by official tests: for example, the orange risk reported the symptoms and the red one tested positive.

3.2. Privacy and Transparency

Applications can be sorted into two groups: centralized, those with data processing on cloud servers; and decentralized, with processing within the devices. In the centralized model, health authorities have higher control, while the decentralized offers more security for citizens' privacy. Apple and Google support the decentralized model. In Germany, they emphasize the project's philosophy is the decentralization of technology; the population has more confidence, and the government does not concentrate on data storage.

We analyzed the ten applications from the seven privacy principles from Cavoukian (2009):

- **Proactive not Reactive; Preventative not Remedial:** nine applications already have clear information about the privacy policy and the data destination on the official website. In Brazil, the privacy policy was only found in the application, upon download.
- **Privacy as the Default:** eight applications explain how long the data will be stored, and that it will be automatically deleted after a certain time, without requiring any user action. The only ones that do not specify are South Africa and Brazil. In Israel, even those location data considered irrelevant will be stored for seven years.
- **Privacy Embedded into Design Privacy:** seven applications make open-source code available and invite people to participate and inspect the code security. The only ones that do not mention being open source are New Zealand, Norway, and South Africa.
- **Full Functionality:** Exposure Notification technology creates a temporary identity and does not require the user to be logged in; you can use the application without providing personal data. The apps with this technology are from Germany, Italy, and Uruguay.
- **End-to-End Security:** Some applications have partnerships with several companies and government agencies; sometimes from different countries, so with different

legislation. Thus, they need to be responsible for data in all processes, which can be more difficult, as in the cases of India, Israel, Germany, and South Africa.

- **Visibility and Transparency:** Even declaring that a lot of user information is not required, some applications ask for permission to access many device features, such as Singapore, Israel, and South Africa.

- **Respect for User Privacy:** Not all applications clearly explain how the user can request their data, as in Israel, Italy, and Brazil.

Society has been discussing privacy, and many applications already have concerns about these issues. As the legislation is different in each country, the approach is more or less restricted.

3.3. Citizen Participation

In general, the applications' promotional material invites the population to help fight the coronavirus. Being everyone's problem, they claim that citizen participation will bring more data and better results. We highlight some projects that report citizen participation, at the beginning and during the use of the app, from:

- **South Africa:** They developed the application to include people without technology; thus, to use the QR code, users without a cell phone can print the code and take it in their pocket;

- **Uruguay:** The government credits the Uruguayan technicians' efforts and the participatory attitude of all citizens for the country position with cutting-edge technology and to implement, verify and certify the app;

- **India:** There is a reward program for those who find a bug in the app and help to improve security;

- **Singapore:** The government's digital services agency proposes to design for citizens, bringing solutions after listening to them. They constantly test and iterate to understand citizens' pains and to build better products;

- **Germany:** The government website invites all citizens to participate in application development. They credit the global open source community as a partner;

- **Norway:** Initially they tested in three cities before expanding to the entire country. The idea was to find out if it would have adherence and improve the product, but it was not completed;

- **New Zealand:** The app only works with active citizen participation: the user should scan manually the QR code, and the company voluntarily prints the poster.

Despite the official sites report of citizen participation, as described above, we did not find an explanation for this occurrence. Thus, it is challenging to explore what is efficient and engaging. Anyway, we noticed higher cooperation in the code development of the applications.

We analyzed the development applications time, as some took longer since the first case of COVID-19 or since WHO declared a pandemic (Figure 2). Thus, the released time influenced

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the application's performance. Also, we highlighted the announcement of the Exposure Notification technology, which some countries used later.

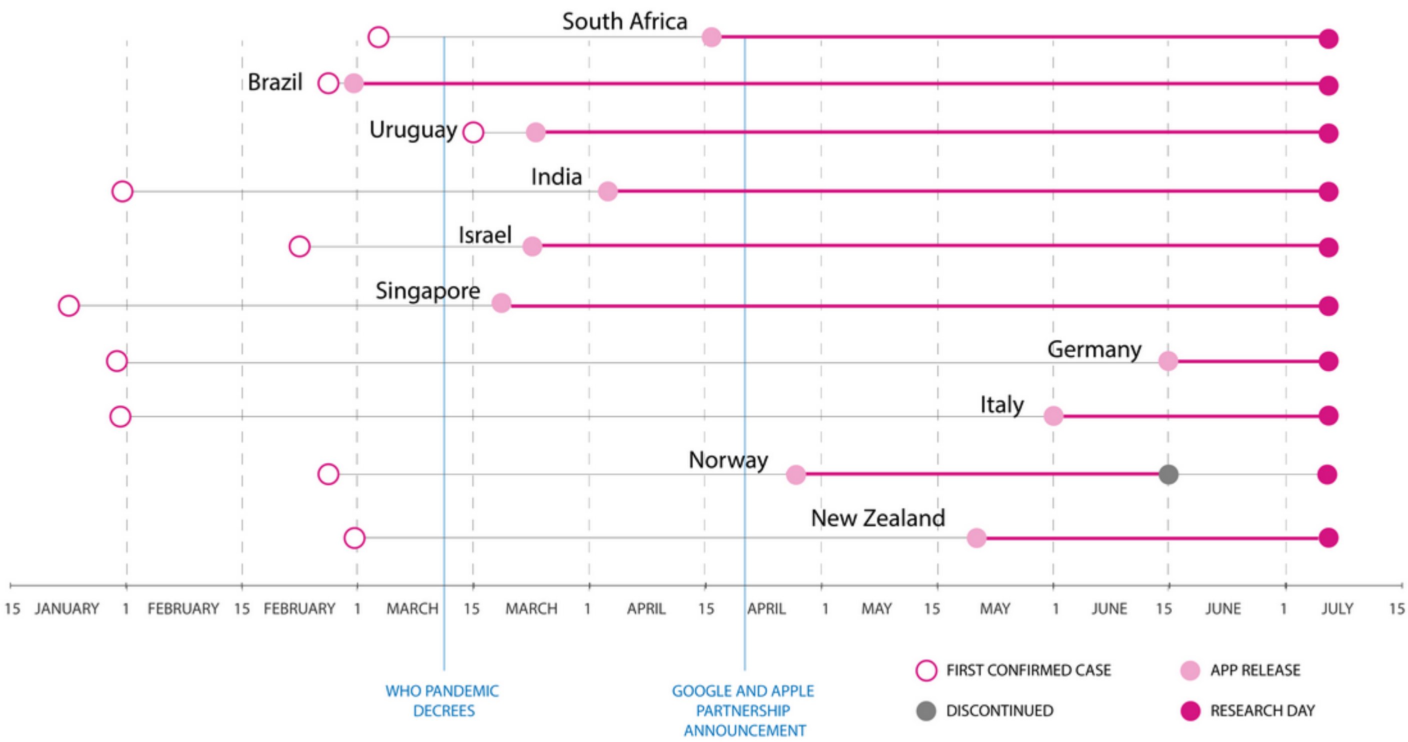

Figure 2. Development applications timeline.

The apps' effectiveness is yet unknown, as they have been running for a short time and there are other factors involved. In the case of Italy, for example, the application was launched after the country's epidemic peak; therefore, perhaps citizens are no longer so engaged. In Uruguay, as there are few cases, the communication emphasizes that, even so, it is important for the population to use the app.

Figure 3 shows the relationship between the average application rating in Apple and Google stores by the number of confirmed cases on the research day (5/7/2020), the number of user reviews per day (since some applications have been available for longer), and if the code is open.

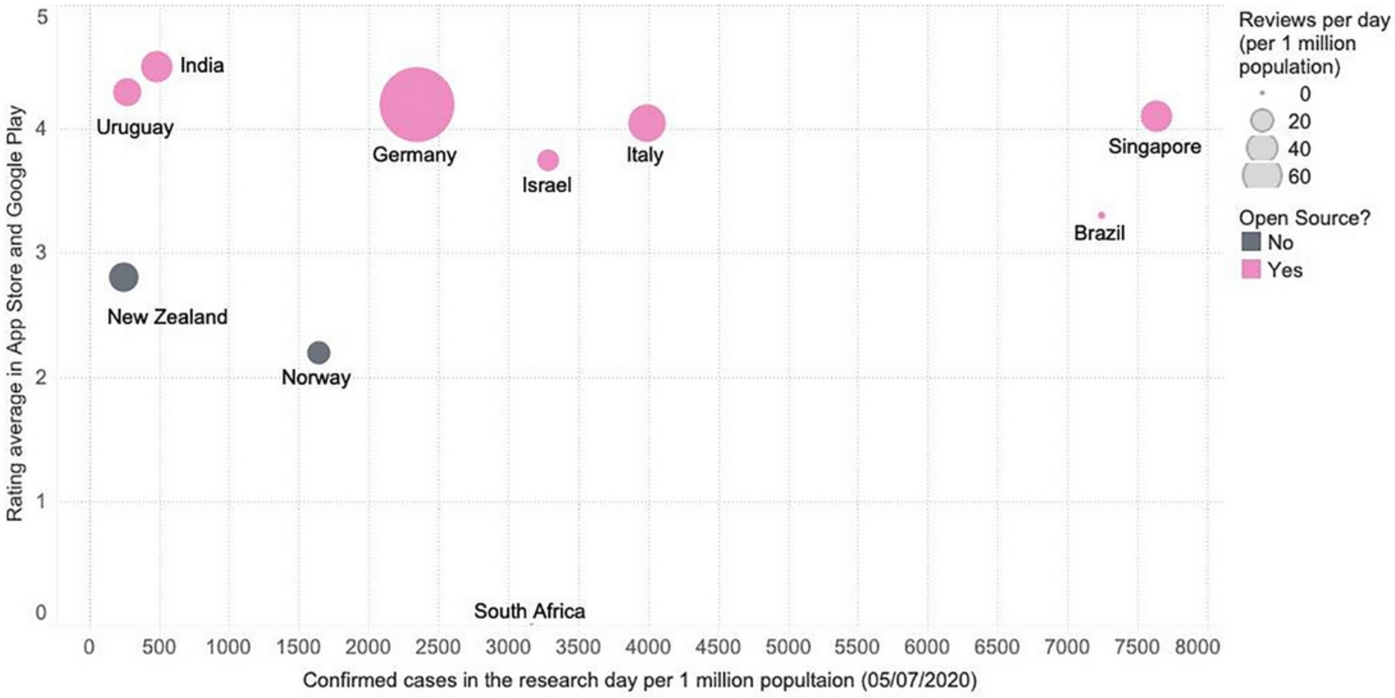

Figure 3. Chart with applications rating per confirmed cases.

The best rating apps in app stores is open source. However, it is not possible to make a direct relationship between the evaluation of the application with combating new confirmed cases, as there are many factors involved.

3.4. Risks and challenges

The challenge is not only to know where a person went but also the type of place. Marino et al. (2020) say that a multidisciplinary approach is necessary, as the complex simplification of a heterogeneous territory ignores essential urban elements to understand higher or lower propensities to contagion.

Another issue of ethics and privacy is the South Africa case, where business employers are responsible for scanning QR codes and checking who is allowed to enter. This dynamic can be very invasive and embarrassing, even more, if the country has a racial segregation history.

In Brazil, the lack of data transparency and application utility are challenges, since the app's content was available in other media. This lack of clear utility added to the privacy issues also bring doubt on the relevance of these products. In the Norway case, the application has already been discontinued; the Norwegian Data Protection Authority notified it about data use. They believe that COVID-19's low cases do not justify the privacy violation.Figure 3. Chart with applications rating per confirmed cases.

Another challenge is transparency and trust from the population to enable their participation. According to Kitchin et al. (2015), when people play a central role in data gathering, it is assumed an objectivity method to produce transparent, impartial, and bias-free data. Data can be measured and recorded in numerous ways, and each can be interpreted differently.

For Carugati (2020), a possible solution for fairer technologies is to create a citizens' council that regulates the algorithms. Resolving social problems requires that many voices be heard, the original lesson of democracy, meaning better citizen governance.

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The partnership of different authorities is important for transdisciplinarity in innovation. According to Mulder (2018), when a core group is shaped from a bottom-up initiative, it has strategic support included and remains representative of the community in general. Co-creative partners participate in multiple initiatives, which allow them to act as connectors and cross-different levels in the ecosystem, strengthening the social fabric.

This partnership is important not only to ensure the project continuity but also because transdisciplinarity brings different visions to innovation. For Manzini (2015), design for social innovation helps the protagonists to achieve results they would not be able to achieve alone. These social forms "appear with widely differing characters and purposes, but they have one clear characteristic in common: their existence requires the active, collaborative participation of all interested parties." (p.77)

4. CONCLUSIONS

The study results may contribute to designers by giving information on privacy issues in handling citizens' data, an overview of available technologies, the challenges faced, and how to communicate clearly with the population. As presented previously, this research was a temporal cut. The study had a time limitation, so it was not possible to evaluate the product full cycle, such as it was elaborated and concluded.

Therefore, it would be relevant to analyze the applications during and after the pandemic to understand if their use will continue, if the data will be erased or manipulated for other purposes, and if this type of application was relevant in this context. For future work, the research could investigate apps in languages other than English and federal apps. Some cities' populations could be larger than in some countries.

The information available in the official media is limited and partial, so the researcher should investigate with transparency and without biases. Being a time frame, technologies can change, applications can be updated, or others can arise, but the concepts analyzed in this research are broader. They can be discussed and applied in other initiatives, not only in the pandemic context.

ACKNOWLEDGMENTS

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ENDNOTES

[1] https://www.pepp-pt.org/

[2] https://www.google.com/covid19/exposurenotifications/

[3] https://www.apple.com/covid19/contacttracing

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Design Strategy and Case Study of Distributed System Resilience in the Chinese Context

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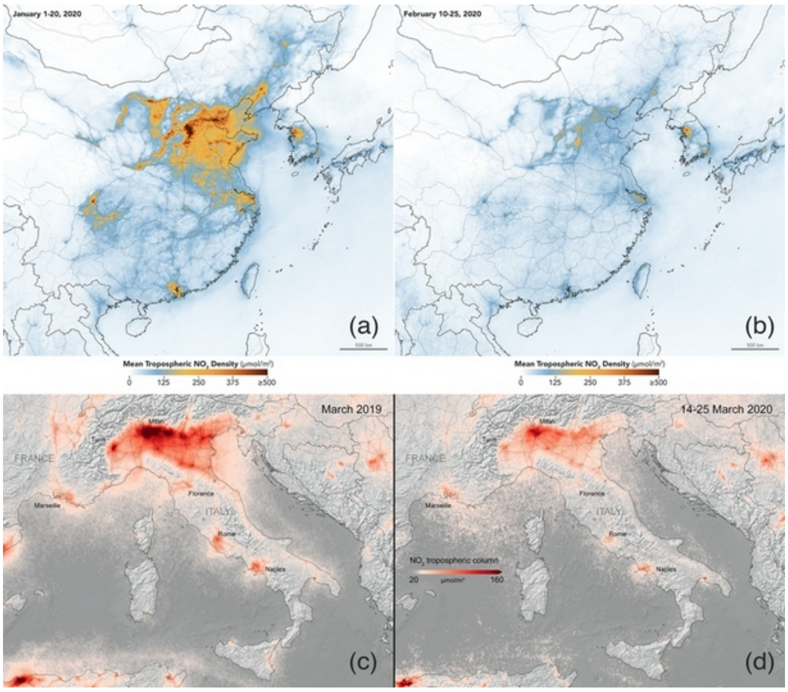
ABSTRACT

Whether for a large-scale complex challenge or a radical change, a more resilient and sustainable socio-technical system needs to be implemented. The distributed system is a new trend of sustainable transition of the socio-technical system, and the research on its related design strategies contributes to a better understanding of its nature; moreover, it helps to define the role of designers, allowing them to deal with future challenges in a more controlled manner. This paper reveals an in-depth understanding and discussion on the resilience of socio-technical systems and on the relationship between distributed systems and resilience. It selects and analyzes three representative cases, combined with a series of response measures taken by Wuhan, China during the COVID-19 outbreak. Three types of distributed system design strategies suitable for China are identified.

Keywords: Radical change, distributed economics, distributed system model, socio-technical system, resilience

1. PANDEMIC AND RADICAL CHANGE

As of June 2020, the sudden COVID-19 pandemic had infected more than 10 million people, becoming perhaps the greatest global challenge faced by mankind since World War II (UNDP, 2020). Research from NASA and ESA shows that in China and Italy, where the situation was most severe in the early stage of the epidemic, the NO2 concentration in the atmosphere changed significantly within two months of the outbreak. This reveals that the spread of the virus has had a serious impact on human activities worldwide. People have realized that the implications of such radical change extend to a global scale and that the threat and impact of the virus goes far beyond human health; in order to prevent the spread of the virus as effectively as possible, the world has entered a “great pause” (Janoo & Dodds, 2020). Many countries have closed their borders, and remote working and the online life have gradually become the norm. A study from the Harvard School of Public Health believes that COVID-19 will continue to affect the world in social, economic, and other fields in the next five years (Kissler, Tedijanto, Goldstein, Grad, & Lipsitch, 2020), meaning that humans must learn how to coexist with the constantly mutating virus. At the same time, the “great pause” has made us realize the fragility of our socio-technical system (STS) and triggered a series of discussions about social, economic, and cultural resilience and adaptability.



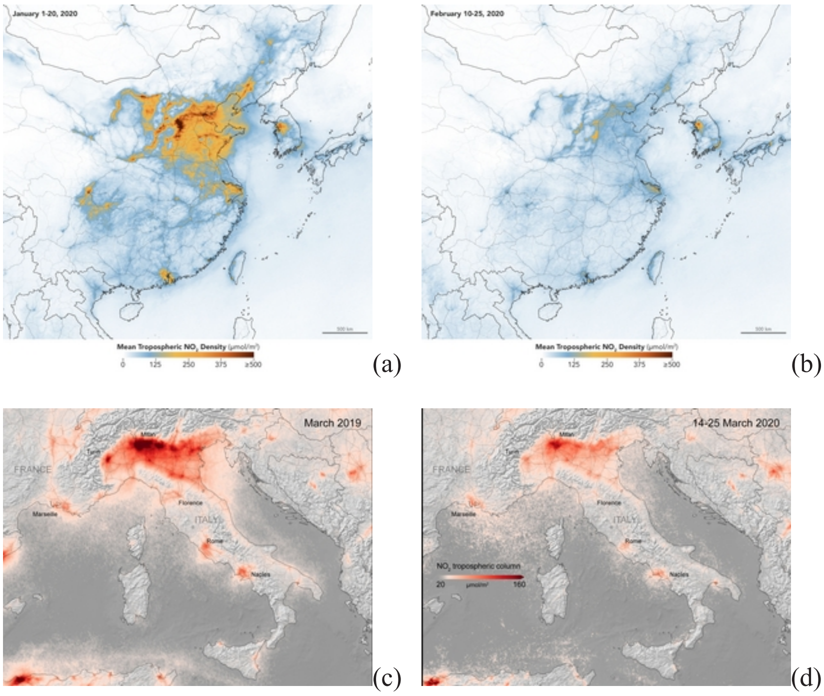


Figure 1: Changes of NO_2 concentration in different regions and time periods. Jan 2020, China; (b) Feb 2020, China; (c) Mar 2019, Italy; (d) Mar 2020, Italy

A substantial part of the research on radical change comes from discussing how to trigger a transformation of the existing development model into sustainable development through technological innovation, social innovation, and business model innovation (Leong, 2017; Stø, Throne-Holst, Strandbakken, & Vittersø, 2008; Tischner & Verkuijl, 2008; Verganti, 2008). Although we have always been aware of the possible impact of climate change, financial crisis, war, and other factors, we are still relatively optimistic that we have enough time to devise countermeasures. Despite being warned about the 2° Fahrenheit increase in global warming, we believe that it is not too late. Before COVID-19, there was no imminent risk that could stop society's current development model; for this reason, new sustainable economic paradigms such as circular economy and distributed economy could not disrupt the mainstream status of Business as Usual (BaU)(Temesgen, Storsletten, & Jakobsen, 2019).

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However, the radical change brought by the outbreak of COVID-19 completely changed the trajectory of globalization.

All industries, individuals, and organizations have stepped up the fight against the pandemic, and designers are no exception. On GitHub, designers from all over the world have contributed several pieces of personal protective equipment (PPE) that can be 3D-printed. Many "designs for epidemics and health" have also emerged on major social media and design platforms, covering everything from products to service systems. However, it should be noted that in the face of radical change, a superficial design movement cannot fundamentally solve the problem. As designers, we must acknowledge that the root cause of the problem is not only a tangible lack of infrastructure and equipment but also the lack of resilience of the STS that supports our society's operation during the epidemic is the core problem that needs to be resolved. Designers need to examine and understand the STS under the influence of radical change and wicked problems through a more flexible, systematic, and broad perspective (Manzini & M'Rithaa, 2016).

2. RADICAL CHANGE CALLS FOR A RESILIENT SYSTEM —— DISTRIBUTED SYSTEM

For a long time, human society has been a "risk society" surrounded and affected by severe events such as natural disasters, wars, financial crises, and climate change. Therefore, the sustainability of a society lies in its recoverability to overcome crises and resist pressure and destruction (Beck, Lash, & Wynne, 1992; Manzini, 2015; Walker & Salt, 2012); in ecological and social ecosystems, Holling calls this *resilience* and defines it as the persistence of a system's relationships and ability to absorb external changes (Crawford S Holling, 1973; Crawford Stanley Holling, 1996). With periodical changes and development, the concept of resilience has also begun to be widely used in the discussion of STSs. Taysom and Crilly proposed three main characteristics of resilience in STSs (Taysom & Crilly, 2017):

- **R1-** resilience to resist changes and influences
- **R2-** resilience to regeneration and recovery
- **R3-** resilience to adaptation and change

These three characteristics can also be expanded as three strategies for providing resilience to STSs:

- **S1'-** Respond to the changes and impacts caused by radical change through strengthening and resisting
- **S2'-** Respond to the changes and impacts caused by radical change through regenerating and recovering
- **S3'-** Respond to the changes and impacts caused by radical change through adapting and changing

With the continuous integration of social and technological innovation, a new STS created by a distributed system is gradually replacing the traditional centralized system. The structure of the distributed system shifts from a hierarchical to a heterarchical one. Compared with the central system, the distributed model (whether an economic or a system one) is considered to effectively improve the resilience of infrastructure, promote social innovation, and reduce environmental pressure (Biggs, Ryan, & Wiseman, 2010; Manzini, 2015; Manzini & M'Rithaa,

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2016). Especially in the production and consumption fields, such as food production, renewable energy generation, manufacturing, information and knowledge, and so on, distributed systems have been widely promoted, gradually penetrating and affecting the existing economic model (Emili, 2017; Kohtala, 2016; Petrulaityte, 2019).

With the transition from centralized to distributed system, resilience is closely related to its degree of distribution. To better clarify this connection, we propose a model describing the relationship between the degree of distribution and system resilience. The relationship between the distribution degree of a system and its resilience are explained in Figure 2. When the degree of distribution of the system is low (centralized system), a large-scale and high-complexity task or challenge (or a radical change) requires the system to utilize a certain amount of resources and energy support, and the challenge (radical change) puts the system under great pressure. As the system gradually transforms from centralized to distributed, the time, resources (materials, people, and so on), capital, and energy required for the system to deal with large-scale and high-complexity tasks gradually decrease and eventually become tasks performed by independent nodes (i.e., from ENIAC to laptop). At the same time, the system will also face new, more complex and large-scale tasks/challenges. With the further integration of technology and social innovation, a complex large-scale task will eventually be borne by the creativity and productivity generated by a node, and the STS at this time can face more complex challenges. This is a dynamic process of reciprocating cycles; on the one hand, it can be understood as a positive correlation between the degree of system distribution and system resilience, that is, the higher the degree of system distribution, the stronger the system resilience; on the other hand, it also revealed that in the face of complex and changeable systems and scenarios, we must flexibly choose and apply appropriate strategies to improve the resilience of the system.

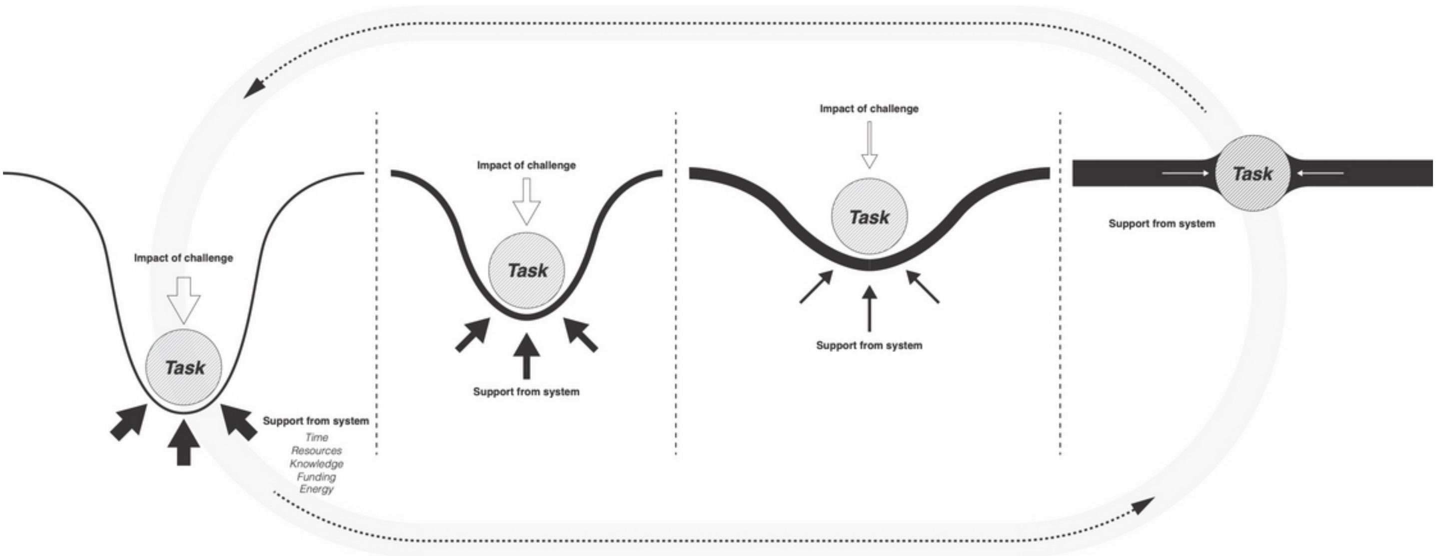

Figure 1: The relationship between the degree of distribution and flexibility of the social technology system (Author Credit)

From the perspective of social organization structure, China's social technology system is a highly centralized hierarchical structure; on the other hand, its technical system has formed a highly distributed heterarchical structure. Due to this combination of organizational centralization and technology distribution, China's choice and application of resilience strategies when facing radical change is unique. We will expand on this uniqueness further by exploring three cases that highlight the kind of alternative solutions that we might be able to create if we could build a better understanding of the system.

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3. CASE STUDIES

The following three cases are from Wuhan, China during the COVID-19 pandemic and represent three different response methods of the system in the face of radical change. The three cases correspond to the resilience of resisting change, the resilience of regeneration and recovery, and the resilience of adapting to change, respectively and reveal the differences and reasons of the strategies adopted by the system under different elasticity driving.

3.1. Square-Cabin Hospital In Wuhan

In the early stage of the epidemic, all hospitals in Wuhan and the surrounding cities experienced severe congestion, and many patients or suspected patients swarmed in for further testing, diagnosis, and treatment. In the face of such emergencies, the entire medical system of Hubei Province faced the dilemma of a lack of resources (medical equipment, beds, and so on), manpower, and experience. The most severely affected medical system in Wuhan and the surrounding cities found itself on the verge of collapse. To cope with the situation, the government decided to establish temporary square-cabin hospitals. Since January 23, 2020, 16 square-cabin hospitals had been constructed, and a total of 12,000 patients had been admitted. The separation of patients in the square-cabin hospital was effective. The ground eased the pressure for hospitals in Wuhan and the surrounding areas. In April 2020, all square-cabin hospitals in Wuhan were closed, marking that the COVID-19 pandemic has been effectively controlled in China—at least temporarily.

Figure 3. Top view of the square-cabin hospital in Wuhan (Credit: The Telegraph, 2020)

The first way to deal with the radical change system is to quickly resist its impact by implementing some kind of change that would prevent the system from crashing in a short period of time. From the case of the square-cabin hospitals, it can be learned that the vast majority of resources, funds, and energy can be selectively and temporarily mobilized in local areas to complete a large-scale and highly complex task through a top-down strategic system. By increasing the number of nodes in a short period of time and establishing connections with the system, it can gain time for the system to make necessary adjustments when facing radical changes and reduce damage to a certain extent. However, we cannot expect a central top-down strategy to provide permanent protection once and for all. This strategy may only be a short-term emergency measure, but it will be highly effective. Both Beijing during the SARS period and Wuhan during the COVID-19 period proved this point.

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3.2. Doctors' Inn

On January 23, 2020, Wuhan has shut down due to the pandemic and suspended all public transportation in the city. Many doctors and nurses could not return home to rest or reach their workplace smoothly due to traffic reasons. Xiao Yaxing, a hotel manager in Wuhan, launched a hotel support service for a medical staff, established a fast communication and information release platform through WeChat's group function, and united a total of about 300 local hotels to provide accommodation for doctors and nurses in nearby hospitals. Taking advantage of the relative convenience of hotel's location, it was used as a transfer station for materials, so that the support team in the surrounding area could pick up and drop off materials when passing through Wuhan. These hotels used as temporary residences for medical staff are called "doctors' inns."

Figure 4. Volunteers preparing medical resources for the hotel (Credit: Kai Xiang, 2020)

The second response to the radical change system is to remedy the system through bottom-up, spontaneous behavior. After top-down measures have gained time for the system, the system needs a more durable strategy to cope with challenges and increase flexibility, which requires nodes in the system to adopt a more proactive approach. In the case of the doctors' inns, we find that the occurrence of a radical change will cause the connection between nodes in the system to be severed, and the bottom-up approach can quickly restore this connection in a short period of time. The above strategy can also strengthen the node that originally formed a weak connection in a short time and "grow" a stronger network in the process of system recovery.

3.3. Community Griders & Volunteers

Since 2019, the Wuhan Municipal Government has standardized the community grid for urban management in accordance with the standard of 300–500 households, or a resident population of about 1,000, and has assigned a "grider" as manager for each grid. The main responsibility of the grider is to inspect and discover problems in municipal engineering (public) facilities, city appearance, and environment as well as social management affairs in their management area (namely the grid) and to verify, report, and record them; the grider is also responsible for notifying the related unit that is responsible for the problem and assisting in solving it. At the same time, the grider is responsible for collecting, sorting, and analyzing related information and data of their community, advancing suggestions for urban governance optimization in the grid. After the outbreak, griders, as the people with the clearest information and conditions in the community, became a critical hub and link point in

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community control and management. However, due to the complex situation, the number of grid members was limited, and each family's situation was different; similarly, the large number of people complicated the situation. Therefore, a group of volunteers including community leaders and administrators was temporarily recruited for maintaining daily life and provide supplies to the residents of the entire community.

Due to the lockdown of the city, all communities in Wuhan adopted a 24-hour closed management. Many communities have elderly residents who do not use the internet or mobile phones for shopping; therefore, a considerable number of them had to rely on community grid members to assist in the purchase and delivery of food and medicine. In addition to the medication problems of critically ill patients, community griders were also responsible for distributing everyday supplies in the community and for keeping statistics and managing the health status of the residents in their community.

Figure 5. Grider Feng Feng helping elderly people purchase daily medicine (Credit: Xingxin Zhu, 2020)

The third strategy for dealing with radical changes is to gradually form/generate a new mechanism in the process of bottom-up and top-down actions, which can be a new policy, a new mechanism, new social consensus, and so on; in this way, the system can adapt to making changes in the face of impact. Hybrid strategy requires the system to propose a new and far-sighted strategy from top to bottom before radical change occurs and put it into practice. At the same time, the grassroots/bottom nodes have a clear understanding of related policies. When the radical change comes, each node has a clear understanding of its own responsibilities/responsibility, and the relationship between the nodes will follow the challenge according to the impact, flexibly adjusting the strength of the relationship between different nodes.

4. DISCUSSION

Through the discussion of the cases above, we identified the strategies and mechanisms of a system for responding to radical changes in three different scenarios:

1. Bid time for the system through a top-down approach (temporary, partial, and selective) – **resisting**
2. Through a bottom-up approach, nodes autonomously and spontaneously rebuild and strengthen connections (weak social relations briefly become a strong relationship) – **recovering**

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3. Hybrid, top-down, predictive, preventive mechanism + combination of self-organizing behavior of bottom nodes (establish a long-term cooperation) – **adapting to change**

These three strategies provide inspiration for how designers can make more effective design interventions for more resilient STSs.

First, we believe that with the continuous integration of technology and social innovation, the popularization of distributed systems will enable society to have better resilience in response to radical changes. However, at this stage, we also cannot ignore that the centralized strategy will have a significant positive effect in dealing with great changes by mobilizing social resources and concentrating power in a specific region, system, and cultural context. The formulation and implementation of this top-down strategy requires a decision maker and a policy maker to develop a more comprehensive and far-sighted strategy with broader system thinking; on the other hand, it also requires more designers to participate. In the strategy formulation process, a kind of "glue" is used to fill the gap between different stakeholders.

Second, in the post-pandemic stage, design needs to participate in the creation, repair, and regeneration of the STS in a more active way, injecting greater vitality and greater flexibility/ resilience into it. At the same time, we have also noticed that some practices based on distributed system models play an active role in the epidemic. With the support of distributed design and manufacturing, local residents can obtain PPE and information/knowledge more conveniently and quickly. With the help of social media platforms, which are even faster and often more accurate than the government, an information platform regarding the spread of the epidemic has been created for public reference. In the future, we believe that more distributed economic models will have a greater and more positive impact on the resilience of the STS at different levels, which will surely generate a large number of new design opportunities, design strategies, and design methods.

Last, design interventions should be more deeply involved in activities that change system resilience rather than shallow interventions. In the superblock project in Barcelona, the designer deeply engaged in the cooperation between the Barcelona City Council and the Urban Ecology Agency, reshaping the neighborhoods of Barcelona, providing high-quality public space for local residents, improving the mobility of the streets, and enhancing social cohesion. It is worth learning that the implementation of superblock shows that the improvement of the STS does not often require huge changes or the reconstruction of a large part of the infrastructure. This purpose and effect can also be achieved through small-scale, low-cost actions; therefore, in the future design of distributed systems, the participation of all stakeholders, especially low-level citizens, will be a key point of the design process, representing one of the best ways to ensure that the design output is accepted by society.

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STRATEGIC DESIGN RESEARCH JOURNAL

Strategies of Design for Social Innovation and Design Activism in the Promotion of Positive Social Capital During the COVID-19 Pandemic in Brazil

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ABSTRACT

This case study aimed at mapping initiatives of social innovation that have promoted positive social capital during the COVID-19 pandemic in Brazil. To this end, information about the actions and their developers were collected online and further described using the forms "Light Format" and "In-Depth Format", from the toolkit developed by the Design for Social Innovation and Sustainability (DESIS) Network. In addition, interviews with the people involved in the projects were carried out in order to obtain further details. From the promising cases mapped, 15 were selected and categorized according to their field, coverage area and target. Finally, the initiatives were assessed based on the concepts of design for social innovation (Manzini, 2008) and design activism (Fuad Luke, 2009; Thorpe, 2012). The analysis showed that whether the actions proposed had the design framework conceptions as a theoretical basis or not, the projects indeed adopted design strategies to reach their goals, leading to positive impact in the social, economic and environmental areas and thus promoted positive social capital.

Keywords: Design for Sustainability, Design for Social Innovation, Design Activism.

INTRODUCTION

The course of the COVID-19 pandemic in Brazil, as in many other countries, has been catastrophic. The country is among those where fewer tests per million habitants are carried out (Ritchie, 2020) and also one of the few where the central government is against physical distancing and quarantine measures to contain the spread of the virus. According to the World Health Organization (WHO), without proper testing, contact tracing and isolation of confirmed cases, the disease can spread quickly and cause societal and economic disruption in addition to shocks in the health and social care systems (WHO, 2020a). In this sense, studies based on the 1918 flu pandemic have shown that the faster and the stronger is the response from the government, the better is the economic recovery (Dizikes, 2020).

For developing countries, the novel coronavirus (SARS-CoV-2) poses extra challenges. In Brazil, approximately ¼ of the population was living below the poverty threshold in 2018, according to reports released by IBGE, the Brazilian official statistics institute (Neves, 2019). Since housing and sanitation had already been far from the ideal prior to COVID-19, the simplest of the recommended precaution against the virus—i.e., washing the hands—is hindered even more (WHO, 2020b). Furthermore, aid actions from the central government towards the population have been scarce during this time (Schymura, 2020; UOL, 2020). Hence, the sum of these factors leads the country to become the new global epicenter of the pandemic (Gamba, 2020).

Despite the critical scenario, signs of solidarity have also arisen in Brazil. Some companies have arranged coordinated actions to support small businesses as well as to facilitate fundraising for poor communities (Labs, 2020); some of these actions can in fact be described as social innovation initiatives. Therefore, the goal of this paper is to map which of them can be classified as social innovation initiatives according to the description forms "Light Format" and "In-Depth Format" from the toolkit developed by the Design for Social Innovation and Sustainability (DESIS) and details obtained from the projects' developers. The assessment of the initiatives was based on the concepts of design for social innovation (Manzini, 2008; Thorpe, 2012) and design activism. The analysis also took into consideration the cases whose actions were replicable to other contexts or not.

1. DESIGN FOR SOCIAL INNOVATION AND DESIGN ACTIVISM IN THE PROMOTION OF POSITIVE SOCIAL CAPITAL

When it comes to sustainability and promotion of sustainable lifestyles, designers have been, historically and to this day, more part of the problem than the solution of such matters (Papanek, 1973; Dormer, 1990; Manzini, 2008). Nonetheless, with a paradigm shift, this area can contribute for sustainable development, by applying the three pillars of sustainability—environmental, economic and social ones. They must be indissociable, focusing on fulfilling "the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987 p.41).

Developing ideas for design and designers to effectively contribute in such a complex scenario is not a simple task. In fact, it would be likely impossible for someone, being this person a designer or not, to find a solution alone. Therefore, the best and feasible ideas will often come from distributed and team work, especially when considering that the problems themselves vary among countries according to their development rate, among innumerous other factors (Cardoso, 2016).

Over time, designers have started to realize and understand the potential of their field of work in terms of effective transformations. Since their practices are often responsible for either suggesting or setting new lifestyles and values, thus generating societal changes, they have actively sought to balance social, economic and environmental aspects of sustainability in their projects. Although the concepts of sustainability and activism were yet to be defined, early moves had already envisaged such efforts. One of the first initiatives was fostered by the Arts and Crafts movement, which started around 1850 with the aim of claiming better working conditions and wages as well as raising awareness about industrial pollution (Fuad-Luke, 2009). The force of movements such as this one is still spreading and, nowadays, there is probably no school of design worldwide that does not assert minimally the importance of sustainable practices.

In the last decades, the aim for sustainability has become an imperative, as the negative impacts of the contemporary urge for production and consumerism become more evident every year. Consequences such as natural disasters, ascent inequalities, local diseases, epidemics and pandemics challenge people in new and complex ways. Fortunately, human beings are natural problem solvers. Now more than ever, the benefits of the globalized world allow for solutions that had been developed for one particular context to be replicated elsewhere (Manzini, 2015), which is consistent with the Manzini's definition of design for social innovation: "creative recombination of existing assets (...) which aim to achieve socially recognized goals in a new way" (Manzini, 2015, p. 11). In other words, design for social innovation lies on new products, services and models that meet social needs through collaboration and therefore bridge social relationships (Murray, 2010).

In addition to design for social innovation, the authors understand sustainability and better life conditions as goals pursued by the design activism. Activism, by definition, is "the use of direct and noticeable action to achieve a result, usually a political or social one" (Cambridge, 2020). Although activism can also be regressive (Thorpe, 2012), the lens of this article will focus on analyzing the promotion of positive social capital through initiatives that adopted strategies of both design for social innovation and design activism during the COVID-19 emergency context in Brazil. More specifically, this article will address real cases that facilitated collective action, thus generating reciprocity between individuals and communities and, somehow, encouraging civic engagement (Fuad-Luke, 2009).

According to Thorpe (2012), there are some methods among the general activist methods and tactics that are likely applicable as methods for the design activism. The main differences between the conventional and the design-related ones lie on their propositional characteristics—proposing instead of opposing—and their duration. The methods are essentially related with the type of work developed, such as organizing, services, advocacy, mobilization, and solidarity. While organizing is to work within communities, for instance, in design activism this method is described as the use of co-design and other participatory, self-design, or design-enabling processes. Services provide facilities and training, whereas in design it is mostly related to humanitarian design of structures and services. Advocacy is about working on behalf of others, regardless of their involvement; in design activism, it is generally conducted in order to advocate for those that cannot do it for themselves, such as nature and ecosystems. Mobilization is the most ephemeral and conventional method, through which elements of protest, competition and temporary structures[1] are used. Finally, the solidarity method refers to engaging in cultural discourse by making use of critical design, critical architecture, and fundraising (Thorpe, 2012 p. 163).

Tactics are the means to achieve the intended goals. They can be conventional or design-related. Thorpe (2012) presents a list with twelve design activist tactics and their descriptions, ranging from artifacts (protest, service and demonstration), to communication, connection, rating system, competition, exhibitions, research and critique, event, conventional, and social exchange. The tactics, which addressed the closest the mapping of this study, are listed on Table 1. They grounded the choice of the materials and methods protocol used for the analysis of the initiatives.

Table 1: Design activist tactics

Tactic	Description
Service artifact	Service structure, system, product, space, place, plan or graphic: humanitarian aid to victims, for example, of war, disaster, poverty. Some groups are victims of their environments, for example, disabled people.
Demonstration artifact	Demonstration structure, system, product, space, place, plan or graphic: a better alternative to the status quo typically seen as a positive, if imperfect effort[2], a model that others can use.
Connection	Linkages such as doorways, gateways, borders, bridges or view corridors, attempts to make physical or visual links that often repair, restore, signify or enrich social and environmental conditions

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Tactic	Description
Social exchange	Links among people, consultation/stakeholder input, self-build, co-design: efforts to make social connections, and weave social fabric, hinging on specific relationships (as opposed to general ideas of "community").

Note: Additional info and sources if adapted from another document. Adapted from Wolff and Amaral (2016).

The identification of the cases followed Manzini's (2008) principles, and further descriptions were obtained by fulfilling the forms "Light Format" and "In-Depth Format", from the toolkit developed by the Design for Social Innovation and Sustainability (DESIS).

The first stage was mapping several promising cases developed and operated because of the pandemic situation. At first, the research was based on cases reported by the local press or shared on social media, which caused a bias towards Parana region, where the authors live. Due to WHO's and local governments' recommendations to stay at home, in-person visits and interviews, indicated by the DESIS toolkit, were impossible; therefore, the authors decided to expand the investigation to other Brazilian states and also internationally through snowball technique, since the mapping was being performed remotely by digital means. Besides that, cases were also gathered using combined search strings such as 'COVID-19' and 'social projects' or 'innovative projects' or 'mitigating impact' and a temporal filter on Google to assure the initiatives were from mid-March 2020 on.

The next step consisted in analyzing each case separately, having their descriptions completed in the "Light Format" form; then, a pre-assessment of the case was done based on four indicators:

1. Presents a new way of organizing daily life;
2. Offers social benefits;
3. Offers environmental benefits; and
4. Is replicable in other contexts.

If the case fulfilled all the criteria items, it was eligible for further assessment, according to Manzini (2008).

The promising cases collected were categorized in a list which consisted of all the data obtained about them, including contact information of the person (or group) responsible. The initiatives presenting a substantial amount of data, and whose developer was contactable for a follow-up interview, were selected. The interviews aimed at gathering more information to properly understand how the innovative actions work, what their social, environmental and economic benefits are, and whom they favor. One of the interview's outputs is a flowchart of the actions' operation.

After that, each case had its "In-Depth Format" form from the DESIS Network toolkit filled and the data collected in the interviews were arranged in a design for social innovation framework. In addition, the strategies concerning design activism, intentionally or not intentionally adopted, were listed. In order to compare the cases and check for similarities and differences among them, the inputs are presented on the following sections of results and discussion.

2. RESULTS

After filling the "Light Format" form, fifteen different cases presenting a wide variety of actions within many work fields and distinctive coverage areas were selected, being the Brazilian ones prioritized. From the fifteen cases, five operate locally, four have a state-wide coverage, four are able to develop actions nationally, and only two work internationally. Table 2 and 3 show the details.

Table 2: Number of initiatives by coverage area

Coverage area	Range	Number of promising initiatives
Local	The initiatives take place in a specific neighborhood, city or small region, mainly due to physical aspects or logistics.	5
State	The initiatives range state wide, connecting two or more cities of the same state.	4
National	The initiatives present characteristics that allow them to operate in different regions of the country. Language and other logistic demands can be limiting factors for their expansion.	4
International	The initiatives take place mostly online, connecting people and ideas without demands of physical interaction or logistics.	2

Table 3: Promising initiatives, field and activities

Area/Field	Name	Actions	Coverage area
Technology - Health	Médicos de Máquinas (*Machine Doctors*)	Repair of mechanical ventilators for hospitals, mostly free of charge. Altogether there are 200 volunteers working on it.	State: Paraná
Technology - Health	Atitude 3D (*3D Attitude)*	Provide personal protective equipment (PPE) for healthcare professionals free of charge.	State: Paraná
Technology – Information	Startups vs. Covid19	Gather startups' solutions that help to directly or indirectly mitigate COVID-19 and its effects, fostering innovation and knowledge sharing.	International
Security – Violence against women	Isoladas Sim, Sozinhas Não (*Isolated, not alone)*	Union of major cosmetics brands in Brazil to address gender violence through awareness and creation of a support network.	International: Latin America
Connection between donor and beneficiary - General	Paraná Solidário (*Solidarity in Parana*)	Digital application for smartphones that allows direct donation from citizens to charity programs. It works as a bridge for the donation of products such as food, clothing, furniture, appliances, animal food, and others.	State: Paraná
Connection between donor and beneficiary - General	Vizinho do Bem (*Good Neighbor*)	Repository website where people who are willing to help and those who need help can register to offer/ask for services (classes, psychologic treatment etc.), products (food, clothes, furniture etc.), and others.	National
Connection between donor and beneficiary - General	Existe amor em Curitiba (*There is love in Curitiba*)	Repository website where people who are willing to help and those who need help can register to offer/ask for services (classes, psychologic treatment etc.), products (food, clothes, furniture etc.), and others.	Local: Curitiba – Paraná
Connection between donor and beneficiary - Food	1 milhão de 1 Real (*1 million of 1 Real*)	Crowdfunding campaign with a minimum donation amount of only R$1,00.	Local: Curitiba and East Coast - Paraná
Connection between donor and beneficiary - Food	Rango Dobrado (*Doubled food*)	Encourage people to buy an extra package of food for donation, helping other vulnerable people. The hubs of donation and collection can be anywhere.	National
Connection between donor and beneficiary - Food	Mesa solidária (*Solidarity table*)	Promoted by grocery stores, restaurants, and other food suppliers to encourage their clients to donate packages of food and takeaway food to vulnerable people.	Local: Praia Grande - Santos - São Paulo
Connection between donor and beneficiary - Food	Corona no Paredão (*Corona's challenge*)	Distribution of food stamps through electronic benefit transfer (debit card system) for residents of vulnerable areas over an interstate network.	National

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Area/Field	Name	Actions	Coverage area
Economy - Food	Compre do Produtor (*Buy from producer*)	Website and WhatsApp network connecting farmers and consumers.	Local: Guarapuava - Paraná
Economy - Food	Liga na Causa	Website to connect people in social distancing with local small business, such as restaurants, bakeries, and patisserie to help them to keep operating despite the restrictions, sometimes offering products at cost price.	Local: Curitiba - Paraná
Economy – Mapping of business and services	Mapa de máscaras (*Mask map*)	Connect dressmakers who make masks with consumers.	National
Economy – Mapping of business and services	Bem aqui (*Right here*)	A collaborative platform with the objective of providing the population with a tool that shows which business or services are authorized to operate.	State: Paraná

Table 3 shows that almost half (7) of the mapped promising initiatives are dedicated to connecting people in need with those willing to help; four other cases tackle economic issues, and three 3 are more related to technology issues. As for the fields, cases are food-related, which evinces that this is probably one of the most prominent problems exacerbated by the pandemic situation.

Based on this scenario, the authors decided to deepen information about the following cases: Mapa de Máscaras, Rango Dobrado, Corona no Paredão, Médicos de Máquinas, and Compre do Produtor—three with national coverage, one covering the state of Paraná and one operating locally. As for the field, three of them are food-related.

The first two cases, Mapa de Máscaras (Mask map) and Rango Dobrado (Doubled food) aim at helping vulnerable people and were developed by the same company with different social partners in each case. The company is part of the B corporation system and intend to create social and environmental positive impact, by balancing profit and purpose in order to build a more inclusive and sustainable economy (BCorporation, 2020). The role of the company in the projects was to create, host, and manage their online platforms and to design their visual identity. In the case of Rango Dobrado, they have also created infographics to explain how the project's actions would work.

Mapa de Máscaras (Mask map) connects dressmakers who make masks with consumers through a nationwide digital online platform. In so doing, it creates or widens a source of income for these workers while allowing buyers to purchase different kinds of masks. The platform functions as a shop window for the masks and offers support about how to wear them. The users are responsible for the trading (sell/buy), contact, payment, and delivery actions.

Rango Dobrado (Doubled food) promotes the creation of hubs where one can buy and/or donate an extra package of food to help people in vulnerable conditions. The initiative has a digital online platform to register hubs, which can be located anywhere in the country, but actions are carried out locally. Those include raising awareness about people in need and allocation of donation boxes tagged with proper identification.

Corona no Paredão (Corona's challenge) distributes food stamps through electronic benefit transfer (debit card system), which only allows the purchase of food and hygiene products by residents of vulnerable areas over an interstate network with national reach. The initiative was developed by an established social organization already familiarized with promoting cultural activities, sports training, and professional reintegration in susceptible poor areas since 2013. Corona no Paredão's goal is to prevent hunger from increasing in these zones and to enable people to stay at home during the pandemic situation. This way, they would not need to leave their houses to look for a job or food, therefore reducing the risk of contracting and spreading the virus in their communities. The distribution of food stamps relies on the help of local leaders who know community members, who can guide and support them better.

Médicos de Máquinas (Machine Doctors) works repairing mechanical ventilators for hospitals in Paraná, mainly public ones, which are mostly free of charge. The initiative started at the Federal University of Paraná with students and professors of a specialization course in Maintenance Engineering and now comprises approximately 200 volunteers. The idea is to extend the lifecycle of this type of medical equipment, reducing the efforts to purchase or build new ones, since the pandemic situation has made it more difficult to trade products and components. The initiative is operated through various partnerships that allow access to mechanical or electronic components for equipment repair and to a shared logistics system that collects and delivers equipment to hospitals.

Compre do Produtor (Buy from producer) emerged from the suspension of market fairs that has prevented local small farmers from the Guarapuava region from having a physical space to sell their products. The initiative was planned in partnership between the Guarapuava's Secretariat of Agriculture and the Central of Associations of Small Producers. Its aim is to connect farmers and consumers through an online platform (developed in partnership with a local website agency) and a popular instant message application. The operation's characteristics limits its coverage to the Guarapuava region. The producer's association is responsible for the logistics, receiving orders and delivering products while the municipality employees manage the online platform.

3. DISCUSSION

The mapping presented above allowed a comparison between the five cases, as shown in Table 4. As previously mentioned, three of them act nationwide, one statewide, and one locally. The target audience of each project varies from vulnerable people, such as in the case of Rango Dobrado (Doubled food) and Corona no Paredão (Corona's challenge), to ordinary consumers who need to be connected with local producers, as in Mapa de Máscaras (Mask map) and Compre do Produtor (Buy from producer), as well as to hospitals in need of ventilator machine repairing, which is the target audience of Médicos de Máquinas (Machine Doctors). It is worth mentioning that, due to the recommendations for social distancing, all initiatives have been carried out with the aid of some sort of online mediation.

Table 4: Case comparison

Name	**Mapa de Máscaras (*Map mask*)**	**Rango Dobrado (*Doubled food*)**	**Corona no Paredão (*Corona's challenge)***	**Médicos de Máquinas (*Machine Doctors*)**	**Compre do Produtor (*Buy from producer*)**
Target audience	Ordinary consumers	Vulnerable people	Vulnerable people	Hospitals	Ordinary consumers
Innovation in daily tasks	Allow people to buy masks in nearby places via an online platform.	Allow people to donate in nearby places listed on an online platform.	Provide a food card to vulnerable families.	Make medical equipment repairs viable and free of charge for public hospitals.	Make agricultural products available for purchase on an online platform.
Social benefit	"Create	Allow people to	Food aid for	Allow more people	Promote the local

Name	Mapa de Máscaras (*Map mask*)	Rango Dobrado (*Doubled food*)	Corona no Paredão (*Corona's challenge*)	Médicos de Máquinas (*Machine Doctors*)	Compre do Produtor (*Buy from producer*)
	opportunities to seamstresses that need a new source of income."	find assistance in nearby places.	socially vulnerable people.	to have access to health-related technology.	market of agriculture.
Environmental benefit	Since it is local, it decreases the impact of product transportation.	Since it is replicable and local, it decreases the impact of the product transportation.	Through an online platform and donation cards, it allows minimal logistics to decrease the impact of donation transportation.	Extending the product life cycle, reducing the amount of waste produced.	Since it is local, it decreases the impact of the product transportation.
Economic benefit	The platform is hosted by the company. There is no cost for announcing the products on the website. Consumers buy and pay directly to the dressmakers, without any fees.	The platform is hosted by the company. The users who create the hubs can reuse plastic boxes, avoiding the costs of creating them. The vulnerable people who need food do not have any costs either.	There are many partner companies donating money and providing the debit card system. In addition, the social organization offers an online platform that enables personal money donations.	The partnerships provide most of the components and logistics. For other components, the initiative raises money fixing ventilator machines for private hospitals.	The platform was offered by the municipality, and the local producers offer their products on the website. Consumers spend a minimum of R$20, choosing how to pay for it (online or upon home delivery).
Possibility of replication in another context	Since it is a platform, it can be easily replicated.	The system is easily replicable in an organic way, through manuals.	Since it is a platform and a card donation system, it can be easily replicated.	The initiative only depends on a group of volunteers specialized in the maintenance area and can normally be replicated.	Since it is a platform, it can be easily replicated.
Classification of design activism	Connection; Service artifact.	Connection; Service artifact; Demonstration artifact; Social exchange.	Service artifact; Connection; Social exchange.	Service artifact; Demonstration artifact.	Service artifact; Connection; Social exchange.

Pre-assessment of the cases in the initial mapping validated all the promising initiatives as social innovation ones: they all present original ways of organizing daily tasks (such as shopping groceries and garment, having access to food, and finding equipment maintenance services), offering social and environmental benefits. The authors could also identify a number of economic benefits and the possibility of replication in different contexts.

Regarding the design activism tactics, four of the five initiatives were described as using the connection tactic: Mapa de Máscaras (Mask map), Rango Dobrado (Doubled food), Corona no Paredão (Corona's challenge), and Compre do Produtor (Buy from producer), since they can be considered as view corridors, i.e. display windows or showcases for displaying products for consumers or as bridges to link vulnerable people to those who can help them. The service artifact tactic was identified in all the cases, once they all function as aid for victims of the COVID-19 pandemic, which can be classified as a disaster of global proportions. Two initiatives, Rango Dobrado (Doubled food) and Médicos de Máquinas (Machine Doctors), also seem to have adopted demonstration artifact as a tactic, one for being intrinsically replicable and the other for being structured in such a way that it could be used by more universities almost immediately. Finally, the social exchange tactic was related to three projects: Rango Dobrado (Doubled food), Corona no Paredão (Corona's challenge), and Compre do Produtor (Buy from producer), with more evident social fabric.

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4. CONCLUSION

This paper briefly presented the mapping of initiatives developed during the COVID-19 pandemic in Brazil in order to identify whether they adopted social innovation strategies to mitigate some of the social and economic damage in the current scenario. In the mapping's first stage, promising cases were surveyed and listed. Fifteen of them were later described using the DESIS "Light Format" form for pre-assessment and classification; of those, five were further investigated. In order to interpret how the initiatives operate as well as how they promote positive social capital, intentionally or not, the concepts of design for social innovation and design activism were used.

The descriptions of the projects were clear in demonstrating that they all fill one or more important social, economic, and environmental gaps left by the pandemic. The analysis showed the efforts as grounded in solidarity and coordinated group actions helping small business, freelancers, and vulnerable communities, which sustained their classification as social innovation initiatives. Design strategies, such as tactics from design activism, were identified, conferring the initiatives the potential to operate properly in the aftermath of the current scenario.

In light of the results of the present study, future studies could further investigate how conscious the initiative developers were about the use of design strategies. Furthermore, considering the DESIS protocol adopted, the authors identified further benefits regarding the mapped cases, especially economic ones which were added to the case comparison table. So they would suggest the addition of an economic benefit criterion to the pre-assessment stage, since this aspect remains understated in the protocol and needs to be sorted out in order for most cases to initiate and thrive. Machine Doctors, for instance, need partnerships with components manufacturers and transportation service providers in order to make sure the components needing fixing get to the volunteering "fixers." Regarding design, the addition could support future theoretical evaluation as a systemic thinking overviewing the whole sustainability aspects considering a new economic paradigm based on values of ethics, fairness, solidarity, cooperation, distribution and wellbeing.

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ENDNOTE

[1] Temporary structures are meant to raise awareness about important social issues. For instance, the sheer amount of garbage produced by a single family could be displayed in a public space (let us say, a shopping mall) to call the people's attention to "the other side" of consumerism.

[2] Imperfect efforts refer to artifacts that are used for demonstration purposes before acquiring their final, polished form.

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Design for Resilience: Mapping the Needs of Brazilian Communities to Tackle COVID-19 Challenges

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ABSTRACT

The COVID-19 pandemic brought the urgency in the search for innovative solutions in different areas of knowledge to mitigate the effects and impacts of the disease, whether on health, social or economic terms. Urban and socio-economic determinants of informal-settlement communities make COVID-19 challenges even harder to be overcome, requiring local and situated solutions that consider their livelihood diversity. This manuscript shows the results of an exploratory pilot study which addressed the potential of participatory design to contribute to mitigating COVID-19 effects and impacts, identifying the problems, adaptative strategies, challenges for and needs of Rio de Janeiro and Belo Horizonte communities. It was drawn from triangulation of methods and analysis of multiple (primary and secondary) data sources. The needs of communities were raised through online roundtables with community members, representatives of NGOs, designers, architects and researchers. Analysis of the roundtables was conducted collaboratively by the researchers through online tools, including Affinity Mapping, and 5 Whys. The findings point out the needs of communities clustered in 6 major themes, five of which indicate potential areas in which participatory design can play a meaningful role and need to be further investigated.

Keywords: Community Needs, COVID-19 Challenges, Design for Resilience, Informal Settlements, Participatory Design.

1. INTRODUCTION

This exploratory pilot study[1] aims to identify COVID-19 challenges for informal-settlement communities, defining problems, adaptative strategies, and needs that are caused or exacerbated by the pandemic. It explores the potential of participatory design and co-design to build community-led solutions to problems expressed by community members addressing their related areas of challenges and needs. These were identified through two online roundtables that brought together active community members, NGOs' representatives, designers, architects and researchers from three universities (Lancaster University, UFMG, UEMG). A third roundtable was conducted to validate the results with participants.

The results show that, in addition to the evident demands related to the pandemic (such as making masks and other personal protective gear, assuring income and food, etc.), there are potential opportunities for participatory design contributions in communities, such as:

- improving the information/communication system about the disease and its effects,
- supporting social organization that enables collaborative initiatives (i) to reduce the effects and impacts of the pandemic, and (ii) to generate innovative solutions and strategies for suitable and sustained prevention of the disease,
- strengthening networks and partnerships, scaling initiatives and improving their accountability,
- building dialogues between public officers and communities, and
- recognising the value of women in facing pandemic.

1.1. COVID-19

On the 12th December 2019, the first case of a new type of coronavirus was officially recognised in Wuhan (Hubei, China), causing a highly communicable disease with a high mortality rate between (just under) 6% and 18% (re-estimated mortality rates by Baud et al, 2020). The pandemic was declared by the World Health Organization (WHO) on the 11th March 2020 (WHO, 2020) and has been bringing impacts on the world population such as health and economic crises as well as exacerbating sanitation problems. Several compulsory measures, which include (1) the construction, expansion or adaptation of hospitals to the conditions required to face the pandemic (Moghadas et al, 2020), (2) development of new medical and personal protection equipment (Tabah et al, 2020), (3) accelerated research for the development of vaccines and medicines (Lurie et al, 2020), (4) severe travel and human displacement restrictions (Chinazzi et al, 2020), and (5) creation and imposition of social isolation rules aiming at contributing to the disease control (Bavel et al, 2020). In this context, design problem-solving approach has been used in several initiatives worldwide, whether for the development of medical (e.g. Marchese, 2020) and personal protective gear (e.g. BBC, 2020), whether for creative approaches to creating effective means for the dissemination of information on the disease and its symptoms (e.g. Escola de Design, 2020; UFMG, 2020).

Brazilian cities began the quarantine in March. On the 16th March, the State of Rio de Janeiro announced the first measures to tackle COVID-19, such as the suspension of schools' activities, football games and events, shopping centres and gyms closures, among others (Procuradoria Geral do Estado do Rio de Janeiro, 2020). Belo Horizonte also closed "non-essential" services and recommended remote work, among other measures (Prefeitura Municipal de Belo Horizonte, 2020).

Belo Horizonte had over 6,000 confirmed cases and 144 deaths due to COVID-19 by the 1st July, according to the Health Secretariat (Secretaria Municipal de Saúde, 2020). In Rio de Janeiro, by the same date, there were over 57,000 confirmed cases and 6,618 deaths, according to the Health Secretariat of Rio de Janeiro State (Secretaria de Estado de Saúde do Rio de Janeiro, 2020).

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1.2. Informal-settlement communities

Problems caused and exacerbated by COVID-19 are far from being solved, especially among informal-settlement communities (Corburn et al, 2020). In Brazil, the spread of the disease among residents of informal settlements, also known as "subnormal agglomerates (SBAGs)"[2] (IBGE, 2010), "*favelas*" or "(fragile or vulnerable) communities/territories" is of particular concern.

The characteristics of these territories vary across the country. Conditions generally related to these areas include geographic features that are not favourable to regular and safe urbanization, lack of urban infrastructure such elementary public services (waste collection, sewage treatment, water and energy supply, etc.) and the absence of a formal address (IBGE, 2010). Their population is predominantly composed of black and brown people, with a low level of formal education, income sources based on informal or low-income activities (e.g. cleaning, construction work, and waste picking and collection) and female-headed families (Musumeci, 2016).

Houses are usually overcrowded, shared by several generations of a family and sometimes by more than one family. The size and high density of these areas influence the residents' quality of life, making the conditions of accessibility, ventilation and insolation critical (IBGE, 2010). These hard-living conditions lever particular forms of social organisation. As of 2010 (IBGE, 2010), 11.4 million people, around 6 per cent of the Brazilian population, lived in *favelas*. Rio de Janeiro city concentrates the largest population living in SBAGs with 1.4 million people in 763 agglomerates. In Belo Horizonte, about 307,000 people lived in 169 agglomerates. These are the most recent official figures since the 2020 census was not concluded due to the pandemic. Besides, there is a lack of official qualitative assessments (IBGE, 2010).

There is the need for accessible public data that contributes to understanding the reality and dynamics of these territories and challenges for communities, including an up to date characterisation of urban infrastructure such as elementary services' coverage and quality, and the accessibility to technology services among others. Neglecting infrastructure corresponds to missing "essential aspects of aesthetics, justice and change" (Star, 1999, p. 379). How can one effectively address these challenges for communities and provide effective policies without knowing their features and extension?

1.3. Participatory design for community resilience

Resilience is considered "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management" (UNISDR, 2016, p.22).

A disaster is "a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts" (UNISDR, 2016, p. 13). Therefore, this pandemic situation is understood as a disaster.

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Effects of a disaster are usually widespread and can be long-lasting, testing the capacity of communities and societies to overcome those using their own resources, requiring support from external sources at regional, national or international levels (UNISDR, 2016).

Most studies looking at community resilience and participatory approaches in emergency and recovery contexts have focused on natural disasters situations. In this context, the resilience of disadvantaged communities relies on community capability-building related to self-organisation, access to resources, network strengthening, collaboration, and to mechanisms that contribute to holding community-led plans and efforts accountable (Berke et al, 2011).

Successful participatory approaches to recovery and post-disaster reconstruction favour community empowerment, ownership, commitment to implementation, trust-building between communities, public officials, and key stakeholder groups, contributing to more resilient communities and to sustainable and inclusive actions and solutions. The sustainability relies on the capabilities of communities built throughout co-development processes to self-organise, access needed resources, and reinforce networks rather than on outcomes themselves (see Berke et al, 2011; Bott & Braun, 2019; Schilderman & Lyons, 2011; Vahanvati & Beza, 2017).

Global guidelines on disaster prevention, preparedness, hazards mitigation, and recovery are approached from a risk management perspective (e.g. UNISDR, 2015; UNISDR, 2016), failing to address socio-cultural determinants and livelihoods' diversity that influence the sustainability of proposed policies and solutions to these.

Capability-building is critical to overcoming recovery challenges and building community resilience. Sen's (1999) capability approach expands the meaning of development beyond the narrow economic view that reduces development to measures such as income and Gross Domestic Product (GDP), emphasising the role of "the effective use of participatory capabilities by the public" (p. 18) as well as of appropriate public policy to enable people "to live the kind of lives they value - and have reason to value" (p. 18). In practice, there is still the need to address the plurality and autonomy-building of communities to promote well-being and capability-building (see for instance Escobar, 2018).

The emergence of participatory design methods can be traced back in the 1960s regarding public decision-making processes in the USA, and systems development during the 1970s in Scandinavia (Sanders & Stappers, 2008; Sanoff, 2007). The notions of participatory design and co-design capabilities are related to (1) designers' traditional skills set that enables tools development (Sanders & Stappers, 2008), and (2) management methods regarding the facilitation of visioning and strategic planning together with communities (Sanoff, 2007). Co-design concerns "collective creativity as it is applied across the whole span of a design process", being a specific instance of co-creation and referring to "the creativity of designers and people not trained in design working together in the development process" (Sanders & Stappers, 2008, p.6).

Participatory design processes are multidirectional learning processes by which designers, diverse stakeholder groups and citizens learn together throughout the process. Three clusters of capabilities are identified in participatory design processes from different mainstreams of participatory design literature (Huybrechts et al, 2018):

2. The capability to visualise – when design teams consciously collaborate with citizens to improve their capabilities "to collectively visualise their different views on matters of concern in their city" (p. 83);

3. The capability to reflect together – refer to confronting different views. This is also acknowledged as capability of knowledge abstraction, and evaluation, being considered speculative in nature;

4. The capability to act – related to enhancing "the confidence of designers and citizens in their capability to take collaborative action" (p.83) regarding the reflections through the use of a design language.

Although communities and their organisations have played a noteworthy role in dealing with disasters throughout history (Patterson et al., 2010), and community engagement is essential to successful disaster recovery, contributing to community resilience and stability, risk assessment and urban planning processes are still often being operated by experts without sufficient community engagement (Meyer et al, 2018). Participatory design, especially its approaches, processes, and methods have no visibility in the disaster discourse and are not systematically investigated. In participatory studies, participation ranges from data collection methods to research approaches such as Participatory Action Research (PAR). Hence, the potential of 'active participation' (Sanoff, 2007) through participatory design and co-design is still under-explored regarding emergencies and community resilience-building.

Health and well-being are beyond the absence of disease and span interwoven life's aspects, being related to lifestyle, and other cultural and socio-economic determinants, including infrastructural ones (i.e. OECD, 2020, Crisp, 2020). Participatory approaches demonstrate proven effectiveness and positive shifts, for instance, in Water Sanitation and Hygiene (WASH) in Least-, Low-, Middle-Income countries using Participatory Hygiene and Sanitation Transformation (PHAST) methods (see for instance Kariuki et al, 2012; Dumba et al, 2013). However, participatory design methods are still under-explored in WASH-related areas as well.

2. METHODOLOGY

This qualitative and exploratory pilot study was developed thanks to the collaboration between Lancaster University, UFMG and UEMG. Triangulation of methods (Eisenhardt, 1989; Yin, 1994) was used, including online roundtables, mobile application group discussions, observation during the roundtables, and desk research. This methodology approach was drawn from multiple data sources, including primary and secondary data which were collected and analysed as follows.

Primary data was collected through two online roundtables which were carried out in June. The roundtable script and the analysis process were collaboratively co-developed by the authors. One online roundtable had participants from two Belo Horizonte communities, and another had participants from three Rio de Janeiro communities. Each roundtable lasted around two hours. A third roundtable was conducted to validate the results.

The secondary data collection included public data (NGOs' and community members' Instagram and Facebook posts, websites, press news) and literature review focused on participatory approaches to community resilience-building in emergencies and on mainstreams of participatory design, COVID-19 in the world and in Brazil with emphasis on the disparities and demographics of *favelas* in Brazil.

The sample of this research was purposively selected. The screening of participants provided opportunities for mixed and balanced gender participation and considered participants who are not suffering from bereavement or other distress. The screening was conducted by the researchers on the ground, who were already engaged with the communities, through phone calls. Alternatives of participation such as flexibility regarding the meeting application and the option to have one-on-one discussions were also strategies put in place as a contingency plan to mitigate against participant distress.

Table 1: Belo Horizonte (BH) online roundtable

Roundtable role	Gender	Related Community / Role
Participant 1	Male	Community A / NGO representative and community member
Participant 2	Male	Community A / NGO representative
Participant 3	Female	Community B / Kindergarten teacher, community member and volunteer
Participant 4	Male	Community B / NGO representative and community member
Mediator	Female	Lancaster University / Research Associate
Time moderator	Male	UFMG / Master student
Observer 1	Male	UFMG / Professor
Observer 2	Female	UEMG / Professor
Observer 3	Female	UEMG / PhD candidate

Table 2: Rio de Janeiro (RJ) online roundtable

Roundtable role	Gender	Related Community / Role
Participant 5	Female	Community C / Nurse, doula and community member
Participant 6	Female	Community D / Journalist and community member
Participant 7	Male	Community D / NGO representative and community member
Participant 8	Female	Community D / Educational project founder and community member
Participant 9	Female	Community E / Social movement representative and community member
Mediator	Female	Lancaster University / Research Associate
Time moderator	Male	UFMG / Master student
Observer 2	Female	UEMG / Professor
Observer 3	Female	UEMG / PhD candidate

Note: informal-settlement community E refers to an occupied building in RJ. The notes regarding this informal settlement specifically are identified as 'RJ (building)' on the maps (results).

The online roundtables were run in the first language of the participants. They were audio and video recorded, transcribed and translated. The analysis of the participants' talks was carried out by identifying and selecting problems, adaptive strategies and challenges around five topics: (1) sources of information, communication means and impacts on routine; (2) prevention; (3) diagnosis and treatment; (4) support, and (5) change.

Problems and adaptive strategies were identified in the participants' speeches in these first four areas. The researchers' notes were clustered according to the similarity between them through cross-reference using an online Synthesis Wall that included areas for each theme and related problems, adaptative strategies and challenges.

Challenges were further explored and developed through two design tools and one engineering method (How Might We [HMW] questions [IDEO.org, n.d.], Synthesis Wall [or

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Affinity Mapping] [Service Design Tools, n.d.], and the 5 Ws [see for instance Ohno [1997]). Changes' and challenges' analyses were conducted through additional cross-reference considering the exploratory HMW questions and 5 Whys topics that led to the identification of 6 themes (regarding needs that should be considered to address the challenges) through another affinity mapping.

Additionally, a group was created through a mobile application for each roundtable group with the purpose of supporting participant-technology interactions, serving also as ice-breaker before the roundtables and providing additional opportunities to ask any question and further discuss the topics after the roundtables.

Our findings were rooted in the real context of the communities, considering the views and perceptions of community members actively involved in COVID-19-related initiatives in their communities and NGOs' representatives who have been engaged with these communities. Our contribution relies mainly on what can be learnt from these as pointed out by Stake (2000, pp. 446-447): "Potential for learning is a different and sometimes superior criterion to representativeness". As emphasised in ethnography we are interested in understanding viewpoints, "surfacing silenced voices" (Star, 1999, p. 383).

3. RESULTS

The maps below show the results regarding problems, adaptive strategies, areas of challenges and the relationships between them. Notes that refer only to the context of Belo Horizonte communities were identified with '**BH**'. Notes that refer only to Rio de Janeiro communities were identified with '**RJ**'. Notes that refer only to the community E informal settlement were identified with '**RJ** (building)'. The remaining ones without any indication were mentioned by community members in both cities.

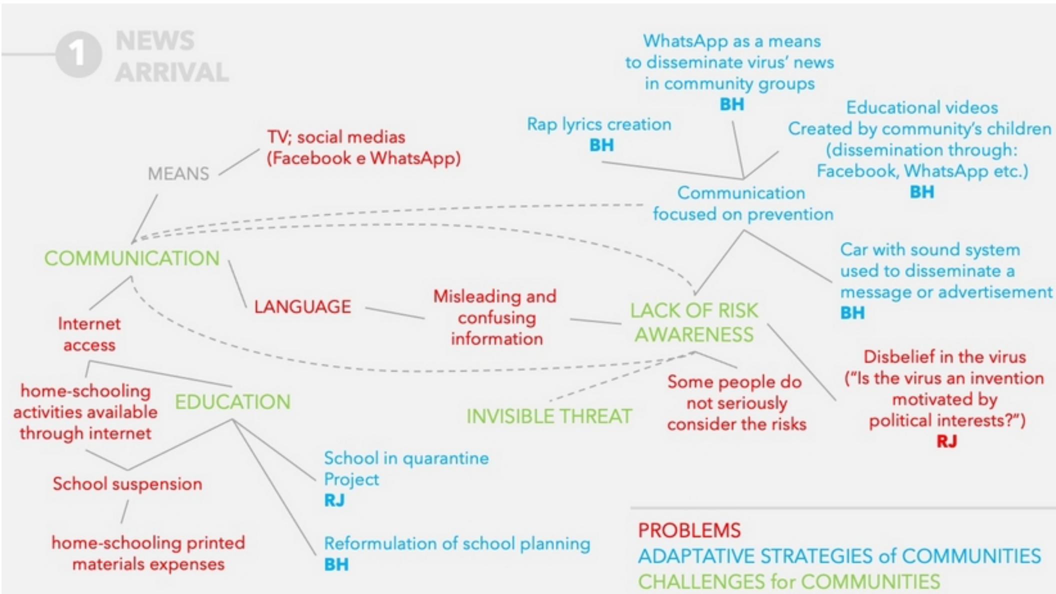

Figure 1. Theme 1: news arrival - sources of information, means of communication and impact on routine.

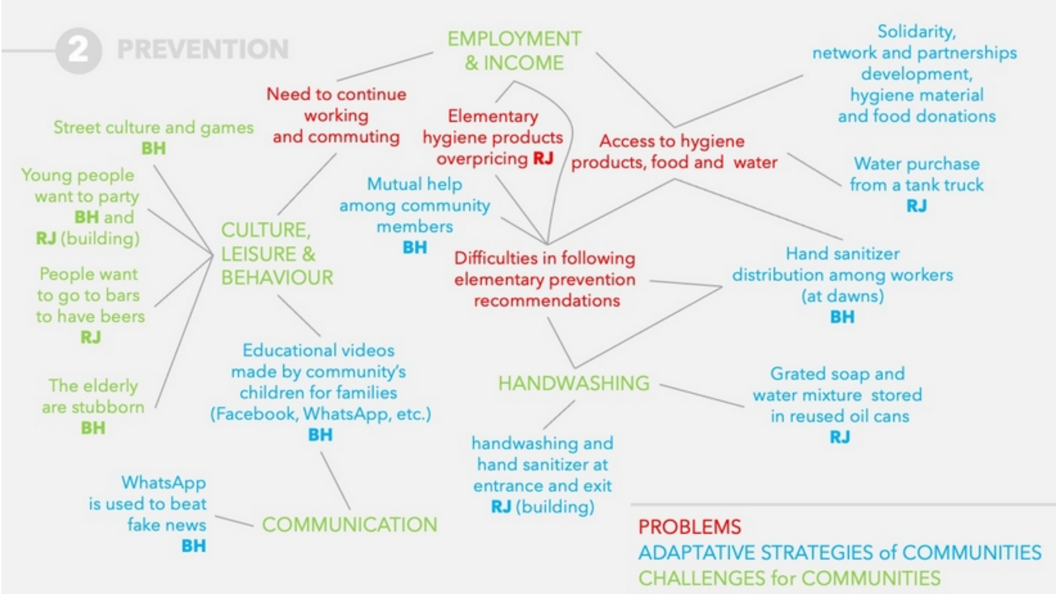

Figure 2. Theme 2: prevention.

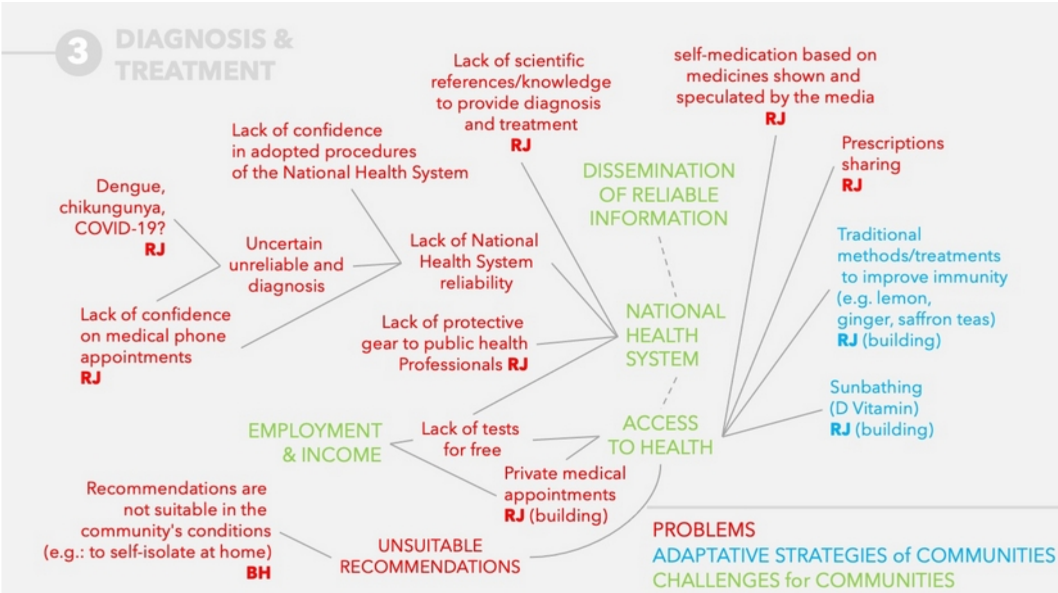

Figure 3. Theme 3: diagnosis and treatment.

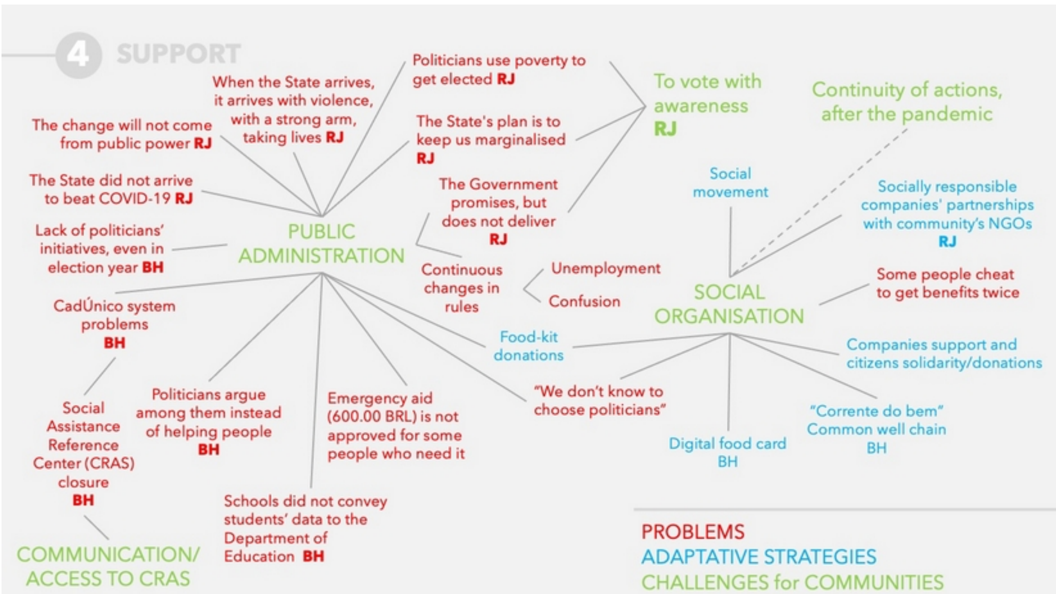

Figure 4. Theme 4: support (public sector, institutions and other organisations).

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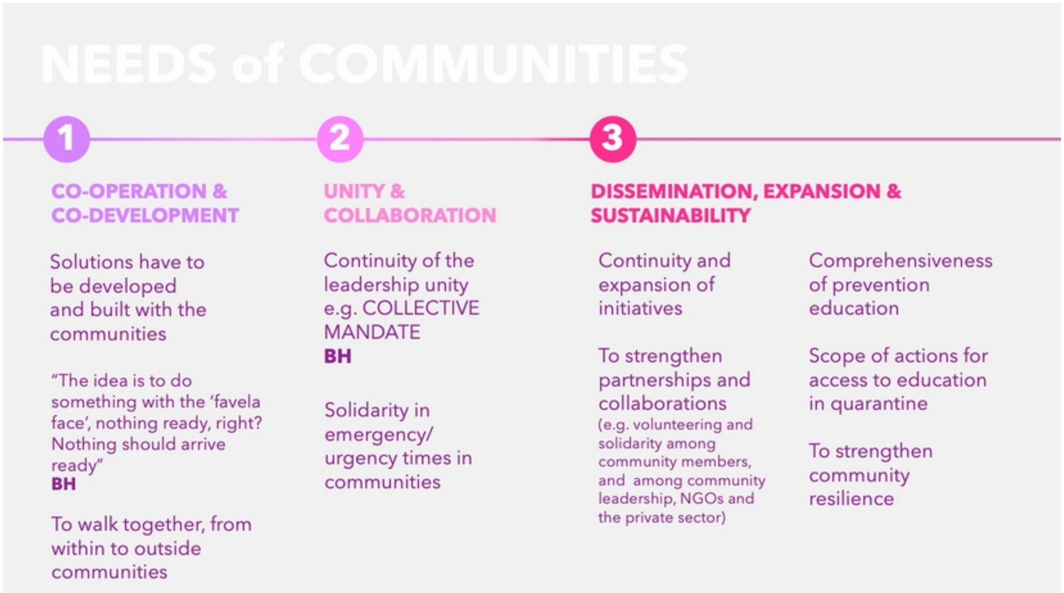
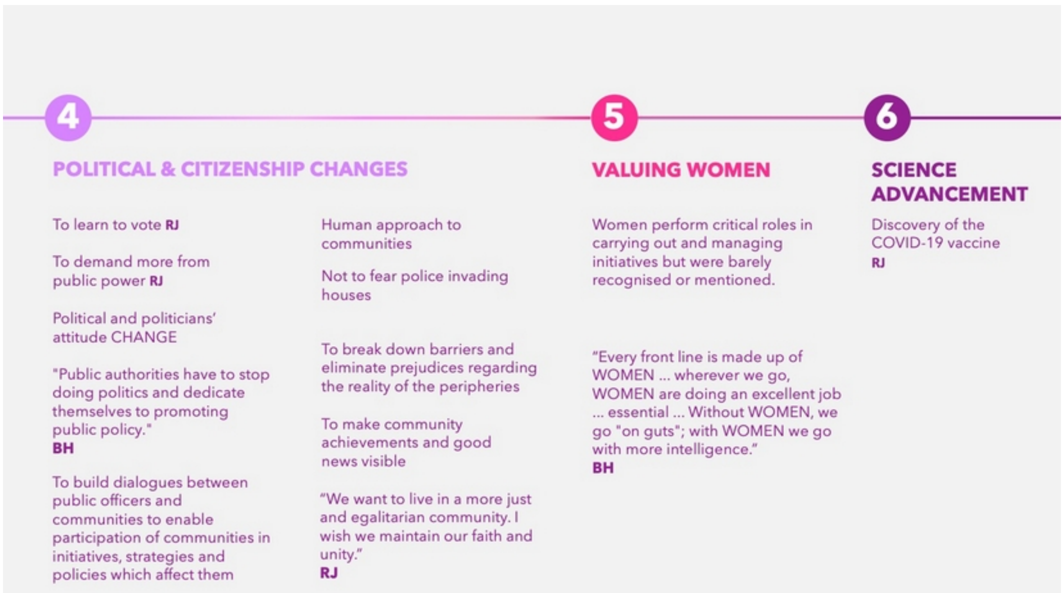
Figure 5. Areas of challenges.



(a)



(b)

Figure 6. Needs related (a) to themes 1, 2, 3 and (b) to themes 4, 5, 6.

4. DISCUSSION

Prior literature on community resilience using participatory approaches to emergency and recovery emphasises the importance of community-led solutions, stressing the needs (1) to hold local planning efforts of communities accountable, (2) to reinforce community self-organisation and networks, building capabilities and enhancing their access to needed resources, including external ones. This literature on emergencies focuses mostly on natural disaster emergency and recovery. Besides, the main guidelines on these situations adopt a risk management perspective, failing to address livelihoods diversity, including socio-economic and cultural determinants.

This pilot study looked into community resilience potential through a design lens and identified intersections with the findings of other participatory studies on community resilience. In the context of the pandemic in communities, the need to develop, test and implement community-led solutions to enable comprehensive and sustained initiatives which can mitigate COVID-19 effects and impacts on these communities was recognised. COVID-19 threats also exacerbate existing problems. Additionally, the need for mechanisms that can contribute to the accountability of community-led plans and solutions in order to promote equality and justice in the distribution of benefits was identified.

The importance of participatory design in the pandemic situation drew attention to needs, beyond the above-mentioned aspects in the disaster context, such as:

- To inform policy briefs and recommendations,
- To build dialogues between public officers and community members,
- To set collaborative, respectful, plural and human strategies to beat and mitigate COVID-19 effects and impacts on communities in diverse thematic areas (see Figure 6) as emphasised by community members during the validation process.

The political environment characterised by conflicts involving power disputes and corruption scandals as well as politicians' attitude as 'tourists' close to the polls aggravate the situation, influencing on community disbelief in COVID-19 threats (see Figure 1 problems) and community distrust of politicians (see Figure 4 problems). Communities do not believe that a positive change can be brought from politicians' initiatives (see Figure 4 problems) and have acknowledged the critical role of active community members, NGOs and private sector partnerships and collaborations as a way to mitigate the COVID-19 effects and impacts (see adaptative strategies of communities in Figures 1, 2, 3, 4). Most strategies are community-led.

Furthermore, the need (1) to co-design sustained initiatives and extend existing ones, (2) to eradicate the stigma and prejudice towards communities, and (3) to recognise the value of women were pointed out throughout roundtables conversations (Figure 6). This pilot study contributed to initiating dialogues and reflections (Huybrechts et al, 2018) with community members employing visualisation tools and research techniques. It also highlighted relevant themes (themes 1 to 5, Figure 6) to be addressed through collaborative actions utilising participatory design to co-design plural solutions, strategies, actions, and inform policies.

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5. FUTURES RESEARCH AND LIMITATIONS

This study contributed to understanding community members' perspectives and initiatives to cope with the pandemic threats and pointed out areas that still need to be investigated and developed through future participatory design research. They range from short-term to long-term development to contribute to community-led solutions and initiatives. Our findings are not statistically significant as the sample of this study was very small, and it would be very difficult to statistically define enough participants considering this research timeframe, resources, and especially the accessibility of participants to technologies (required to preserve their safety in the current pandemic circumstances). This is a typical feature of real context studies that differ from lab experiments (see for instance Paulus et al, 2015). Moreover, the knowledge gap regarding *favelas*' and informal-settlement characteristics and up to date demographic data still hamper the understanding and extension of the challenges for and needs of vulnerable communities. Thus, future research can contribute to understanding the applicability of participatory design, specifically of the potential of co-design of collaborative initiatives, in emergency and recovery situations, theme that is still under-researched.

ACKNOWLEDGMENTS

We thank Lancaster University support, all community members and NGOs' representatives who provided us with their meaningful insights into their realities during these uncertain times. We also thank Dr Emmanuel Tsekleves and Isadora Paloma Linhares Ribeiro for their participation and contributions to this research.

ENDNOTES

[1] This pilot study was funded by a Lancaster University Seed Corn grant

[2] The subnormal agglomerate is a cluster composed of at least 51 households. Most subnormal agglomerates lack elementary public services, occupying or having recently occupied (public or private) land owned by others. They are high-density areas and their buildings are usually disorderly arranged. In some Brazilian cities, small SBAGs predominate fragmented in the urban setting. In others, there are rather large ones, with over 10,000 houses (IBGE, 2010).

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Field Hospitals to Face COVID-19: Requirements and Lessons Learned in the Design and Construction of the Lagoa Barra Hospital – Brazil

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ABSTRACT

The construction of field hospitals has been a strategy adopted worldwide to face the consequences of the pandemic impacts caused by COVID-19 on healthcare systems. Specific characteristics of this pandemic, such as different ways and speeds of the disease transmission, and the implications at the population health and the productive system, has made the project, management, and construction of field hospitals for the patients with COVID-19 present specific features. In this work, for each phase of the FHLB implantation, we present the main concepts, premises, restrictions, and challenges, focusing mainly on the needs programs of the project that guided the configuration of the environments, the definition of the circulation flows, the typology of the beds, the main management tools used during the project's planning and control process, and in the lessons learned.

Keywords: COVID-19, Emergency Assistance, Field Hospital, Temporary Hospital.

1. INTRODUCTION

At the end of 2019, an unknown type of coronavirus, initially identified in Wuhan – China, caused a disease called COVID-19. Due to its high capacity for contagion and to impact the population health, COVID-19 put the global public healthcare institutions on alert. The World Health Organization defined the disease as a pandemic on March 11, 2020 (WHO, 2020). The first case in Brazil was registered on January 23, 2020, and, since then, the curves of cases and deaths increase exponentially. The public healthcare system became incapable of attending all the infected population, causing a collapse due to the high demand in several Brazilian cities.

In the "COVID-19 Clinical Management Protocol in Primary Healthcare" mild cases require therapeutic management and social isolation. In contrast, severe cases are submitted to clinical stabilization procedures, and the highly severe ones need to be directed to emergency service or a hospital (Brazilian Ministry of Health, 2020). According to Brazilian Association of Intensive Care (AMIB) and Brazilian Association of Emergency Medicine (ABRAMED), the referral to the Intensive Care Unit (ICU) or the Inpatient Unit (IU) is defined according to the severity of the clinical condition detected during the screening performed on the patient who arrives at the hospital. For ICU admission, the highest degree of survival and patient capacity is also assessed, based on the organic dysfunction score SOFA (Sequential Organ Failure Assessment) (AMIB and ABRAMEDE, 2020).

In a study conducted in March 2020 by the Brazilian Association of Intensive Care, in 450 hospitals in Brazil (13,695 beds) it was found that the average stay of patients with COVID-19 in the ICU is ten days, with a 30% lethality rate and 67% of patients needing mechanical ventilation. According to Bertoni (2020), it was also found that the need for a highly equipped and available ICU is essential to reduce the lethality rate of highly complex patients.

In March 2020, AMIB estimated the need for 3,200 ICU beds, in addition to the 16,000 existing in the Unified Health System, considering an occupancy rate of 95% (AMIB, 2020). According to Rouhollah et al. (2018), in abnormal situations like this, in emergency related to public health, provisional units, by providing medical services at any time and place, have been a solution adopted to reduce the effects of delays in handling victims and the number of deaths. Field hospitals are deployed in a wide variety of settings, including natural disasters, epidemic outbreaks, armed conflicts, and refugee crises. Different treatment strategies and hospital structures are designed for each scenario. In the case of treatment with COVID-19, basically, two models of hospital structures are used. In the first, sports gyms, convention centers and other places where there is already a certain level of infrastructure are used, such as Riocentro Pavilion (Rio de Janeiro- Brazil), Liacouras Centre at Temple University (Philadelphia - USA), Hall 1 of the Belgrade Fair (Serbia) and High-Performance Badminton Centre (Caldas Rainhas - Portugal). In the second, subject of this study, new facilities are built, such as those that were built at the Pacaembu Stadium (São Paulo - Brazil), Maracanã Stadium (Rio de Janeiro - Brazil), in Central Park (New York - USA), Ostra Sjukhuset (Gothenburg - Sweden) and Wuhan (China).

Unlike temporary units that only receive victims of low and medium complexity before they can be safely transported to permanent facilities, field hospitals for those infected with COVID-19 must also be built to receive highly complex patients. In this study, the intensive care unit beds were designed to meet all the premises and care that a seriously ill patient requires. Every hospital department also followed the same concept. Thus, for example, to avoid contamination and protect health professionals, a specific system for filtering contaminated air and antechambers with pressure differentials has been strategically designed to segregate between “clean” and “contaminated” rooms.

The intensity in which COVID-19 affects human health, especially lung function, besides causing a significant portion of patients to need hospitalization, also demands a substantial number of ICU beds and the construction of field hospitals intended for patients infected with COVID have specific characteristics. Besides, the project, management, and construction processes of field hospitals during this pandemic have also presented specificities, since several units of this type are demanded simultaneously, and the pandemic has had several consequences for the productive system and the labour market, such as contamination of workers and product shortages. In this context, during these processes, at various times, professionals resent information that enables more efficient and effective decisions, not only due to the lack of previous experience but also due to the lack of literature on the subject.

This work contributes to filling this gap by presenting the requirements and lessons learned in the construction of the Field Hospital Lagoa Barra (FHLB). We approach the project's needs programs, the dimensioning of the environments, the definition of flows, the construction phases, and the management tools used during the project planning and control process.

2. METHOD

The information defined by the authors as necessary for this work, mainly related to the characteristics, premises, and conditions of the enterprise, and the management procedures and tools used, were obtained by the first author, who worked as the project manager. Thus, it was also possible to collect and summarize the experiences about the enterprise since its initial phase. Daily, at the end of the working day, the information obtained was analyzed by the authors to identify inconsistencies and the need for complementation.

After completing the data collection stage, based on the reflective and interpretive analysis of the information obtained, we ordered and summarized this information according to the structure adopted for this work. The work was written jointly by the authors, aiming to integrate the different perspectives, multiplicity, and plurality of approaches.

3. MAIN CHARACTERISTICS OF THE FHLB

The FHLB was constructed in an area called Lagoa Barra, in the city of Rio de Janeiro-Brazil, offering care to patients from the Brazilian Public Healthcare System diagnosed with COVID-19. With a constructed area of approximately 7,400 m², the FHLB has 99 beds in the Intensive Care Unit (ICU), 101 in the Inpatient Unit (UI), 10 in the Screening Unit, and support, assistance and technical areas (Figure 1). The design and construction of the FHLB were carried out from April 6 to 25, 2020.

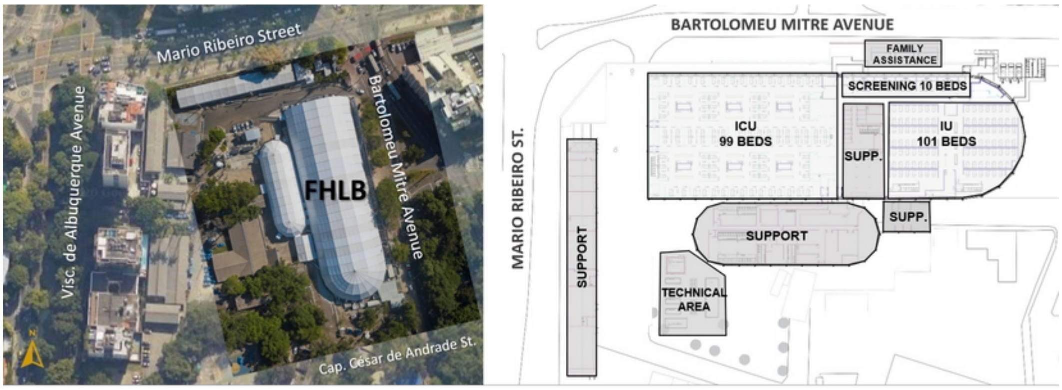

Figure 1. Location and layout of the FHLB.

4. PROJECT DEVELOPMENT

The architectural project of FHLB was developed in 10 days and had a workforce of approximately ten professionals, including architects, engineers, and health professionals. However, due to the short deadline established for the delivery of the project (20 days), the project development process had to be done in parallel with the project's planning and control and construction processes (Table 1).

Table 1. FHLB macro schedule.

PROCESS DESCRIPTION	TIME (DAYS)
PROJECT	10
PLANNING AND CONTROL	20
CONSTRUCTION	20

The FHLB's executive project met all the necessary premises and considered the demands and expectations of the clinical staff that would operate it. The development of the project

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was divided into two stages: Definition of the General, Specific and Complementary Needs Program, Dimensioning of Environments, Definition of Flows, and Typology of Beds. Table 2 shows the schedule of the FHLB project development processes.

Table 2. FHLB detailed schedule.

PROCESS DESCRIPTION	TIME (DAYS)
PROJECT	10
GENERAL PROGRAM	3
SPECIFIC PROGRAM	3
COMPLEM.PROGRAM	3
SIZING ROOMS	5
FLOWS DEFINITIONS	5
TYPOLOGY OF BEDS	5

5. GENERAL REQUIREMENTS OF THE FHLB NEEDS PROGRAM

The project started with a meeting with the health professionals of the future unit, aiming to obtain data for the FHLB's Essential Needs Program, which served as a basis for the 99 Intensive Care Unit (ICU) beds for highly complex patients and 101 Intensive Unit (IU) beds for mild and low complexity patients;

- 60 ICU beds equipped with mechanical ventilators for highly complex patients with respiratory problems, with the possibility of duplication (a “Y” connection was provided coupled to the Oxygen outlet);
- All beds with mechanical ventilator have an outlet with a battery system suitable for cases of power failure;
- 20 ICU beds equipped with a dialysis system for evidence of renal failure;
- Individual monitoring system in all ICU beds, according to the municipal legislation Law nº 5714 (Municipality of Rio de Janeiro, 2014);
- Ten screening beds for the level diagnosing of disease severity with individual bathrooms;
- Computed Tomography and mobile X-ray;
- Nursing call in all beds and baths;
- Rest area and food for health professionals;
- Outside space for family member's assistance.

6. SPECIFIC REQUIREMENTS OF THE FHLB NEEDS PROGRAM

One of the critical concepts for implementing a hospital with inherent contaminated areas due to coronavirus is the segregation between “clean” and “dirty” areas. Clean spaces are those in which there are no confirmed patients with COVID-19 (Assistance, Screening, and Support Areas). “Dirty” areas are the ones where patients are treated (ICUs and UIs).

The segregation zones between "clean" and "dirty” locations were strategically chosen according to the internal flow of patients and healthcare professionals. Areas with differential pressure, called antechambers, are inflated compartments with positive pressure

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that prevents the airflow (negative pressure) from a “dirty” area from invading a “clean” environment. Therefore, it is possible to minimize the contamination of objects and health professionals who have not yet undergone the process of dressing. Figure 4 outlines the distribution of areas and Figure 5 shows the details of the segregation site, as well as the air flow process.

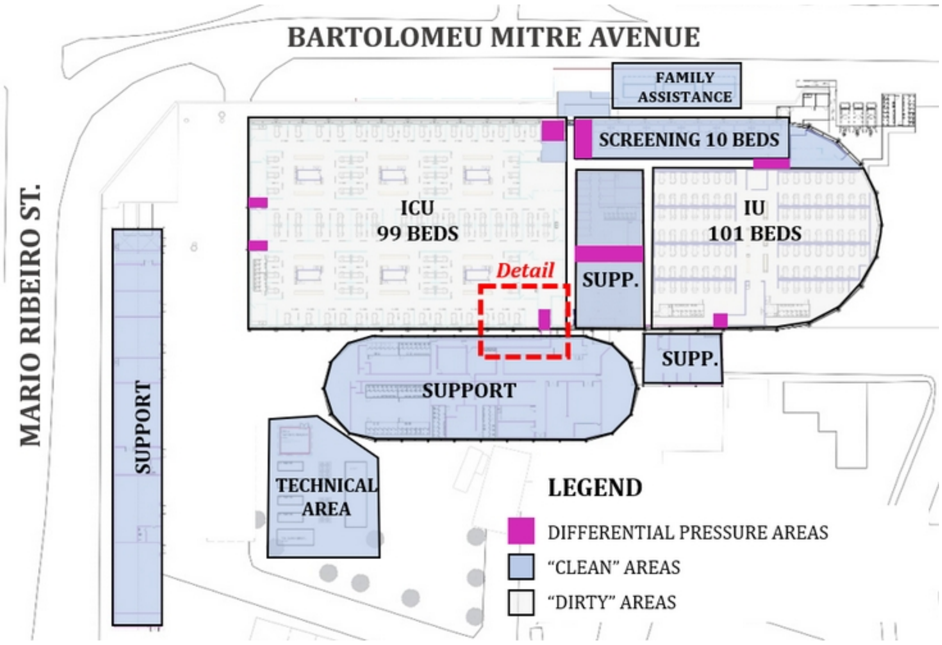

Figure 2. “Clean” and “dirty” areas” and antechambers.

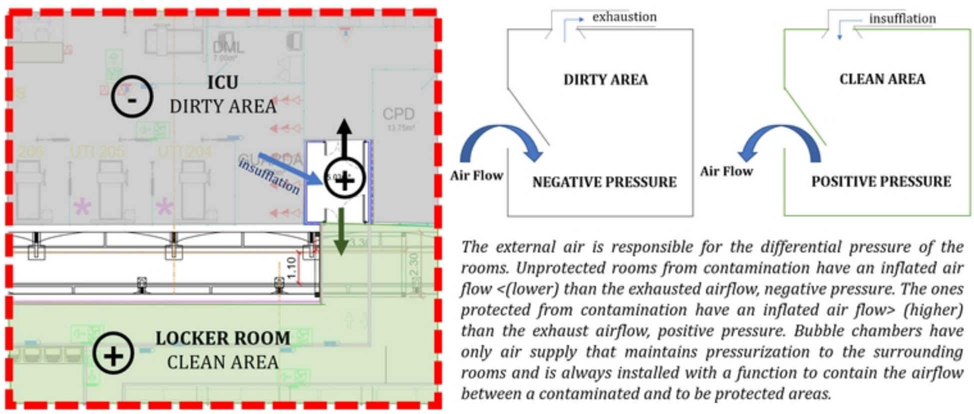

Figure 3. Example of segregation site - Detail of the antechamber between tents.

7. DIMENSIONING OF ROOMS, DEFINITION OF FLOWS AND TYPOLOGY OF BEDS

The premises for the HCLB project followed the recommendations of regulation nº. 50 (RDC, 2002). The RDC 50/2002 was established by the Brazilian National Health Surveillance Agency (ANVISA) as the main document to guide medical facilities construction and operation. The resolution came into force on February 21, 2002, and it details the quantity and size of medical spaces and building installations, environmental comfort and circulation conditions, infection avoidance measures, and fire safety protocols.

Each sector of the HCLB was designed according to the specific characteristics of the pandemic. In Figure 6, it can be noted that the top five spaces that overcome what the legislation recommended are related to the entrance of ambulances, pharmacy, and storage

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of clothes (clean and dirty) and garbage. The COVID-19 approach demands intense cleaning processes and continuous replacement of the items used during the patient's treatment.

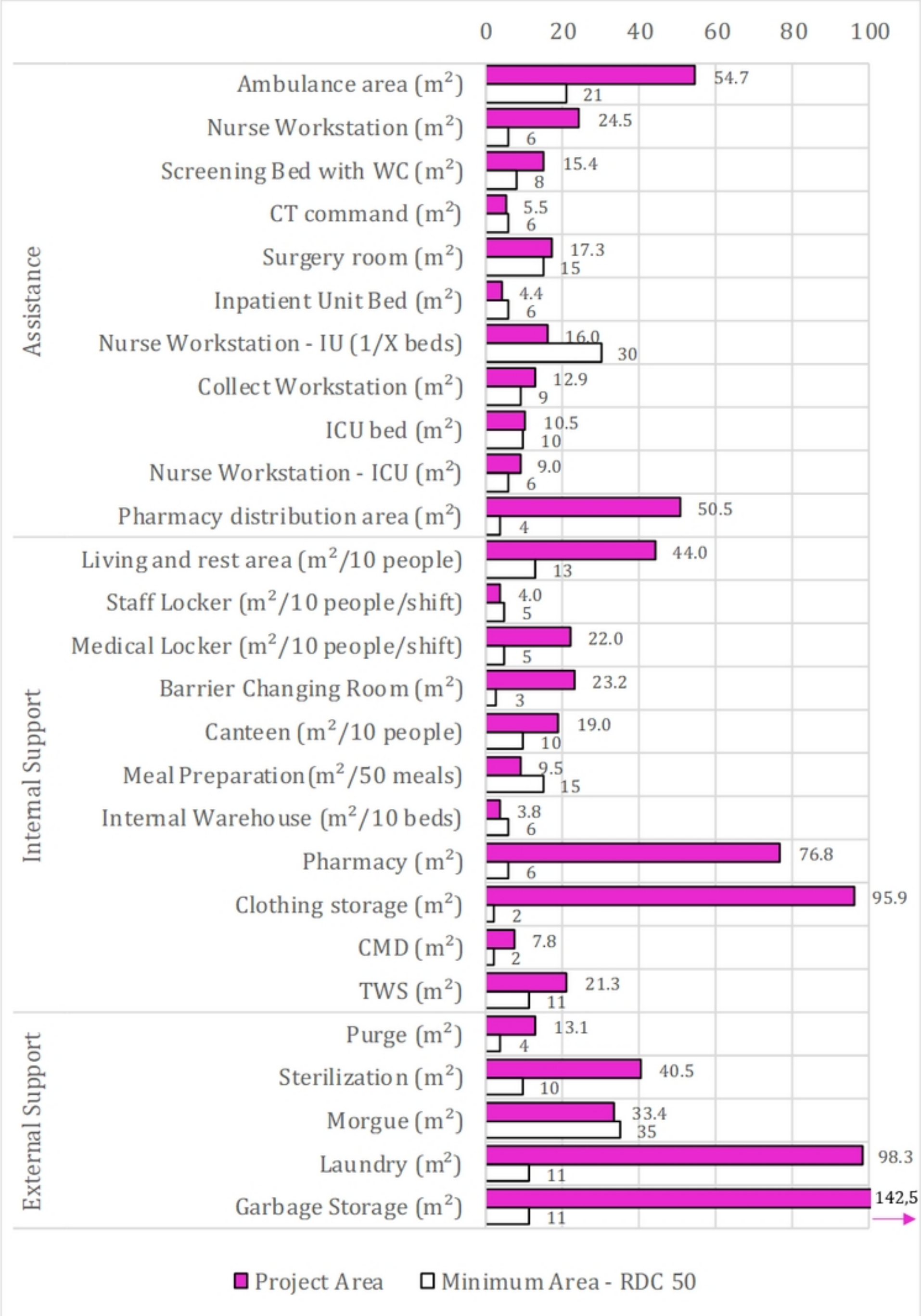

Figure 4. Comparison of areas projected and minimum recommended (RDC 50).

Subsequently, internal and external flows were designed in order to avoid crossing people, medicines, clothes, and contaminated and clean supplies. For the external environment, six inflows and outflows were defined: patient/companion, doctors, collaborators, clean inputs, dirty inputs, and morgue. The internal flow of patients and collaborators consists of the admission of the patient and, necessarily, undergo an evaluation in the screening sector so that the health professional can measure the degree of complexity of the disease. After that, they would take them to the respective sector, ICU, or UI. Both external and internal flows are shown in Figure 7.

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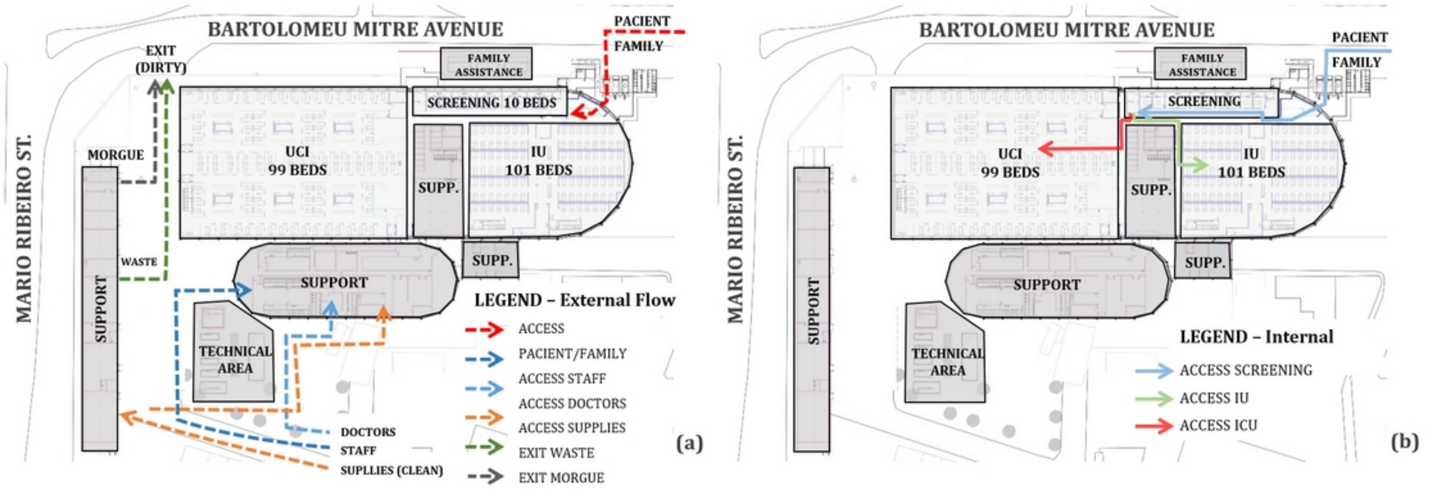


Figure 5. Circulation Flows: (a) External and (b) Internal Flows.

Due to the evaluation of the screening sector, patients with stable health conditions are referred to inpatient units and those of greater severity to intensive care and allocated to beds according to the level of complexity. Four types of beds were designed, one for UI (Type 1) and three for ICU (Types 2, 3, and 4). Type 1 beds are used for stable patients and ICU beds that have been stabilized to undergo an observation period. Type 2 beds are for medium severity patients and types 3 and 4 for highly complex patients. The difference between types 2 and 3 is that in the latter, patients who need mechanical ventilation are treated. In typology 4, in addition to the use of respirators, dialysis mechanisms were provided for renal treatment. The characteristics of each typology are shown in Figure 8 and summarized in Table 1.

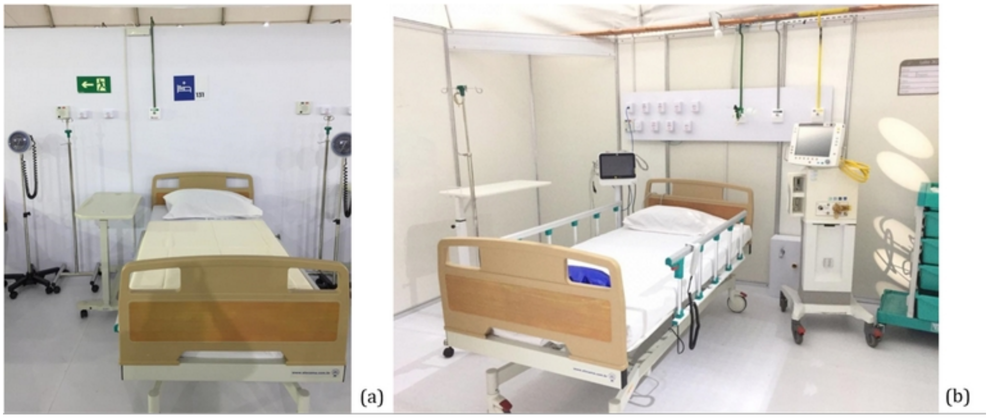
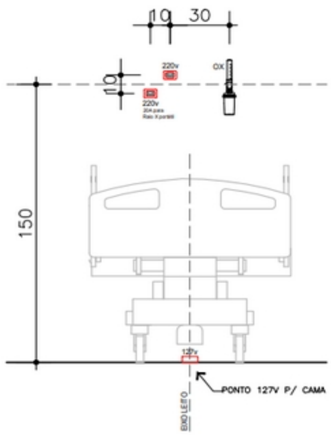
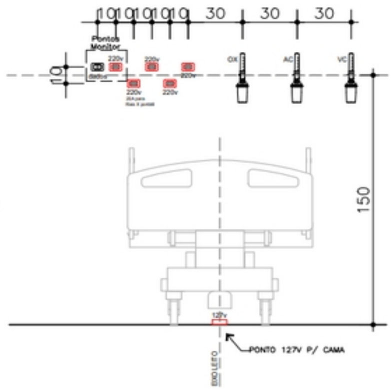
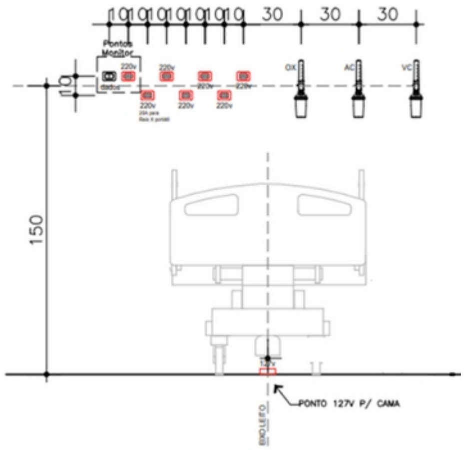
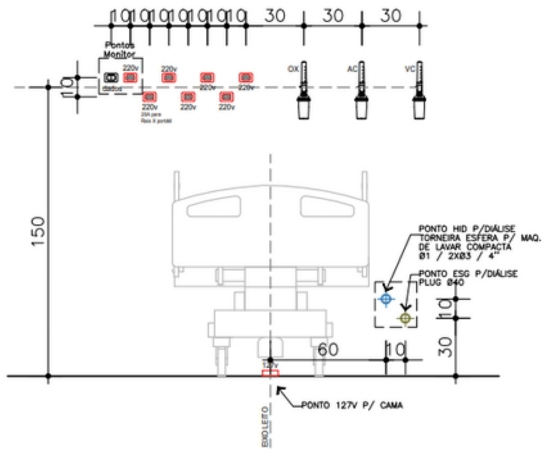


Figure 6. Examples of beds: (a) Type 1 and (b) Type 4.

Table 3. Typology of bed.

TYPE 1 – IU Patients of low complexity	TYPE 2 - ICU without ventilator Patients of mild complexity
	
• 1 pt 127 V (bed) • 1 pt (OX) • 1 pt 220 V – 20 A (x ray) • 1 pt 220 V – 10 A (extra)	• 1 pt 127 V (bed) • 3 pts (OX, CA e VC) • 1 pt 220 V – 20 A (x ray) • 3 pts 220 V – 10 A (extras) • 1 pt 220 V – 20 A (heart monitor) • 1 pt (data for heart monitor)
TYPE 3 - ICU with ventilator Patients of high complexity	**TYPE 4 - ICU with ventilator and dialysis Patients of high complexity**
	
• 1 pt 127 V (bed) • 3 pts (OX, CA e VC) • 1 pt 220 V – 20 A (x ray) • 4 pts 220 V – 10 A (extras) • 1 pt 220 V – 10 A (nobreak for ventilator) • 1 pt 220 V – 20 A (heart monitor) • 1 pt (data for heart monitor)	• 1 pt 127 V (bed) • 3 pts (OX, CA e VC) • 1 pts 220 V – 20 A (x ray) • 2 pts 220 V – 10 A (extras) • 1 pt 220 V – 10 A (nobreak for ventilator) • 1 pt 220V – 20 A (monitor) • 1 pt 220 V – 20 A (heart monitor) • 2 pts 220 V – 20 A (dialyse) • 2 pts (dialyse: water and sewage)

8. PLANNING AND CONTROL OF CONSTRUCTION PROCESSES

Just as the pandemic scenario is atypical, the planning and control process for this enterprise was no different. The FHLB had its planning phase parallel to all the other enterprise activities (Table 4), due to the short time to complete the construction. Another particularity was the need for daily reviews of the physical and financial schedule because as the works progressed, the management team was faced with new scenarios, services, and even loss of the workforce due to contamination.

Table 4. Activities of Planning and Control phases

PROCESS DESCRIPTION	TIME (DAYS)
PLANNIG AND CONTROL	20
SPONSOR AND GP NOMINATION	1
TIME DEFINITION	1
SCHEDULE AND BUDGET	19
MANAGEMENT TOOLS	19

The planning process started with the demand to build the hospital. The first step was to nominate the Sponsor and Project Manager. Subsequently, the project team schedule and detailed project budget were defined. Due to the acceleration in the number of people infected by COVID-19 and the increasing scarcity of beds in the public sector, the deadline for completion of the hospital was the central premise considered for the success of the project. The management tools used during the Construction Planning and Control processes were:

- Deadline and Cost Management: Physical and Financial Schedule, to monitor deadlines and cash flow; Cost Spreadsheet of Services Performed (incurred and trends) to compare economic and financial advances; Weekly reports of physical and financial monitoring to be sent to the sponsor;
- Production Management: Daily field reports to highlight the activities performed daily; Control of equipment hours worked, to check possible idleness; Daily Video Team Meetings Calls for suggestions, criticisms and general project issues; Daily Monitoring of Physical Progress to check at the end of the day which schedule was not fully executed; Daily Staff Control to monitor how many employees worked at the end of the day; Check-List of deliveries to verify that deliveries were in accordance with the project;
- Safety, Healthcare, and Environment Management: Daily monitoring of the temperature of all employees entering the construction site (fever is an indication of COVID-19 contamination); General and specific PPE (masks and alcohol gel) to avoid contagion; Documentation control of companies and employees (ASO, CT, PPRA, and PCMSO) to guarantee the liability of contractors in the event of accidents at work;
- Supply Chain Management: Acquisition and management of all materials and services acquired in compliance with corporate compliance requirements;
- Suppliers Assessment: At each delivery, suppliers were evaluated according to the following criteria: quality, deadline, support service, safety, and organizations. In this way, the construction team decided if there was a need to change the supplier or just an adjustment of conduct.

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9. CONSTRUCTION OF THE FIELD HOSPITAL

Worldwide, the selection of the constructive model of a field hospital may differ due to aspects related to medicine and health, and engineering. On the one hand, consideration should be given to the evolution of the number of people infected and killed by COVID-19, forms of treatment depending on the clinical condition and the number of professionals involved in the hospital operation. On the other hand, it must also be considered which spaces are available to build a temporary unit, investment level for construction, the deadline for project completion, and technical capacity for building. The construction of the FHLB obeyed all these needs.

To meet the deadlines and costs established for the HCLB, a temporary construction structure was used, similar to those adopted in sporting events and shows, due to three factors: for being a structure usually known and of quick assembly; for meeting the characteristics of the land selected for construction; and for meeting the need program. Besides, another important reason for achieving the final objective was the great parallelism between all activities, as shown in Table 5.

Table 5. Work Schedule

DESCRIPTION	TIME (DAYS)																				
CONSTRUCTION	20	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
PRELIMINAR SERVICES	5	x	x	x	x	x															
ELEVATED FLOOR	5	x	x	x	x	x															
TENT ARCHES	5		x	x	x	x	x														
CANVAS COVER	7		x	x	x	x	x	x	x												
VINYL FLOORING	5							x	x	x	x	x									
INTERNAL WALLS	9							x	x	x	x	x	x	x	x	x					
INSTALATIONS	11				x	x	x	x	x	x	x	x	x	x	x	x	x				
FINISHING AND CARPENTRY	3														x	x	x				
VISUAL IDENTITY	2																x	x	x	x	x

FHLB's construction process consisted of setting up support tents, assistance, and container systems that were used as restrooms. After assembling the elevated floor and lifting the tent arches, it can be covered with canvas so that workers could work internally without the action of the weather. Then, the entire laminated vinyl floor was installed. The room partitions were initially designed to be in a modular system of aluminium tubes in TS type panels (OCTANORM). This modular system gained prestige due to the ease of use of the material and, mainly, the system assembly productivity. However, due to many field hospitals that were being built at the time, the supply of this system was impaired, which forced us to also use another construction method: the construction of partitions in wooden walls covered with Nappa.

The data facilities and closed-circuit monitoring were built with security level to protect the privacy and provide the necessary analyses to the health professionals. The hydraulic and sewage facilities were installed under the raised floor and ascended through holes in the floor to feed the entire hospital distribution network. This criterion was also adopted for electrical installations and medicinal gases, supplied using equipment located in the technical area and distributed through apparent piping, as shown in Figure 11.

As advantages, it can be highlighted the productivity and ease of maintenance. For shortages of water, electricity and medicinal gases, HCLB has the following autonomies: 48 hours of water supply through internal reservoirs; 45 hours of power supplied through a generator system; 30 minutes of autonomy of own batteries in case of delay in entering the generator system for IT installations and electrical outlets dedicated to specific clinical engineering

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equipment; approximately seven days of oxygen supply (OX), from a second oxygen tank; and variable autonomy of Vacuum (VC) and Compressed Air (CA), ensured by a central VC and AR cylinder used as a backup, where the autonomy varies according to the number of cylinders currently available. Also, in parallel with the above steps, the air conditioning of all the tents that make up the FHLB structure was built, which corresponds to the availability of 600 tons of refrigeration (TR) or 7.2 million BTU / h, considering the air renewal system.

The climatization of ‘clean areas’ was made through a textile duct, chosen due to its flow rate capacity, renovation of air, and lightness of the material. On the other hand, in ‘dirty areas’, air conditioning Splits type was chosen to insufflation and an independent renovation air system. To both areas, the adequate temperature projected is between 20º and 24º. Figure 11 exemplifies the functioning of both zones mentioned.

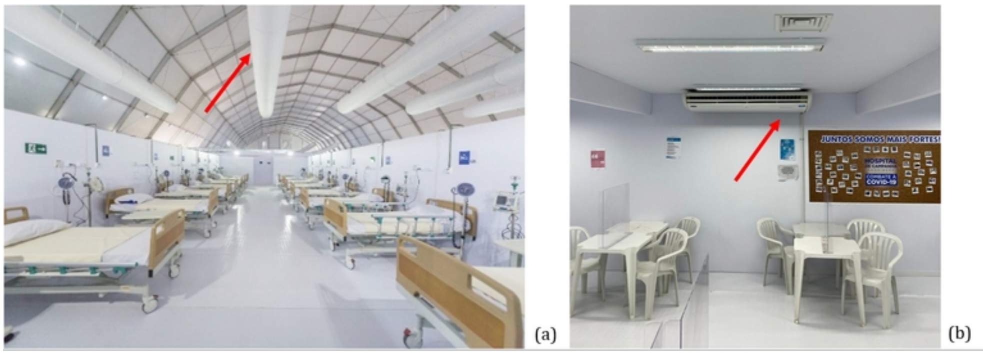

Figure 7. Types of refrigeration: (a) Textile ducts in dirty areas and (b) Splits in clean areas.

10. CONCLUSIONS AND LESSONS LEARNED

The Field Hospital concept has incorporated evolutions and expansions over time, mainly due to the nature of its purpose. Provisional units have been built around the world as an emergency way to assist victims of armed conflicts, natural disasters, epidemics, and pandemics, as is the case with the new coronavirus, which required field hospitals to be built worldwide. Planned and constructed according to the characteristics of the situations faced, they can have variable physical structures and must be easy to transport and install, to be viable even in remote or hostile regions. Each Field Hospital has the specific infrastructure to ensure safety for patients and employees, prevention and control of infections, provision of supplies, water supply, sewage, and solid waste collection, and provision of medical care at various levels of complexity.

The design characteristics and constructive methodologies of field hospitals for COVID-19 treatment may vary, mainly depending on the demand of patients and available physical space. The Pacaembu Campaign Hospital, in São Paulo, and the Campaign Hospitals Parque dos Atletas and Maracanã, in Rio de Janeiro, are examples of hospitals with similar characteristics to this study. In both cases, patients' demand was discharged for low and high complexity cases, which required hospital beds and intensive treatment.

In care units such as the Clementino Fraga Filho University Hospital (HUCFG / UFRJ) and Rio Centro Campaign Hospital, both in Rio de Janeiro, the existing structures have been adapted. In the case of HUCFG, due to the low demand of patients, constructive interventions aimed at adaptations were low. In addition to forecasting high patient demand, the Rio Centro Campaign does not have a hospital infrastructure, but rather a convention center, demanded a more significant effort of design and construction.

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The design and construction of the FHLB were developed according to two main objectives: to meet the specificities of treatment of patients and to prevent the transmission of infectious particles between people. In this sense, taking into account the recommendations issued by the Brazilian Association of Intensive Care Medicine AMIB (2020), the electrical, hydraulic, and HVAC installation projects were developed to provide adequate environments and equipment for intubation and continuous monitoring, for hemodynamic support and dialysis, for surgical procedures, and X-ray and ultrasound examinations at the bedside and in a specific room, aiming at improving diagnosis and the therapeutic plan.

Aiming at isonomy in the care of patients with disabilities, the project considered the ABNT NBR 9050: 2015 standard requirements, especially concerning horizontal and vertical signage, bathroom size, floor characteristics, circulation space for wheelchair users, and ramps access. Also, all bathrooms are equipped with electric showers, ensuring hot water for patients and healthcare professionals.

Some challenges of designing and building this enterprise model are not unlike any other, such as: the logistics of inputs, preparation and control of physical and financial schedule or specialized labor. However, within the scenario in which the FHLB construction project was inserted, it is worth highlighting three specific challenges.

The first concerns the context in which the enterprise was developed: a short period of 20 days and the need for the enterprise planning and control to be carried out during a pandemic, whose consequences were also reflected in the reduction of public transport for the workforce, in the worker's fear of contaminating family members, in the scarcity of hospital PPE such as masks and gel alcohol, in the absence of contaminated workers, among other factors that impacted productivity. Also, the events market, the sector that provided the most significant amount of inputs and construction services, had little experience in this type of situation, which meant that the schedule needed to be reviewed daily, also because the productivity indexes were not known in the civil construction market, which required the planning metrics to be obtained during activities.

Second, concerns the lack of knowledge of specific aspects of the pandemic by the designers and other Brazilian professionals dedicated to the design and construction of hospitals. Also, the labour used, although having extensive experience in temporary installations, had no previous experience in plants with the necessary characteristics, which required a great deal of interaction between designers and contractors.

The third concerns the characteristics and configurations of the internal environment, which demanded specific strategies to protect patients and health professionals against the contamination and spread of the virus, such as, for example, an HVAC system containing specific filters that prevent the dispersion and spread of droplets expired indoors; pressure differential zones that segregate "dirty" and "clean" environments, and circulation flows designed and integrated with strict safety processes. In addition, there was also a concern that other contaminants could penetrate the internal environment.

To provide subsidies for the design and construction of field hospitals for the prevention of epidemics that have characteristics like those of COVID-19, for each phase of the project, we summarize in Table 6 the main concepts and premises and their respective conditions.

Table 6. Phases of the Hospital implementation: premises and restrictions.

Phase	Premises	Restrictions
Project Elaboration	Needs Program	1. The capture of health professionals' demands and expectations; 2. Definition of a program of general needs (number and model of beds, specification of support and assistance areas), specific (characterized by the reason why the unit is being implemented) and complementary (meeting corporate and government requirements);
	Segregation between 'clean' and 'dirty' zones	A strategic choice for transit locations for infected and non-infected people. Use of specific filtering equipment to prevent the spread and proliferation of the virus. Use of antechambers with pressure differential so that "clean" environments, positive pressure is contaminated by "dirty" environments, negative pressure;
	Procedures Room	Located in a "clean" environment with air conditioning with specific filtration;
	CT and mobile X-Ray	Specific clinical engineering requirements for virus diagnosis. Located in a "dirty" environment;
	Sizing Rooms	The sizing must be carried out according to the relevant regulatory agency in each country. In Brazil, it is N ° 50 (RDC, 2002)
	Internal and External Flows	Avoid crossing contaminated and clean people, medicines, clothes, and supplies;
	Beds Typology	1. UI (TYPE 1) - low complexity patients; 2. ICU (TYPE 2) - medium complexity patients, does not require the use of mechanical ventilators; 3. ICU (TYPE 3) - highly complex patients, requires the use of mechanical fans; 4. ICU (TYPE 4) - highly complex patients, requires the use of mechanical ventilators and a dialysis system;
Planning and Control	Project Time	Definition of Sponsor, Project Manager, and Project Team;
	Management Tools	1. Time and cost monitoring tools; 2. Tools for monitoring field services; 3. Tools for monitoring the safety, health, and environment of employees; 4. Tools for monitoring contracts; 5. Tools for assessing suppliers;
Construction	Constructive Model	1. Choice of the provisional structure according to the assembly speed, ease of implantation in the available terrain for the construction of the hospital and technical capacity to accommodate the needs program; 2. To guarantee the 20-day construction period, there was a need for parallelism between all field activities; 3. All apparent infrastructure facilities for productivity gains and ease of maintenance; 4. A central cooling system through textile ducts capable of overcoming the entire perimeter of the hospital; 5. Guarantee of autonomy for vital systems of operation of the unit (water, electricity, medical gases, and plugs to service clinical engineering equipment);
	Activity Sequencing	1. Preliminary Services; 2. Installation of the Raised Floor; 3. Installation of tent arches; 4. Installation of the Canvas; 5. Installation of the Vinyl Floor; 6. Installation of partitions; 7. Electrical, Hydro-sanitary, Medical, and Special Gases Installations; 8. Finishes and Joinery; 9. Visual Programming

To detect points of improvement for future projects of this nature, after the end of HCLB activities, meetings were held with designers and professionals who participated in the unit's operation. We found three points that deserve featured. The first refers to the proportion of ICU and ICU beds. Patient volumes admitted to the unit were mostly of high complexity, which meant that the proportion 50% initial threshold for beds of UIs and ICUs did not correspond to the need. The second point concerns the space allocated to the screening beds. Because it is a unit exclusively for patients previously tested positive for SARS-CoV-2, this bed typology was oversized. With that, this space could be better used for another purpose, such as ICU beds. Finally, although no case of contamination between patients and health professionals demonstrated the effectiveness of the system HVAC, antechamber doors designed with pressure differential, not always remained closed, mainly due to the hospital routine. Devices with automatic closing would resolve this issue.

The present study has two main limitations. The first relates to the possibility that some important contribution has not been addressed in this analysis. However, an attempt has been made to present all the construction processes of the case in question. The second concerns the constructive variability of a Field Hospital, depending on the purpose, time of construction, availability of materials and services, and technological and financial contributions.

It is not known when there will be another outbreak, such as coronavirus. However, as a suggestion for future research, three possibilities are pointed out. The first is a comparative study between the different structures for provisional units, seeking to identify the main construction methods and application for each environment, considering regional climatic factors, market availability for each model, and an analogy between investment levels with tight deadlines.

The second, a bibliographic review of hospital solutions adopted in highly infectious environments. In this article, it was presented the applied solution in FHLB that enables healthcare professionals donning and doffing and to use the support areas with low risk of contamination and dissemination of the virus. The implemented solution was in the HVAC discipline, causing a pressure differential that prevents the virus from entering "clean" environments. Other subjects and solutions can be presented and broaden the debate in this regard.

And finally, the last suggestion is a study, through qualitative analysis, of different user's experiences in field hospitals build for this COVID-19 pandemic.

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Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency

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ABSTRACT

In response to the COVID-19 global pandemic, the Colombian Ministry of Science and Technology launched the call for research proposals "MinCienciatón". The call invited researchers in different fields to submit solutions that help to mitigate the health emergency produced by the spreading of the virus worldwide, including ideas for the isolation of infected patients and the protection of medical staff. In this context, the LAB LAHC1 was selected to produce a Portable Epidemiological Isolation Unit. A Product of the laboratory's research in polyhedral geometry and ephemeral architecture, we designed a pneumatic structure which allows for the treatment of infected patients as well as the isolation of medical staff and equipment. In the event that the health system becomes saturated, this system will allow the sanitary authorities to expand their hospital capacity when needed. It will also allow for the installation of field hospitals in isolated areas within the national territory that do not have the necessary infrastructure to cope with the sanitary crisis.

Keywords: Biomedical Design, Pneumatic Structures, Ephemeral Architecture, Polyhedral Geometry.

INTRODUCTION

According to the information provided by the Ministry of Health (2020), the Colombian government established a four-phase strategy to respond to the contingency produced by the Covid-19 pandemic. During the first two phases, the health authorities expect to treat infected patients in traditional health providing institutions. The third and fourth phases correspond to critical situations, in which it is expected that the health system will become saturated, and patients will have to be treated in provisional facilities adapted to cope with the contingency. According to this panorama, there is a general concern for highly populated zones that do not count with the necessary amount of Intensive Care Units to deal with a situation of elevated rates of contagion. Likewise, the situation is worrying in remote areas of the national territory that have low capacity health facilities or that simply lack of health provider care centers.

Taking into account the aforementioned context, it is very likely that at some point of the sanitary crisis the health authorities will have to adapt large covered areas (sports centers, exposition halls, warehouses, etc.) to create temporary care centers. In such spaces, it will be crucial to guarantee the appropriate spatial and functional conditions to treat infected patients and to prevent the spread of the virus.

As a contribution to the efforts made by national and local governments to face the emergency, we put into function of the current needs the results of previous experimental projects – related to lines of research in ephemeral architecture, non-conventional structures and polyhedral geometry. In response to the call MinCienciatón for research proposals launched in march 2020 by the Ministry of Science and Technology, we proposed the design and production of a Portable Epidemiological Isolation Unit (to which from now on we will refer to simply as PEIU). In accordance with the briefing of the call, PEIU is a device "for the management of patients with COVID-19 and other acute respiratory infections, guaranteeing the safety of health professionals" (2020).

Selected for funding by the Ministry of Science and Technology, PEIU is a system that allows for the construction of temporary health facilities based on concepts of flexibility, adaptability, portability, low cost and a fast track low-technology fabrication approach. These features of the proposed system are of particular interest in the current context because they allow for an expedite and low-cost manufacturing process, a simple assembly procedure that does not require specialized workforce for installation and maintenance, and the possibility to transport the isolation units to any place within the national territory. In addition, the designs allow for variations of size and shape which will let the system to be easily adapted to respond to the variable spatial conditions of the potential implementation sites.

PEIU is a pneumatic structure made of PVC fabrics, and it is composed of a series of 2 frequency icosahedral geodesic domes interconnected through cylindrical tunnels. This structure can be used both for the treatment of infected patients in aseptic and well-ventilated environments and for the isolation of medical staff and equipment exposed to the virus. Additionally, in agreement with the recommendations of the World Health Organization, the system will guarantee:

- Permanent surveillance of the confined space from the exterior of the domes.
- The possibility of adapting ventilators, hand washing equipment, purifiers or nebulizers, and other required medical equipment inside the domes.
- The connection to hydraulic and electrical installations in accordance with the requirements of field hospitals.

Next, we will present the project's background, the design methodology and concepts underlying the development of PEIU, its materialization process, and the preliminary results and conclusions of production of the system.

1. PROJECT BACKGROUND: SOME NOTES ON PNEUMATIC STRUCTURES

Pneumatic structures are defined as building systems whose shape and stability are determined only, or in great measure, by a pressure difference created by the injection of gases, liquids, cellulose or granular substances (Nader, 2019). These structures work by traction, they use the loads parallel to the membrane and convert them into parallel vectors that create tension on it.

Several explorations about pneumatic structures were made during the last century, but the research on this field began in the eighteenth century with the invention of the hot air balloon (Chi & Pauletti, 2005). In architecture and construction, pneumatic structures were broadly used during the twentieth and early twenty-first centuries (Gomez-González et al. 2011). Some paradigmatic explorations about the use of pneumatic structures in the design of spaces include Frederick William Lanchester's pneumatic architectural system, developed in 1917, Walter Bird's development of large span structures, produced during the 1950's, Frei Otto's research about the formal configurations of pneumatic structures, as well as Dante Bini's creation of the Binishell system, which uses inflatable membranes as formwork for the construction of shells in reinforced concrete. Other paradigmatic researches on the use of pneumatic structures in architecture include the construction in 1970 of the U.S. pavilion in Expo Osaka, Norman Foster's design in 1971 of a temporary structure for the offices of CLT in England, and the development of vacuumatic structures by William A. Hanna and John Gilbert, which represents the latest theoretical advance in the field of pneumatic structures.

Throughout the twentieth and early twenty-first centuries, pneumatic structures have been largely used for military, emergency, exposition and storage purposes. Today, this type of structure is still used for covering large spans in warehouses and shopping malls, as well as in experimental buildings that combine the use of pneumatic structures and other building systems such as space lattices and wire meshes. Some paradigmatic examples of the contemporary use of pneumatic structures in the design of spaces is the Eden Project, by Grimshaw & Partners, and the Beijing National Aquatics Center, also known as Water Cube, designed and built for the 2008 Olympic Games by a consortium made up of PTW Architects, Arup, CSCEC and CCDI.

Pneumatic structures are usually constituted by a membrane (that can be fabricated with polymers), stiffening cables and ballasts that support and stabilize the structure, compressors or fans that inject and maintain air inside the structure, and air locks to prevent the loss of internal air pressure. These kind of structures can be of three types according to the magnitude and control of the pressure, and the direction of injection of the stabilizing fluid. The first type is constituted by low-pressure structures (supported with air). The second type includes high-pressure structures (inflated with air). The third type is composed by hybrid systems that combine low and high-pressure techniques. According to the direction of the injection of the fluid, pneumatic structures can be of positive pressure, if they are injected with a stabilizing fluid, or of negative pressure, if they work by means of the extraction of air (Figure 1).

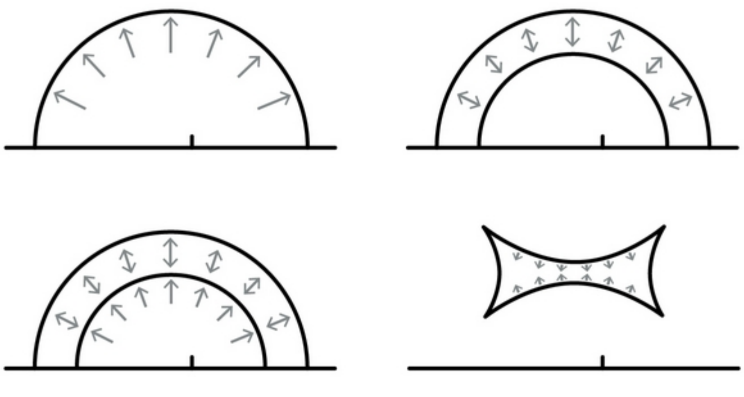

Figure 1. Four types of pneumatic structure: Low positive pressure, high positive pressure, hybrid (low and high positive pressure), high negative pressure.

Various aspects of pneumatic structures are of particular interest for the development of PEIU (which, accordingly to the classification of pneumatic structures presented above, is a low positive pressure pneumatic envelope based on the use of membrane skins). As mentioned before, the current sanitary crisis will require the construction of temporary facilities that must respond, among other aspects, to criteria of portability, low cost and a low-technology fabrication approach. Crucially, pneumatic structures can be built with light and cheap materials, they can be produced rapidly, they are foldable, transportable and easy to install, and their construction and assembly doesn't require highly specialized machinery or workforce. These aspects permit to create large and light structures in little time with a relatively small budget.

2. DESIGN METHODOLOGY AND CONCEPT: LESSONS FROM NATURE

In recent years, the LAB LAHC has accumulated considerable knowledge and experience in the line of research of "nature and geometry". Following Buckminster Fuller (1982), who claimed that nature works according to minimum energy requirements and is the perfect result of what he calls "spatial compressions", we accept that the universal law of energy is that systems always seek and find their more efficient state and that in consequence, natural systems always find autonomously the most adequate spatial arrangements. For instance, superficial tension is responsible for some insect's ability to stand on water without drowning; of course, nobody explained insects the principle of superficial tension. In the same way, several natural systems discovered themselves that the spherical formation is the shape that can encapsulate the biggest amount of volume with the lowest possible surface area. Thanks to this universal principle, bubbles have the shape we know. According to the aforementioned natural law, the molecules that constitute the thin layer of the membrane of the bubble self-organize to find the most compact configuration (Wang et al., 2018). In this way, they achieve the form with the smallest necessary surface to enclose the quantity of air contained inside them.

By acknowledging the capacity of natural systems to find the most efficient and the smartest spatial solutions, we look at nature as a means to translate its functioning into a constructive language. This method is a means to explore spatial solutions adapted to the needs of the construction of the built environment. This approach is at the core of the development of PEIU, a project in which we explore concepts of polyhedral and synergetic geometry to solve efficiently the spatial needs of emergency structures.

Amongst regular polyhedral, the icosahedron is the one which shape is closer to that of the sphere, if one takes into account the relation between its surface and its volume (Coexter et al., 2012). An example of the efficiency of this shape is the shell of icosahedral viruses, which take a spherical shape to protect the genetic material with the lowest possible protein investment (Figure 2).

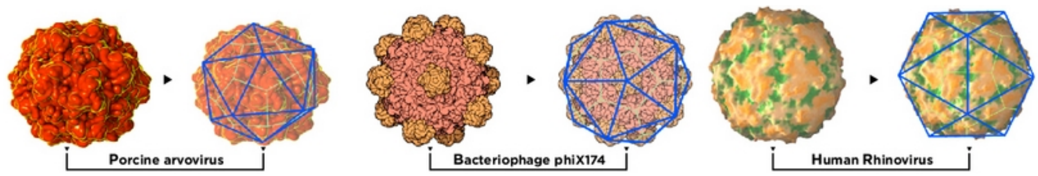

Figure 2. Icosahedral viruses: Porcine Parvovirus, Bacteriophage phiX174, Human Rhinovirus. Image adapted from: Kateryna Kon, http://pdb101.rcsb.org/motm/2; http://www1.biologie.uni-hamburg.de/b-nline/chimes/virus/introicos.htm

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This kind of shape is ideal for the production of pneumatic structures for two reasons. One is the abovementioned efficiency of the icosahedron in terms of the relation between surface and volume. The second reason is that the triangulation of the surface reduces the load received by each one of its faces, because the seams that join them function as load transmitters that replace the use of cables. According to the above, the icosahedron offers two interesting features that suit two major needs of our briefing: low material consumption and stability. For these two reasons, we chose it as the basic spatial typology for the production of PEIU.

The icosahedron is the regular polyhedron more similar to the sphere, and it is the symmetric polyhedron that circumscribes the biggest number of great circles: G.C = (faces / 2) + (vertexes / 2) + (edges / 2) (Fuller, 1982). However, the icosahedron is not as efficient as the sphere. To achieve the highest efficiency of the shape, an icosahedron of frequency 2 was created accordingly to the steps described below (Figure 3):

- The icosahedron is inscribed into a sphere.
- The center of the sphere is found in a way that, under the conditions determined by the previous step, it coincides with the center of the icosahedron.
- Radial axes are drawn towards the surface of the sphere intersecting each one of the 30 edges of the icosahedron at its center.
- The intersection points are projected towards the surface of the sphere on the direction of the radial axes, thus generating two edges and one vertex out of each one of the pre-existing ones.
- The new 30 vertexes are connected to each other to generate 60 extra edges. Through this process, starting from the Icosahedron as a geodetic sphere of frequency 1 (20 faces, 30 edges, 12 vertexes), it is possible to obtain a geodesic sphere of frequency 2 (80 faces, 120 edges, 42 vertexes).

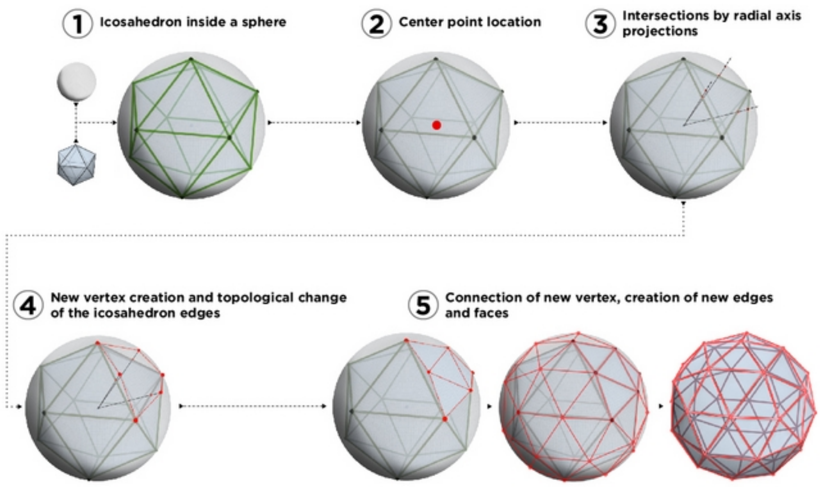

Figure 3. Steps for the creation of a geodesic sphere of frequency 2.

In this way, we created a shape that gets closer to the sphere's degree of efficiency; the above through the optimization of the integrity pattern of the geometry by describing 121 large circles. To obtain the dome, the resulting geometry is sliced into two equal parts using as cutting axis any of the 6 large circles coinciding with the planes described by the edges with the same length (Figure 4).

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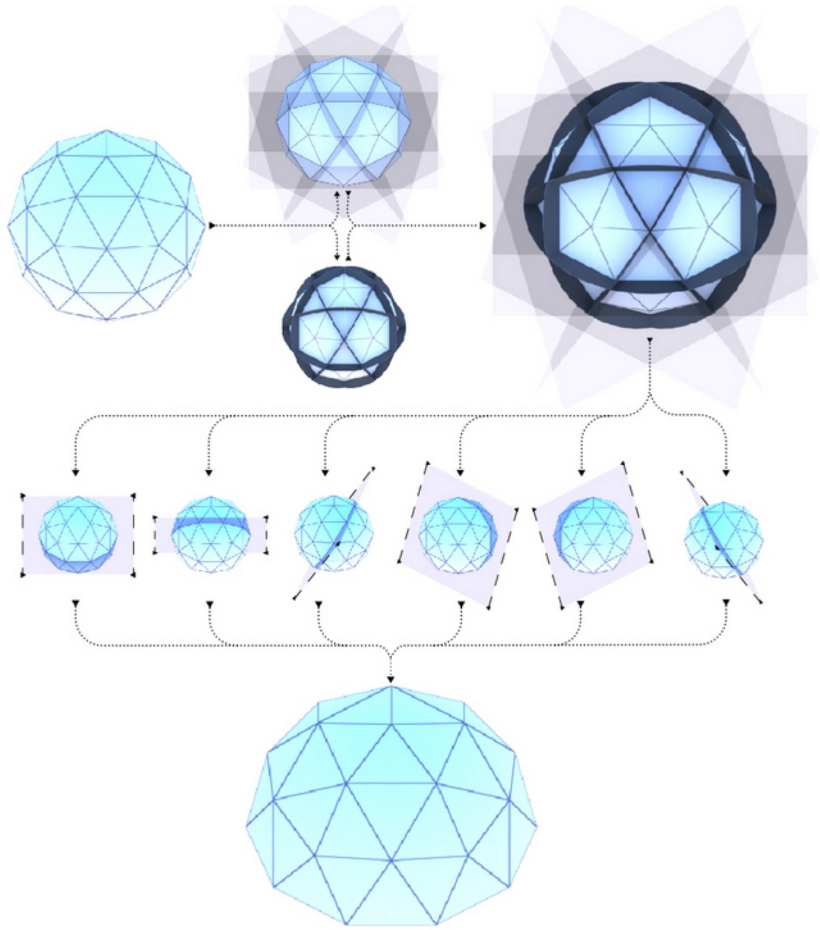

Figure 4. Creation of the dome through the slicing of the icosahedral geodetic sphere of frequency 2.

The resulting dome provides the geometry to create the isolation units. To create the full system, it is necessary to group and connect several domes in the most space-efficient way. As shown in Figure 5, since the sphere is an omnisymetric geometry, it permits the creation of packages of identical shapes for the maximal optimization of space.

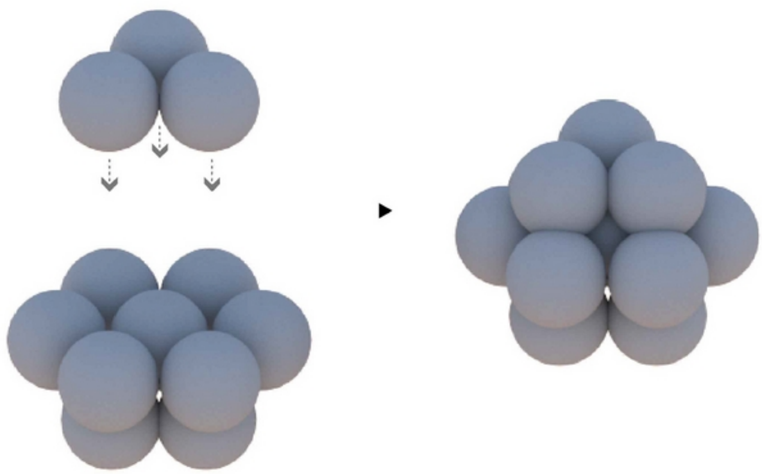

Figure 5. To create a package, six spheres are placed around one sphere, then three spheres are placed above and below.

Since all the isolation units of the system must be built directly on the ground, the form-finding process is focused on the search of the most efficient assemblage of several domes on a plane. This is made through the superposition of an hexagrid (made of regular hexagons of minimal diameter 5m) and the geometry of municipal sports centers in Colombia (which are the spaces where it is more likely to install PEIU when needed). The most optimal configuration is achieved through the grouping of thirteen domes in which the three central elements are replaced by a cylindrical shape that becomes the aisle that interconnects the whole system (Figures 6, 7 and 8).

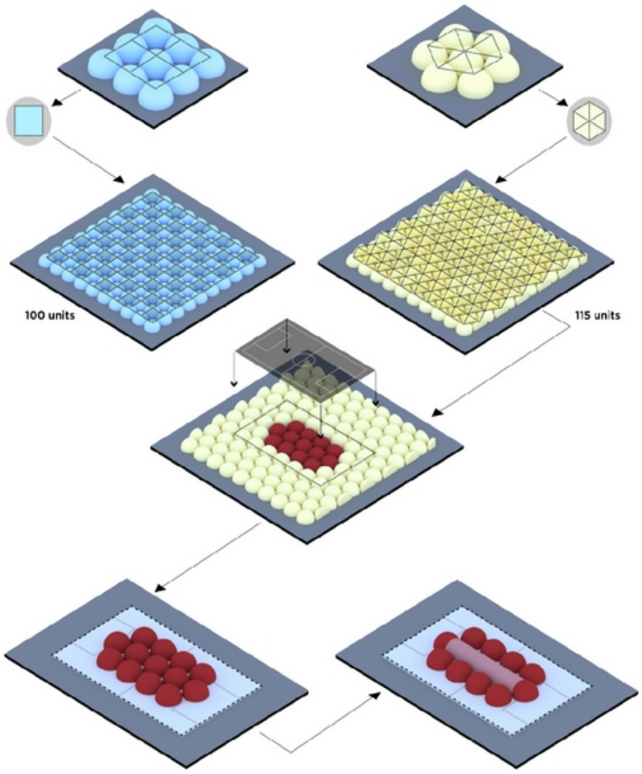

Figure 6. Form-finding process for the definition of the floor plan configuration of the system.

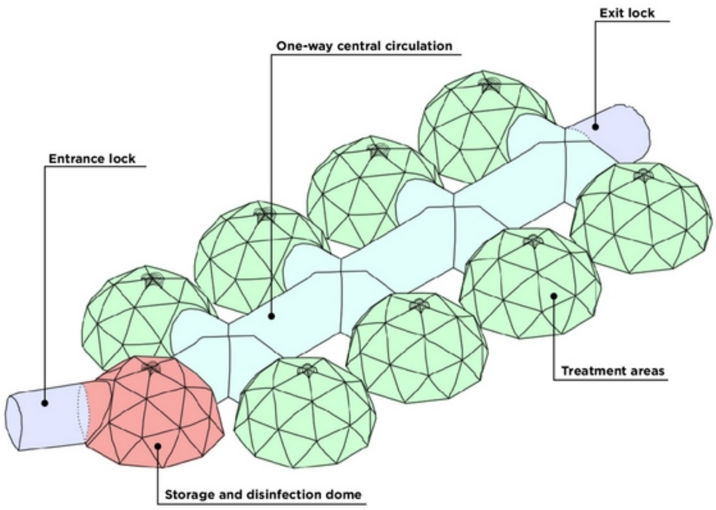

Figure 7. Axonometric view of an arrangement of nine domes connected by a cylindrical tunnel.

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Figure 8. Rendering of a possible in-situ configuration of PEIU.

Although the most probable configuration of PEIU is the one described in figures 8 and 9, we have considered other possible design scenarios (Figure 9). As a matter of fact, the possibility of finding variable situations in the different contexts in which PEIU could be installed, requires the definition of a flexible design system. To achieve the flexibility of the design solutions, we have developed a parametric model that will allow us, when needed, to adapt the design solution to variable context requirements with little effort (Figure 10).

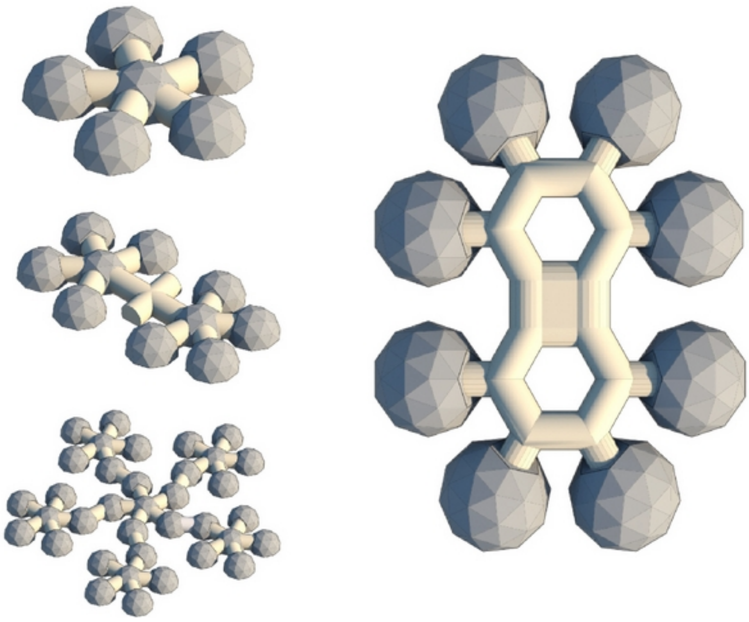

Figure 9. Alternative configurations of the system.

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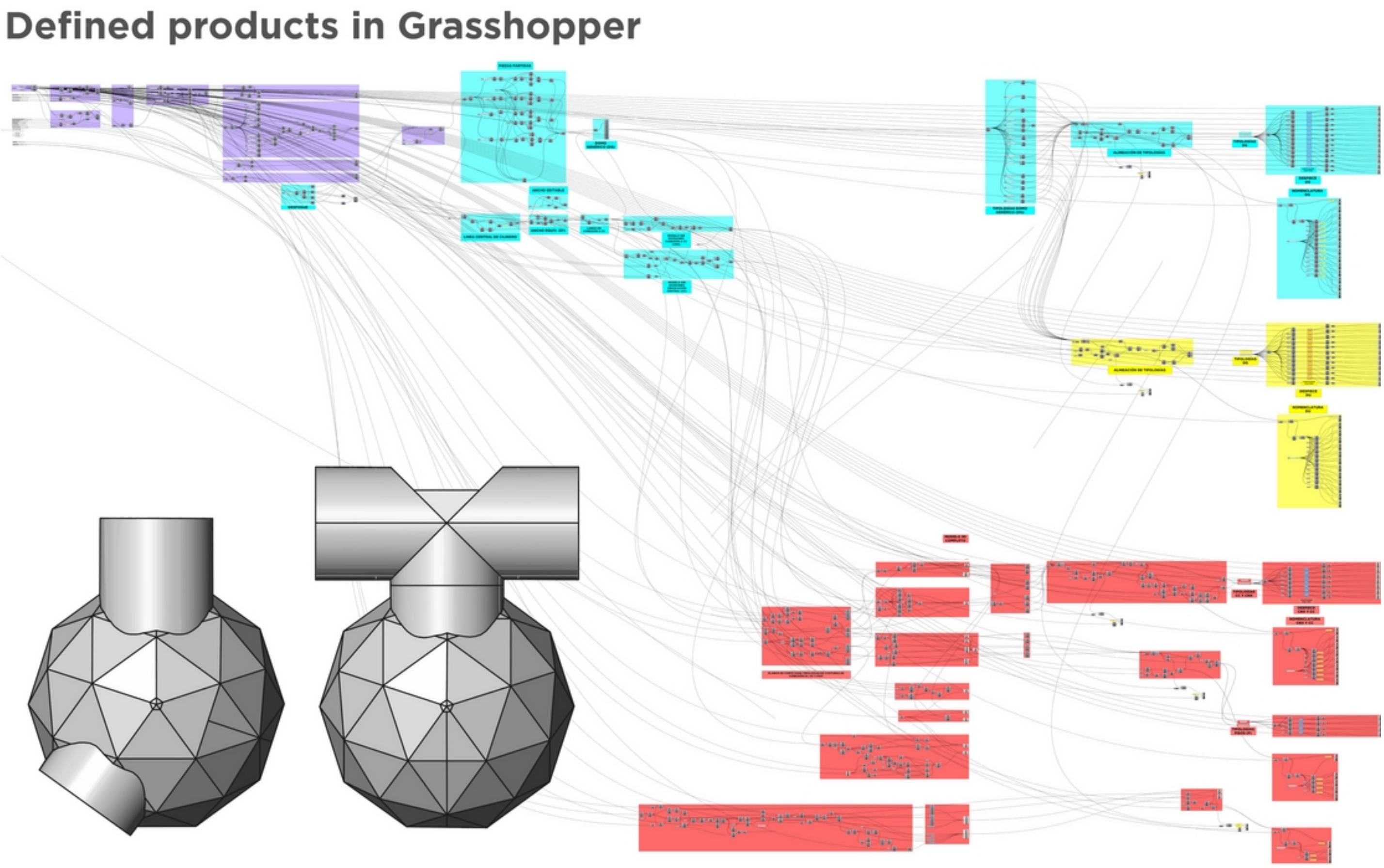

Figure 10. Generative algorithm in Grasshopper that allows the production of variable configurations of the basic geometry of PEIU. The design parameters allow for changes in the size of the dome, the configuration of the floor plan and the shape of the tunnels.

3. DESIGN REQUIREMENTS

After defining the basic geometry of the system, the detailed design of PEIU included various criteria related to the spatial needs for the treatment of patients, the ventilation and the quality of air inside the system, and the connection to electrical and hydraulic supply networks, required for the installation of medical and sanitary equipment into the isolation units.

According to the recommendations for the treatment of patients with infectious diseases, when it is not possible to locate the patients in individual spaces, it is suggested to place them in rooms shared with other patients having the same active infection, and to guarantee a spatial separation of at least one meter between patients and between patients and visitors. The diameter of the domes (5m) allows to locate in each module two beds with the corresponding medical equipment, leaving enough space to adhere to the recommended distances. Additionally, each dome has an internal division that works as an extra protection barrier and which guarantees a minimum of privacy for hospitalized patients (Figures 11 and 12).

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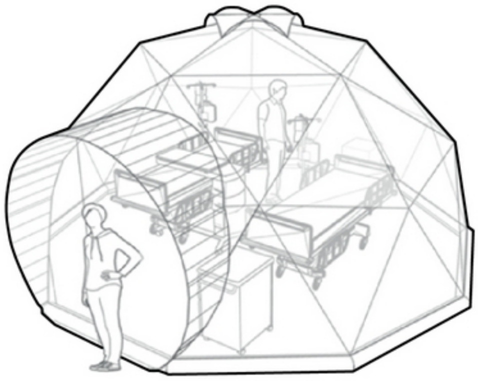

Figure 11. Distribution of the isolation unit according to the spatial criteria for the treatment of infected patients. Perspective view.

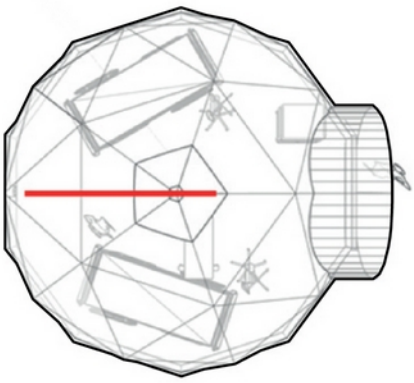

Figure 12. Distribution isolation unit according to the spatial criteria for the treatment of infected patients. Top view.

To guarantee the effective isolation of patients, the space inside the domes must be confined. Access is limited to carry out sporadic tasks, such as inspection and disinfection, and, for this reason, the correct ventilation of the module is an essential design aspect. The adequate ventilation of the system is achieved thanks to the injection of air from the outside by means of a centrifugal motorized fan. To guarantee the structural stability of the system, the volume of air that is injected must be replaced permanently. To do so, a vent opening at the top of the domes allows for the evacuation of hot air. In addition, to the preservation of the structural stability of the system, the renewal of air permits to keep an adequate temperature inside the isolation unit and, more importantly, to guarantee the good quality of the air inside it.

The quality of the air is directly related to the quantity of air exchanged. According to the recommendations of the World Health Organization, in order to guarantee the quality of the air in health facilities it is necessary to assure an ideal ventilation rate of 160 liters per second per patient (with a minimum of 80 liters per second per patient). In consequence, to achieve the recommended ventilation rate in the isolation unit, it is necessary to renovate the air of each dome at a rate of 576 m3 per hour. The total volume of the PEIU is 1.140m3 and it uses six centrifugal motorized fans that inject 6.840 m3 per hour. Since the system is composed of 9 domes plus the circulation tunnels, the actual ventilation rate per dome is of approximately 684 m3 per hour.

In addition, in order to assure that both the incoming and outgoing air is clean, it is filtered at the inlet and outlet points. Finally, in order to separate the domes from the aisles and to keep the structural integrity of the system when opened to enter or to leave it, both at the entrance of the domes and of the tunnels a series of floodgates are installed that avoid the loss of air pressure when the system is opened (Figures 13 and 14).

Regarding the installation of sanitary and medical equipment inside the isolation units, it is necessary to allow for the connection to electrical and hydraulic supply networks. For this reason, each dome includes a piece that functions as an interface between the inside and the outside (Figure 15).

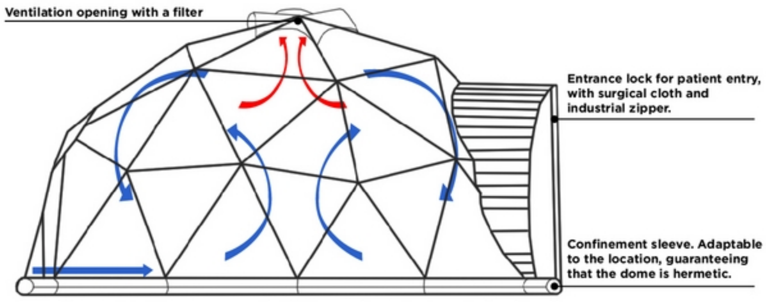

Figure 13. Air circulation system inside the isolation unit. Left view.

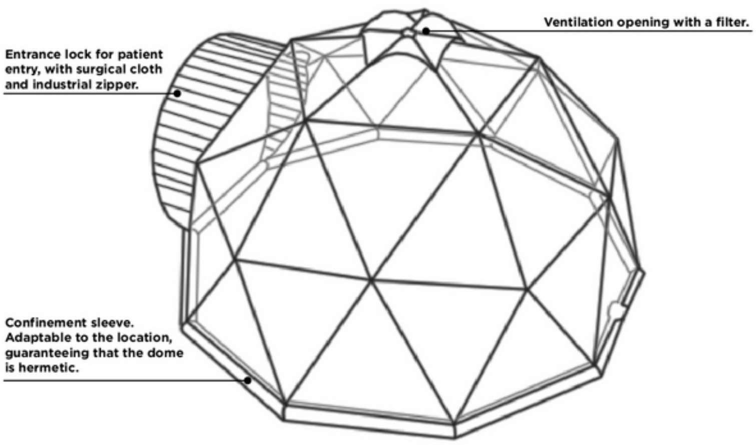

Figure 14. Main components of the isolation unit. Perspective view.

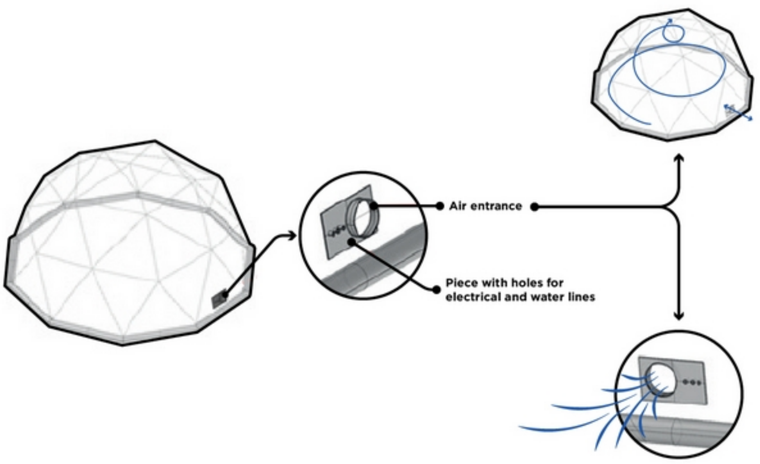

Figure 15. Interface piece for the connection to motorized fans and electrical and hydraulic supply networks.

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4. MATERIALITY AND MANUFACTURING

In response to the needs of the system, the structure is entirely fabricated with polyvinyl chloride (PVC) fabrics of varying caliber and transparency. This material was selected because it is both malleable and resistant, easy to clean and fully recyclable, and it is used for the construction of all the envelopes of the domes and tunnels. The seams are machine stitched, and the sluices and doors are made with high traffic zippers and reinforced with detachable fiberglass rods to stiffen them.

After the definition of the appropriate geometry and integrity pattern of the structure, the exploded/explored assembly is produced (Figure 16). These drawings can be used to make mold templates to trace the patterns on the material (when hand cut), or they can be transferred directly to a laser cutting machine (when this technology is available). This means that both cutting and patterning can be performed in an analogous way, by means of digital manufacturing processes, or through hybrid options. In this sense, the construction process can be adapted to the conditions of the manufacturing environment.

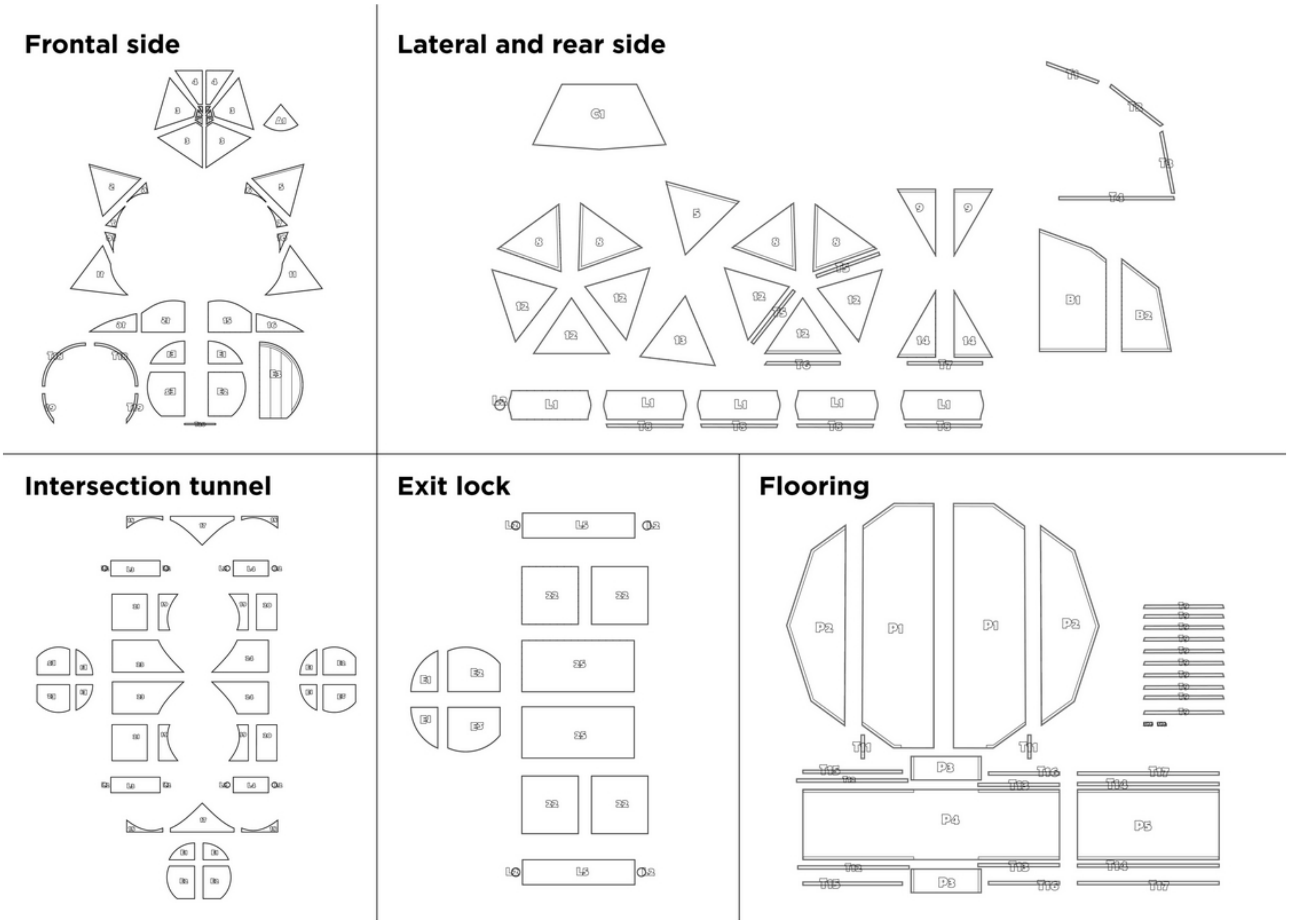

Figure 16. Exploded assembly of the basic constructive elements.

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To make the domes, it is necessary to join the 30 isosceles triangles to make a series of pentagons. These pentagons are connected between them through the vertexes, and the remaining spaces are filled with the 10 equilateral triangles (Figure 17). To build the tunnels and the floor, the different parts of the floor are joined according to the assembly pattern and then stitched to the domes and to the tunnel. The system is sectioned into five large units that are connected amongst them at the time of assembly by means of hook and loop closures (Figure 18).

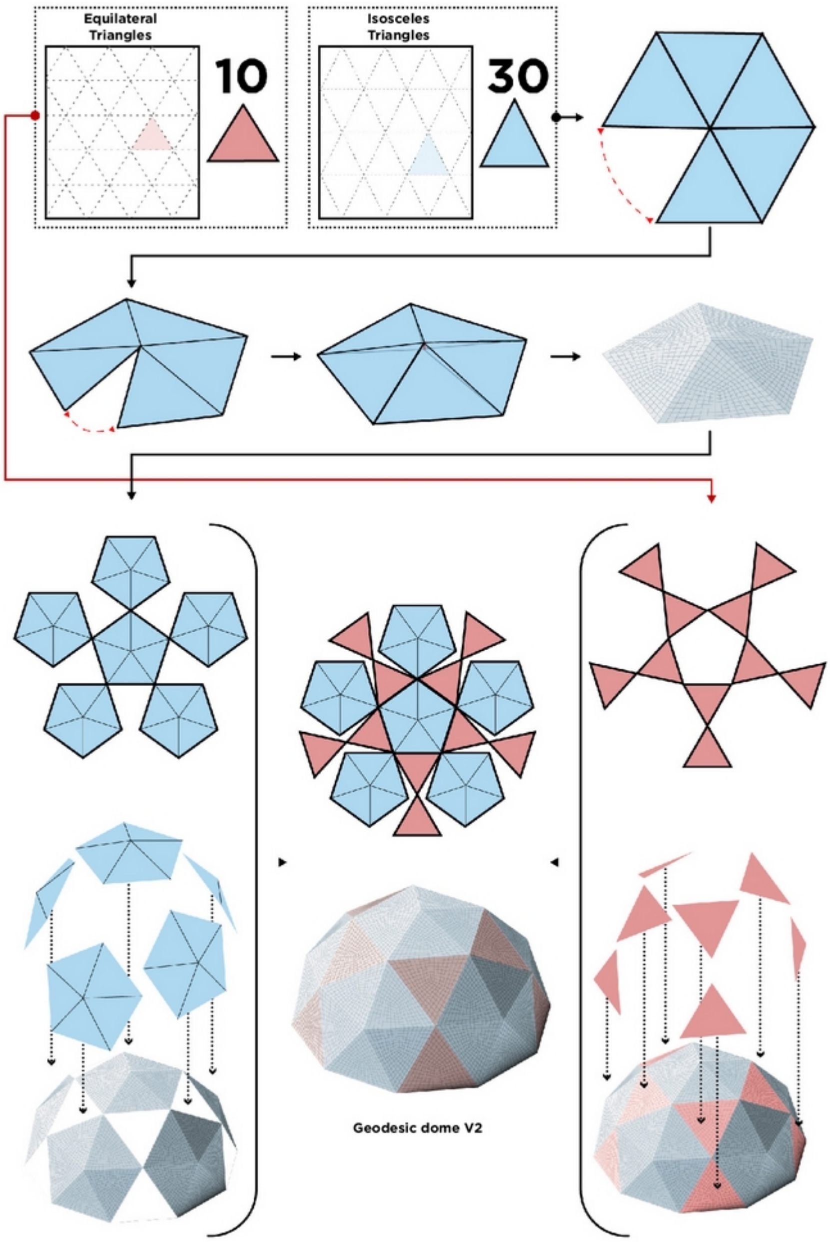

Figure 17. Building instructions for the assembly of the dome.

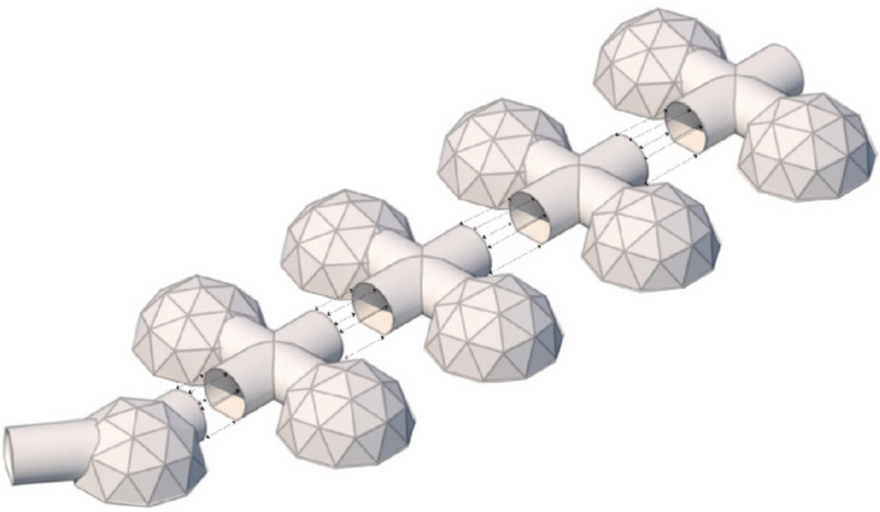

Figure 18. Sectioning of the system into five larger modules.

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After being assembled, the structure is inflated and stabilized with air driven by 0.5 horse power centrifugal fans with a flow rate of 16 m3 per minute. The stabilization of the structure (Figure 19) is complemented by the seams (which function as a stiffening wire mesh), the confinement sleeves located at the bottom of the domes and tunnels (which are filled with water to add weight to the structure), and the anchoring elements (which allow to attach the system to the existing structure at the installation site).

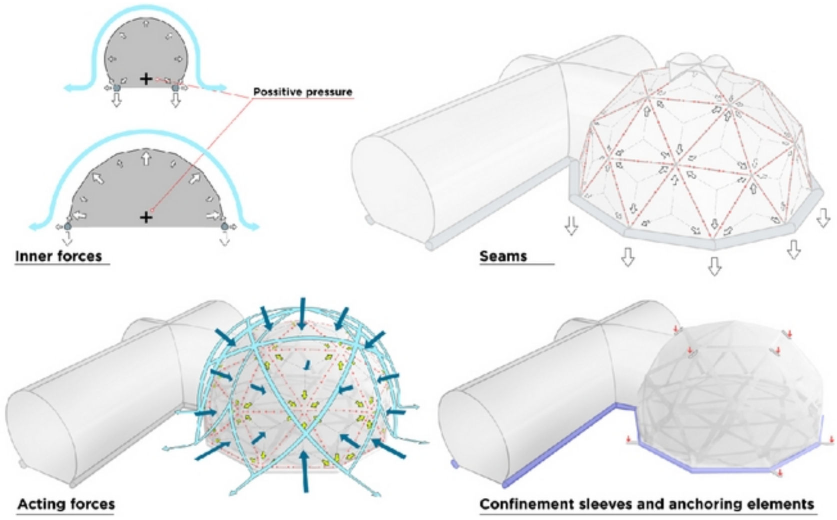

Figure 19. Stabilization system of the pneumatic structure.

5. PRELIMINARY RESULTS AND CONCLUSIONS

Through a feedback process that involved the assessment of various one-to-one scale prototypes of the system and the corresponding adjustment to the designs, we validated the overall design concept, and we were able to collect a great amount of quantitative and qualitative data regarding the manufacturing process and the functioning of the system (Figures 20, 21 and 22).

Figure 20. One-to-one scale prototype of the basic construction module of the system.

Figure 21. One-to-one scale prototype of the entire system.

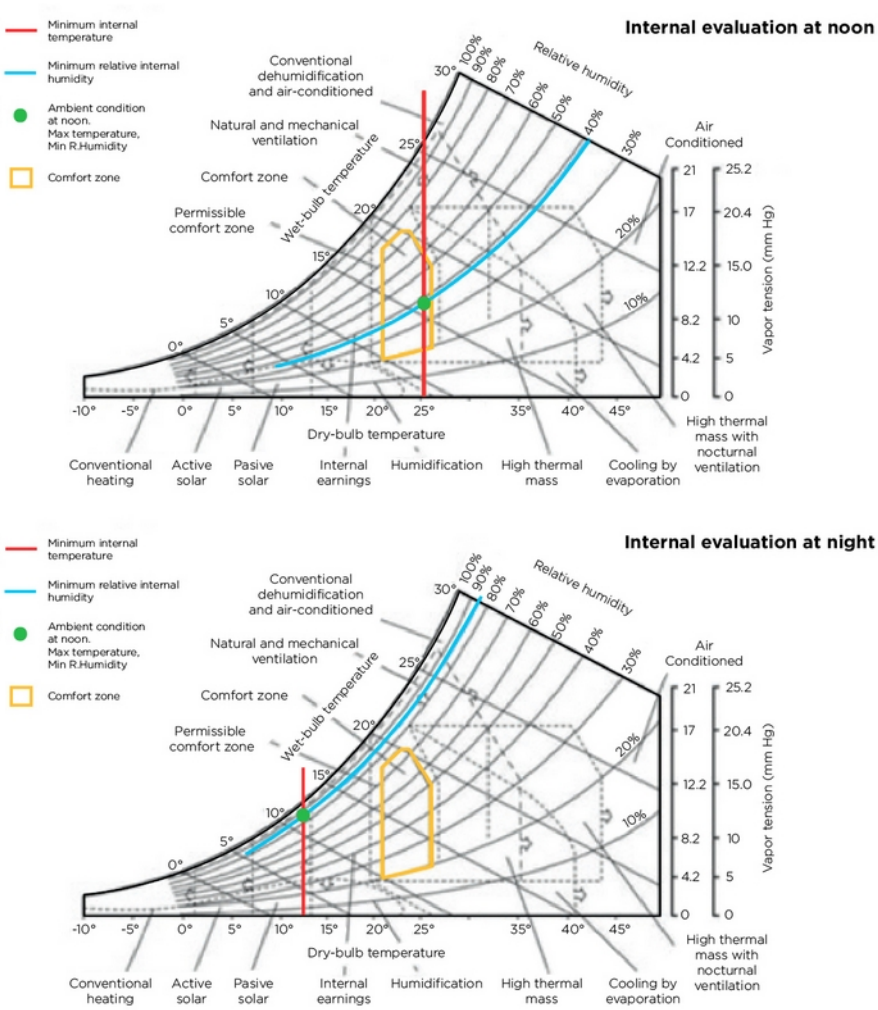

Figure 22. Analysis charts of the habitability conditions inside the isolation units.

By means of the abovementioned feedback process, we could identify a series of aspects which improvement rebounded in a more efficient building and assembly system and ameliorated the performance of the PEIU. These enhancements involved solutions to

Manrique, C. A. N., Pérez, A. L. P., Calonge, H. G. R. & Quin, C. A. C. (2020). Portable Epidemiological Isolation Unit. Ephemeral Architecture for Covid-19 Emergency. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 401-417. DOI: 10.4013/sdrj.2020.133.09

improve the portability of the isolation units, to simplify the joints between its composing elements, to reinforce the stability of the structure, and to improve the habitability conditions inside the space/dome (Figure 23).

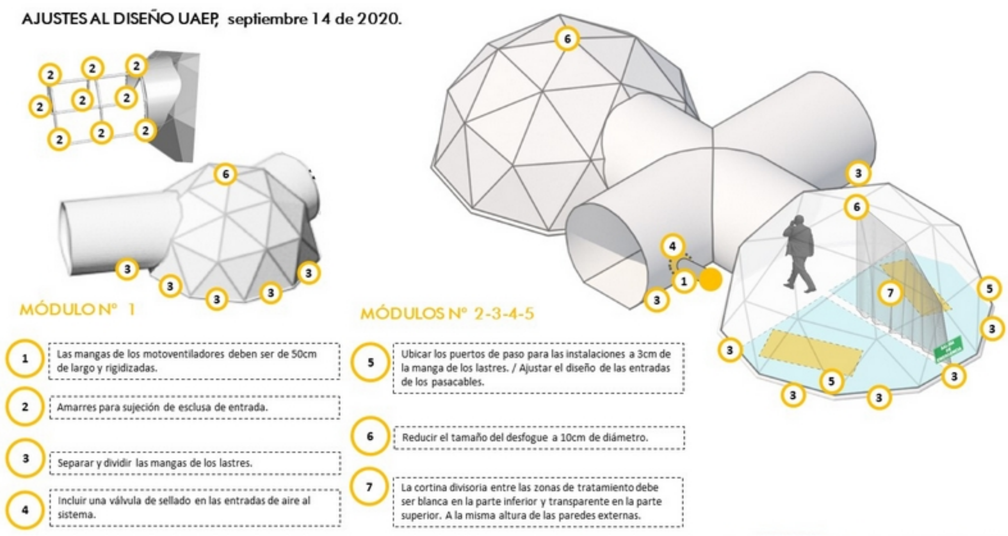

Figure 23. Assessment chart of the prototypes.

After these enhancements, we consider that the PEIU has reached the TRL level 8 of the "Technology Readiness Level" measurement system (Tomaschek et. al, 2016). The foregoing means that the project has been tested and approved, and that it is ready for its implementation. However, due to the evolution of the pandemic in Colombia, the isolation units have not yet been used for the treatment of patients in provisional health facilities. In consequence, to date we do not have data about the performance of the PEIUs under the conditions of the third and fourth phases of the strategy established by the Colombian government to respond to the contingency produced by the Covid-19 pandemic. Currently, the isolation units requested by the Ministry of Science and Technology are being manufactured, and the patenting process of the system is underway. The implementation strategy is being studied along with the Ministry of Health and the National Army, which will be in charge of the transportation and installation of the units in different parts of the territory.

In the current context, in which the Latin America region and the Caribbean represent 22.92% of the total reported cases globally (Inter-American Development Bank, 2020), we expect that the development of PEIU will allow the Colombian sanitary authorities to expand its hospital capacity when needed. We also expect that this kind of initiative, which bonds academia and the public sector in the search for design solutions to the pressing needs of our time will endure. More importantly, we expect that this joint effort will become a means not only to solve the emerging problems of a hyper globalized society, but a means to imagine an alternative future in which the search for answers to a global pandemic, global warming and global precariousness will not be a design issue.

ACKNOWLEDGMENTS

The members of the LAB LAHC would like to thank several institutions and people whose help has been crucial for the development of the project: the Ministry of Science and Technology and the Colombian National Army; at La Salle University, the staff of the Faculty of Habitat Sciences and of the Vice-rectory for Research and Transfer, especially Fredy Alejandro Martinez, Alexandra Prada and our dedicated research assistants Ruth Amelia Cala, Nicolás Pardo and Felipe Diáz; and, last but not least, Hugo Quintero and his team for the technical support.

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LHF Connect: A DIY Telepresence Robot Against COVID-19

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ABSTRACT

This contribution describes a case study of a "do-it-yourself" (DIY) opensource service and related product to help combating the COVID-19 emergency. It illustrates the birth of LHF Connect, a project designed to facilitate communication between patients isolated in COVID-19 hospitals' ward and their relatives. LHF Connect is a teleoperated robot that can move in autonomy around the hospital. A User Centered Design approach, methods and specific tools helped in managing crucial steps of the design process such as i) the collection of needs coming from the context, stakeholders and end-users; ii) defining the service blueprint; iii) imagining finishing concepts; and iv) managing the communication activities. The initiative has been promoted by a multidisciplinary team of researchers (mainly roboticists with the help of specific competences coming from Design discipline).

Keywords: Communication, COVID-19, DIY, Opensource, Robotics, Telepresence.

INTRODUCTION

Since the beginning of March 2020, Italy has been the first European country strongly affected by the COVID-19 outbreak. As a consequence of this, the government put in place restrictive measures for the population to contain the spread of the virus: the so-called lockdown. In a short time, the whole world had to look for effective measures to limit the damage caused by the pandemic. To date (July 1, 2020) more than 10 million infections and 500,000 deaths have been reported worldwide due to the virus. Almost all states affected by COVID-19 have imposed the so-called "social distancing", the restriction of access to public places, offices and schools, and a travel ban. This led all citizens to change abruptly their personal and family life, as well as their working habits, thanks to tools that allowed working and communicating despite physical separation. If at first, some people's reaction was to postpone appointments and meetings for a couple of weeks, as time went by (and weeks became months), it appeared clear that long times would have passed before returning to the pre-COVID normality: a new normality started to take shape.

1. THE DEMATERIALIZATION OF CLOSENESS: THE WAY TO REMOTENESS IS NOT OBVIOUS AT ALL

All the encounters and meetings that previously took place in presence have been dematerialised and became once again possible thanks to technology. A pivotal role in this transformation was played by audio-video communication tools able to manage many remote users, examples include Microsoft Teams, Zoom, Google Meet, Skype, Cisco Webex, Bluejeans, Houseparty, etc. This transformation has been true for companies, switching in remote meetings between colleagues, clients, and suppliers, but also for events, fairs, conferences and training activities. Moreover, also personal encounters changed, for example in the way one heard from their relatives and friends during the lockdown phase. Most in-presence encounters have been transformed virtual and remote, dematerialised and digitized.

Observing this transition, two observations can be made. First, all communications became technology-dependent and mediated, which means that the richness - quantity and quality - of the information transmitted depends on the used technology. If, on the one hand, tools that manage well the audio and video data of many users are available, currently we do not have technologies that can faithfully convey the experience of a meeting in presence, which is composed of many physical elements, such as non-verbal communication, body language and proxemics, and is strongly influenced by the context (environmental and cultural).

A second observation concerns the timing and methods available to express and discuss among participants. The digital tool stiffens the modality of communication between people, caging the possibility of expression into predetermined time slots. This way of being together and communicating limits the naturalness and multiformity of the discussion between people who – in presence – dispose of different informal moments to confront each other. Consider, for example, that informal discussion, networking and brainstorming often take place also during coffee breaks and taxi rides. Currently, technology seems to fail in reproducing the completeness and complexity of human nature.

In general, during the early phases of the pandemic, there was controversy about what technology could and should do to help in solving the emergency. In particular about Robotics, on April 9th 2020, Riccardo Luna wrote provocatively on La Repubblica: “Ma che fine hanno fatto i robot?” (What happened to the Robots?) (Luna, 2020). Major scientific journals have been following the debate, inspired by what happened in the past and by fiction (Murphy, 2020). In their editorial on Science Robotics, “Combating COVID-19-The role of robotics in managing public health and infectious diseases” published on 25 Mar 2020, Yang et al. asked: “Could robots be effective resources in combating COVID-19?”

1.1. A Case Study

The case study that we report, comes from the field of research in robotics for rehabilitation and human cooperation and shows the contribution that the Design discipline has provided to this experience, by helping in managing some crucial aspects. In particular, the case study illustrates LHF Connect, a small avatar robot (teleoperated remotely by volunteers) designed to connect people isolated due to the COVID-19 with their relatives and friends: the first working prototype of LHF Connect and service blueprint was developed in about 3 weeks (on April 9th it was tested in hospital).

The support of the Design discipline has been crucial for some specific aspects such as: i) collecting and reading the needs in order to design a technological concept able to help in combating the COVID-19 emergency in a short time; ii) managing the service blueprint of the solution proposed, iii) diffuse the project to make it available to the largest audience possible in a short time and to local institutions and hospitals. Finally, iv) some concepts for the finishing of the robot have been produced.

2. A USER CENTERED DESIGN APPROACH

Since its beginning, the LHF Connect project adopted a User-Centered Design approach (UCD), considering users and their needs, together with the stakeholders' requirements, at the centre of the entire design process. We pursued this goal following a holistic approach that considered both the physical and cognitive characteristics of individual users (in most cases patients in COVID-19 wards of hospitals), as well as the social and organizational aspects of hospitals during the pandemic emergency. The process has been inspired by Norman & Draper (1986): end users have been involved as well as stakeholders identified, such as doctors, nurses and all personnel that works in the institutions (hospitals and nursing home) that accommodate COVID-19 patients, as cleaners, administrative staff and managers.

A first prototype has been delivered in two hospitals of Tuscany in early April 2020, then tested and refined following users' and stakeholders' indications until June 2020. The UCD process was characterized by a spiralling recursive design process that started from inquiries about the needs during the emergency and followed with context specifications, service design and usability testing.

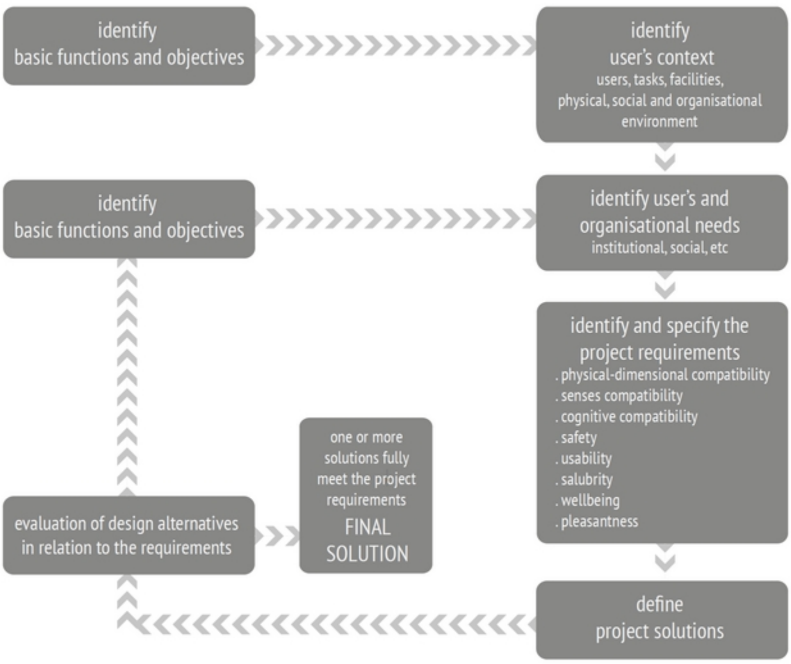

Figure 1. The UCD approach applied to the LHF Connect design process (Fubini, 2009).

The Design discipline had the opportunity to actively contribute to the development of LHF Connect. If for scientists in robotics, the goal - above all - for basic and medium-term research is represented by the technology itself, through the LHF Connect project the short time to develop the application conquered the centrality of the entire design process. Focusing on the application of a technology means dealing with end-users and the stakeholders, defining a service with strong time constraints and context specifications.

It was thus possible to apply the approach that sees the "designer as an apprentice" (Beyer and Holtzblatt, 1998). Contextual inquiry was promoted to foster this idea revealing some important issues:

> "Seeing the activities reveal what matters. Nobody can talk better about what they do and why they do it than they can while in the middle of doing it. Seeing the work reveal details. Talking about work while doing it protects the master craftsman from the human propensity to talk in generalisations. Seeing the work reveals structure. A master craftsman teaches his apprentice how to do the work. This is what he is expert at. But a designer must understand structure and implications: the strategy." (Beyer and Holtzblatt, 1998)

Moreover, the SAY-DO-MAKE model from Sanders and Dandavate (1999) provided the methodology to be applied during the users' observations and inquiry to tailor specific solutions – mainly related to the service design – oriented to context needs, to the robot usability and the final users' experience. The authors wrote that for an appropriate understanding of user experience there is the need for a set of different data sources: Verbal data ("say", what people know and say); Data on behaviours ("do", watch and observe what they do); Data on emotions and dreams ("make", the use of non-verbal means to describe and represent the experiences).

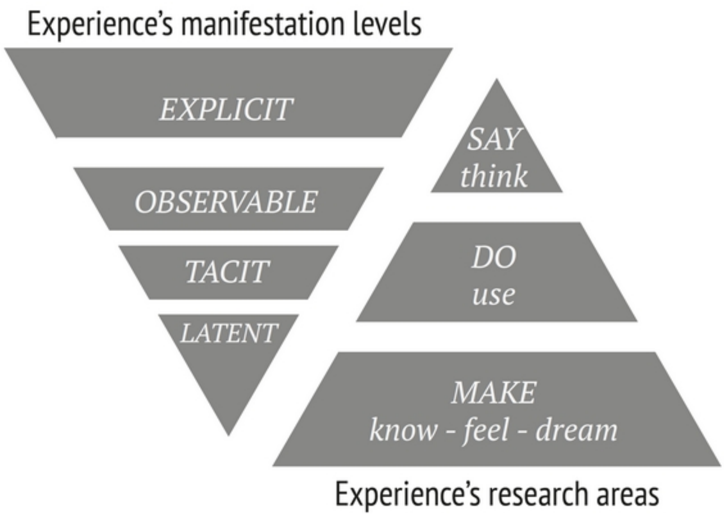

Figure 2. The SAY-DO-MAKE model from Sanders and Dandavate (1999).

2.1. A coalition of researchers against COVID-19

During the lockdown, many initiatives were raised to help in combating the pandemic. As said, technology had a central role and in Italy, the Makers Movement had a primary role in imagining solutions that could be available in **a short time** (Bassi, 2020). Time and availability constraints had a central role in combating the pandemic with tangible solutions. A collection of **short-time projects** proposed during the emergency has been made available on the Tech for Care platform (https://techforcare.com/en/solutions/). This platform constitutes a sort of coalition to bring together the ability of communities of technology experts to respond to the pressing needs of all emergency workers. The website presents three areas: Needs (intended as the needs collected from emergency workers); Solutions (technologies and projects); Implementations (FabLabs and companies that could implement and produce solutions). Projects are accessible and available to everyone.

In parallel, also those products with a high level of technological readiness and potentially available for general use in the **medium term** constitute a reference to define a sort of state of the art of the technological solutions that could be useful to fight the emergencies deriving

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from the global spread of COVID-19. Italian Institute of Robotics and Intelligent Machines (I-RIM), a non-profit organization of national stakeholders that promotes robotics to improve citizens' quality of life and well-being, has analysed different solutions on an online collection of Pilot Projects: 70 examples of technological demonstrators, tested in the clinical field, that can be developed into products useful in combating the virus.

Within this context, **LHF Connect project was designed to be a short-term solution** and finds among its main sources of inspiration two specific studies conducted by I-RIM that collected and interpreted needs arising during the pandemic. I-RIM launched **two questionnaires** to collect needs during the different phases of the pandemic to gather information on the citizens' needs, to investigate problems that people face to work safely and efficiently, and to understand the impact such a dramatic time had on their psychology (Sciutti et al. 2020).

I-RIM developed the first questionnaire to understand the needs related to the lockdown phase, with the scope to limit the possibility of contagion during professional activities, while a second one has been launched after the lockdown, in early July 2020, to investigate the objectives necessities but also psychological needs of the recovery phase.

About 200 people answered the first questionnaire describing how the pandemic influenced their life and work. Respondents were mostly working in healthcare (about 30%), research (about 19%) and education (about 9%). Activities were found to have moved to agile working at a rate of about 50% of respondents, forcing many to abruptly switch to a novel, virtual work dimension, characterized by the impossibility of natural interaction with colleagues, patients, and students (Sciutti et al. 2020). Many participants mentioned the possibility of teleoperation in different fields (with the use of drones and autonomous machines) to diminish infections.

Figure 3. This word cloud that resume answers at the following question: "Do you have any suggestions on how technology can help?"

3. THE BIRTH OF LHF CONNECT PROJECT

3.1. COVID-19 Hospital Needs: Identification and Definition Of Tasks

Since the COVID-19 spread in Italy, the team of researchers focused on some **unstructured in-depth interviews** (Rizzo, 2009) **with sanitary staff and primaries** from different hospitals and co-designing with them possible solutions. Since the beginning, one necessity emerged clearly: patients were isolated in COVID-19 hospital wards, without any possibilities of being visited by relatives. Many of them were elders, whom the digital divide (Romano et al. 2015) often prevents the possibility of using audio-video communication tools. The result was the complete isolation of these patients and leaves as sole information

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to their relatives the medical bulletin provided through a short phone call made by nurses. Many patients passed away without having the possibility of saying goodbye to their loved ones. Moreover, COVID-19 hospitals suddenly faced an increase in patients, the sudden need to treat them without compromising the health of the hospital personnel: clinicians, nurses, technicians, and cleaners. This made the personal protective equipment used to safely get in contact with patients and the surrounding environment become pivotal, together with the need for a continuous re-supply (Griffin et al. 2020, Ranney et al. 2020).

On the other side, hospitalized patients were kept isolated from the outer world and their only relations were with "draped" clinical personnel, often barely recognizable. Nevertheless, patients needed support, comfort, proximity, and reassurance (Negro et al. 2020). This fact, together with the fear and anxiety shared with many other serious illnesses, compromised the psychological status of the patients, who coped less favorably with acute and post-acute symptoms. In this context, one of the needs for caregivers was to provide some psychological relief that may reduce the burden of comorbid mental health conditions and ensure the wellbeing of those affected.

Hospitals recognized the need to help patients to get in touch with their family, helping the elders with tablet and smartphones to arrange video calls (Wakam et al. 2020). Dedicated services and infrastructures rose all over the world (Ohannessian, Duong et al. 2020). At the Humanitas Mater Domini in Castellanza (Varese) nurses used a tablet for this scope (Rainews, 2020). The same happened at Policlinico di Bari (Il Quotidiano, 2020) and Ospedale Martini in Torino (Torino Oggi, 2020). In Bergamo, Croce Rossa Italiana started a service to provide video calls in COVID-19 wards. Voluntaries entered the COVID-19 ward to provide patients with video call on a tablet (CRI, 2020). If on one hand these initiatives go in the same direction as LHF Connect , by providing a sort of video call service, on the other hand, some disadvantages emerge from these initiatives: i) often nurses are strongly involved in providing the video call service while the opportunity/challenge was to free them, already overloaded of many patients; ii) otherwise, volunteers in presence are needed, with a significant expense of time and disposable personal protective equipment, which is necessary to enter in the COVID-19 ward; iii) volunteers are exposed to the possibility of contagion; iv) tablets or smartphones have to be touched with the possibility to convey the contagion.

3.2. Project Brief: Low Hanging Fruits From The Research Know-how

Thanks to the team's strong experience in research for **telepresence** with humanoids robots (for a definition: https://en.wikipedia.org/wiki/Telepresence) ideas came up quickly: their know-how could be adapted in helping to overcome this lack of communication. The concept, generated around the end of March 2020, was to realize a remote-controlled robot (teleoperated by remote volunteers) that could move around in the hospital ward, carrying a device for video-communication directly to the patients' bed. A simple robot, named LHF Connect, that could be easily replicated in different hospitals during the lockdown, without requiring specific competences. The name LHF indicates the acronym Low Hanging Fruits, i.e. those fruits of the tree of most advanced robotic research, which maturated in the recent years and are now at hand, for a vast and immediate application.

LHF Connect project - using robotics and in particular telepresence - provides some *advantages* when compared to other similar initiatives: i) the service could be managed remotely, offering the possibility to free medical personnel, already overloaded by the many patients; ii) no volunteers are needed in presence, with significant savings in terms of time and disposable personal protective equipment; iii) the telepresence robot remains in the COVID-19 ward, without any possibility of being a possible vector of the contagion; iv) all operations are managed remotely so that it is never necessary to touch any device onboard the robot.

3.3. Time and Availability Constraints

The technology to provide robots for telepresence with a mobile base is already there: the issue was not to hit any technological barrier, as demonstrated by **products already on the market** such as Beam Pro, InTouch Vita, Ubbo Expert, Zora or Pepper (for more information visit: www.irim.it/en/pilot-projects/). Unfortunately, they were simply not enough to face the emergency, very expensive and usually designed for other purposes. Moreover, most of the products mentioned could not be produced in a short time. Other projects **such as** AlterEgo (https://www.youtube.com/playlist?list=PLzEoYml21jz5Xraq_-x07uf0TgLIXxVc7) were already meant and tested for assistive teleoperated purposes but, unfortunately, are still **research prototypes**.

3.4. The Concept

The teleoperated robot was assembled using off-the-shelf hardware, easily available even during the lockdown (e-commerce never stopped delivering in Italy), to be assembled and used by non-specialized personnel. The service is managed remotely by the external coordinator (a volunteer). A voluntary teleoperator drives the robot to the patient's bedside and calls the relatives from the mobile device onboard LHF Connect. It uses standard communication software (WhatsApp), for three-way communications. The teleoperator starts the communication, then leaves the meeting, and returns when the allotted time is finished, to gently stop the conversation and take the robot elsewhere. All personal information is managed by the external coordinator, who guarantees correct privacy management (according to the General Data Protection Regulation UE 2016/679). The call request is either from the patient or the family.

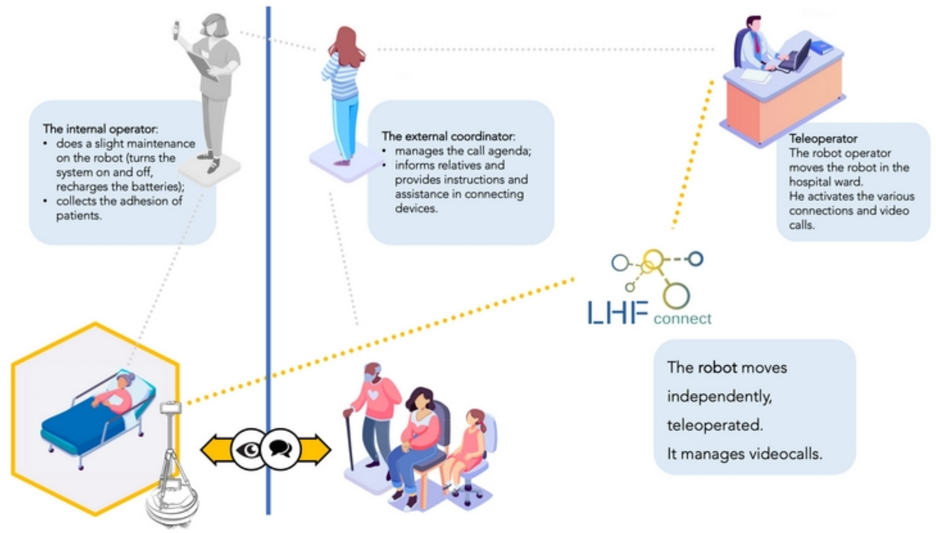

Figure 4. The LHF Connect concept.

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4. LHF CONNECT

The robot hardware is a system consisting of a mobile base (vacuum cleaner robot), a tripod (photo stand) with video communication tools (tablet PC, cameras, speakers) onboard, with an open-source software based on multi-platform web technology. The system does not require any specific competence to be assembled and teleoperated. The estimated cost per purchase of hardware is 1,200 €. The prototyping carried out so far has been possible thanks to the use of a commercial robot made by iRobot, who provided access to internal control routines for a limited number of machines. One of the challenges encountered during testing was the wi-fi connectivity inside hospitals. LHF Connect now provides very robust communication protocols to travel across halls and rooms, switching from an access point to access point and overcoming local holes in the network, which are always present.

The first two weeks of the LHF Connect design phase passed while trying different models of vacuum robots and developing the software, the user interface, and the communication protocols. On April 9th, 2020, LHF Connect entered the hospital to be illustrated and tested with doctors and sanitary staff.

A major limitation of LHF Connect was the lack of arms and hands to interact with the environment: in some hospitals, rooms had closed doors: in this case, LHF Connect would have to ask a nurse to open the door.

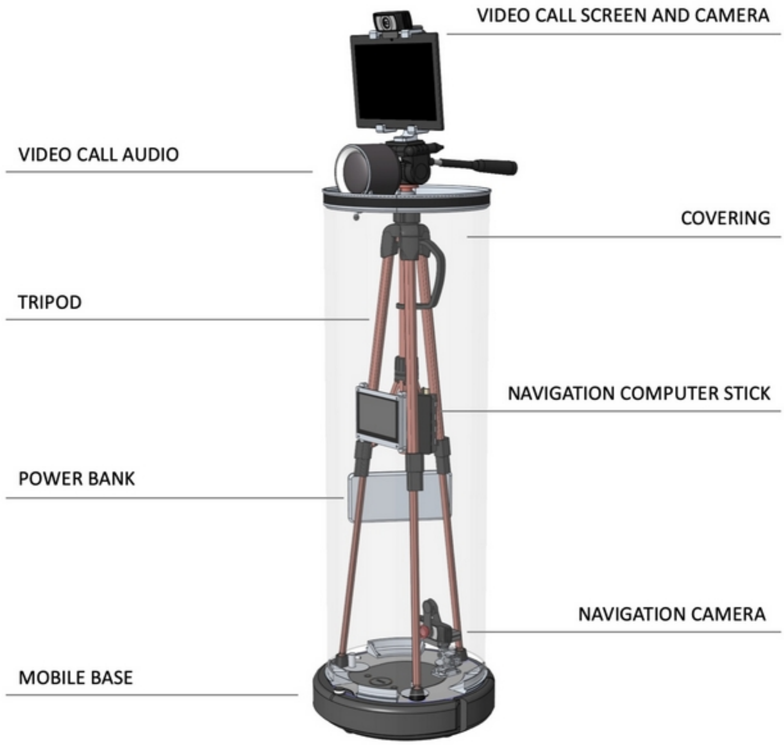

Figure 5. The LHF Connect teleoperated robot.

4.1. An Opensource Project With Many Fields Of Application

Since LHF Connect is an opensource project, all instruction to assemble hardware parts are accessible; the software, developed for this specific purpose is freely downloadable. LHF Connect was promoted in local communities and sanitary institutions and the team offered support to replicate the robot and customize the service.

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Beyond the global pandemic, LHF Connect has met the interest of the health care environment mainly, in particular hospitals with long stay wards, infectious diseases or where fragile patients are present. Moreover, the project found interest from nursing homes for elderly persons and residences for persons with disabilities.

4.2. Service Design, finishing and further assessments

The service blueprint proposed for the first trials was composed by the "Call cycle" and the "Daily routine". As it's possible to observe, patients are not actively involved during the whole process to simplify their participation. Core activities are leaded by an external coordinator and a volunteer who teleoperates the robot. In particular, service design allows to operate inside hospital departments without being physically there. This gives external operators (volunteers) the possibility to concentrate in communicating and encounting patients and relatives with the care needed. Other design goals were meant to reach some advantages (cfr. 3.2).

Moreover, LHF Connect project has great customization possibilities. Service blueprint could be customized, the hardware could be assembled and finished in different ways: in terms of aesthetics, but also to ameliorate its functionality. Finally, the robot could be implemented for other purposes. Future developments of LHF Connect will deal with contextual needs research in collaboration with national associations operating in hospitals. This activity is meant to conduct co-design sessions to test prototypes in the field. Moreover, we will conduct experiments to reveal the social and emotional role played by the robot in the hospital (Alves-Oliveira *et al.* 2015) also characterising final aspect and finishing (in particular for kids environments). These goals are possible thanks to a national research funding won (on November 2020, Fondo Integrativo Speciale Per La Ricerca (Fisr), Avviso Per La Presentazione Di Proposte Progettuali Di Ricerca Finalizzati Ad Affrontare Le Nuove Esigenze E Questioni Sollevate Dalla Diffusione Del Virus Sars-Cov-2 E Dell'infezione Covid-19).

Call cycle

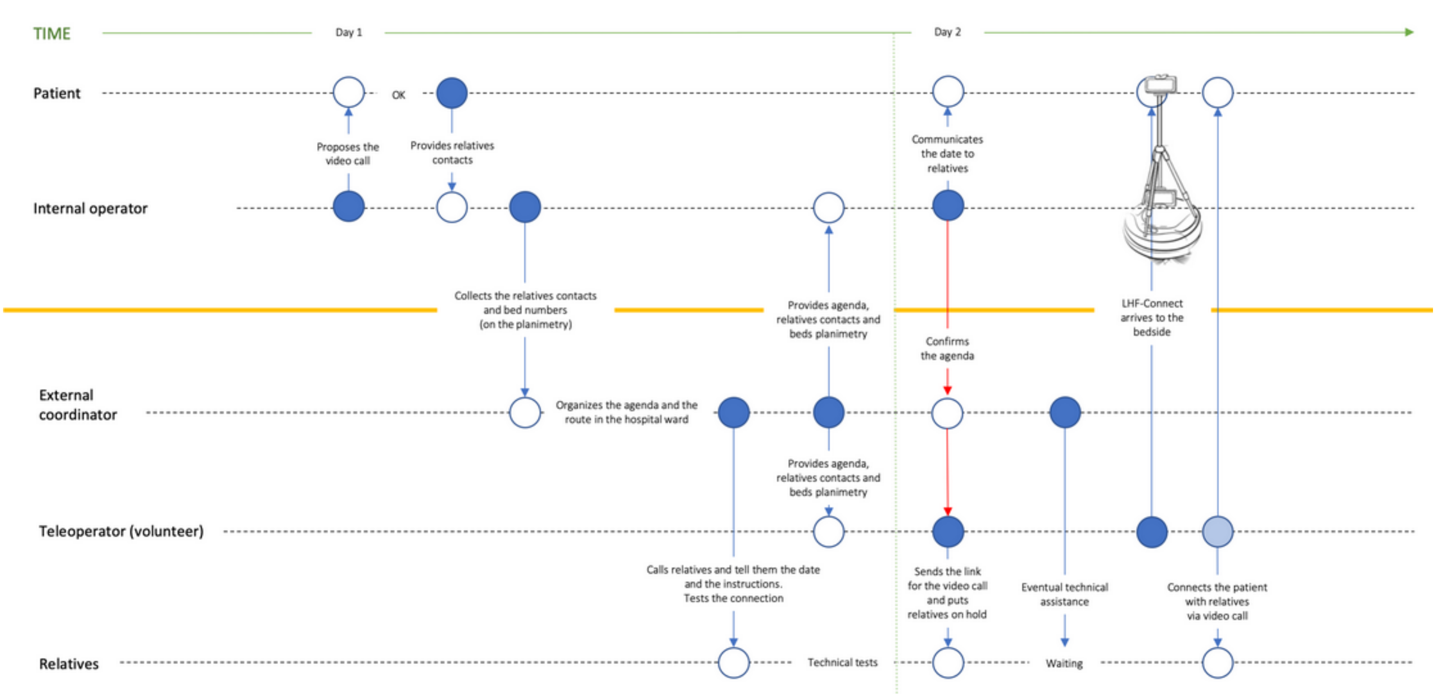

Figure 6. The LHF Connect call cycle (service diagram).

4.3. The Apuane Hospital Experience (Massa)

On April 9, 2020, thanks to the collaboration and interest of the hospital staff, the first LHF Connect prototype was tested inside a non-COVID-19 department within the Apuane hospital (Massa). The trials carried out in the department were successfully completed, the remote control did not show insurmountable difficulties, despite the problems related to the discontinuity of the internet connection used for the purpose. The robot tested a video call with a patient, without particular obstacles. The experiment was attended by some of the members of the robot development team, as well as by doctors, nurses and privacy experts.

LHF Connect met the enthusiasm of the medical staff who showed interest in continuing the experimentation by modifying the service design: this department has expressed its willingness to experiment the robot with a nurse teleoperating the robot from inside the hospital, to guarantee total respect of privacy norms and take advantage of the consolidated knowledge in dealing with hospital patients.

Figure 7. April 9, 2020: the first LHF Connect entered the Apuane Alps hospital (Massa).

4.4.The Cisanello Hospital Experience (Pisa)

On April 10th, 2020, a second prototype of LHF Connect entered the Cisanello Hospital, in a non-COVID-19 ward, and - a few days after - in a the COVID-19 area. Testing sessions are still ongoing at Pisa hospital. In the COVID-19 ward and intensive care area, the teleoperated robot was tested for video calls between patients and relatives. The hospital staff was impressed by the robot and the service proposed. The hospital staff also proposed to test the robot for other purposes such as remote-monitoring and tele-consulting in intensive care units.

Figure 8. April 9, 2020: the first LHF Connect entered the Apuane Alps hospital (Massa).

4.5. The As.far.m RSA Experience (Induno Olona – Varese)

Local organizations have implemented robots for their guests. Among the most significant example there is the Assisted Healthcare Residence As.far.m (RSA), a nursing home in the province of Varese, which created an LHF Connect giving it a different body (hardware support for devices). The tablets are mounted on a plexiglass structure with two suction cup supports. This implementation fully captured the spirit of LHF Connect, which provides an open-source technology and a simplified method of realization (through products available through e-commerce), but which is suitable for transformations and customizations: the robot has been enriched with an open compartment and a shelf that allows guests to receive magazines and small objects directly in their room.

Figure 9. LHF Connect at As.far.m in Induno Olona (Lombardy).

4.6. Finishing

To ameliorate and shorten the disinfection procedures necessary fort the robot twice a day, we also studied a possible solution to cover it. Two concepts were generated, imagined as a case to be used on top the simplified solution proposed in the manuals (always buildable with commercial products available online).

The first concept developed is a cylindrical plexiglass cover (in three parts linked one to the other by iron hooks) with a dome on the top. The second concept, lighter and cheaper, uses a transparent polycarbonate compound panel held in place by plastic circular supports.

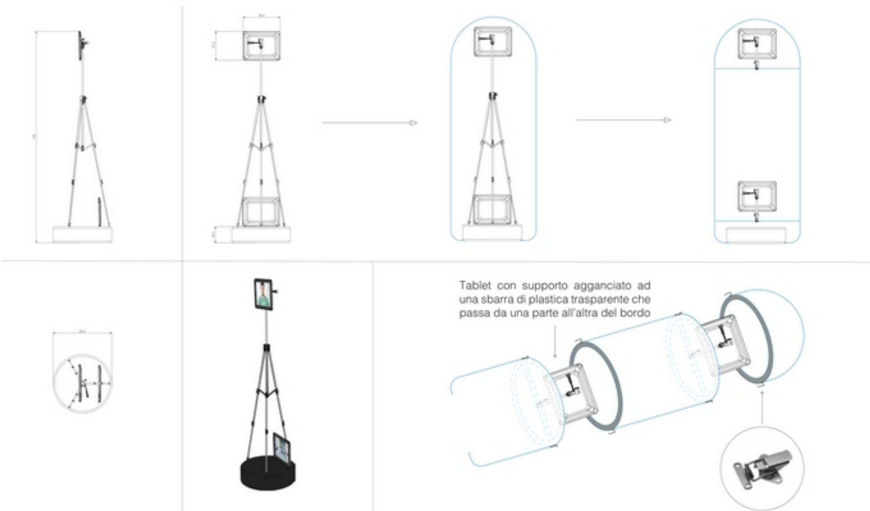

Figure 10. Concept 1 for the LHF Connect finishing to facilitate the disinfection procedures.

Fossati, M. R., Catalano, M. G., Carbone, M., Lentini, G., Caporale, D., Grioli, G., Poggiani, M., Maimeri, M., Barbarossa, M., Petrocelli, C., Vivani, P., Calderini, C., Carrozzi, L., Ferrari, M. & Bicchi A. (2020). LHF Connect: A DIY Telepresence Robot Against COVID-19. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 418-431. DOI: 10.4013/sdrj.2020.133.10

4.7. The LHF Connect Communication Strategy

In order to spread the LHF Connect project, it was necessary to promote it broadly to get in touch with as many people as possible throughout the national and international territory who could need and implement it in local contexts. For this reason, press channels have been used for general dissemination aiming at broadcasting high-level information in national, regional and scientific newscasts. The news has been also launched on social channels. Besides, the project has circulated on important channels for the scientific community, such as IEEE Spectrum. The website constitutes the hub where all the information is collected and where it is possible to find all data useful to replicate the system. Communication activities brought back important feedbacks from companies interested in robotic innovations. In particular, many organizations that manage residential facilities for fragile people demonstrated interest in developing teleoperated robots for different purposes, such as telemedicine, telemonitoring and tele rehabilitation.

4.8. The Website

The LHF Connect website constitutes the hub where is possible to download all manuals to replicate the robot without specific competences. The website architecture is simple and clear, divided into intuitive sections:

- **What it can do**: essentially the reason why LHF Connect was designed and its functionalities. Contents are communicated with few slides and short videos that illustrate different tasks that the robot can accomplish.
- **How it is done**: this section collects all manuals to build the robot. The section is completed with a FAQ, Anomalies management section and a specific forum.
- **Self organise** and **Operating on the territory**: sections dedicated on how it could be possible to organize an LHF Connect service and case studies realized in Italy (with a call to action – if required by the organization);
- **Gallery**: photo and video gallery that tell the LHF Connect story, since the first prototypes until the last trials.

Instructions have been designed to easily assembly the hardware: list of hardware parts needed, assembly manual, 3D model and cad files. Manuals are provided to set up the software for the robot and the remote control, control flows (Automate), Apps (Android and web app RTC), accompanied by a repository in GitHub. Instructions illustrate how to implement the service: remote control, daily management, and disinfection manuals are available on the website.

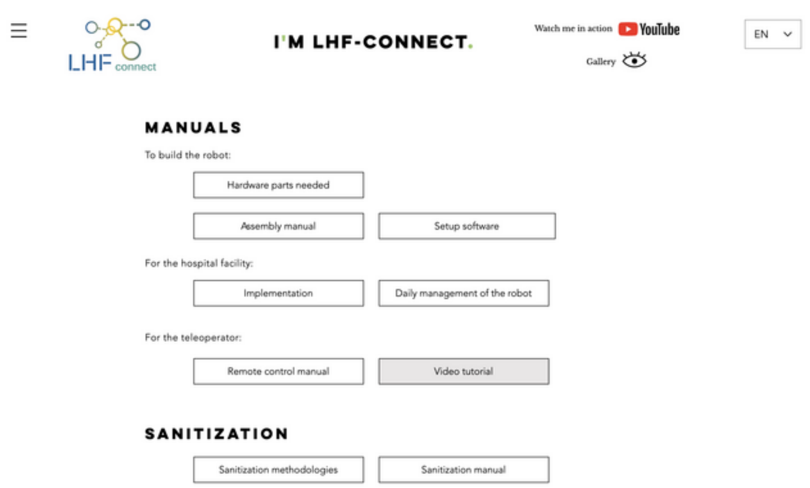

Figure 11. A screenshot from the LHF Connect website containing all manuals to replicate the robot.

Fossati, M. R., Catalano, M. G., Carbone, M., Lentini, G., Caporale, D., Grioli, G., Poggiani, M., Maimeri, M., Barbarossa, M., Petrocelli, C., Vivani, P., Calderini, C., Carrozzi, L., Ferrari, M. & Bicchi A. (2020). LHF Connect: A DIY Telepresence Robot Against COVID-19. *Strategic Design Research Journal.* Volume 13, number 03, September – December 2020. 418-431. DOI: 10.4013/sdrj.2020.133.10

5. CONCLUSIONS

LHF Connect represents a case study where professionals coming from different fields of scientific research collaborated profitably to achieve a goal in a short time. LHF Connect established confidence in the possibility for effective robotics solution to urgent needs, such as patient-family communications in COVID-19 hospital wards. Thanks to the continuous work carried out together with different stakeholders within the hospital environment, the potentiality of a telepresence robot for different purposes emerged (as remote consultations and telemonitoring). These applications are not limited to the pandemic and will certainly be tested in hospitals in the future. Possibilities could flourish if telepresence robots would be equipped with manipulation capabilities able to interact with non-structured environments, such as the AlterEgo robot prototype. This kind of teleoperated robot could open doors, carry small objects, but also caress a person and help remote encounters to retrieve a sort of physical interaction, stimulating a renovate human-machine interaction. As noted in the introduction, virtual meetings are currently made up of the only audio and video components, while the physicality of teleoperated robots could help in interacting with the context, increasing the possibilities of use, but also stimulating the exploration of the physical component in human relationships.

Figure 12. Left: LHF Connect during a video call at the Cisanello hospital (Pisa). Right: AlterEgo shakes hands at Maker Faire Rome 2019 (photo credit: Corina Daniela Obertas).

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Individual protection mask with improved filtering properties: 3D printed solution guided by design materials selection

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ABSTRACT

The COVID-19 pandemic has mobilized most countries to investigate multiple virus mitigation interventions, the face protection masks are among the main ones. Filtration and breathability are important factors in the applied materials choice. Design plays a fundamental innovative role in developing new products and materials that meet this emergency demand. 3D printing allows adjustments from an industrial production to answer an increasingly specific demand. This process allows the printing of a poly (lactic acid) (PLA) filter mesh with Tourmaline (TM) for a mask made in a triple layer with cotton fabric. One of the properties of TM is the negative ions emission, which allows capturing particles dispersed in the air. PLA is a bio-based and biodegradable polymer, with the corn as it's most effective source. It makes it a good choice for the project, aiming to be aligned to environmental issues. In addition, the cotton application and the modeling directed to the domestic sewing use make the project accessible to the population, adaptied to digital and personal manufacturing and aligned to the Maker Movement.

Keywords: 3D Printing, COVID-19, Design & Materials.

INTRODUCTION

COVID-19 emerged as a cluster of pneumonia cases in Wuhan, a city in China's Hubei Province. It was, thus, named by the World Health Organization (WHO) in February 2020, meaning corona virus disease 2019 (WHO, 2020). The 21st century was marked by epidemics such as: SARS Cov in 2002 and MERS-CoV in 2012, both caused by the coronavirus; the Ebola epidemics in Africa; and the avian influenza (H5N1) epidemic. They were controlled in more favorable time and space. But, although H1N1 influenza in 2009 caused a devastating death rate (Dawood et al., 2012), COVID-19 will cause more than 2 million deaths (Walker et al., 2020). COVID-19, also caused by a coronavirus identified as SARS-CoV2, is perhaps one of the greatest global health challenges of this century (Werneck & Carvalho, 2020).

Strategic virus mitigation procedures have been taken. Denominated as non-pharmacological interventions (INF), the strategies are designed to reduce the population contact levels and thus reduce viral transmission. When singly applied, the strategies present lower impact on virus transmission, requiring a combination of multiple interventions (Ferguson et al., 2020). Some of them are: social distance for the entire population, preventing agglomerations, closing schools and universities, and the use of facial masks by the population, known as an important virus barrier method (Brazilian Ministry of Health, 2020; Ferguson et al., 2020).

Initially, was detected that the transmission occurred by respiratory droplets released in cough, speech or sneeze (Mcintosh et al., 2020). Later was also considered the transmission by the so-called aerosolized or aerosolized cores, that are capable of remaining suspended in the air for long periods of time (WHO, 2020). Considering that, the Brazilian Ministry of Health (2020) determined the use of cloth masks by the population. According to Technical Standard 04/2020 GMIMS/GGTES/ANVISA, this measure, when combined to other hygiene care, minimizes the spread of droplets while still asymptomatic (ANVISA, 2020).

One of the related concerns about that solution is the filtering effectiveness, which have been stimulating materials researches aiming such property. Materials with air filtration purpose are already applied in interface to textile materials for several sectors such as air conditioning equipment or vacuum cleaners (Mao et al., 2019; Liu *et al.,* 2020).

In contexts where solutions require a broader perspective, a multidisciplinary team formation is necessary. For this moment, when functional, emotional and aesthetic issues are interconnected in the construction of solutions more easily absorbed by the population, the different knowledge areas collaborative work increases the chances of success of the adopted solution. Design has increasingly been recognized as the element responsible for the development of solutions that promote quality of life improvement linking innovation, technology, research, business and users (WDO, 2020).

In a multidisciplinary team, as the case of this project, the designer takes the responsibility of human factors related to the materials selection. The professions heart is to understanding people's needs, turning it into opportunities to co-create solutions. As important as the technical requirements, the usability requirements must be considered, improving the users experience in interface to the product. The weighted materials selection, considering different dimensions of requirements, makes the user receive the sensations and interpretations predetermined in the project (WDO, 2020; Karana *et al.,* 2016).

Users and objects interaction is composed by different levels of experience, being the second defined by Moles (1981) as the mediator between man and the world. One line of reasoning, involves the distinction between practical, aesthetical and symbolic functions of a product, with possibility of each artifact involve different proportions of each function (Löbach, 2001). The same distinction can be applied to materials, with the practical function related to the cognitive dimension, involving the materials characteristics; the aesthetic function is related to the affective dimension, involving the emotions and pleasures promoted by the material; and the symbolic function is related to the conative dimension, involving the decisions and attitudes taken under the material's influence.

For this solution creation were construed connections between materials engineering, understanding materials properties and potentials, and the design, understanding users needs under ergonomic, functional, production and emotional perspective. Based on this comprehension, this article presents, as a main focus, a protective mask prototype development project, which acts against the COVID-19 causer virus spread. The project consists of a fabric mask with three layers. The intermediate one presents filter properties, due its composition of polymeric material containing tourmaline particles as a filtering and antibacterial material. The research is divided into: phase of polymeric materials laboratory

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experiments, which started two years ago; and the prototype development phase, in which users tests will require one year to complete. Currently, the research is in the laboratory testing phase, focused on the polymeric material used for the filtering grid development. The tests seek to prove the air filtration activity effectiveness, both of the textile material and of the tourmaline.

1. LITERATURE REVIEW

1.1. Tourmaline filtering properties

Taking into account the masks use recommendation as protection against COVID-19, one of the concerns is the filtering effectiveness (OPAS, 2020). The demand for Personal Protective Equipment (PPE) encourages researches into materials with air filtration properties.

One of the investigated materials is the Tourmaline (TM), a kind of natural mineral, which can absorb dust and hazardous substances to purify air, due its self-polarization property, releasing negative ions, besides its infrared radiation (Mao et al., 2019, LIU *et al*., 2020). Recent researches in this area, as the Wang et al. (2020) example, reported the addition of graphene to enhance the negative-ion release performance of TM. As stated by them, 0.5% of graphene, in relation to tourmaline mass, can improve the air purification effect of tourmaline by over 11.9%, and this will produce vital environmental and social influence.

On the other hand, Mao et al. (2017) investigated the filtering effect on fine particle of warp-knitted mesh fabrics treated with five different concentrations of TM. According to them, the TM concentration should be enough to generate sufficient electrostatic interaction on the fabrics to absorb fine particles. They concluded that the filter mesh fabrics with 30% concentration of tourmaline (m/v) and the structure of one by two insertion had the optimum filtration efficiency.

Results indicate that up to an ideal level, the increase of tourmaline percentage added to the fabric led to a voltage rise and a consequent greater particle attraction, reaching a filtering efficiency of 64.8%, against 30.2% efficiency without its insertion (Mao *et al.,* 2019). One of the strategies to promote the expansion of the particle retention capacity in a filter is the fibers static loading. To be considered a good filter, it must be able to preserve, for as long as possible, high charge levels (Yu *et al.*, 2015).

1.2. Design, digital manufacturing and polymeric materials

Design performances its role of gathering different fields so that the product meets the user's needs. Science, technology and design are different and autonomous fields with their contexts and ways of acting in the world. Design has considerable potential when joined to scientific and technological fields in innovation processes. Bonsiepe (2013) considers that when a design project is related to science it should not be interpreted as a postulate by a scientific design or with the purpose of transforming design into science. When the theme requires it, the design must resort to scientific knowledge. Design isolated performance can fall into the aesthetic formalism (Bonsiepe, 1997), not involving the practical and symbolic functions into the configuration of a product. The configuration can be understood as a process of materializing an idea, within a broader, general concept. Providing the products with aesthetic functions meets the user's multisensory perception, since the senses are globally activated, and one-dimensional perception is rarely possible. On the other hand, products can perform suitable practical functions that satisfy physical needs, fulfill the fundamental conditions for man's survival and maintain his physical health (Lobach, 2001). Symbolic functions serve as a backdrop for products with a greater practical function, requiring an interpretation of certain socio-cultural contexts (Bürdek, 2005).

While the craftsman used to create objects with a main function, subordinating the other functions to this central one, industrial civilization and series production conceded the function of organizing the object structure to the designer. Not only the general function is introduced, but also the visual aspect, the practicality and durability (Moles, 1981). The materials applied to products play an important role in their functions, which become more defined through user's perception when in contact with a multisensory experience (Ashby, Johnson, Marques, 2011). Bürdek (2005) considers that materials, when added to their visual, tactile and auditory expression, form the solid basis of the designer's work. It is very important to balance the object's technical and semantic aspects. This polarity between the material and the symbolic aspects is a characteristic of products or artifacts according to Riccini (2005), as they are instruments and bearers of values and meanings. It is up to the designer this polarity reconciliation, projecting products as a result from the socio-technical process interaction.

Among the various materials used throughout human history and design, plastics were the materials chosen by many designers in the 20th century due to the great versatility of production processes (Fiell & Fiell, 2009). They went through innovations demanded by the First Industrial Revolution, and later by the Second Industrial Revolution, including incorporation into the chemical industries (Koplos & Metcalf, 2010).

Transformations in materials and production processes availability have, throughout history, guided changes in different areas of human life, leading to longevity, quality of life, population concentrations and demographic growth increased (Anderson, 2012). As result of those transformations was also possible to see negative environment impacts, with the increase of solid residues, in most part composed by plastics.

Those factors have promoted changes in people behavior, mainly in relation to consumption. Movements like Consciousness Consume became more intense over the recent years, with people thinking deeply about products origin, the materials applied, how they were produced, and the social, economical and environmental impacts promoted (Akatu, 2020). Another response to mass production was the purpose of people to being part of the products concept or production processes. The Do It Yourself culture became more popular, culminating in the Maker Movement, supported by Digital Manufacturing technology and the Open Design culture, favoring sharing (Anderson, 2012).

Digital fabrication consists of using digital information from a project to produce a physical object by computer-controlled processes. Its technologies are an alternative to serial production, allowing local and customized manufacturing. Its application allows, in some cases, the adjustment of industrial production system to meet an increasingly specific and variable demand (Barros & Silveira, 2015). The equipment is divided in two technology systems: materials addition or subtraction, and is currently understood as rapid prototyping technologies.

One of the most known additive technologies is the Fused Deposition Modeling (FDM) 3D printing, for its affordable price and materials availability (Volpato *et al.,* 2017).

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One of the most used material in FDM 3Dprinting is the poly (lactic acid) (PLA), for its translucency and wide range of available colors, as well as being bio-based and enabling a greater detail finishing (Wijk & Wijk 2015). Besides those factors, for this research, the material was one of the chosen ones because of its biodegradability, reducing the negative impacts of its discard, and its biocompatibility to the human body (Nampoothiri *et al.,* 2010).

PLA presents a considerable lower biodegradability rates when compared to polycaprolactone (PCL), which also offers greater flexibility (Niaounakis, 2015). PCL became commercially available following efforts to identify synthetic polymers that could be degraded by microorganisms. PCL is a hydrophobic, semi-crystalline polymer; its crystallinity tends to decrease with increasing molecular weight (Woodruff & Hutmacher, 2010). Those properties motivated some tests with PCL for this research.

Additives are substances inserted to improve or modify polymers properties (Callister & William, 2012). The present research contemplates the polyethylene glycol (PEG) use as PLA polymeric plasticizer due its good miscibility (LI *et al.*, 2015). Nanocomposites are also incorporated into the fibers by masterbatch method, a mixture of additives dispersed in a chosen polymer compatible medium (Shen *et al.,* 2015). This research involves the TM use as PLA additive to produce a filament used in the protection mask filtering mesh 3D printing.

2. DEVELOPMENT

2.1. Materials

The following materials were used in this research: Natural poly (lactic acid) (PLA) filament; Polyethylene glycol (PEG 6,000) (cod. 812550) ; Micronized white TM ; 650 TN Unicotton Fabric (frame: canvas, plain, mesh; composition: 100% CO; weight: 170.0g / m^2; 4.95oz; width: 1.70m; 67").

2.2. Product project: individual face mask with improved filtration capability

To the mask project, were collected information about standards towards the product, ergonomic information and usability tests with the involved team. Were, then, reunited the main requirements that should be considered in the material and the product development.

This research follows ABNT PR 1002: 2020 standards (AFNOR, 2020) for designing a fabric mask with respiratory filter. The standard recommends the use of fabrics composed by 100% cotton and weight from 90 to 210 g/m^2, or synthetic fabrics with 4 to 10% elastane. The materials choice influences the mask's filtration and breathability.

The acceptable breathability for a surgical mask is less than 49 Pa/cm^2, while for non-surgical masks, an acceptable pressure difference, across the entire mask, is less than 100 Pa/cm^2. The filtering of cloth and mask fabrics varies between 0.7% and 60% (AFNOR, 2020).

According to the WHO (2020), the masks must have three layers: an inner layer of hydrophilic material such as cotton; a hydrophobic intermediate filtering layer of non-woven synthetic material or polypropylene; and an outer layer in hydrophobic material such as polyester, polypropylene (OPAS, 2020).

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In relation to the dimensions, was defined that the masks must meet Brazilian population average morphological measures, tanking as reference the COVID-19 targeted population, following anthropometric data from ISO/TS 16976-2: 2015. The technical specifications with masks modeling followed the technical sheet ET-010 (SENAI, 2020).

Based on the data collected, requirements were defined in three main groups: technical, functional and aesthetic. Besides the filtering capability, the mask must be easy to use, transmit to the user the message of security and of quality, as well as easily adapting to what the user is already used to, not representing a point of concern. The requirements are shown at Table 1.

Table 1. Mask project requirements

Technical Requirements	Functional Requirements	Aesthetical Requirements
Hydrophobic Layer	Adaptation do body curves	Visually neutral, adapting to different users
Filtering Layer	Breathability	Sense of security
Absorbent Layer	Anthropometrically ergonomic	Sense of quality
Adapted fabric composition	Soft touch	
	Foldable, for easily keeping	

2.3. 3D printing filaments production

The commercial PLA filament was granulated with granulator , and later manually mixed with the plasticizer PEG 6.000 in different average molar masses and contents. They passed through an extruder at 178°C of temperature, and 3.0 rpm of extrusion speed. The filament samples generated were: PLA/PEG (1), with 1% of PEG; PLA/PEG (5), with 5% of PEG; PLA/PEG (10), with 10% of PEG. Part of the filaments were pelleted and hot pressed which underwent mechanical tensile tests .

Compared to pure PLA, the sample PLA/PEG (1) did not show significant differences in the tensile strength property. But there was a property decrease while the PEG proportion increased to 5 and 10%. However, the PLA/PEG (10) sample showed a decrease in elongation at break. Li et al. (2015) attributed this to the phase separation between PEG and PLA caused by the exceeded solubility limit of PEG in the PLA. The values of the mechanical tensile properties found in the literature for PLA/PEG 6,000 mixtures (5%) were: 40.5 MPa for tensile strength, 557 MPa for Young's modulus and 8.1%, for elongation at break (Liu et al, 2017). According to the results, the PLA/PEG (5) sample was chosen as the ideal PLA/PEG ratio for having better mechanical properties.

Pure PLA and the three filament samples also underwent tests to evaluate the ideal 3D printing temperature. On a FDM printer the temperature tower test was carried. This test allows the evaluation of the best nozzle and bed temperatures to work with each filament based on the pieces final finish observation. It is also possible to determine the best work temperature for each material, since there are temperature variations along the piece (3D LAB, 2020).

The files were obtained from a 3D models sharing community . Figure 1 brings the printed towers picture, using as material the pure PLA filament and those with different PEG contents, under the temperature ranging from 185 to 220°C with a 5°C variation each 1 cm of printed height.

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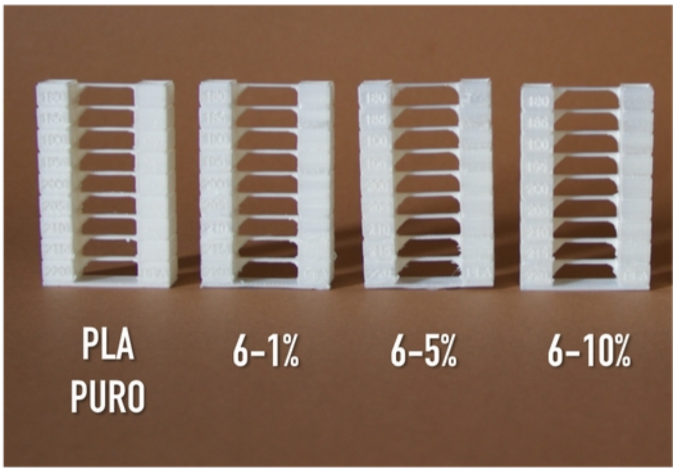

Figure 1. 3D printed temperature towers with four filament samples.

The printed towers were digitalized and the images were analyzed using the Image J. software. The hollow area (h area) was measured (Figure 2a) and also the X distance, related to the maximum bridge width extremities (Figure 2b).

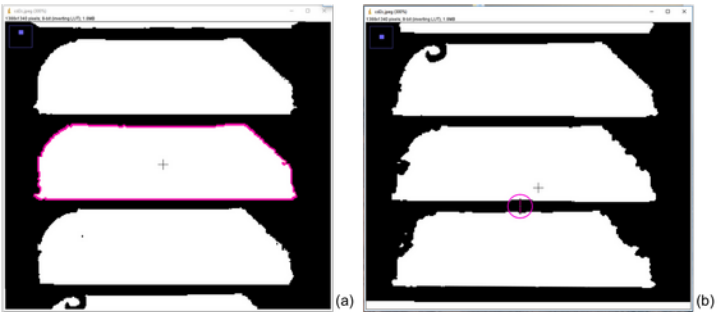

Figure 2. area measurement: (a) hollow area; (b) distance X.

The smaller the h area, more polymer residues from the printing can be seen into the hollow area, meaning that the better work temperature is the one with results pointing to the largest h area. The results showed that 185°C was the worst printing temperature for three of the samples because it presented the smaller h area. On the other hand, the distance X measures the bridge's warping. The shorter the distance X, the less it warped and the better the printing temperature is. The temperature of 220°C had the shortest distance X for three of the samples, and thus, was the one chosen for mesh printing.

After choosing the PEG content and the ideal temperature for 3D printing, the TM powder was added to the PLA/PEG (5) sample. To produce the TM loaded filament, the micronized TM was firstly mixed with PEG using a 1: 1 (w/w) ratio. The mixture was melted and oven-dried at 40°C for 24 h. Then it was grounded and sieved trough a Mesh 100 to obtain the powder masterbatch (MB). Filaments were thereafter produced following the procedure previously described for PLA/PEG.

2.4. Filter mesh 3D printing

Geometric models were printed as a test for the filter mesh prototype. Geometric patterns were developed in Solidworks 2013, and available models were used. The printing parameters were: 220°C nozzle temperature, 0.2 mm layer thickness, and 70°C bed temperature.

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The geometric models were generated by the concept of Representative Volume Element (RVE), using the smallest possible repetitive volumetric element (Lomov et al., 2001). Geometric shapes with connection spaces offer greater mesh flexibility allowing better adaptation to the user's face. Different geometric patterns were printed (Figure 3 a) and show the structure flexibility (Figure 3 b).

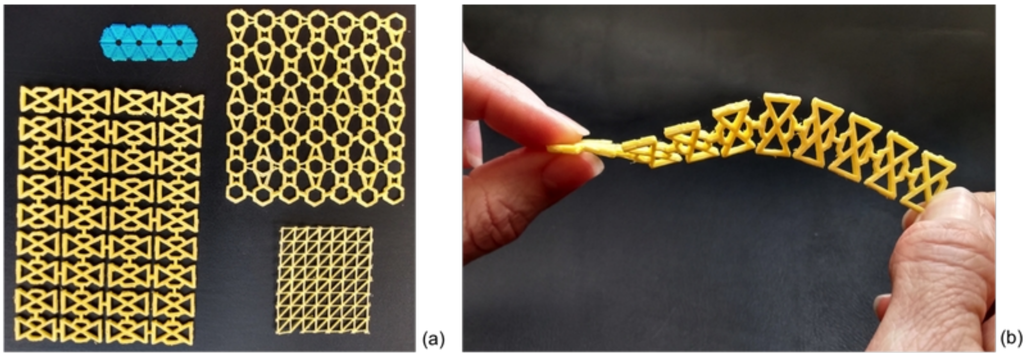

Figure 3. 3D printing: (a) geometric patterns (b) structure flexibility.

Considering the PLA mesh low flexibility, added to lower comparative biodegradability rates, impressions were also made with PCL. PCL is widely used in medical applications due to its biocompatible property, besides of being approved by U.S. Food and Drug Administration (FDA) (Vijayavenkataraman et al., 2019). The polymer presents mechanical properties compatible to diverse applications, being the most highlighted ones it's low melting temperature, non-toxic nature, flexibility and softness (Fox et al., 2020). Furthermore, it can be easily processed by any polymer fabrication technology (Arbade et al., 2020).

Some prototypes of filtering meshes were printed with PCL filament containing tourmaline, showing dimensional stability (Figure 4 (a) and (c), and resistance to folding avoiding breaks of the mesh (Figure 4 (b)).

Figure 4. filter printed in PLA / PCL: (a): dimensional stability (b) flexibility (c) dimensional stability.

2.5.Final project development: selected strategies

After the results obtained during the mesh filtering production by 3D printing, was possible to decide what strategies of manufacturing, applied materials and distribution would be available and adapted to the mask project. Towards the materials selection in product projects, Ashby (2012) says the good project works, but the excellent project brings pleasure. Table 2 brings the relation between market needs and current standards; the solutions that the project should consider to meet the needs; and the strategies adopted from the practical point of view for its solution.

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Table 2: Project strategies related to market needs and product requirements

Market needs	Project requirement	Adopted solution
Adapt to the WHO recommendation	Hydrophobic Layer	It was preferred a environmentally responsible solution besides the fabric affordance
	Filtering Layer	Insertion of a separated filter
	Absorbent Layer	100% cotton fabric
Good filtering property	Trapping particles dispersed in the air	Use of tourmaline as an additive in the filter, because of the self-polarization and release of negative ions
	Physical barrier promoted by the fabric weight	The three layer mask improves the filtration
Good breathability	Materials that balance the distance between fibers and the particles retention	The cotton presented equilibrated properties between breathability and filtering. The fact of being natural fibers favors the filtering
Affordable to users over the world	Locally producible	3D printed filtering solution – open source file to print
		Affordable modeling to domestically production
		Accessible materials: tourmaline, cotton fabric, PLA and PCL
	Low cost solution	National materials and Accessible productive process as domestic sewing machine and FDM 3D printing
Lower environmental negative impact	Separate part substitution	Removable filter
	Low discard impact	Bio-based and biodegradable materials as PCL, PLA an cotton fabric
	Use of wasted materials	Cotton fabric from reused clothes pieces, tourmaline as waste of jewelry sector, and PCL and PLA as waste of 3D printing process
Ergonomically anthropometric adapted	Alignment to ISO/TS 16976-2: 2015 statement	The mask modeling was based on the statement, being anthropometric aligned to the population's faces measures
	Easily adaptable to face curves	PCL shows grater flexibility to geometrically adapt
		Adopted geometry to the filter mesh favors the flexibility
		Natural fibers present in cotton fabric makes it more soft and foldable
	Comfort in contact with the skin	Cotton fabric and PCL soft touch
		PCL and PLA biocompatibility
Visually neutral	Form	Modeling in rectangular form
	Color	Cotton fabric presents a great available colors range, adapting to different users
Easily adapt to what users are already familiarized	Mask models which people have already seen in other contexts, such as medical, dental, cosmetics, and others	Common modeling mask
Biosecurity	Side margin sealing	Adapted to the ET-010 SENAI statement
Sterilization	Virus inactivation high temperatures	Cotton fabric allows contact with high temperatures
	Easily washing	Cotton fabric allows chemical products contact in the washing process
	Allow separate parts washing	Easy filter extraction and replacement from the mask
Easily transport	Allow the mask fold with no damages	PCL and cotton fabric are foldable materials

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Taking into account the adopted solutions, the mask was produced on a domestically sewing machine. Figure 5 shows an illustration of the final product (mask) with three layers, being: an inner and outer layer in the same fabric (100% cotton); an intermediate layer in the form of a PLA/PEG (TM) filtering mesh. The inner layer has an 6.0 cm (approximate) opening on the back, as shown in figure 5. The opening function is to allow the filtering mesh insertion.

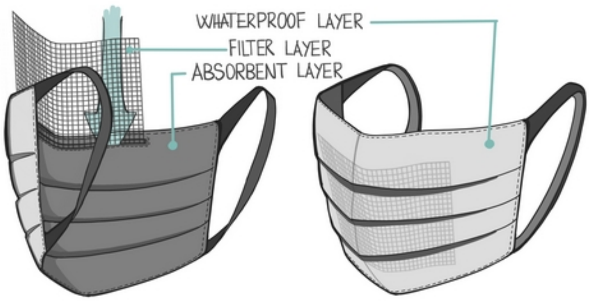
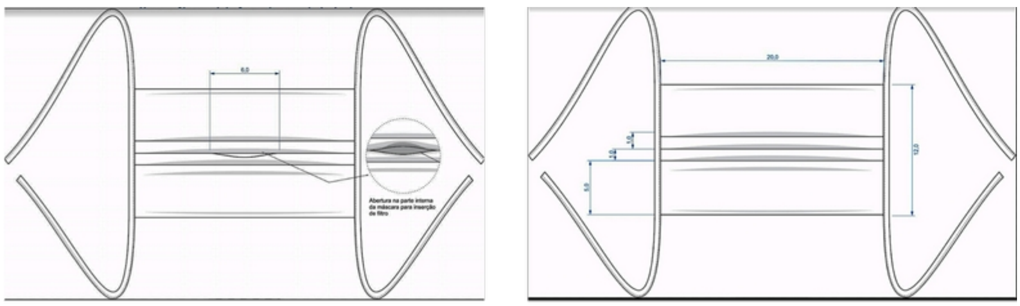


Figure 5. Mask illustration with filter (a): back (b) front

The fabric mask prototype applies to the user's routine activities, not indicated for hospital or dental use. It was based on the technical specification ET-010 (SENAI, 2020), used for making in industrial or semi-industrial machinery. The measures of the finished mask are: 20.0 cm wide and 12.0 cm high. The mask body has three central folds of 1.0 cm each. A side seam holds the elastic of 5.0 mm wide and 20.0 cm long on each side of the mask. Figure 6 shows the mask technical drawing, with the reference measurements for the production.



(a) (b)

Figure 6. Mask's blueprint (a): front (b) back (SENAI, 2020)

WHO recommendations (2020) that masks should have three layers were also followed, with an intermediate as a filter. The materials choice is based on the criteria of filtration efficiency (FE) or filtration, breathability, number and combination of used materials, format, coating and maintenance according to OPAS (2020) guidelines.

The project was made using Illustrator software and the fabric was cut using ECNC laser cutting equipment for better edge sealing and better finishing.

The mesh filtering capacity will be evaluated in future works, while the textile materials has already passed through tests that evaluated the particles capture. Corona virus particles are

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spheres with approximately 0.125 microns (125 nm) diameters, with 0.06 microns smallest particles and 0.14 microns largest (Zhu, 2020).

The tests evaluated the effectiveness of mask materials in capturing 1.0 micron and 0.3 micron particles. They offered reasonable estimates of each material effectiveness in capturing 0.1 micron particles – the corona virus size when it is not in droplets form (Robertson, 2020).

The inner and outer layers fabrics choice was based on research data about breathability and filtering of homemade masks materials (Robertson, 2020). The materials with the greatest filtering power were those with the least breathability. The 100% cotton T-shirt achieved breathability close to the N95 mask and filtration of only 3.4% of the 0.3 micron particles. But when they used a double layer of the shirt, the filtration increased to 15%. This shows that the weight and thickness of the material are important factors for facial masks and justifies this research choice for of 100% cotton fabrics with 170.0g / m^2 and 4.95oz for both the inner and outer mask layer.

The cotton fabric choice is due to the study in which is proofed that natural fibers generally filter better than synthetic fibers. In addition, synthetic fibers tend to be smooth and uniform, while natural fibers are rougher and more irregular. The natural fibers irregularity is likely to make them better at capturing small particles (Robertson, 2020).

3. CONCLUSIONS

In front of an emergency situation, such as the one faced in recent times with COVID-19, several areas are committed to proposing quick solutions to issues related to individual protection and contamination risk reducing. Design, however, due to its nature linked to the human behavior understanding and needs, has a greater capacity to develop solutions that go beyond. The proposals connected to the design activity take into account, in addition to the practical functional aspects, the emotional dimension and the environmental, social, cultural and economic impacts.

In the proposal developed in this research, design worked in all of the project stages, bringing its systemic look. The project went through the survey of needs, the understanding of the current topic statements, in contextual research, reaching a grouping of requirements that led the material and the product development. The proposed product exemplifies the potential of the designer's performance in a multidisciplinary team, as an element responsible for the connection between materials technical information, their production processes, and the subjective aspects of human behavior and needs. The fact that the demand is still very current, makes still necessary the proposal validation, being submitted to steps for further development and possible adjustments to its solutions.

The research has been successful during its development, the mask showed few limitations in terms of use, as it follows ergonomics and materials adequacy standards. The research boundaries may consist of investigating the mask effectiveness as a protection against the coronavirus. That will require a study in interface with volunteer users, preferably those professionals with greater exposure to the coronavirus. As the sampling, another limitation may also be the specialized laboratories request, in order to analyze the masks, demanding partnerships and support from other institutions and universities.

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The project has large application in Brazil, once it is the world's largest tourmaline producer. The state of Minas Gerais, where the research has been conducted, stands out as the state of greatest production in the country due the region of Eastern Pegmatitic Province of Minas Gerais. However, the research applies to other countries that are also tourmaline producers, such as in Africa: Nigeria, Mozambique, Zambia, Madagascar, Namibia, Tanzania and Kenya; in Asia: Afghanistan and Sri Lanka; in North America: USA (Pala and Mesa Grande, both in California) (CORNEJO, BARTORELI, 2009).

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A Distributed Product-Service System for Mask Provision during COVID-19: an Action Design Research Study in Brazil

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ABSTRACT

The provision of Personal Protective Equipment (PPE) for COVID-19 demanded initiatives beyond the sole provision of physical artifacts, urging the development of new services and system innovations in order to produce effective solutions. In this paper the authors report one of such initiatives, where a streetwear brand (ÖUS) and Paraná Federal University have joined efforts to develop a sustainable Product-Service System for mask provision, aiming at the protection of vulnerable school children in the surrounding area of a shoe manufacturing plant in the state of Ceará, one of the epicenters of the pandemic in the country. This consisted of an Action Design Research where, due to the pandemic context, all participants were in social isolation and, therefore, the design process was carried out remotely. In the article, the authors explore in-depth the induction of a more distributed economy paradigm on the PSS Design. A distributed approach presents itself more aligned with the health requirements during pandemic, with a higher potential to contain locally the flow of people. Furthermore, it also addresses the need for generating income locally, thus merging the health and economic concerns of the pandemic.

Keywords: Distributed Economy, Personal Protective Equipment, Product-Service System, Sustainability.

1. INTRODUCTION

Since its first confirmed case on 26th February 2020, Brazil has become (June 2020) the epicenter of the SARS-Cov-2 infection that causes COVID-19 in Latin America (Candido et al., 2020). Regional and nationwide efforts to tackle the pandemic have shown that the industry was not prepared to rapidly supply the large demand of PPE (Personal Protection Equipment) required by the health sector. Indeed, the Brazilian Medical Association registered 7,897 complaints of health workers about the lack of PPE, from March to April 2020 (BMA, 2020). In order to contribute to the provision of PPEs, not only for the health workers but to the population in general, companies from different sectors have voluntarily repurposed their capabilities. Other institutions have also gathered to support these initiatives, such as city councils, professional associations, NGOs, and universities.

A similar phenomenon has occurred around the world, mostly with a product-oriented emphasis, ranging from the design and manufacturing of masks (UEL, 2020), face-shields (Kalyaev et al., 2020; UFPR, 2020), smart masks (Ghatak, 2020), 3D printed ventilators (Zastrow, 2020), ventilators for two patients (Pooler et al., 2020), 3d printed nasal swabs for test kits to door handles that can be opened using an elbow (Zastrow, 2020). Service-oriented initiatives have tackled issues such as remote medicine (Kavoor et al., 2020), digital patient self-triage and self-scheduling (Judson et al., 2020) and laboratory services for comparing materials for PPE (INOVA USP, 2020). However, there was a lack of studies that consider integrative approaches that integrate products and services for the provision of PPE. Under such context, the authors set the assumption that the Design of an integrated mix of products and services (Product-Service System) for PPE provision would offer an opportunity to drive the economy towards a more distributed approach, thus contributing to merge both the health and economic aspects of the pandemic.

A Product-Service System (PSS) can be defined as an integrated and comprehensive value offer model that combines a mix of products and services, locally viable, appropriate, and relevant. This mix of products and services need to be able to fulfill the needs of each customer, offering a viable business model for the producers/providers. To be effectively sustainable it has to result in positive societal impact, whilst reducing environmental impact and promoting economic equity (Santos, 2018). The development of a PSS enables more radical and systemic innovation such as the adoption of more Distributed Economy, characteristics that were urgently demanded by the pandemic crisis.

Distributed Economy was firstly defined by Johansson et al. (2005) as a "selective share of production distributed to regions where activities are organized in the form of small scale, flexible units that are synergistically connected with each other". It is characterized by local small-scale production units connected to each other through a collaborative and synergetic network. These local units provide local needs near or at the point of use, including artifacts /services demands across the product life cycle and business process. Hence, they are more capable to offer on-demand solutions and having a higher level of multi-user participation (Santos, 2018). A distributed Economy has the potential to enhance the generation of local income (Rosa, 2012; Duarte & Santos, 2019). Furthermore, due to the multi-user participation aspect, Distributed Economy works as a learning process that contributes to built-up relevant long term capabilities within local communities.

The subject of a Distributed Product-Service System was explored in an Action Design Research project developed in Brazil on an industry-university partnership during COVID-19. The focus of the project was on the provision of masks for vulnerable school students, with simultaneous attention at the system level regarding the reduction of environmental impacts and a contribution to foster the local economy. More specifically, the project explored the adoption of a PSS oriented towards a Distributed Economy.

The 23-19 Project (the name of the project is inspired by the "password" that monsters used when "contaminated' by children on the movie Monster S. A.), was part of an "Integrative Learning Activity" (ILA), implemented in May 2020 by the Product Design Course of Paraná Federal University. This ILA has adopted full remote activities and involved a total of thirty students and seven professors from the Design Department of Paraná Federal University (UFPR). On the industry side, the partner was OÜS, a Brazilian streetwear brand specialized in shoes. The company was established in 2008, with headquarters in Curitiba, Paraná capital, Southern Brazil. Its shoes manufacturing process took place largely at Dilly factory, based in Brejo Santo, State of Ceará, Northeast Brazil. This State was one of the COVID-19 country epicenters during the project, with approximately 136.785 confirmed cases and 6.868 deaths in July 2020 (MINISTÉRIO DA SAÚDE, 2020).

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OÜS has championed the idea of using the manufacturing plant located in Brejo Santo to contribute to the pandemic combat. The intent was to use their manufacturing competencies - materials, production skills. infrastructure, and logistics - to provide PPE for the school children in the surrounding region. To facilitate access to local knowledge the project has integrated local partners, including the Ceará Design Professionals Association (ACDesign) and lecturers/students from Ceará Federal University (UFC) and Cariri Federal University (UFCA).

2. THE IMPACTS OF COVID-19 ON SCHOOL CHILDREN

The study focused on school children between 9 and 13 years old. Worth mentioning that one of the unique characteristics of the COVID-19 pandemic was the low hospitalization and mortality rate among children. On the other hand, children were experiencing additional harm due to social isolation, lack of protective school placements, increased anxiety and reduced public health care provision (Crawley et al., 2020). Social isolation, the withdrawal of peer support, the lack of structure, and support of the school environment, added to the increased anxiety provoked by the risk of COVID-19 infection on their parents. Furthermore, social isolation has resulted in domestic violence exposure and abuse increase (Crawley et al., 2020). In Brazil, the effect of such context on mental health was particularly serious for the most vulnerable children living in the poorest areas of the country, where the health and social services were less present due to the burden provoked by COVID-19 on the public services.

The negative emotions caused by COVID-19 can lead to somatic symptoms among children that, in turn, can cause significant physical and mental discomfort. The study of Liu et al. (2020) reinforces this perspective, having identified that the concern for life and health was associated with a higher likelihood of somatic symptoms among primary school students. This concern was associated with anxiety, but not with depression. The authors inferred that with appropriate health education, the implementation of effective prevention and control measures could contribute to reducing concerns regarding the threat to life and health, thus reducing anxiety (Liu et al., 2020). Thus, PPE along with other health measures has to be widely available to children, particularly those in a vulnerable situation.

When analyzing the adequate level of usage of PPE among children, various contextual factors come into place and are relevant to understand the Product-Service System. The study of Chen et al. (2020) investigating the status of hand hygiene and mask-wearing among primary school students in Wuhan, China showed that 42.05% of the primary school students had a good behavior of hand-washing and 51.60% had a good behaviour of mask-wearing. The study has found that grade, mother's educational background, and residence were variables associated with the level of mask-wearing. However, Chen et al. (2020) also call attention to the fact that personal protection of primary school children is often overlooked when the subject is prevention measures, with more attention given to hand-washing and mask-wearing among healthcare workers. Furthermore, children in social vulnerability may be more strongly affected by diseases or their side effects (Bender et al., 2020). Therefore, during the interaction of a PSS with these children, the school becomes a key touchpoint, as it is necessary to guarantee the continuity of various critical services during the pandemic, such as feeding programs and remote learning.

3. RESEARCH METHOD

The authors adopted an Action Design Research (ADR) method. This is a research method that enables contribution to knowledge via prescriptive proposition and evaluation of artifacts, merging the abductive logic of Design Science Research with the learning cycles that characterize Action Research. Based on Sein et al (2011)´s proposition, the Action Design Research on this project adopted four stages, as illustrated in the next figure:

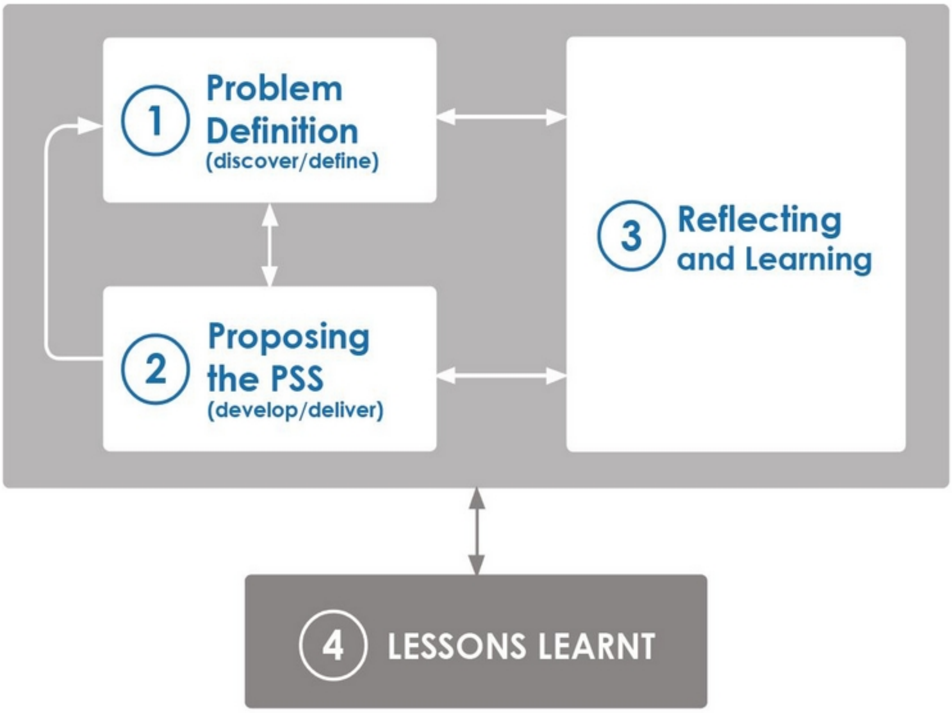

Figure 1. Stages of the Action Design Research Method (adapted from Sein et al., 2011).

The didactic process of application of the discipline involved two main phases, one focused at the PSS level and other focused on the Product Design oriented towards the PSS concept. Next table details the tools used in the first phase of the project, which is reported in this paper:

Table 1. The stages of the ADR method and connection with the project schedule

Stage	Techniques	Results
Stage 01 - Problem Definition	Desktop Research (System); Persona, ; 635 technique; Benchmarking (product/services); Moodboard;	Product+Service System Requirements)
Stage 02 – Proposing the PSS - Generating Alternatives and Detailing (System)	Alternatives: Heuristic Cards for Sustainable Systems; Brainstorming; Storyboard 01. Detailing: Tomorrow headlines; Canvas; System Map; Blueprint; Customer Journey; Storyboard 02	Product+Service System Alternatives and Detailing Concept
Stage 03:Reflecting and Learning	Remote Workshop	Assessing the Viability, Attractability and Strategic Alignment of the proposals
Stage 04: Lessons Learnt	Crossing of Concepts of the Distributed Economy and Final Alternative of PSS	Assessment of the implications of a PSS for promoting a distributed economy during COVID-19

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4. RESULTS & ANALYSIS

4.1. Stage 01: Understanding the Problem (Discover/Define)

On Stage 01 (Problem Definition) the university-industry team focused on understanding the problem as well as the system requirements for the main stakeholders. The activities on this stage involved the use of Desktop Research, an international Benchmarking of product/service solutions for PPE provision as well as remote open-ended interviews with students and teachers from Ceará State. This stage reinforced the understanding that the sole provision of physical artifacts would not be effective since the masks did require proper management after the usage phase to avoid further dissemination of the virus.

The available knowledge at the time established that the initial spread of the virus occurs by direct contact or through transmission paths to droplets which are found to stable for more than 24 hours (Van Doremalen et al., 2020). It passes through the mucous membranes, primarily the nasal and larynx mucosa and, then, it goes to the lungs, by respiratory tract (Gennaro et al., 2020). There was no vaccine for COVID-19 and, therefore, prevention measures were the main strategy to deal with this virus, including (1) covering coughs and sneezes with tissues; (2) washings hands regularly with soap or disinfection with hand sanitizer containing at least 60% alcohol; (3) avoiding contact with infected people; (4) maintaining an appropriate distance from people; and (5) to refrain from touching eyes, nose, and mouth with unwashed hands (6) use of face masks (CDC, 2020; Gennaro et al., 2020).

The provision of face masks was selected as the main focus of the project since it was a central requirement for the opening up of the schools, although there was no clarity regarding when that would occur. Health care workers were recommended to use certified N95 or Filtering FacePiece 2 (FFP2) when performing aerosol-generating procedures and to use medical masks while providing any care to suspected or confirmed cases (Gennaro et al., 2020). Meanwhile, regular citizens were recommended to wear cloth face coverings in public settings.

The benchmarking has confirmed the need for adding several services into the system in order to support the mask´s life cycle. Indeed, due to their toxic nature, masks worn by children during the pandemic must be transported properly to laundry services and/or specialized toxic waste collection. System waste can be treated by various methods (thermal, chemical, biological and mechanical processes or even by irradiation technologies) which can also include incineration, if properly treated fly ash, SO2 and other pollutants (ANVISA, 2020). In Brazil, COVID-19 waste regulations within health care facilities require the use of a red sac for waste management and services that remove these sacs at least once each 48 hours (ANVISA, 2020).

The information collected at this stage of the project allowed the establishment of the main initial requirements of a PSS for school children mask provision:

1. Allow free access to masks to school children in poorer areas: the system must integrate alternative forms of economic viability that not require payment from those children;
2. Integrate services for the life cycle management of masks (ex: cleaning, tracking, recycling, customizing);
3. Communication with school children have to consider non-digital approaches as some families did not have access to the internet or computing facilities;
4. The system should consider the integration of other facilities in the neighborhood beyond the school itself, due to the precarity of their infrastructure and scarcity of space;

5. Promoting a more distributed economy whilst tackling the pandemic: integrate as much as possible local resources (equipment, skills, and materials) and local stakeholders;

6. Enable effective engagement of school children, gamifying where necessary and possible;

7. Allow more active engagement of factory workers in the system (training, online advice, franchise, home production, among others).

4.2. Stage 02: Proposing the PSS (Develop/Deliver) and Stage 03: Reflecting and Learning

Stage 02 focused on generating, select and detail system alternatives. Due to the social isolation imposed by COVID-19, a remote creativity workshop was carried out, using brainstorming, 635 technique and storyboards. A set of heuristic cards supported the creativity process, contemplating the economic, social and environmental dimensions of sustainability at a system level, contributing to the speed and quality of the creative process. The heuristic cards were made available via an open online platform. Worth mentioning that none of the participants, including the lecturers themselves, have any previous experience in developing a creativity workshop remotely.

The dynamics of interaction were different from conventional face-to-face creativity workshops and have to be learned as the action unfolded. For instance, in the brainstorming session, all participants could write simultaneously their ideas on the same sheet, whilst they present orally their propositions. Clustering and ranking ideas were also carried out with simultaneous handling of information by all participants.

Three main concepts of PSSs were developed: (1) the first concept was a result-oriented PSS for the provision of ownerless masks and their respective life cycle services (e.g. cleaning, recycling) performed by local stakeholders; (2) The second concept consisted of a product-oriented PSS, focused on the donation of masks by involving ÖUS customers as the financiers. In this second concept, when purchasing PPE for his/her use, the OÜS consumer could also donate a PPE to children in social vulnerability, previously mapped on the PSS platform; (3) The third concept is a user-oriented PSS that consisted of a platform that would integrate local artists to customize the mask´s aesthetics, conceived as pre-manufactured kits that would be assembled and sold by the local community, enabling local income generation.

All three concepts, the PSS has emphasized not only the social and environmental dimension of sustainability but, a more distributed economy, the project intentionally integrate green economy principles such as valuing local culture, foster local entrepreneurship, valuing local resources and prioritizing network organizations.

These three concepts were presented, evaluated, and refined with the collaboration of the OÜS company team and the partners from the State of Ceará. Following their feedback the selected concept merged concepts 01 and 02, integrating services to support the life cycle of masks as well as involving ÖUS customers as one approach to finance the system. Figure 2 shows the Blueprint of the PSS concept.

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PSS: PPE MANAGEMENT IN COLLECTIVE SPACES

Blueprint	Order: First contact	Order: Decision support	Order: Acquiring	Order: Manufacturing	Use: Delivery	Use: Use and Monitoring	After Use: Maintenance	After Use: Discard
TOUCHPOINTS	- Digital media; - Social networks; - Youtube; - OUS Website and App - Demand Manager (eg NGOs)	- Digital media; - Demand management platform;	- Digital media; - Contact with the manager (tel, email, etc.); - Automatic return via email;	- Web / Application (order tracking);	- Phone / app scheduling; - EPI / Van Delivery ÖUS Partners; - Physical / Digital Manual (Youtube);	- Signaling / Manual; - Poka-yoke; - Online app tips, email;	- App; - PPE withdrawal support contact;	- App alert for the need to purchase new PPE;
CUSTOMER ACTIONS	- Search for solutions on the web; - Contact OUS, through the website or tel; - Receive call from the manager;	- Simulate service registration on the website; - View partnership options delivery times, frequency of maintenance; - View product quality certification;	- Select PPE / sponsorship mode; - Register, receive confirmation of sponsorship; Select PPE, laundry and recycling company;	- Track order and delivery status;	- Receive the PPE; - Download application and fill data; - Receive training and feedback on usage data;	- Use of PPE according to app alerts; - Participate in the training provided on the platform;	- Receives alert of the need for hygiene and waits to collect PPE for local laundry;	- Receive warning of need for disposal; - Cooperatives / recycling company collects PPE;
Line of interaction								
FRONTSTAGE	- Make content available on digital media; - Contact with manager;	- Offer online support; - Provide different forms of sponsorship; - Offer PPE portfolio;	- Provide online field for registration and indication of sponsors; - List of cleaning and recycling companies (local);	- Provide website / app status; - Confirm quantity, variety and delivery times;	- Delivery through ÖUS logistics partner;	- Offer online support with information on the correct use of PPE and signs of wear; - provision of educational material for raising awareness;	- Regular weekly collections; - Offers online support;	- Offers online support; - Indication of times and days of withdrawal;
Line of visibility								
BACKSTAGE	- Keep digital media updated; - Search for demand / sponsors work with prospective managers / NGOs;	- Prospect different sponsors; - Online exhibition of results; - Design portfolio of PPE of different sizes and strength;	- Receive and manage orders, stocks and distribution; - Organize production of PPE / contact partners; - Receive sponsorship;	- Manufacture Dilly PPE + Component partners + Laboratory; - Update information in the tracking system;	- Offer a platform with usage and care information; - Manage the use and longevity of the items;	- Manage usage, sending alerts reminding you of the necessary precautions (email, msg in the app, etc.)	- Send warning indicating users schedule of possibilities for removing the EPI for mainte-nance;	- Manage the need for disposal; - Send alert indicating places for cleaning;
Line of internal Interaction								
SERVICE OF SUPPORT	- Marketing support; - IT support; - Contact with demand managers (NGOs); - Update demands / Sponsorship;	- IT Support - Design tool based on sponsors; - Logistics partners for delivery and management of PPE; - PPE analysis laboratory;	- IT support: update data on the website / app; - Sponsorship / demand data manager; - Partners: Laundry, recycling company;	- PPE analysis laboratory; - Component partners; - Have IT support to track PPE delivery and update data on the website / app;	- OUS Partner Logistics; - Informational support on conditions of use; - IT support, update data;	- Prepare training content, User Manual; - IT support, update data on the website / app;	- IT support, update data on the need for cleaning the PPE; - Sending alerts; - Maintenance EPI withdrawal;	- IT support, update data, send PPE withdrawal alerts; - Outsourced Logistics; - Recycling company;

Blueprint

Figure 2. Final Blueprint matrix detailing the final concept generated.

In the ordering phase, the system does require registration from clients (school directors) which then can select local stakeholders able to clean or recycle their masks. Also, in the use phase, the system does include learning activities for both the children as well as lecturers. Its operation does require additional IT supporting services, enabling school directors to closely control the situation of PPE among its students. This is in line with the proposition of Bender et al. (2020) that states that the provision of information about COVID-19 would help to reduce students' fears and anxieties about the disease and support their ability to deal with possible secondary impacts on their lives. In this way, education can encourage students to become champions of disease prevention and control at home, at school and in their community, disseminating good practices to others, including adults, on how to prevent the spread of the virus.

This Blueprint unveils that the PSS concept does require partnerships with stakeholders that are not currently connected with the issue of mask provision. This includes recycling cooperatives, NGOs inserted within low-income neighborhoods, and even city council educational departments. The lack of stakeholders in Brejo Santo with specific competencies for cleaning and recycling masks would require the involvement of training and certification organizations at the system level.

The Customer/Business Journey presented in Figure 3 graphically represents the various stages on which the school directors and the school children would have to be involved as well as their relationship with the company. It is possible to see the interconnections between OÜS´s customers (who can purchase and/or donate a PPE through the OUS platform) and the representatives of collective spaces for children (public or private) who wish to order PPEs. The concept proposes that in addition to purchasing PPE for their children, private institutions could sponsor PPE for public institutions, where there is a scarcity of resources and poor facilities.

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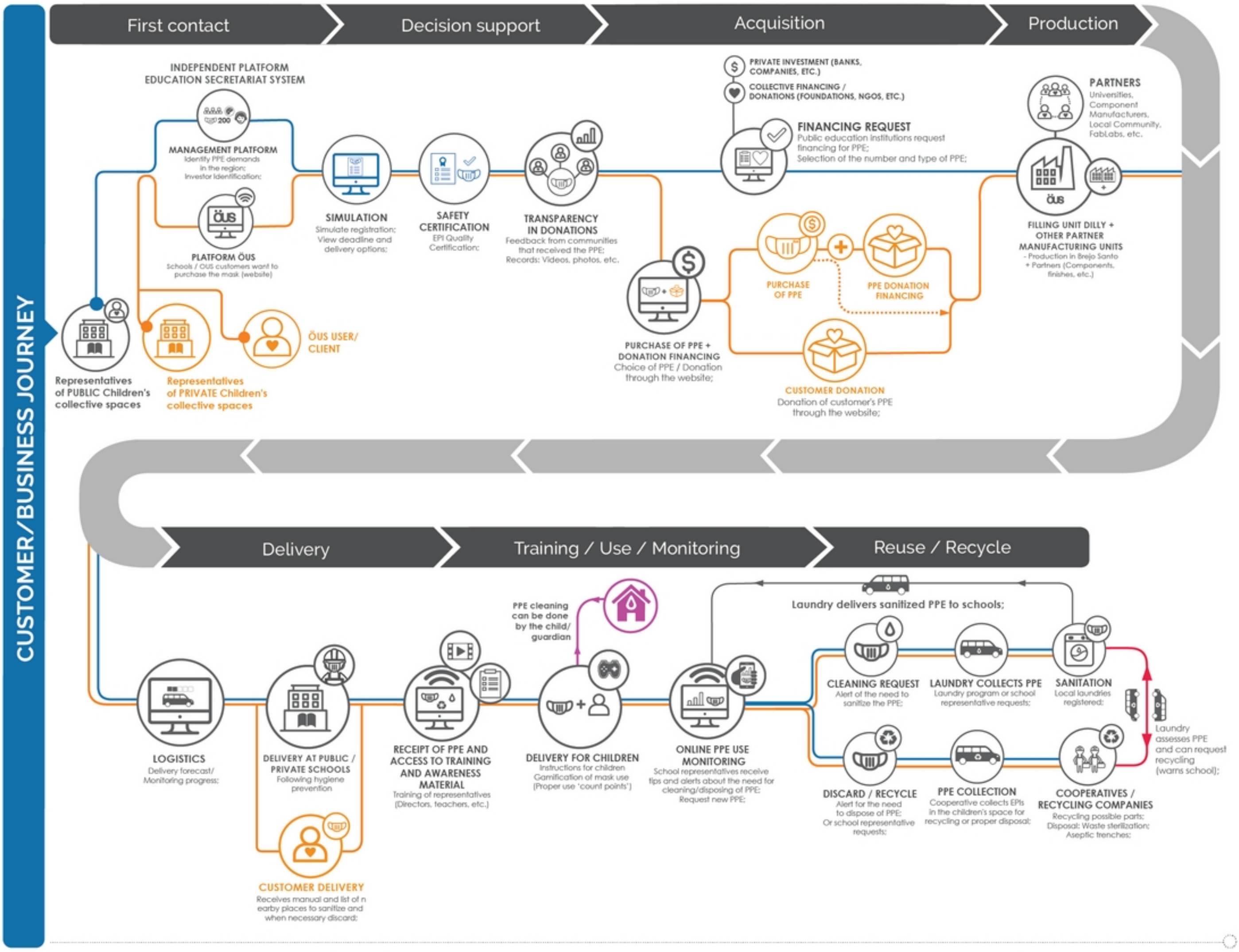

Figure 3. Final proposition for the Customer / Business Journey.

The System Map in Figure 4 represents key material, information, and financial flows among the main stakeholders of the PSS concept. The proposed system map was divided into four clusters of activities: Design, Manufacturing, Logistics, and Use (Figure 4). All these clusters employ a distributed approach, including the use of local cooperatives of transportation to implement the logistics required around the masks.

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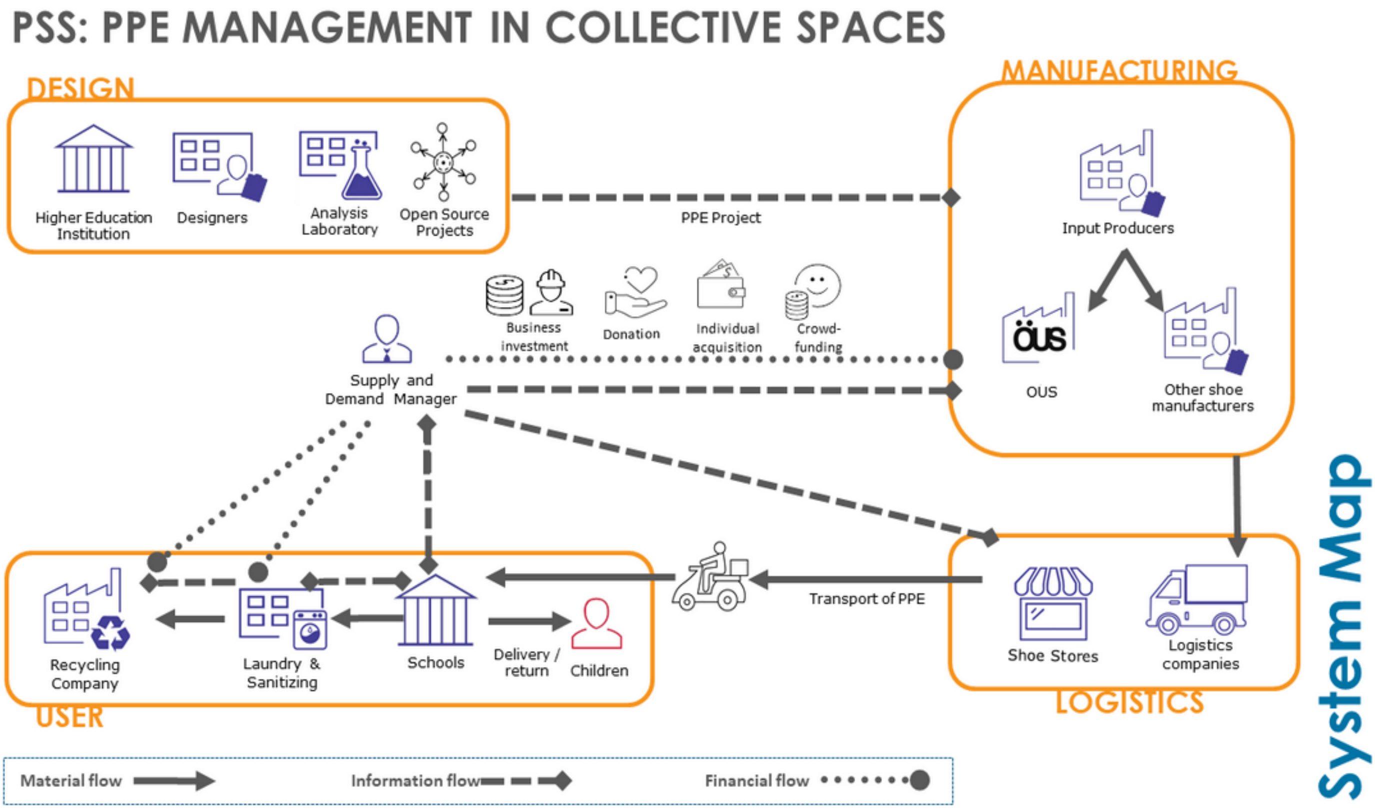

Figure 4. Final System Map for the final concept.

Other financial alternatives have been integrated into the map, such as private investors, donations, crowdfunding and individual acquisitions. A central stakeholder emerged on the PSS Design: a supply and demand manager. Its role is to coordinate the flows among the various stakeholders, synchronizing the demands of the schools with the manufacturing firms and service providers and, also, presenting the existing demands to potential donors.

The business proposition underlying the PSS concept is synthesized on the canvas presented in Figure 5. The 23-15 Team concluded that the PSS concept had the potential to reach not only primary schools but any other collective spaces for children in the State of Ceará (ex: daycare centers, nurseries, scout groups, churches, playgrounds in shopping malls). Again, the business focuses on a distributed economy paradigm, involving local stakeholders for supply/demand management, manufacturing, fundraising, education, logistics, hygiene and recycling of PPE (Figure 5).

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Figure 5. Business Model Canvas for the Distributed PSS for Mask Provision

To freely distribute the knowledge embedded into the system, the concept adopted an open-source ethos. As a result, the products developed subsequently to the PSS Design, as illustrated in Figure 6, are now freely available on creative commons license. The mask concept proposed by the 23-19 team sought to employ materials and mechanisms already used and known by the partner company ÖUS, to facilitate and make their production feasible. Some of the differentials of the mask concept are found in the possibilities of personalization and customization that the child would have, through patch bonding, name writing, different ways of fixing the mask lace on the back of the head. The mask also proposes the application of a thermochromic pigment, which changes color if the child's skin temperature exceeds 37°C. Such mechanisms alert teachers, guardians of the children, or any other stakeholders present in the system, helping to control possible contamination

This open ethos was widely adopted by do-it-yourself (DIY) and maker communities during the COVID-19 pandemic. According to Zastrow (2020), as soon as the health systems around the world were at risk of running out of crucial equipment to treat people and protect health workers, these communities have initiated immediate actions to close the gap. Groups virtually gathered by social media and apps such as Facebook and Whatsapp have become centers of PPE supply and demand. An example is "Open Source COVID19 Medical Supplies", a Facebook virtual community with more than 70,000 members where volunteers shared trade, materials, sterilization procedures and other sources tips (Zastrow, 2020). The implications of such ethos on the project are seen on the System Map where other shoe brands could be integrated without any copyright barrier.

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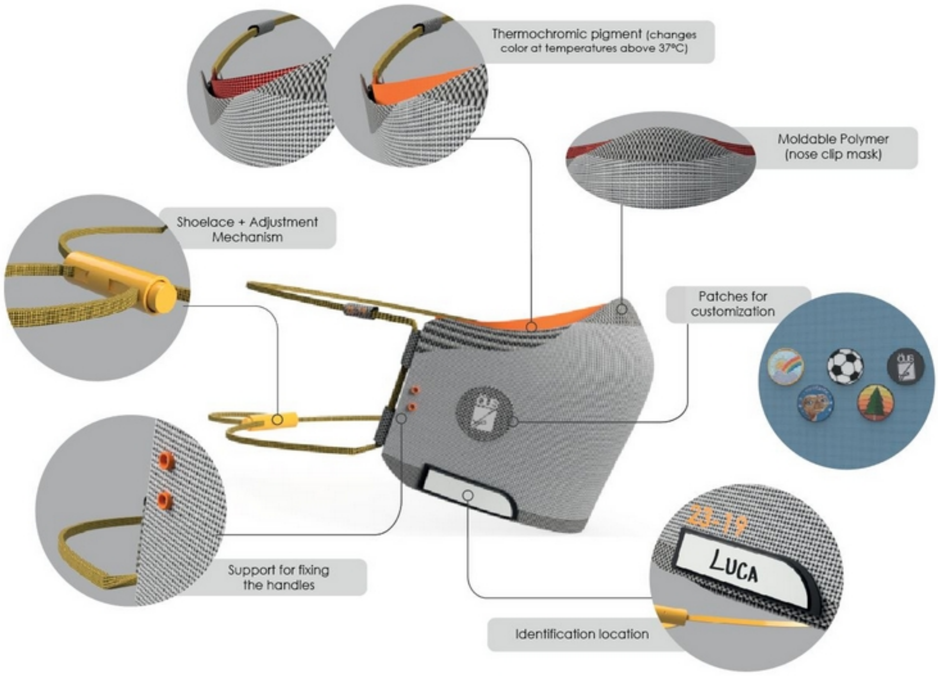

Figure 6. Masks Designed for the PSS Concept.

4.3. Stage 04: Lessons Learnt

The pandemic has unveiled that highly centralized global supply chains, often operating with the logic of lower margins and large scale production, resulted in greater vulnerability and poor resilience to global disruptions at the local level. That was the case of Brejo Santo, in the State of Ceará. Similarly to Shokrani et al. (2020) analysis, the knock-on-effect of halting the economy due to the quarantine in combination with the rapid increase in demand at a global level has resulted in a shortage of PPE. Stringent border controls over international trading and other logistical and public accounting constraints have prevented fast supply from low-cost mass manufacturer sources (ex: China, Indonesia) (Kalyaev et al., 2020).

This rapid Design project, where all participants worked remotely, showed that demand for a more distributed economy during COVID-19 was relevant not only for the Design and Manufacturing stages of PPE but, also, for all life cycle stages. As anticipated by Yu et al. (2020), health-related waste increases exponentially during a pandemic, with potential sources including not only hospitals but a wide range of installations, including domestic waste (ex: masks). This rapid increase in waste volume requires agile responses that centralized solutions cannot provide. If improperly treated, it may accelerate the spread of the disease.

Shokrani et al. (2020) argue that such situation demanded swift adaptation of local supply chain networks, with a critical need for speed associated with a higher emphasis on the use of local resources and competencies, with cost-effective and rapid production. Indeed, on the Action Design Research project reported in this paper, the COVID-19 context has organically driven the Design team to a concept characterized by the adoption of a Distributed Economy approach. The forced role immersion of the entire Design team as mask "clients", living in social isolation and with health concerns rivaling economic concerns, has contributed to following this direction.

5. CONCLUSIONS

The study has shown that the Design of a Distributed Product-Service System for mask provision for children school was able to address the divide between health and economic concerns that appear during COVID-19. While the effectiveness of the PPE, which is necessary for this health emergency context, could be reinforced by the actors and activities distributed throughout the PSS, the economy can be strengthened by the efficiency given by the proximity of such network. Hence, although a rapid conclusion of the pandemic was certainly the desired outcome, it presents itself as an opportunity to drive a Distributed Economy.

The project itself has been testing and improving to be implemented by the ÖUS company. The distributed approach of the project attracted several partners, such as Brejo Santo's city hall and the local education office. These stakeholders were mobilized in favor of the project implementation feasibility and the reflection of the project, which is systemic. The secretary of education agreed with the learnability aspect of the PSS, as it fosters the local economy and involves an extremely relevant collaboration network in facing the pandemic.

It is still necessary to elucidate some points of experience with remote teaching, regarding the context of the Design graduation experience. Some stages of the project demanded greater interaction between the participants, as in the case of the creative workshop, being access to the internet and open online platforms of fundamental support for a live debate. However, it should also be noted that despite the group of students and project participants having access to the online system, there is still a gap in Brazil regarding this aspect. Within the target research, for example, in order to obtain the feedback of children on the alternatives of masks generated, the bridge between teachers and parents was made using video calls by cell phone, which involved limited interactions, to show the concepts. Thus, it is important to highlight that many regions still have poor access to the internet, or simply do not have access, which must be considered to have a more inclusive education and economy. Considering these diverse factors, it is important to highlight that developing a PSS that has effective implementation measures, especially for vulnerable communities and children, is really a challenge.

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Towards strategic design: the experience of two Colombian MSMEs

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ABSTRACT

This qualitative-interpretive study reflects on the experience of two MSMEs that adapted rapidly to meet the need for protection products and maintain their production in the midst of confinement decreed by the city and country authorities, as a containment measure for the pandemic caused by the Covid-19, and where design was a key factor. The different experiences are organized taken the Product sociotechnical Cycles (PstC) model as a conceptual basis, analyzing the case studies from the organizational capabilities of industrial design, as well as from design-driven innovation. The article ends by summarizing the learnings, emphasizing the value of design with a strategic focus, in these processes of change.

Keywords: Covid-19, Product Development, Facial Protection Elements, Organizational Capabilities, Innovation.

INTRODUCTION

The Covid-19 disease caused by the worldwide spread of the SARS-Cov2 Coronavirus took everyone by surprise. Colombia was no exception and a few weeks after the confirmation of the first cases, the first lockdown was decreed. The vast majority of companies had to stop activities, re-think and adapt themselves to the new condition. Some companies were able to continue working, while others chose to send their workers on vacation, then suspend contracts, later fire people, and in many cases, closed their businesses, either temporarily or permanently.

Two companies in the manufacturing sector that reacted immediately to this situation were Ergofactos S.A.S. and Cointec S.A.S. The first is a microenterprise dedicated to the design, production and marketing of products and services aimed to improve the working conditions of people in different sectors, while the second is dedicated to the design, manufacture and marketing of injection steel molds and plastic products, as well as the injection service. Both companies created new product lines that would allow them to continue operating, while offering an ad hoc product to mitigate the spread of infection. What factors influenced the companies' ability to react? What problems did they face and how did they adapt? Those are some of the questionings that have led to the primary question of the study: What is the role of design in business to boost the organizational and innovative abilities, facing unexpected changes, such as those generated by the pandemic? This article is outlined into four parts. The first introduces the method of the case analysis.

The second part demonstrates the case studies, while the third section shows the analysis of the experiences in operation of the defined variables. The article closes with the lessons learned and the main conclusions, while setting out future studies.

1. METHODOLOGICAL APPROACH

This is a qualitative-interpretive study that is founded on two business case studies that involved design in a strategic manner, including directly from professionals of the companies that participated in the decision-making process. The study was conducted in three phases. The first consisted of the description of the experience of each of the businesses in conceptual terms of the Product Sociotechnical Cycles (PstC) model (García-Acosta and Lange-Morales, 2020; García-Acosta, 2016). In the second phase, the case studies were analyzed from two perspectives: the organizational abilities related to design (Aguilar & Hernández, 2012) and innovation (Na, Choi & Harrison, 2017). In the third phase, starting with the case analysis, concludes the guiding lessons from the research question, which are organized in learning lessons and conclusions.

2. CASE STUDIES

The studied companies worked on three elements of facial protection. Ergofactos developed masks for public use (see http://www.ergofactos.com/), while Cointec developed face shields (see https://cointec.com.co/) and safety goggles for facial and eye protection, taking the specific requirements in the health sector into account. Figure 1 presents each of the products.

Figure 1. Analyzed products.

The companies' experience in the design and development process of their products is described below, organized in the phases proposed in the PstC model (García-Acosta, 2016; García-Acosta & Lange-Morales, 2020). This model proposes three stages: origination, transfer, and destination, and includes seven phases: vision, concept, development, production, marketing & logistics, use & services, and disuse & support. There are different processes carried out in each phase, which vary greatly depending on each company.

2.1.The experience of Ergofactos

This company experienced a decline in demand for its products but never stopped its production, since these are requested by the floriculture sector and this group of companies were not submitted to the confinement regulations. However, mobility restrictions, confinement and not having access to the facilities involved a significant change in their operation. Tables 2, 3 and 4 summarize the most important milestones of their mask design and development experience.

Table 1. Experience of Ergofactos in the Origination stage

Phase	Processes	Description
Vision	Strategic purpose	In line with the values of the company, especially ethical performance, the process started with the desire to participate in the search for solutions to address the pandemic. The first interest was to develop a product focused on those sectors of the economy that did not cease their activities (such as perishables industry where the floriculture and food industries are located), and that as foreign to the health sector should not use masks N-95 or disposable facemasks, for their use is privileged to doctors and nurses involved in patient care.
	Stakeholders' aspirations	• Maintain the livelihood of the company's employees, with the awareness of caring for their families. • Contribute to the health care of the working population, and their need for protection against a new biological risk. • Use the socio-technological resources available to the company to supply a scarce product in a period of crisis. • Keep collaborators active to prevent psychosocial risks associated with the new life condition.
Concept	Diagnosis / problem / opportunity	Proposals were developed based on the technologies available in the organization. The company's network of stakeholders was maintained, but with the imminent risk of contagion by COVID-19, they were kept in confinement and preventive isolation throughout the development of the product. This forced them to perform isolated but interconnected processes for transmitting information, decision-making, transportation of raw materials, samples and prototypes, and sourcing and procurement activities. Figure 1 shows the relationships between stakeholders and the difficulties faced.
	Requirements and determinants	Ideas and alternatives were presented through sketches and models in 2d and 3d tools (see figure 2). The meetings were held virtually. The values of the organization were taken into account in the concepts proposed (i.e. high-quality service, responsible design with the environment, and the strengthening of networking, see figure 2).
	Pre-concepts, ideas and alternatives	Decision making was oriented to: • Privilege product alternatives that could be manufactured during the pandemic period, with all the economic, mobilization, and resource scarcity implications that this entails. • Favoring alternatives that could be easily established in the market and in the shortest time possible. • Prioritize alternatives that promote an agile production response and that are also consistent with the production capabilities of the operators. • Benefit alternatives that involve new or known processes, but with low cost of implementation.
Design and development	Detail design	The detailed design was carried out taking the guidelines issued by the Colombian Ministry of Health and Social Protection and the recommendations of the FNOS as reference (French National Organization for Standardization) regarding the following aspects: Materials, sizes, manufacturing process, packaging, cleaning and disinfection of areas, among others.
	Prototypes / validations	32 models and prototypes were manufactured where the characteristics of the product were evaluated and modified to ensure that the supplies and materials available in the market fulfill with the desired protection quality. In the validation process, materials were tested to verify that they effectively prevented the passage of particles through different layers and provisions. Figure 3 illustrates one of these tests.

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Phase	Processes	Description
Production	Process / technology development	The production sheets were delivered to the collaborators to start the production of the series of masks, with the respective manufacturing specifications, size of materials, and order of assemblies. They were also trained in biosafety protocols and the adequacy of their working place to meet hygiene requirements. Another intervention consisted in purchasing machinery to pack and seal bags, with the required adaptation of the working place.
	Parts manufacturing	It was easy to execute. The production was done simultaneously with the marketing and logistics stage, this was due to the speed with which the growth of the pandemic lead to act.

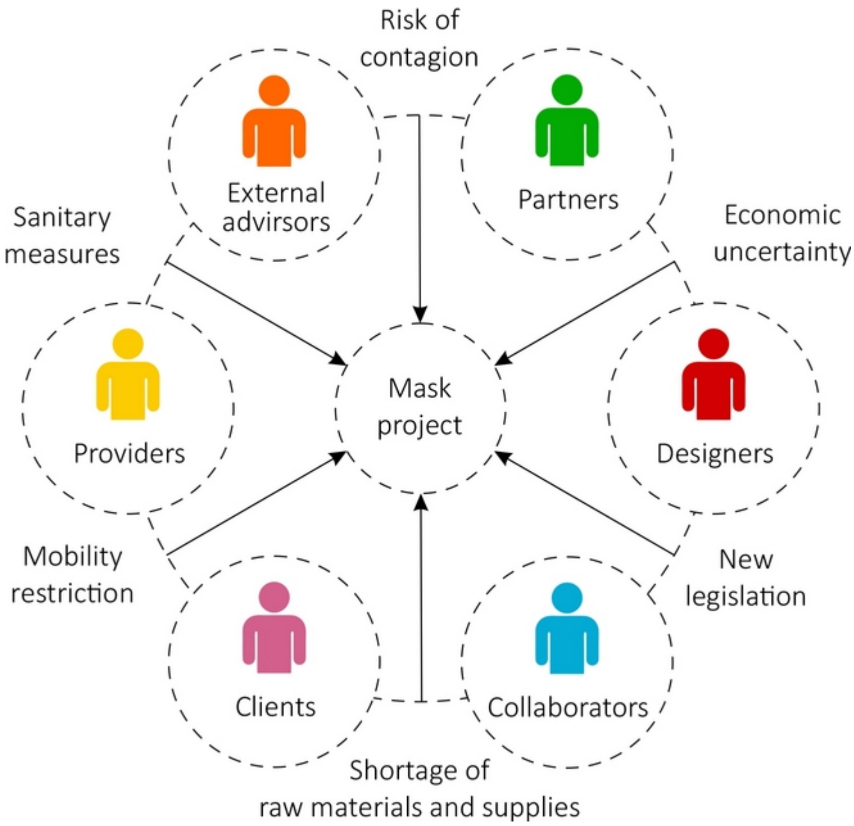

Figure 2. Stakeholders and difficulties of the COVID-19 context.

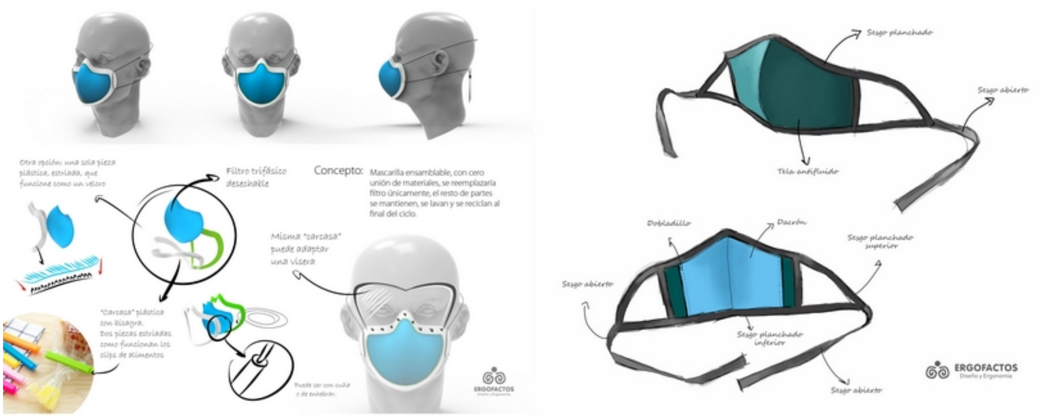

Figure 3. Sketches of design alternatives.

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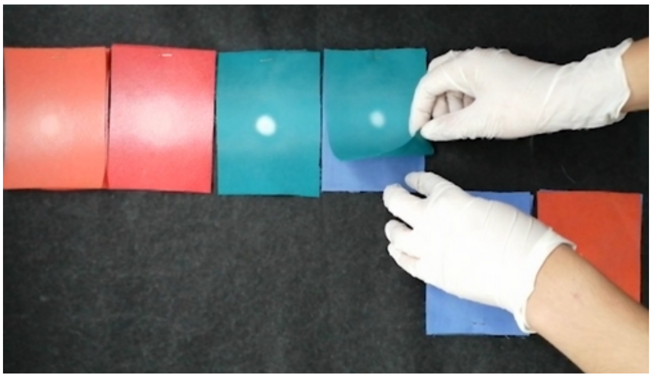

Figure 4. Materials testing.

Table 2. Experience of Ergofactos in the Transfer Stage

Phase	Processes	Description
Marketing	Packaging	This process was solved during the production process itself, taking into account the need to deliver the sealed product to the end-user, in order to avoid contamination during transport.
	Display and supply	Marketing processes were referred to the company's digital platforms and website. The first to know and adopt the masks were the company's regular clients, who maintain a long-standing business relationship.
	Distribution and transportation	This process implied a great challenge since the demand for dispatches that transporters are dealing with made the operation difficult and slowed down delivery schedule.
Procurement	Sale / purchase	The company was not used to retail, which led to the implementation of another distribution channel, modifying the administrative and logistics processes.
Incorporation	Instruction and training	To help with the adoption of the mask by the user, each package is delivered with a use and maintenance guide that educates users and encourages the use of the mask while teaching how to care for it.

Table 3. Experience of Ergofactos in the Destination Stage

Phase	Processes	Description
Use and services	Supplies / provision	Filter packages are offered to replace the original mask filter to ensure product effectiveness.
	After-sales service	As it is done with the rest of the company's products, the product was monitored, seeking to maintain quality, evaluating customer satisfaction, and then incorporating product improvements if necessary.
	Feedback to previous processes* (design and development / display and supply)	One of the characteristics that the company found was necessary to modify was the size of the mask; although the guidelines of the aforementioned guides were followed, it came out to be small on some faces. For this reason, three sizes were quickly developed and short usability tests that had not been done at the design and development stage were conducted. This modification improved the experience of use greatly and fortunately, it did not affect production rates. This change also involved an adjustment to the website as well as in all the advertising material used in the sale of the masks, which from that moment on were offered in three sizes, two for adults and one for children.
Disuse and support		Until now there has been no support in the disuse of the product, since it is a mask that must be handled as biological waste; in this regard, users were only instructed on their correct disposition in the use and maintenance guide. Regarding the leftover materials from the production or scrap process, the company maintained its policies for the best use possible of raw materials and recycling.

The feedback processes are not exclusive to the destination stage, but are of vital importance in the narration of this experience.

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2.2. The experience of Cointec

This enterprise limited its operations to ongoing injection services. The lockdown also reduced their products' commercialization. This situation forced the company to quickly think of solutions to remain active in the market. Tables 5, 6 and 7 summarize the most important aspects of the adaptation of Cointec to this new reality.

Table 4. Experience of Cointec in the Origination Stage

Phase	Processes	Description
Vision	Strategic purpose	Due to the fact that the company had to stop operations and close by order of the government, the company management analyzed what were the possibilities of reactivating operations and what would be the dynamic with the work team. For Cointec, the most important thing is human resources, which led them to take a strategic turn based on design to be able to start operations and have a product that would generate income during this pandemic, and at the same time, allow them to respond to the call to solidarity made by the National Government, in which it asked Colombian manufacturers to create products for the contingency.
	Stakeholders' aspirations	• Keep the company's production active. • Generate income during the pandemic. • Answer the call to solidarity from the National Government for the creation of products for the contingency.
Concept	Diagnosis / problem / opportunity	Cointec integrated innovation and design models to identify the capabilities of the company and from there, resolve how to reach a strategic reconfiguration to reorient the portfolio, working the four stages of integration: observation, analysis, synthesis and execution. The observation took into account the entire logistics chain *i.e.* the portfolio of suppliers and the motivation and culture of the organization, as well as organizational productive capabilities in design, R&D, market for the development of these new products, and the ability to manage resources and production for the creation of plastic products. The generation of a new anti-fog system and a unique production process, allowed the integration of various characteristics to the product in a single process.
	Requirements and determinants	In the face shield, the safety associated with the anti-fog system, protection against micro-drops, flexibility of adjustment of the element, resistance to impact and rapid manufacturing prevailed. The following requirements were added for the safety-goggles, based on interviews and consultancies of various health professionals, as well as a benchmarking of existing products: fit to the face without causing injury and possibility of use together with formulated glasses and half-face masks.
	Pre-concepts, ideas and alternatives	Design alternatives, sketches and models were generated to arrive at the ideal design. These alternatives were evaluated under the existing capabilities and the appropriate materials, in order to generate the adequate characteristics, emphasizing the evaluation of the materials since they had to comply with the specifications of both the national production and those of other countries, which it wants to reach.
Design and development	Detail design	Sizing and shape tests were carried out on different materials and processes available, which led to the selection of the following materials: polypropylene, polystyrene, silicone, PET and polycarbonate.
	Prototypes / validations	In the face shield, 3D prints were made and tested with internal collaborators, verifying distances and possible conflicts when used with other elements (glasses, masks). The process of safety-goggles, that necessarily required a process of greater fit tests, lead to the proposition of a test plan with the respective verification protocols, which is currently in process.
Production	Process / technology development	The production of the face shield required two molds, one for the headband and another for the upper cover, as well as a PET sheet to subsequently assemble the product. In the case of the production of the safety-goggles, the use of the existing headband mold and a visor mold are required, all of them manufactured in-house.
	Parts manufacturing	The entire injection, assembly and packaging process is carried out in-house.

Table 5. Experience of Cointec in the Transfer Stage

Phase	Processes	Description
Marketing	Packaging	This process followed the company’s established standards, but an individual packaging was implemented.
	Display and supply	Three sales channels were used to promote the products: Marketplace, institutional channels based on online marketing and a database developed to reach the corresponding commercial target for each product. Finally, the final customer who is contacted through our page and social networks.
	Distribution and transportation	An agreement was made with a transporter with low-capacity vehicles, which also managed the new line image as a way to position the brand and provide a direct connection with customers.
Procurement	Sale / purchase	To contact clients, established digital channels and telephone are used, offering advice before the purchase, and agreeing a mix service that includes product and transportation.
Incorporation	Instruction and training	Use instructions are sent together with the product. They indicate the user the best way to properly manipulate these elements.

Table 6. Experience of Cointec in the Destination Stage

Phase	Processes	Description
Use and services	Maintenance	One year warranty is offered.
	After-sales service	Post-sale monitoring is done in order to identify how the experience with the product goes on.
Disuse and support		If any part is damaged when using during first weeks, customers can exchange it for a new one. In this case, the client sends the damaged part to the company's facilities and then he/she will receive, besides the new part, a discount. With this process the client will get a longer product life.

Figure 5. Models of design alternatives.

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3. ANALYSIS OF EXPERIENCES BASED ON ORGANIZATIONAL CAPABILITIES AND INNOVATION RELATED TO DESIGN

Two perspectives were considered: organizational design capabilities (Aguilar & Hernández, 2012) and the spectrum of design innovation (Na, Choi & Harrison, 2017), because they characterize design and innovation issues specifically in manufacturing companies and are applicable to MSMEs; besides, they are also oriented towards capacity building and have a holistic vision.

3.1.Analysis of experiences from design capabilities

Aguilar and Hernández (2012) allow us to understand that capabilities are the know-how and that dynamic capabilities imply learning to permanently know-how. Following this approach, the two companies, through the design and development of new products, were able to continue their activities, obtaining at the same time updated knowledge related to the new market segment that, in the midst of the contingency, they selected to work with. In both cases, this showed dynamic capabilities to detect specific niches: Ergofactos targeted the general population and Cointec focused on healthcare personnel. This was done early and in a record time, taking all their organizational capabilities towards inner reconfigurations that allowed them to adequately reach these new niches, by identifying the needs of the end customer, which means to understand their lifestyle, well-being and expectations.

Cointec applied these design capabilities building a network of relationships with external agents to the company such as doctors, anesthesiologists and nurses who provided information on design requirements, and undeniably, allowed to reach an understanding of the evolution of current sociocultural models. The company also created a brand for the health sector looking for the recognition of the new set of products. In the case of Ergofactos, the previously established network of relationships was strengthened and was a key aspect to go ahead with the design, production and distribution of the new products, even with all the members of the company being in different places.

Additionally, in both cases, the new products were articulated to the internal and external vision, applying current technological knowledge and generating additional ones, all this based on the design as a key factor of the whole experience.

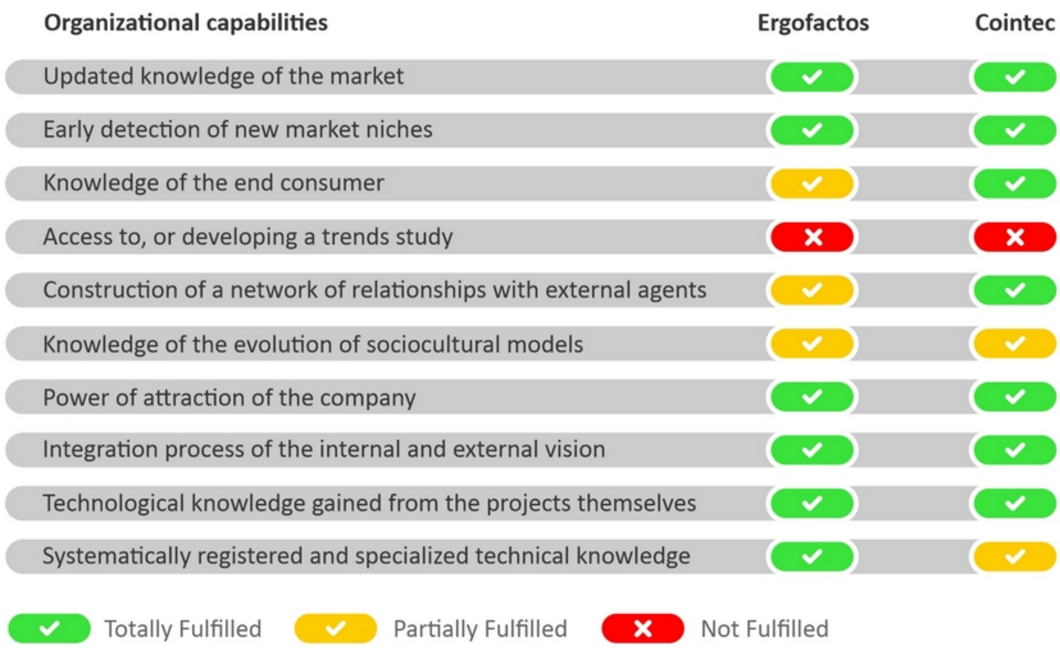

Figure 6. Organizational capabilities applied by the companies. Adapted from Aguilar and Hernández (2012)

Figure 6 summarizes the organizational abilities, pointed out by Aguilar and Hernández (2012), which were completely or partially addressed by each one of the companies

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analyzed, such as those aspects that were not addressed. Both companies applied at least six of the ten abilities completely and, in both cases, only one ability, "access to, or developing a trends study" was not addressed.

In respect to the capability "knowledge of the evolution of the sociocultural models", it is partially fulfilled. In the middle of the pandemic, provisions and guidelines of the State have been evolving to manage the situation, but not only in terms of biosecurity protocol. It is important also observing the changes in the dynamics of society, which have adopted new customs such as social distancing and limited gatherings, among others. The behavior of chatting close, hand shaking, hugs and kisses, and other characteristics of the Latino spirit, have been forced to change abruptly.

3.2. Analysis of experiences from innovation

Taking as a reference the design spectrum proposed by Na, Choi and Harrison (2017), it is possible to identify innovations in the three levels in which design shows up within a company's dynamics. Figure 5 shows the relationship of these manifestations in the three levels.

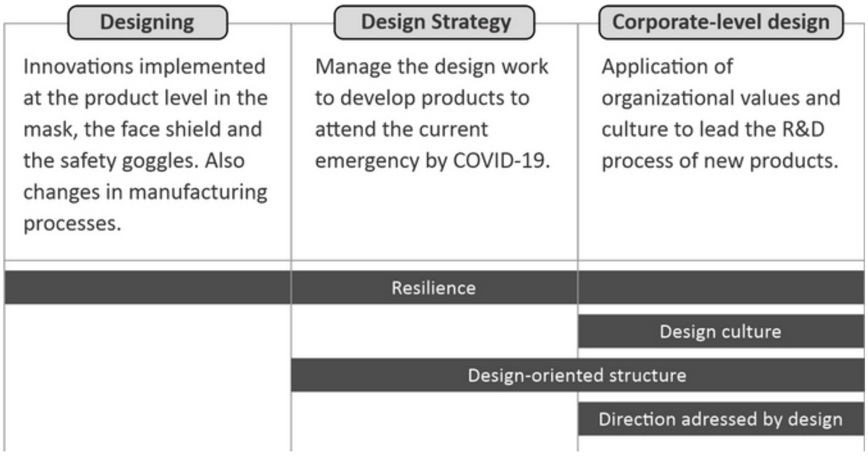

Figure 7. Relationship between Innovations' manifestation and the design spectrum.

3.3. Innovation achieved by resilience

Deserti and Rizzo (2013) propose a way to stimulate innovation processes leading to the enterprises sustainability; according to this theory, organizations may have the ability to anticipate and adjust themselves to different changes that may threaten their purchasing perspectives, before the situation becomes imminently obvious. In this regard, both companies demonstrated resilience by quickly acting and developing new products, in the midst of the economic and social crisis derived from the pandemic. The resilience value becomes clear through the following facts: Ergofactos changed its traditional market niche and sales model and Cointec generated a new line of products, for a new sector in which it had no previous experience.

In this process, the owners of both companies could clearly observe how resilience becomes a real fact, showing itself in everyone's work and attitudes, from collaborators to senior managers. In front of the isolation and quarantines caused by the pandemic, both companies had to make quick and clever decisions to keep running and to respond to the imminent decline of their income from its main economic activity. Having developed products in such a short time and successfully bringing them to the end-user, demonstrate resilience in all areas

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of the organizations, including the R&D team, production operators and the marketing team; all modified their regular activities to adapt in a short time to the new developments of their companies.

3.4. Innovation conveyed by design culture

The second aspect that allowed innovation to show up in both companies is definitely the design culture present in Ergofactos and Cointec. Deserti and Rizzo (2013) define design culture as the set of knowledge, competences and skills that operate in a given context and mediate with production and consumption to develop new products. In line with this approach, the pandemic changed consumption patterns, since it introduced into society a new need related to microbiological protection that was not necessary before. Both companies reinvented themselves to offer products to this new market, and this was possible thanks to the fact that in each organization design is recognized as the core of its work and also to the necessary changes made in the production processes.

Now, the design culture that characterizes these Colombian companies is based on their own values established from the beginning and which are not negotiable, even in times of adversity. Both companies decided to carry out the development of new products under the premise of maintaining jobs, producing according to their capabilities, manufacturing with quality and respecting a good payment of labor, although the market was demanding the opposite.

Masks, face shields and safety goggles, revealed the design culture and values of both organizations, highlighting the following aspects: respect and appreciation to their employees; assessment of the design team; change-oriented work teams; quality in communication processes; design thinking in collaborators; acceptance of risks; decision-making in a timely manner and rational use of resources.

3.5. Innovation through design-oriented structure

Both Ergofactos and Cointec have a business structure that places design thinking at the center of the organization. Both companies have R&D or design areas and an organizational structure that consider these departments as an important factor in the decision-making process. According to Celaschi, Marco, Staszowski, Galisai and Casoni (2009), organizations that have a design-oriented structure can react more quickly and effectively to changes; this was evident in the two cases studied.

Another factor that played a very important role was the fact that both companies were manufacturers, what means that they had the technological and human resources to carry out innovations, unlike companies that only distribute or market manufactured goods and therefore, depend on the producers.

On the other hand, an advantage of the small organizations is that in extreme situations, changing the context, turning toward the design and development of new products can be made easier, the production, as well as the logistics and commercialization that are oriented by design thinking.

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3.6. Innovation conveyed through design-driven direction

A study carried out by Na et al. (2017) on different manufacture companies found that there is a greater tendency towards innovation when those who occupy managerial positions are professionals with knowledge on strategic design, which allows organizations to offer products and services that are adapted to constant markets change. This characteristic is common to both companies, with the difference that in Ergofactos the partners and the manager are both industrial designers, while in Cointec the general manager has worked as an empirical designer during 31 years, time that the company has been in the market, showing that design thinking is not exclusive to professionals in these areas. In any case, a visible head with a design focus boosts innovation processes in all areas of the company.

4. LEARNINGS ORIENTED TOWARDS STRATEGIC DESIGN

Applying strategic design at a macro-level is difficult, because it is outside the direct influence of the actors (Geels, 2005, as cited by de Arruda Torres, 2018). However, the current pandemic generated abrupt changes at this level, forcing sociotechnical systems and niches to adapt, and in this context, strategic design played a decisive role. Next, the main learnings derived from the analysis are summarized with an aim to ease its consideration in future projects.

4.1. Value the design culture in action

Developing a product in times of the pandemic was the occasion to see the design culture in action, acting simultaneously with corporate values. This situation showed up how strategic design thinking should be involved in new forms of distribution, services, social behavior, social innovation and new cultural dynamics. Moraes as cited by Moreira & Bernardes (2014, pp. 111) mentions, "design must deal with the complexity of moving from technique to a technological culture, from production to a productive culture and from the project itself to a project culture". This is essential and should be reinforced under the sociotechnical approach, without getting away corporate values at all. Under this challenging context, owners and managers of both companies were able to identify strategies that let them achieve a comprehensive incorporation of design into the thinking and action of their organizations, including also individuals and communities.

Another lesson is that the design culture must be transmitted two-ways in the organization, from the bottom to the top and from the top to the bottom. The very small organizations are more vulnerable to financial ruin; therefore, the design culture can activate the possibilities to innovate and generate strategies for survival and repositioning.

4.2. Incorporate design thinking at high levels

Ergofactos has designers who accomplish operational, tactical and strategic activities, which enhances design at all levels of the organization. Furthermore, since there are no boundaries between departments, open communication from and about design is encouraged, flowing vertically and horizontally in the organizational structure. Cointec, being a larger company, has a greater separation between departments, but also favor a greater fluidity of design thinking between levels, investing in professional design training for its collaborators. If managers (CEO) don´t have a design thinking focus, there is no way to stimulate the capacities to recognize design as a force that drives innovation and creates value to the whole process of designing, producing and selling new products. In fact, design knowledge does not flow into companies simply because they have a department.

4.3. Organizational capabilities and innovation from design in MSMEs

Building a network of privileged relationships with agents outside the company can boost innovation. MSMEs that are grouped together to manufacture and market can compete in specialized markets not covered by large companies. The important thing is to detect how collaboration networks can be created to enhance their production and marketing capacity. Thanks to the association, productive response capabilities and attention to new markets change and let companies to survive in the midst of a crisis. Adding capabilities instead of competing is a tool that motivates innovation.

In the experiences described in this article, resilience was revealed as a key factor that make possible the display of innovation. Considering the studies consulted, it seems that MSMEs, thanks to their resilience, can more quickly adopt models of design thinking, design management, strategic design and design-driven innovation. To face the challenges that are surely coming due to this pandemic, the companies analyzed will have to continue strengthening resilience. As is has been proved here, resilience is a capacity that enhances innovation in times of crisis. In this sense, one can learn from the flexibility of the textile and fashion industry in East Midlans (Oxborrow & Brindley, 2012), where key elements to survive even in times of economic depression are observed.

In respect to the organizational abilities not addressed, it is important to highlight “access to, or developing a trends study”, because it was not considered relevant in that moment. However, having done a quick analysis of prospective trends, would have even enhanced the design more, in the case of the masks, for example. If they had recognized that this device would return to a piece of clothing, its design could have considered esthetical topics of fashion, beyond only fulfilling the safety requirements, avoiding the saturation in the market as elements of personal protection. In line with the aforementioned, facing the contingency scenarios it is advisable to perform surveillance technology activities, but in a quick and easy way, with agile procedures. The lesson is that this aspect must not forget, not skip, because it may close opportunities in other markets.

Another learning lesson is that the knowledge of the evolution is that the sociocultural models should be updated more frequently, not to create stereotypes of behaviors, that can directly or indirectly affect the products designed for Covid-19 and that can lead to new social practices, and therefore new forms to see functionality, social use, and the usability that people attribute to them.

4.4. Vision of design within the company

Entrepreneurs often do not identify design as a strategic component that leads to innovation. They see the practice of design as a mere operational exercise (designing) that only adds aesthetic, style, visual enhancement and luxury components. A few of them identify and activate it as a tactical design and the least as a strategic design (Moreira & Bernardes 2014; Volkova & Jakobsone, 2013). The paradox is that there is a need for differentiation in the market, but usually design is not recognized as a strategic key to make that differentiation more easily possible. When the value of strategic design is well recognized, it takes the companies to place the designer as the main leader of the innovation process (Alarcón & Ferruzca, 2020). They must empower themselves with strategic design seen as a key element of the managerial process that other professionals sometimes assume. Any company must give space for designers to grow and make career in management and occupy positions involving decision-making mainly regarding the development of new products or the improvement of old ones.

4.5. Vision of design from a political point of view

In Colombian companies, design is usually associated with productivity and not with competitiveness (Franky, Bohórquez & Romero, 2011). Design insertion studies show that the design is provided by the client in about 25% and the copies or adapted copies are around 26%. On the other hand, CEOs, generally do not offer training in design; they just control final design decisions, in more than half of cases (Franky et al., 2011). An effort has been made to implement the strategic value of design in this country. One result is the web information system called Checking Design that allows companies to meet and understand the competitiveness states by sector (Paredes-López; Manrique-López & Carrillo-Bernal, 2016), but MSMEs must use and apply it more often. A state policy of innovation and strategic management aimed at creating a design culture at business level is needed.

5. CONCLUSIONS

Medium and small businesses, for their flexibility at role and organizational levels, can reorient their organizational abilities from the design toward the innovation easily before contingency plans. That characteristic is enhanced by the positioning of directive or managerial positions on the part of product designers and developers, who boost innovation easier. It would be interesting to investigate if the organizational abilities of the design, observed in those medium and small companies, are characteristics of the Colombian manufacturing culture. Therefore, the PstC model is a useful tool to organize the experiences and carry out the respective analysis.

The innovation capabilities are associated with the decision of the directives of the company to act assertive facing the contingency, generating new products, including new markets. It does not matter the size of the organization, but the willingness to innovate as a resilience driver in critical and unforeseeable situations. In this sense, it would be important to go in-depth into the factors that enhance the willingness to innovate and that mobilize the decision-making of the directives to keep the business operating according to the company values. This analysis helps to point out the aspects that contribute to the sustainability and to the growth of the business, from design and innovation.

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Tri-Design: Coordination between Healthcare, Design, and Regulatory Communities

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ABSTRACT

This paper discusses the approaches undertaken by organizations, coordination between healthcare, design, and regulatory communities, to respond to the needs of the COVID-19 crisis and bring about models for agile innovation and disease mitigation. The COVID-19 Design Innovation team was born at the core of a major university to operate as a hub for innovation. In an effort to connect designers, makers, and healthcare professionals, the initiative converged with the main motivation to organize collective efforts to assist in managing the crisis and deliver creative design innovations related to those efforts. Several products were brought about through the initiative efforts: off the shelf solutions and community driven, hybrid prototyping (reutilizing parts), distributed manufacturing, material investigations, and rapid prototyping that turned labs into manufacturing facilities. As solutions reached refinement and healthcare called for volume, solutions were brought to the community as a rapid response to the crisis. Limits of time and production posed challenges, the crisis catalyzed the coordinated efforts to form agile networks of stakeholders working towards a common goal, hacking the COVID-19 crisis by design.

Keywords: Iterative Design, Design Innovation, Rapid Prototyping, Distributed Manufacturing.

INTRODUCTION

The novel coronavirus, known as COVID-19, overwhelmed the medical infrastructure globally, led to a scarcity of Personal Protective Equipment (PPE) and medical supplies required to slow transmission of the disease and properly care for its victims and protect frontline workers. On March 11, 2020, the World Health Organization declared COVID-19 to be a global pandemic (WHO, 2020) and while the world waited for a vaccine, healthcare professionals worked tirelessly to stabilize and care for patients. McKinsey Group (2020) monitored the crisis of supplies and developed a summarized fact base on the availability of medical supplies posed by COVID-19 (see Figure 1).

Current as of April 23, 2020

These perspectives are intended to build from CDC and other guidance based on operations and management experience. Please continue to consult CDC, state health department, and medical societies for the most up-to-date guidance. These perspectives are not intended as a substitute for professional medical advice, diagnosis or treatment. Any actions impacting clinical decisioning should be vetted by the appropriate quality committees within your organization.

COVID-19 critical supply list

Supplies that may currently face, or be at-risk of facing, major shortage

Diagnostics and testing
- ❑ ELISA and RT PCR laboratory equipment and reagents
- ❑ Sample collection tubes
- ❑ Swabs for buccal/nasal sample collection
- ❑ Leak proof cups for aspirate collection
- ❑ Respiratory viral panel (RVP)
- ❑ CT contrast agents
- ❑ Regular basic blood panel supplies
- ❑ Specimen transport bags
- ❑ Rapid influenza test kits
- ❑ PCR testing kits
- ❑ Viral transport medium

Health facilities infrastructure and equipment
- ❑ Mobile, basic diagnostic X-ray system
- ❑ Medical triage/treatment/isolation facilities
- ❑ Portable ultrasound
- ❑ Anesthesia machines
- ❑ Beds
- ❑ BiPAP/CPAPs
- ❑ Nasogastric tubes
- ❑ Suction catheters with tubing
- ❑ CT Scanners
- ❑ Ambulance with air isolation system for transport of contagious patients
- ❑ Isolation room negative pressure HEPA filtration machines
- ❑ Ventilators with portable and back-up power supply
- ❑ Ventilatory peripherals and disposables (i.e. HMEs, HEPA filters, circuits)
- ❑ Hemodialysis machines
- ❑ Peritoneal dialysis machines
- ❑ Hemodialysis tubing/connectors
- ❑ Peritoneal dialysis tubing/connectors
- ❑ Intra-abdominal catheter and caps
- ❑ Central line catheters for hemodialysis
- ❑ Access needles
- ❑ RO water purifier machines

Personal protective equipment
- ❑ Gloves
- ❑ Gowns (disposable and linen)
- ❑ ISO masks (PAPRs, CAPRs, N95s)
- ❑ Surgical Level I/III masks and caps
- ❑ Protective eyewear/face shield
- ❑ Tyvek suits, sleeves, hoods or equivalent
- ❑ Safety box/sharps container (must be labelled "Biohazard")
- ❑ Scrubs

Medical consumables
- ❑ Oxygen

Advanced
- ❑ Home Care Kits for home isolation of asymptomatic cases or mildly symptomatic[1]
- ❑ Antivirals/vaccines (in development)

Medical equipment
- ❑ Infrared thermometer
- ❑ Sublingual thermometers
- ❑ Blood pressure cuffs
- ❑ Leads for continuous rhythm monitoring
- ❑ Cardio hardware devices that connect your leads, BP cuff, O2 saturation meter
- ❑ Laryngoscope, adult, child set
- ❑ Endotracheal tubes
- ❑ Oxygen concentrator
- ❑ Oxygen face mask with reservoir bag, disposable
- ❑ Tubing that connects vents to the wall ports (air and O2)
- ❑ Pulse oximeter, portable and non-portable
- ❑ Syringes: 0.5 ml autodestruct (AD) and 5 ml reuse prevention (RUP)
- ❑ Infusion setup including pumps
- ❑ Oropharyngeal and Nasopharyngeal airways
- ❑ Incentive spirometer/ Acapella valves
- ❑ Bag valve mask (BVM) Tracheostomy kits and devices
- ❑ Nasoenteric tube feeds
- ❑ Tube feed pumps
- ❑ Sequential compression devices
- ❑ IV (device and tubing)
- ❑ Central line
- ❑ Nasal cannulas

Disinfection consumables/ biohazardous waste management
- ❑ Alcohol based hand-rub/sanitizer
- ❑ Bag (disposable for biohazardous waste PPE, clinical waste, no sharps)
- ❑ Body bags (suitable for burial or cremation)
- ❑ Disinfectant
- ❑ Soap, surgical
- ❑ Set: mask, gel and soap for targeted population
- ❑ Bleach

1. Home care kits could include PPE and supportive treatment such as antibiotics and pain/fever relief medication.

Source: Adapted from WHO Critical Items List (last updated March 30 2020) with input from US-based Supply Chain, clinical and infectious disease experts

McKinsey & Company 1

Figure 1 COVID-19 Critical Supply List, McKinsey Group

Due to the highly contagious nature of the virus, PPE is mandatory for safe working conditions and to slow transmission. With massive spikes in cases, the supply chain struggled to meet the rapidly rising demand for medical equipment and PPE. While many large organizations, like auto manufacturers, held press releases claiming a shift from business as usual to manufacture of ventilators and other equipment (Wattles, and Valdes-Dapena 2020), little to no results materialized and shortages continued, forcing medical personnel to reuse masks or take on the risk of going without PPE, often resulting in virus contraction and death. It became clear that local organizations with specialized equipment, facilities, expertise and manpower would be needed in order to meet local demands for PPE to offset the shortage. The inception of a diverse, multidisciplinary team, aligned on specific goals and backed by industry resources, allowed for a 10x improvement on the design cycle time, culminating in highly scalable and implementable solutions to short-term scarcities while production and supply chain adapted to the new demand. This paper discusses the approaches undertaken by organizations, coordination between healthcare, design, and regulatory organizations and the community to respond to the needs of the crisis and bring about models for agile innovation and disease mitigation.

1. DESIGN INNOVATION

As the situation surrounding COVID-19 developed, the challenges associated with the response evolved daily. Local healthcare organizations initiated innovation teams while universities separately mobilized designers, engineers, and scientists to conceive novel interventions. The two groups quickly coalesced under the common goal of solutions for healthcare organizations in need. As momentum was gained, large corporations took notice and helped by donating materials, manufacturing and funding. Networks were formed around trying to coordinate these vast efforts in a productive direction.

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Citizens and universities became distributed manufacturing operations overnight. Through daily design sprints, individual agency, and a constant design-evaluate-recommend cycle, several teams focused on granular ideas started to produce in hours what would usually require several months of effort from a much larger team. These efforts, driven by the urgency of civic responsibility, time sensitivity and the plethora of manufacturing resources, were unorganized. What was missing was an efficient model to coordinate efforts to bring about agile innovation necessary for a rapid response and a single point of contact—a coordinated Tri-Design effort to pull the different forces together: healthcare, universities, and industry.

1.1. UC COVID-19 Design Innovation

The COVID-19 Design Innovation Initiative (2020) at the University of Cincinnati was born at the core of a major university to operate as a hub for innovation (see Figure 2). In an effort to connect designers, makers, and healthcare professionals, the initiative converged with the main motivation to be an organized collective for the rapid creative innovation and prototyping of PPE including masks, shields, respirators, ventilators components, thermometers, nasal swaps, to mention a few.

- The goals for the group were to foster the following:
- Forum and collaboration space to merge talents towards creating agile on-demand innovations for the crisis
- Connect with healthcare leadership to evaluate solutions
- Connect with industry partners to scale viable solutions
- Provide means for community involvement, community manufacturing and accumulate volunteers

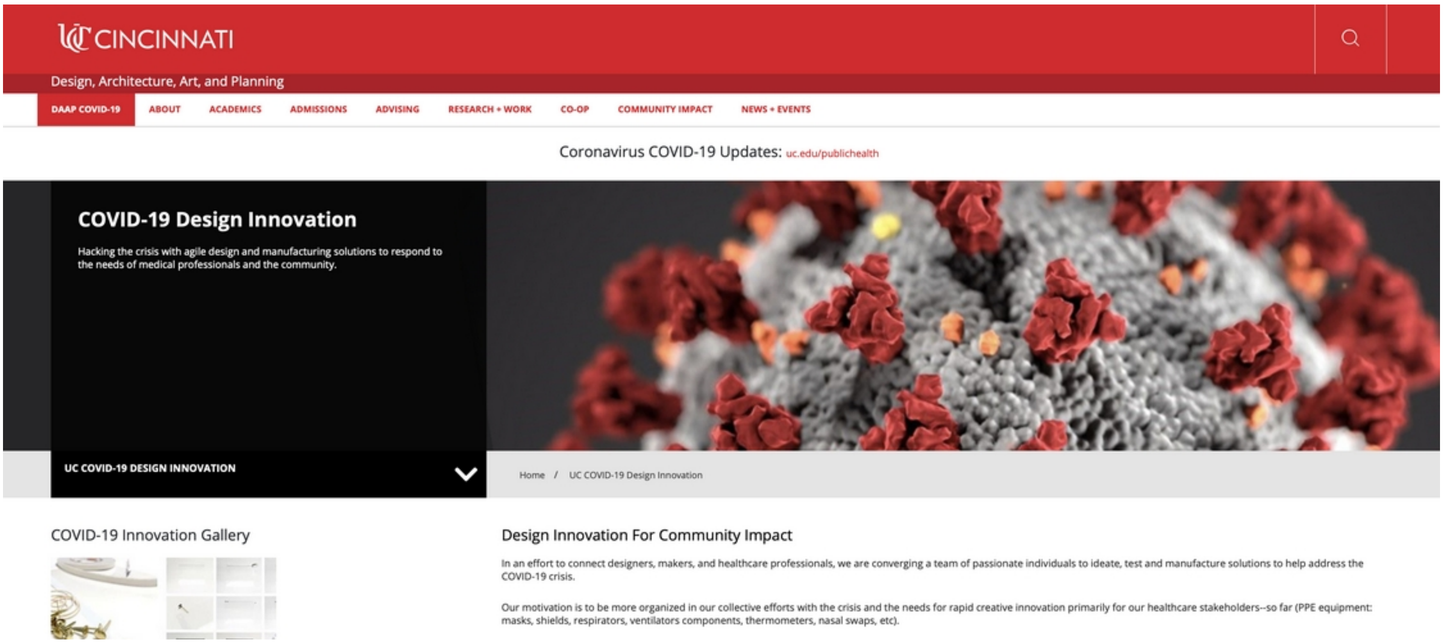

Figure 2 UC COVID-19 Design Innovation Website

While this Design Innovation Initiative was started by a major university, it survived through its partnerships with organizations and colleges involving different expertise areas (e.g., design, engineering, medicine), medical centers, offices of innovation, industry partners with manufacturing capabilities (e.g. laser cutting, ultrasonic welding, sewing, 3d printing).

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The next sections describe in detail the results of the group.

1.2. Off-the-Shelf and Community-Driven Solutions

During the development process, volunteers wanted to help but did not know how to sew. To counter this, some solutions focused on a pattern and assembly and concentrated on using simple tools people are used to operating, such as using staples. These methods would allow those without sewing skills to participate in the mask-making process.

To bond the headband and mask, the team used simple folds and four sets of staples (see Figure 3); two sets of staples fixed the mask material into the form, and two sets to fasten the headband to the mask. This method proved highly effective with a low level of assembly difficulty. Designers organized the mask assembly sets and volunteers conducted the actual assembly. Each volunteer was given a package of mask kits that included masks, headbands, assembly instructions, and university disclaimer sheets.

Both versions functioned well and were received as a PPE alternative to workers who were not patient facing. After the initial trial at healthcare provider, an area institution working for low-income seniors heard of the effort and requested the design. The team retooled and, within a couple of weeks, provided the center with masks.

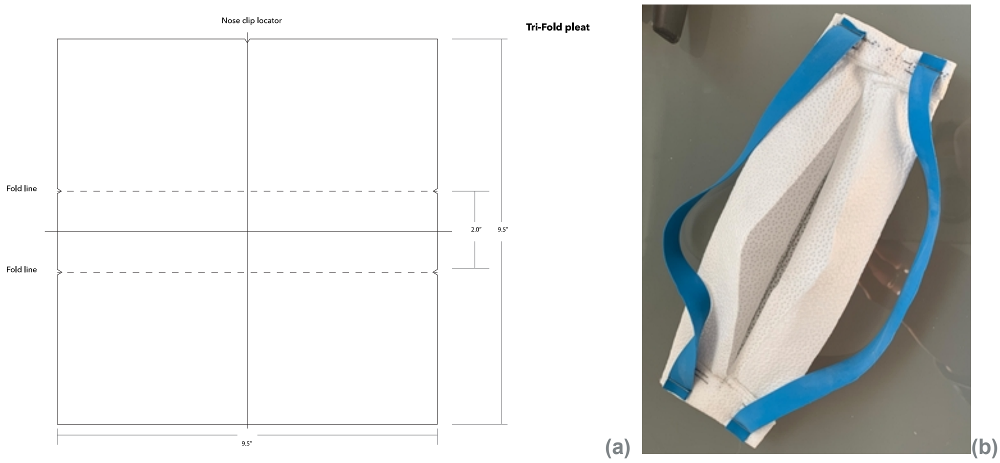

Figure 3 Disposable No-Sew Mask Design

The use of face-shields was also proven to be needed in the healthcare settings, in addition to masks. While many designs were effective, cost and production were variables that motivated the design of a disposable face shield design. The design was driven mainly by the need to have a device that is scalable to be driven by community responders, but more importantly accessible to the general population; a design that can be produced, and assembled from a bottom up approach: utilizing off-the-shelf products (e.g. office supplies) and designing toolkits to mobilize communities to assemble the components (see Figure 4).

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Figure 4 Disposable Face Shield

The design utilizes projection films, a large rubber band, two metal fasteners, and window weather strip adhesive foam as components. A punch hold is the single device needed to assemble the product. At the end, for approximately $0.25 and with an estimated assembly time of two minutes, a face-shield operates as effective PPE. Like the previous example, the design was tested with local healthcare providers which drove the final product design for "manufacturing" and assembly.

1.3. Hybrid Prototyping and Reutilizing Existing Parts

By late March 2020, hospitals were already experiencing dangerous shortages of PPE, especially N95 respirator masks (Jacobs, 2020). While teams of individuals cropped up around the world for sewing cloth masks for individual protection, a standard 80 thread per inch (TPI) cotton is only capable of filtering ~40% of all 0.3-micron particles (Konda, 2020). Medical staff required higher degrees of protection when in direct contact with confirmed patients. Again, working in tight communication with medical staff, engineers and designers at the university developed criteria for N95+ status, which includes the following baseline criteria:

- Can filter 95+% of particles ≥ 3 microns in size
- Forms a tight seal around the mouth and nose, forcing air through the filter media
- Enough compliance to fit a variety of face shapes/sizes

Following the ideas of compartmentalization and modularity, it was proposed to use existing oxygen respirator masks, which were still regularly available and which the hospital had thousands in inventory on site, to form the compliant face seal and develop a custom coupler to allow for an exchangeable filter media. The team worked in parallel to find labs or procedures capable of providing reasonable validation for the media while simultaneously developing a 3D printable coupler to hold a variety of undetermined media. To ensure coupler production could ramp up when the proper solution was developed, the team relied on a distributed network of industry and amateur 3D printers to prototype and stress test designs and print settings.

Early in the crisis, an operating room nurse noted the utility or an existing oxygen respirator mask, that came in several sizes, as a standard part to form a proper seal around a variety of face shapes. Since the respirator had an ISO 5356 taper as a coupler, the geometry was

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modeled, printed, and validated at the hospital within 2-3 days. This meant a variety of designs could be considered for holding filter media and it was known how to attach it to a part that existed in the hundreds and was readily available.

Without knowledge of the filter media dimensions, initially a parametric model was developed that assumed a flat sheet cut into squares with 1cm of height to begin. Squares were chosen as they could be mass produced by hand (see Figure 5). The holder would consist of two parts:

1. Coupler to fit the mask and go from the round taper to a square face
2. Box that would clip into the square face with a compliant mechanism.

Figure 5 Coupler Prototype and Respirator Design

The initial design was rejected as the clip at the back of the filter could allow for air exchange that didn't pass through the media, compromising the wearer as well as the clips being too weak for polylactic acid (PLA) plastic and would break after several uses. The proposed fix was a thicker box that was attached to the coupler and just a lid on the box. The part was, however, designed to be printed without any support material to limit post-processing, saving plastic and increasing print times, and such a design change would require a dramatic increase in support material. After some discussion, it was decided that with a tight enough seal, the filter cap design would not be an issue, but the clip would have to be strengthened.

With the filter media somewhat decided, the cap was reduced in height and the clip strengthened producing the first usable design. The whole thing was fit-tested, and seal tested by nurses and doctors by aerosolizing a bitter compound and subjectively determining if it could be tasted when wearing the mask. With a successful seal, but unknown filter media, the design reached its first benchmark. Once the filter media was confirmed to be surgical wrapping, new problems arose with breathability, surface area, and visual obstruction. The surface area would have to be dramatically increased to account for multiple layers of filter media restricting airflow, but such an increase would also begin to obstruct the wearers view. This problem was quickly eradicated by respirator tubing that was designed to couple to the existing masks could act as an extension of the mask producing the aptly named "elephant" mask (see Figure 6).

(a)

(b)

Figure 6 Progression of Threaded Couplings

With newfound knowledge that Halyard (2020) surgical wrapping could be laser cut, it was decided to abandon the compliant mechanism and switch to circular filters and a rigid threaded cap. Not having experience modeling custom threads, the team focus on modeling and testing thread pitches and clearances for a final design. This ultimately led to the final conical coupler design. Roughly a hundred were produced by various members of the 3D printing network before N95 mask production reached demand and the hospital had normal supplies.

Fully 3d printable mask couplers like the Montana mask (Richardson, 2020) and simple clip mask (Tajduš, 2020) were also appearing. While interesting, these options required several 3D printed parts per mask, which would require long periods of printing time. However, a multi-folded rectangle that created a simple covering piqued interest among the team as it could be 3D printed faster or possibly even CNC routed.

The team began testing several mask configurations using paper to understand how the folds would work and the dimensions to fit a broad spectrum of faces sizes (small, medium, and large to start). Initial testing relied on team members and their families in isolation. It took several iterations over the course of a week to get a reasonable set of origami masks. After the Halyard material was identified and samples were received, the model had to be adapted as the thicker material behaved differently than paper or 3D models when folded.

A major issue was securing the mask to a user's face. A slew of techniques was attempted, from metal clips to twist ties. In this process, it was discovered that some companies use staples to secure elastic bandings and staples were adopted as a fast manufacturing method. As elastic became more and more scarce, other compliant materials were considered. Tourniquet rubber was too rigid, but a quick benchmark at a local medical supply store revealed medical rubber bands that could be easily cut and attached worked well and lasted long enough.

Local hospitals had nurses and doctors fit test the initial design, requesting 20 samples. Industrial design faculty volunteered to build the samples and noted that exchanging rubber bands for a fabric cord would ease the production. The first comments came back that some

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staples were sticking to nurses' cheeks and causing irritation, so it became critical to control the direction of stapling such that the protruding ends faced outwards.

1.4. Material Investigations and Sustainable Production

Across the country, Halyard series surgical wrapping was being considered for use as a filter medium but had yet to be confirmed. In late March of 2020, Dr. Bruce Spiess (2020) at the University of Florida was the first to go on record noting that masks made of the Halyard material are not certified as an N95 mask and are not intended to replace the N95, but could help fill a need for certain health care workers if a critical shortage of masks were to develop (Buletti). Even with this news, surgical professionals familiar with the material were optimistic that the material could meet the N95 criteria removing >95% of 0.3 micron particles.

Only a handful of labs across the country were specifically accredited to run such tests, but similar particle filtration tests were accomplished by utilizing the university's environmental test facilities, normally outfitted for commercial HVAC validation. The data from those tests showed promising filtration of the necessary particles but further testing was necessary to achieve N95 status. While a three-layer approach would be promising, it would dramatically reduce breathability. Breathability is quantified by the pressure drop across the material to achieve a given flow rate. With an ~500 cm2 single layer producing restrained breathing in subjective tests, a three-layer model would need significantly higher surface area or active assistance to allow for unrestrained breathing.

Additionally, this material's intended use is for the sanitary packaging of surgical instruments, however with supply chains for materials at a near standstill during the early days of the pandemic when PPE shortages were highly anticipated, the team was agile in collecting those materials from the hospital and repurposing it as filtration media for disposable masks and respirator mask filters.

100% undyed cotton muslin material widely used for garment prototyping/samples is very appropriate for reusable mask applications. Over 25 pounds of fabric scrap/waste materials collected by UC's Sustainable Fashion Initiative group and the UC Fashion Design program from student fabric waste was used for making 500 of the filter cover masks. The material scraps were sorted for size, sanitized/laundered, ironed and fused with interfacing (using the industrial heat calendar in the Fashion Technology Center) to prepare them for mask production. The materials were and distributed in mask assembly packets for surgical style masks.

This process was not only agile, but also inherently sustainable in that the material would have otherwise been discarded. In this way, the team was able to find a quick response solution to one of the most critical and time-consuming barriers to producing the filters and masks, which was supply chain shortage for materials sourcing.

Early on, it was decided that any solution developed would likely rely on 3D printing and laser cutting processes for speed and agility.

For 3D printing, if any given model took four hours to print on a standard fused deposition modeling (FDM) printer, a single printer could only produce six a day with constant operation. With required volumes being in the hundreds to thousands, the ten or so printers immediately available wouldn't be able to keep up and it became necessary to curate a

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network of individuals and companies with access to such equipment and people to operate them around the clock. A system would have to be developed to allow partners the following:

- *Version Control* - know what models to print and what settings worked best
- *Delivery* - know how to deliver product to hospitals
- *Adaptability* - handle changes and updates to the models
- *Compliance and Sourcing* - what materials were acceptable, and where to get materials when specific ones are needed (i.e. spent Halyard surgical wrapping)

With parallel activity as a key theme, the team purchased a web domain (3d4cincy.com) and began publishing models on it. As new partnerships were formed with individuals and companies, they were directed to the site and regularly asked to print low-volume runs (2-3) of test models. This helped to identify issues with drop-off sites and establish a routine of print-deliver-check. Once a model had been developed that satisfied all specifications, the network could be rapidly mobilized with little to no issues in scaling production.

1.5. Rapid Prototyping and Turning Labs as Manufacturing Facilities

Local hospitals were using up to 500 disposable surgical masks each day. With this volume of PPE being used and discarded regularly, the need to develop a rapid manufacturing system to meet demand for disposable face masks was evident. Additionally, as facial coverings were becoming suggested and required in public, the need for reusable versions were also considered in the design and production of masks by our team. Ad-hoc groups like SewMasks4Cincy (2020) formed to meet the demand of the new market for non-medical grade masks.

As such, the goal was to respond quickly to a shortage and demand by rapidly producing the masks in bulk using the specialized technology that was available to the university: the Rapid Prototyping Center (RPC) and the Fashion Technology Center (FTC). Initially five mask designs prototypes were developed by the university design team, each with its own unique properties engineered to meet the public demand for masks appropriate for various applications, uses and needs (e.g. healthcare workers vs. the public). The designs included (see Figure 7):

- Disposable pleated masks (surgical style)
- Reusable pleated masks (surgical style)
- Disposable dome masks
- Reusable dome masks
- No-sew disposable pleated masks (surgical style)

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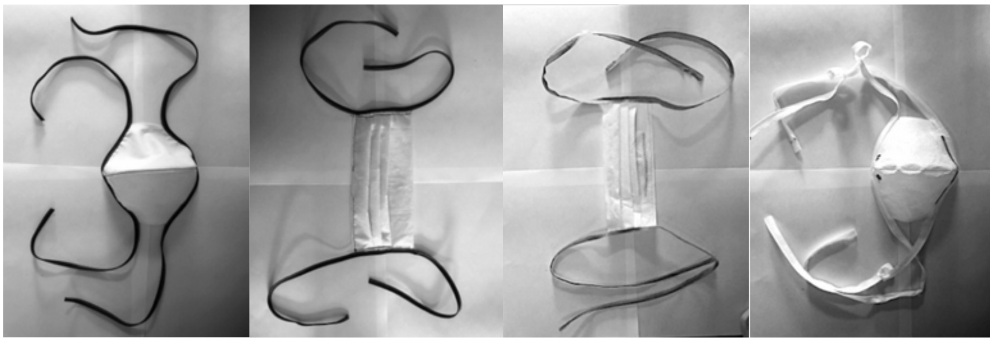

Figure 7 Sewn Masks Styles

The prototypes were tested and approved by members of the medical community at local hospitals, and then put into production at by the university. Five hundred of each mask style were produced using a range of methods unique to each mask's variable materials and construction processes.

The disposable and reusable pleated mask style was modeled after several FDA approved medical grade masks that were provided to our team by local hospitals, cross referenced with other widely used surgical-style masks styles, as well as a pleated filter cover design that was developed and approved by local hospitals with local organization SewMasks4Cincy (2020). The design process included an analysis of standard construction methods including dimensions, pleat depth and strap attachment. Each mask design was adapted to suit the parameters of the technology that would be used for constructing the masks (e.g. laser cutting, ultrasonic welding and heat calendaring and industrial sewing).

Figure 8 Fashion Technology Center Lab Facility for Production of Masks

The dome mask was designed to engineer a more rapid method and material saving technique for cutting using laser cutting system (see Figure 8 and 9). Also, the base shape of the dome mask streamlined construction by eliminating the need for pleats and simplify the pattern shape into a "butterfly" shape, which reduced the number of operations needed to construct the mask base to 1, the center front seam. We were able to achieve faster cutting times with more efficient layouts which used less material overall. Additionally, the dome style had a better overall fit and comfort factor in comparison to the pleated style. This was tested by a local team and was found to have an overall more ergonomic fit for various facial types.

Figure 9 Ultrasonic Welding for Dome Disposable Masks

Much time was spent in the preparation of the materials for laser cutting (see Figure 10). The raw materials for the masks needed to be cut down to size to fit the laser bed and fabrics needed to be laid out and nested in order to get the optimum amount of fabric yield for each cut.

The disposable and reusable versions varied slightly in their construction due to the material being used. Both disposable mask styles used the Halyard-500 polypropylene nonwoven textile for the mask base and the straps. The pleats and straps were stitched on using industrial and home single needle lockstitch (straight stitch) for speed, and then fused using an ultrasonic welding (USW) machine to ensure proper sealing of the material to prevent particles from entering the mask through the stitch holes. USW was also used on the dome masks as ultrasonic welding methods are widely used as a solution for seam joinery where sealing is required, such as medical-grade products like masks. In this way, the design team was able to contribute to the effort by putting to use industry grade, specialized machinery.

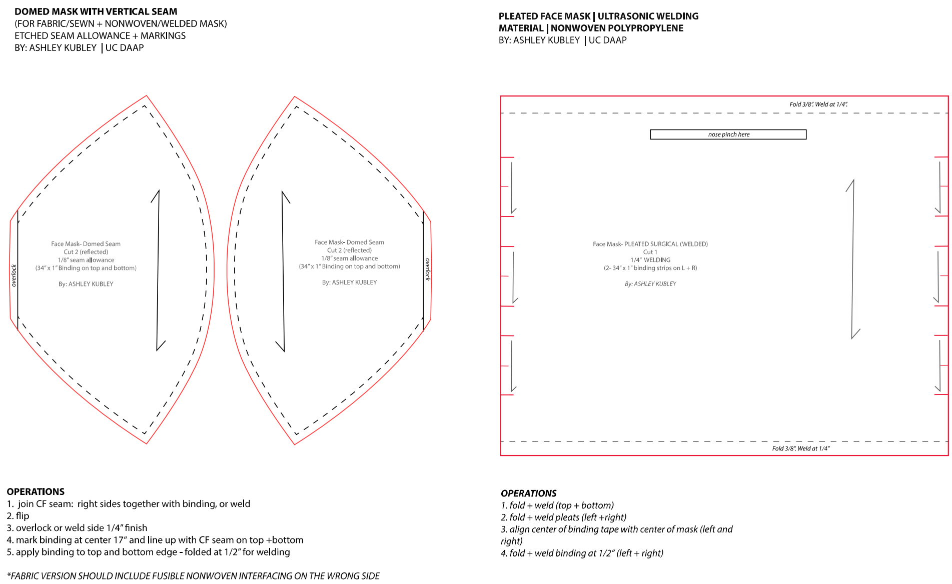

Figure 10 Original Mask Patterns for Laser Cutting

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2. DISCUSSION

Designers, engineers, and innovators were forced to develop novel replacements for limited resources through community engagement and agile development. The team at the University of Cincinnati quickly mobilized and joined forces with local hospitals Tri-Health and UC Health as well as local corporations like Proctor and Gamble to quickly develop such interventions. The team consisted of industrial and fashion designers, nurses, doctors, medical administrators, additive manufacturing experts, supply chain and logistics representatives, and legal counsel.

Much of the teams' success is owed to the compartmentalization of problems and regular, structured meetings supplemented by 24/7 open lines of communication. Problems were given specific scope (i.e. N95+ replacements for medical personnel, N60+ masks for laymen, ventilator production, etc.) and assigned team leads. All members gathered for a daily update call, lasting less than a half hour, where hospital staff went team by team asking for updates and barriers. Open discussion and record keeping then took place with a daily email and over Slack, where each problem team had a channel.

The regularity and rigid structure of communication with all members present and available led to a dramatic increase in the time to iterate. This is best exemplified by the production of a face shield to prevent "splash back" when intubating patients. In a daily basis, a morning call, a new problem was presented by medical staff and a solution was proposed by designers. By noon that day, a first prototype had been constructed and transported to the hospital. By that evening, several nurses had fit tested the shield, noted a few changes, and the administration gave the green light for the manufacture of two thousand shields. A process that typically would have taken weeks or months took a single day to go from problem to implementation.

This regular contact with administrators, users (hospital staff), and assemblers was key to the iterative process that led to successful implementations. With assembly and material procurement being major barriers, funding was initially altruistic and out-of-pocket for many designers before grants came through.

The COVID-19 Design Innovation quick response team worked immediately to aid in the effort by assisting in the design and production of PPE, and developing a plan for material sourcing, production line and distribution, considering many complex and limiting factors that impeded the design and production process as a result of the pandemic, including: limited access to equipment and personnel due to safety protocols in facilities; preparation of materials for volunteers (pickup/dropoff locations as well as packets); and quality control and safety protocols assurance.

3. CONCLUSION

Several key factors contributed to the success of this rapid innovation cycle. Open and regular communication with all parties, daily huddles, regular emails, and channels (e.g., Teams) made sure everyone knew the priorities, status, and barriers of other teams and had access to the same information. Rapid prototyping and frequent user testing - improved the iterative design process and better solutions were found faster. Activating a network of experts, disciplines, backgrounds, faculty, staff and students to design and produce the masks "production line" style remotely was not only a success factor but also a design problem that led to true design innovation. Lastly, teams with specific, narrow goals - with the broad spectrum of problems faced, focus became key to getting results. Even further, building the right kind of team was paramount to their success. Overall, the crisis drove design innovation as:

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- *Multidisciplinary* Diverse teams comprised of engineers, nurses, designers, and administrators came together to be more than the sum of their parts. Multidisciplinary collaborations are necessary for effective design innovation.
- *Communications* Daily communications were crucial for design innovations. Having platforms for fluid interactions, sharing capabilities and frequency of meetings were proven for successful outcomes. However, rigid meeting structures are needed (e.g. focused discussion/elevator pitch).
- *Small Groups* No more than three people to a team meant teams could utilize relationship over bureaucracy to get things done quickly. Also, Clear Leaders Having a point person on each team to coordinate tasks and information, even in open conversation
- *Constraints* Because of the limited availability and supply chain issues, the team had to find creative solutions to sourcing base materials for PPE designs. In the end, Constrains as material access, production time and assembly led to better design innovations.
- *Contextualization* Successful design innovation needs to be connected with the end user and environment. These settings expedite implementable solutions, as well as help better define problems uniting stakeholders for co-innovation.

While solutions reached refinement, hospital admins and medical personnel called for volume and designers and engineers ramped up production. As designers are not uniquely qualified to run assembly lines or optimize manufacturing processes, novel solutions were often met with later pains due to complexity in assembly. This was unfortunately furthered with immediate push back from regulatory bodies within the university and hospital settings, who raised concerns over liability and intellectual property (IP) rights. Hospital administrators pushed for total waivers of liability for the other innovation partners, but regulatory bodies and lawyers were hesitant to provide such immunity on either side. The very practices that allowed for the rapid response to a crisis—ignoring IP ownership by openly sharing ideas and resources--were the very downfall of solutions that became relegated to loading docks and basements around the city, sitting idle while a crisis continued.

While the team contributed to alleviating the scarcity and real health issues around the scarcity of PPE during the COVID-19 crisis, the efforts seemed more responsive than critical as innovative intervention. Fast-paced efforts made the innovation cyclical incrementally improving "band aid" solutions—problem solving issues of adoptability and need versus tackling the problems from the root. This unique problem-solving approach to innovation from problem solving to problem solving—understanding the real problem and real need in the crisis, led to doing as opposed to thinking. The inherent value of design is about its critical aspect--making. The coordinated efforts facilitated agile design but limited the necessary time to pause and evaluate the problem in depth.

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Confronting COVID-19 - The case of PPE and Medical Devices production using Digital Fabrication at PUC-Rio

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ABSTRACT

At the end of 2019, the first cases of COVID-19 were registered. As the disease spread across continents culminating in a pandemic, countries suffered from a shortage of personal protective equipment. In Brazil, the first case was recorded on February 2020. This study aims to describe the experience of creating an interinstitutional network to meet the pandemic's demands and the experience of transforming an academic design laboratory into space for the production of personal protective equipment using 3D printing and laser cutting techniques. The actions described in this study, made it possible to meet the high emergency demand for PPE in the city of Rio de Janeiro, as well as the construction of knowledge both within the scope of building networks to solve complex social problems and about the possibilities of production in an academic environment. The work also addresses the importance of the divulgation obtained by the project -specially on national TV broadcast and social media – as a way to raise society's awareness of design professionals work.

Keywords: COVID-19, PPE, 3D printing, mask, face shield.

INTRODUCTION

In December 2019 cases of an unknown viral disease appeared in Wuhan, Hubei Province, China. These records corresponded to the first cases of COVID-19 (WHO, 2020a). By June 2020, the disease had been diagnosed in more than 7,800,000 people and had claimed 430,000 victims (Johns Hopkins University, 2020).

As the epidemic spread through the various countries, WHO issued guidance on the protection items needed by health professionals working to assist those infected with COVID-19 (WHO, 2020b, WHO, 2020c). The scientific community also made recommendations on the correct use of these items (Ortega, 2020).

The demand reached 100 times more than normal. This high demand, panic buying, and inappropriate accumulation caused a shortage of personal protective equipment (PPE). Prices were twenty times higher. The WHO then, issued a warning asking industries and governments to increase production by 40% to meet global demand. This shortage has left front-line health care professionals without the proper equipment to work on the care of

COVID-19 patients, making them more vulnerable to get infected. For a proper protection it was estimated that these professionals needed about 7 to 10% of surgical masks world supply. The WHO alert also addressed widespread market manipulation with stocks being sold by the highest bidder, causing panic and diplomatic incidents (WHO, 2020d; Boseley, 2020).

Research groups and people involved with 3D technologies and digital manufacturing found the use of 3D printing technology as a way to mitigate the shortage of PPE caused by the pandemic. Initiatives began in the first countries affected by the COVID-19 pandemic in the world like China, Spain, and Italy. As soon as it was possible, studies on the development of equipment - such as face shields (AMIN et al., 2020; SAPOVAL et al., 2020) and masks (SWENNEN, 2020) - were released.

3D printing technologies were already being indicated for use in humanitarian contexts for hyperlocal production. The in-site production of resources needed - such as in developing country's health clinics and refugee settlements - is considered a solution to the logistical and supply chain problems involving humanitarian aid (James & Gilman, 2016; Tatham, 2014).

Considering the history of the PUC-Rio's Núcleo de Experimentação Tridimensional – NEXT - in projects related to additive manufacturing in medicine and health (DOS SANTOS et al, 2019; DOS SANTOS et al, 2013; FRAJHOF, 2015), the mobilization was almost immediate in order to support the emergency response in the lack of PPEs in Rio de Janeiro's public health system.

The objective of this study is to describe the experience of the Department of Arts & Design of the Pontifical Catholic University of Rio de Janeiro – PUC-Rio team in the elaboration of an inter-institutional network and the transformation of an academic laboratory into a PPE production space to supply the city's medical teams demands.

1. NETWORK CONSTRUCTION AND PPE PRODUCTION

In early March, a meeting at *Palácio Guanabara* - Rio de Janeiro's state government headquarters - was attended by some public and private institutions researchers and representatives, as well as members of the state health department. This meeting discussed how it would be possible to build a local and agile production of PPEs and other medical devices due to the lack of world supply for these items.

In order to answer these need an inter-institutional network was established among the Pontifical Catholic University of Rio de Janeiro (PUC-Rio) - through the Department of Arts and Design (DAD-PUC-Rio) - the Industry Federation of the State of Rio de Janeiro (FIRJAN) and the Federal University of Rio de Janeiro (UFRJ) - through the Clementino Fraga Filho University Hospital (HUCFF). The main objective of these Network was to develop, assess, produce, and distribute the PPEs to reference hospitals and institutions in the fight against the disease caused by the new coronavirus (COVID-19).

Despite the extensive manufacturing infrastructure offered by both PUC-Rio and FIRJAN, it was soon realized that the challenge would be quite high. The estimated demand from the health department for each PPE model - such as N95 masks, face shields, goggles - was in the tens of thousands, remarkably high numbers, even for such infrastructure. Thus, it was

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sought to understand which PPE models were simplest to produce, as well as the amount of labor on research and development for them to be available.

Considering the possibilities of infrastructure and personnel, the the administrative officers from the University were asked for permission and support for the initiative, which was accepted immediately. Consequently, this inter institutional network was put into practice so that it was possible to act on several fronts. However, regarding the huge amount of PPE needed by the medical teams, and the physical limits from both digital manufacturing and involved laboratories, it was decided to plan and put into practice a long discussed process - but little performed -: network manufacturing.

Several groups were formed in the most diverse social medias. In these groups were not only representatives from research institutions, but also members of civil society from various backgrounds - such as doctors, designers, engineers, chemists, among other specialties - with a common characteristic, all interested in the maker movement and willing to help in this effort. Thus, a form was shared in order to map out the technologies available by the group. More than a hundred responses were promptly received from makers and manufacturing spaces in Rio de Janeiro, putting their machines and facilities available to support the local response. From this mapping it was possible to visualize the size of the network, the location of members, and the main technologies available for the manufacture of PPE and medical devices. Considering the data obtained (figure 1), we choose to work especially with the Fused Deposition Modeling (FDM) and laser cutting due to its huge availability and low costs.

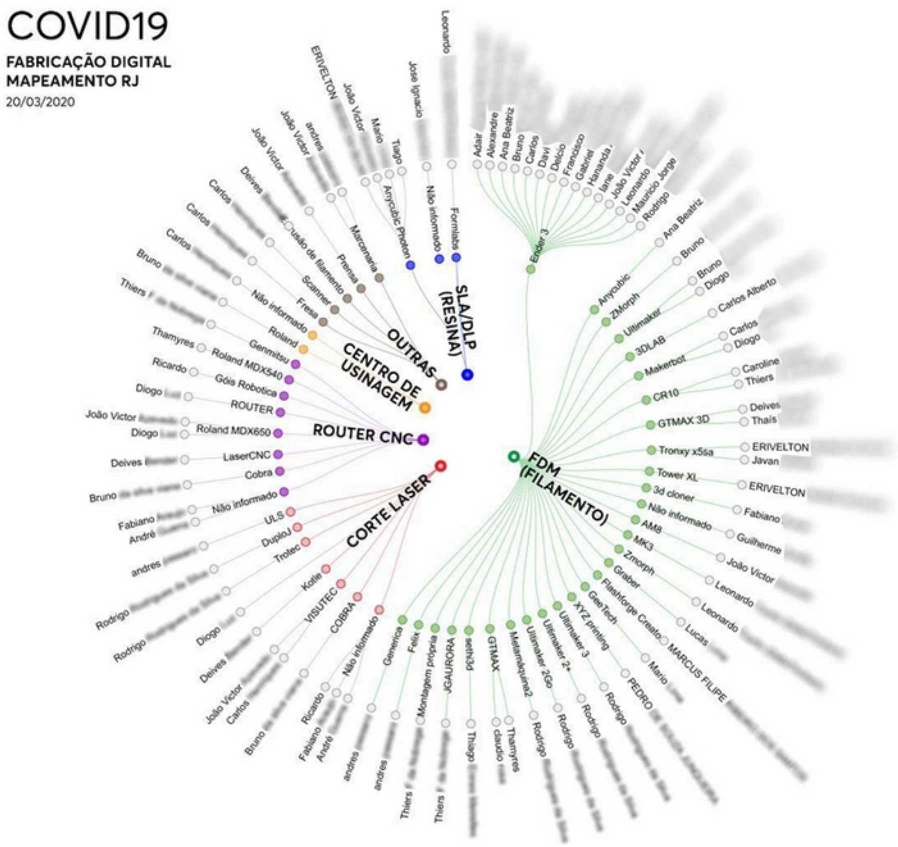

Figure 1 - DataVis obtained through the form sent via internet until March 20, 2020 (source: Dr. Barbara Castro, PUC-Rio)

After this mapping the makers and companies which owned the machines were contacted and inscribed in an internal list. After making sure if they were really interest in participating, they were organized by city areas and material need so it was possible to

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projecte how much material should be order and how many pieces could be produced per week.

The development of these kind of networks brings a lot of advantages such as: experimentation agility, production volume, creative contributions, and cost reduction. However, there are some disadvantages such as information overload, overlapping solutions and egoic conflicts in decision making.

Because of the need for solutions in a small period of time, a lot of design proposals were sent by the whole community. The greater part of them were very raw. Some of them were basic first concepts, which lack on minimal design aspects such as fittings, material availability, inappropriate manufacturing processes and so on. The great majority were not even been prototyped. Nevertheless a constant in this process was the designers' naming and treating them as "miracle solutions" or "the best solution ever", when clearly it was just initial ideas, despite their egoic perceptions – a bad, but real, habit on Design's practice. This kind of mis happenings were solutioned applying a design methodology – developed and used at DAD-PUC-Rio - as a guide for the future decisions: Social Design method.

2. SOCIAL DESIGN

The practice of the Arts and Design department of PUC-Rio is based on Social Design (FABIARZ & RIPPER, 2011; ARAUJO, CÔRTES, & FARBIARZ, 2020), a method that seeks to understand the reality of a certain social group and, based on conviviality and dialogue, develop solutions that enrich local relationships and improve the interactions which characterize those Space. Therefore, it was understood that the role of DAD-PUC-Rio would be a glimpse at the local Space, in order to organize this network and define some premises for the development of the action. Following this path, the developed objects made much more sense in the local health units' interactions.

As usual in the process of DAD-PUC-Rio, it was first defined that we would not "reinvent the wheel". Knowing that the pandemic had already hit other countries hard, solutions which were already in use in these places - and that already had some validation by agencies and medical staff - were sought in order to understand what and how they could be adapted to the reality of Rio de Janeiro. A pilot production was then organized for each item found. With this production it was possible to define its degree of feasibility within the available Network infrastructure. Other important points that were observed on these solutions were the real need at the Rio de Janeiro's front and whether it was in accordance with the national standards of both the Brazilian Association of Technical Standards (ABNT) and the National Health Surveillance Agency (ANVISA).

The second step of the process was the validation of the solutions in the health units. As previously mentioned, it is of fundamental importance the understanding of the object in its real use, in the Space where it will be used, by the people involved in the whole process of its activation. The concrete reality where it will be used is, many times, very distant from the reality of the designer. Therefore, a huge effort should be made to understand the interaction between object x action x user x place. This awareness is a sine qua non condition for the development of products that are, in fact, useful and that, in fact, comply with the interaction to which they were designed (MATTEONI et al, 2020).

3. THE ITEMS

Based on the requirements, several pieces of equipment were obtained in order to understand what was needed in the health centers and could be produced by the network to meet the Rio de Janeiro reality of the pandemic. A lot of equipment were printed and tested, both in lab environment as in field, and thus the focus was set on the following items:

Face shields: after a series of tests with several models available on the Internet, the model developed by Josef Prusa (www.prusa3d.com) – which fulfils European Community health standards - was used as the basis. This model required few changes, such as the type of material (originally designed for PETg, was changed to PLA, aiming at a higher production speed) and a small change in the laser cutting file of the visor (aiming at facilitating assembly by users). The RC1 lite model (a RC1 remixed by a user in Josef Prusa's own repository) and the RC3 model were used, aiming a greater comfort for the different head sizes.

Figure 2 - health professional using a face shield based on RC3 model by Josef Prusa. (source: Luiz Eduardo Carnevale)

Goggles: Although it is an item of fundamental importance, few models were found available. In view of the ease and agility of production, the "lunnette covid-19" model - made available by the user RAIDEN39 in the Cults3D.com repository - was used as a basis. This model required heavy changes in order to be validated by health professionals. Its main structure was totally redesigned - based on the anthropometric features of the Brazilian people - and its lens was also modified in order to facilitate assembly, as well as improve the sealing at the interface with the forehead and the cheeks.

Figure 3 - Health professionals wearing the goggles developed by DAD-PUC-Rio. (source: Raphael Bertani)

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- N95 Mask: several models are available in several repositories. A great number were printed and tested; however, none are in accordance with the Brazilian standards of ANVISA and ABNT, especially regarding sealing with the face and the filtrating element. Hence, a complete redesign was conducted, which at this moment awaits a series of tests with the regulatory agencies.

Figure 4 - DAD-PUC-Rio Team member using the under development TPU/PLA 3D printed N95 prototype. (source: authors)

Video laryngoscope: In view of the need for ventilation for most COVID-19 patients, faster, simpler, and cheaper alternatives to regular video laryngoscopes - whose value may exceed tens of thousands of dollars - have been sought. The solution was based on the Air Angel blade model. Like the other devices, a series of modifications were necessary to meet the local reality in Rio de Janeiro. At the moment, this object is in the validation phase by the medical team and regulatory agencies.

Figure 5 - Video laryngoscope model developed by the DAD-PUC-Rio team based on the Air Angel setup. (source: authors)

Swab: The need for mass testing has been a standard set by the WHO since the first moment of Pandemic. The PCR test is considered the most reliable for assessing the patient as infected or not. This test requires the use of at least three swabs (a small tube with absorbent material at the tip) that collect mucus from the patient's nose and throat for laboratory testing. Although apparently simple, this device has disappeared from the market especially because the absorbent tip material (Rayon) was missing worldwide. Among the solutions

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found on the web, the model developed by FormLabs, draws attention for its ease of production and for having been validated in several North American hospitals. This device has already been validated by the HUCFF team and is currently awaiting the implementation of a new stereolithography printer at DAD-PUC-Rio.

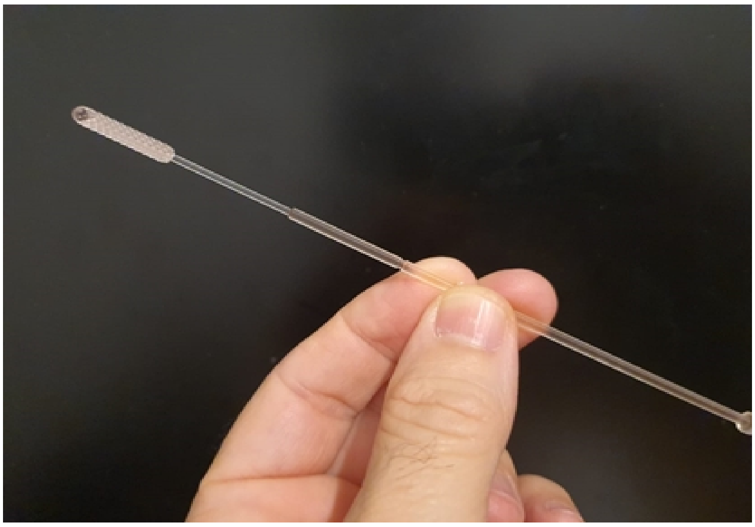

Figure 6 - Swab developed by FormLabs, validated by HUCFF team. The production is under implementation by DAD-PUC-Rio. (source: authors)

4. ASSESSMENT

An assessment network was organized. After being produced, the material was presented to a physician - general practitioner and post-graduated in Design - for evaluation of usability, safety, and visibility. With this initial validation, a group of researchers, technicians, and design students evaluated the objects in relation to their form, toxicity, and sterilization method, as well as in which hospital environments it should be used and which health professional would use it (information obtained from HUCFF).

Figure 7 - Some of the PPE models sent for assessment procedures. (source: authors)

If the artifact was qualified and validated for use, a small pre-production batch was sent for use by the health teams at the Clementino Fraga Filho University Hospital/UFRJ, to be field tested in the COVID wing. In case of approval by them, the object was allowed to be produced regarding the parameters stablished by DAD-PUC-Rio Researchers.

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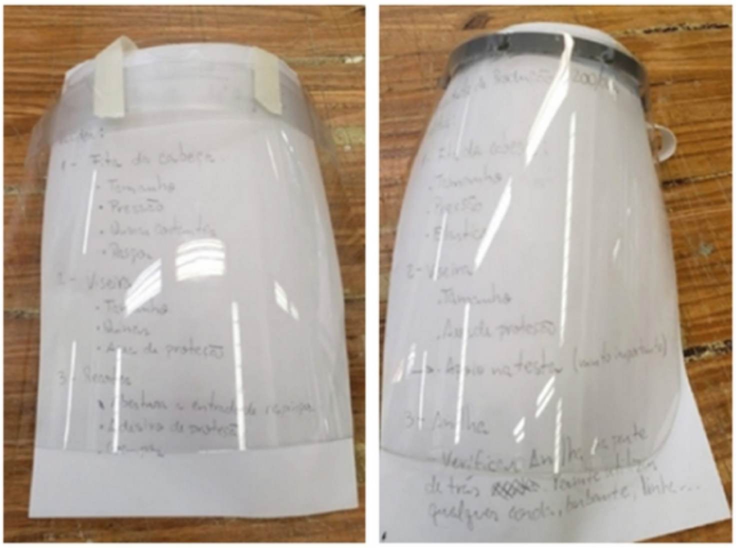

Figure 8 - Pre-production parts sent for validation at HUCFF. Internally we can see some of the questions to the health team which received the parts. (source: authors)

All information necessary for its production, assembly and maintenance was organized in a cloud-based folder, which was shared with all members of the network. The pieces were then produced in a distributed manner and later sent to the Laboratory for Models and Prototypes (LAMP), at Department of Arts & Design of PUC-Rio. Every week the network logistics responsible called al the makers and companies which were enlisted to know how many pieces they made and how much material they need to continue printing more objects. When the member had at least 20 units, they entered on the logistic route, which retrieved the ready parts and delivered more material to continue the production. All the ready items were sent to the LAMP

In the lab, the pieces were selected - as ready, finishing need, or disposable - organized by model, and then arranged in kits - along with other pieces produced - to be sent to health centers.

5. TRANSFORMING THE ACADEMIC LABORATORY INTO A PRODUCTION ENVIRONMENT

The LAMP is a workshop lab mostly used by the students of the Product Design Bachelor's course, but it is open to other students. The laboratory staff consists of three employees, six interns and an average of fifteen monitors during the semester. In describing the space, Câmara (2020), divided it into three main areas: workbench area, machine area and classroom. The workbench area was the main space in the laboratory occupied for production. The workbenches were reorganized and the three 3D printers available in the laboratory - at the time - were moved into space. Usually, the 3D printers are available for the students in a specific room, next to the computers with the software for 3D modeling and preparation of the print files. To these three printers were added five more bought by DAD-PUC-Rio, besides other five borrowed by other sectors of PUC-Rio, such as the Center of Telecommunication Studies (CETUC), which in addition to the machine ceded the employee Marcelo Balisteri, the Department of Informatics, teachers, alumni and partner schools. Besides developing, centralizing, and delivering the parts, LAMP also became a manufacture center of printed parts, being responsible for about 40% of the parts printed by the network. The whole laboratory had the following FDM printing equipment:

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- 6 Creality Ender 3 (printing area 235mmx235mm)
- 2 Ultimaker S2/S2+ (printing area 202mmx220mm)
- 1 Creality CR-10 S5 (printing area 500mmx500mm)
- 1 Cliever CL1 (printing area 120mmx120mm)
- 1 Felix 3.0 (printing area 240mmx205mm)
- 1 Makerbot Replicator 2 (printing area 285mmx153mm)
- 1 Voolt Gi3 (grabber i3) (printing area 200mmx200mm)

Figure 9 - Arrangement of 3D printers in the LAMP (source: authors)

The laser cutting space are located in the machine area. The laboratory has a room with a computer for file preparation and control and another separate room for the laser cutting machine. In the production of PPE this space was essential. Both the face shields and the goggles were produced using this technique.

For the production structure the lab was divided in two spaces: laser cutting space and printing space. The laser cutting space followed the standard layout of the laboratory, except for preparing the material to suit the dimensions of the laser cutter, which was cut into a specific space arranged next to the printing space. The print space was established in the workbench area. The workbenches were reorganized by islands to facilitate the manufacture and organization of the pieces. The scheme (figure 10), adapted from the Câmara study (2020), presents the organization of the lab for PPE production.

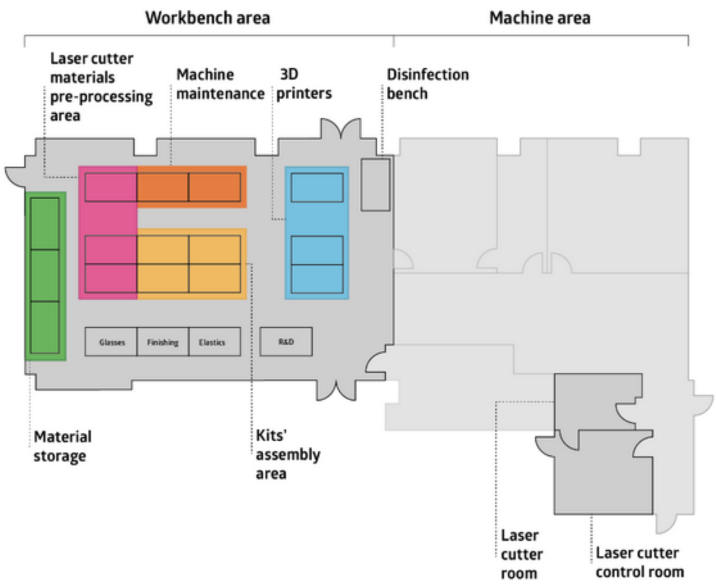

Figure 10 - Organization scheme for the PPE production at LAMP-PUC-Rio. (Source: elaborated by the authors adapted from Câmara (2020)

Dos Santos, J. R. L., Correia de Melo, J. V., Frajhof, L. & Kauffmann, A. R. (2020). Confronting COVID-19 - The case of PPE and Medical Devices production using Digital Fabrication at PUC-Rio. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 488-501. DOI: 10.4013/sdrj.2020.133.15

The printing space was divided into specific areas to carry out the production stages. The central zone was occupied by the kit's assembly area and the 3d printing area. The material storage took three benches in the side of the main space, the same number for laser cutter material storage and preparation. Another two benches were reserved for machine maintenance. One bench corresponded to the space for models in research and development, another was used to cut and organize the elastic bands and next to this was the bench for the finishing procedures of the pieces. The glasses were organized and arranged on a separate bench.

Figure 11 - view of the central island where the kits are organized for distribution. In the background you can see the printing island and on the left the elastics cutting area and the R&D area. (source: authors)

Polylactic acid (PLA), polypropylene (PP) and acrylonitrile butadiene styrene (ABS) filaments were mainly used to produce the printed components of the devices. These materials were bought by the institutions and particular donators and then distributed through members of the network to be 3d printed. Face shields' and goggles' lenses were produced in PET-G (polyethylene terephthalate glycol-modified) 0.5mm thick, which is required by regulatory agencies. The production of these parts was all done at LAMP.'s laser cutter. All the materials were validated as per use, production, and sanitation.

6. DISTRIBUTION

The deliveries were organized according to the hospitals' demand. They filled a form in order to verify the applicant's information and the real need for equipment for the place. This process was complex from the very beginning given the lack of products on the market and the extreme urgency to obtain them. The team, sometimes, found itself in Sofia's choice, choosing which place to send, even knowing the general need.

To avoid an uneven distribution among health units, a method of allocation was developed to contemplate all but focusing first on protecting those professionals in direct contact with COVID-19 patients. The first PPEs deliveries was to the university hospitals. As those institutions were familiar to research and assessment protocols, these centers supported adjustments in production and effective evaluation of PPE quantities per health unit. With this information, a delivery priority was organized for the health centers based on the organization made by the state health department:

- Reference hospitals for the COVID-19 treatment
- Major Emergency Hospitals
- Basic Emergency units

- Emergency medical services (SAMU)
- Basic Health Units and Family Health Units

Knowing that it would still not be possible to deliver 100% of the demand, each unit was contacted in order to inform the number of ICU and Emergency beds. With this number it was possible to count the amount of health professionals per bed in these areas -stated by law- and project a minimum necessary number for an immediate coverage of the most sensitive areas. The aim was to prioritize the professionals in high contact with the virus, and, thus, high risk of infection. Based on this data, each healthcare unit was informed about the quantity available, the priority of delivery and the day to collect.

The equipment was distributed in kits. The face shields were distributed containing the parts necessary for their assembly. The packages were organized containing 25 pieces of each item: 3D printed headbands, laser cut PETG lens and elastic strips for a better adjustment to the head. When delivering the equipment to the healthcare professionals, the team provided information about assembly, handling, and sterilization of the material.

Figure 11 – delivery kits (source: authors)

The researchers realized that the assembling of the goggles required excessive care to avoid breaking the PETG lens. Therefore, it was decided to send to the professionals the kits containing the glasses already assembled. Because of the volume, the glasses kits contained ten units in each.

Figure 12 – Delivery (source: authors)

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7. THE DELIVERIES WERE ORMACHINE MAINTENANCE

Due to the extended use, the machines required constant adjustments and repairs which were not common when used for the laboratory main purposes. The adjustments and repairs consisted of everything from replacement of parts - such as extruder nozzles – to fine alterations for the use of different materials.

Taking into account the number of worked hours and the number of parts delivered, the individual maintenance cost per machine has been greatly low, with most of it being consumable parts replacement such as nozzles, thermistors, PTFE tubing and connectors for the Bowden extrusion system.

Important to note that in some of the replacement cases, the team used parts available at online repositories. The parts ware printed and used to repair the printers' broken components. A real example of "printers printing printers".

8. CONCLUSION

Like other countries affected by the COVID-19 pandemic, Brazil was one of the places where civil society and academia came together to meet the health professional's emergency demands on the Sars-Cov-2 fight front lines. The inter-institutional network, described in this study, made it possible to supply PPEs to a great number of health centers in the metropolitan region of Rio de Janeiro.

By describing the necessary processes for the development of this action at PUC-Rio, this study demonstrates the potential of networks structured between academia and civil society for the solution of complex social problems. The development of a large-scale emergency production established in an academic laboratory, such as LAMP, also provides important contributions about the expansion of the academy role in the solution of emergency social demands.

The solution to meet the demand for PPE through the use of digital manufacturing techniques, such as laser cutting and 3D printing, represents an important factor in the consolidation of this technology for end user products manufacturing.

Another important contribution of these initiative lies on the divulgation obtained by the project. The action developed was widely disseminated. The project was presented in one of the main TV news in the country and in many other broadcast shows. Social media's respected profiles and influencers helped spread this Design approach of the crisis. It was quite interesting because historically, designers face difficulties both in relation to knowledge about the possibilities of professional action and the perception of value about the profession. The elaboration of this action by the Department of Arts & Design of PUC-Rio - together with other sectors of civil society - highlights one of the main functions and capacities of the design professionals: gathering a variety of areas - such as medicine and engineering – and making the result of this union available to society throughout products and services. This logic demonstrates a wide possibility of action for the profession, and may contribute to raise society's awareness of design professionals work .

Some of the devices described in this study are still being developed to enhance and expand the possibilities of use. In future studies, the design process, and the iterations for the improvement of the equipment will be explained.

The city of Rio de Janeiro has approximately twelve thousand health professionals (TOKARNIA, 2020). Since March, the LAMP-PUC-Rio production made possible the distribution of around sixteen thousand faces shields and three and a half thousand goggles for the front-line professionals.

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STRATEGIC DESIGN RESEARCH JOURNAL

Co-design of Do-it-yourself Face Shield in Japan Under COVID-19 Pandemic

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ABSTRACT

Along with the spread of open-design environments and various types of digital fabrication tools (e.g., computer numerical control machines, laser cutting devices, and 3D printers), the "maker movement" or "personal fabrication" has been spreading worldwide over the past decade. This case study introduces grassroots activities in Japan that employ personal fabrication tools to manage the COVID-19 crisis, focusing on the co-design of do-it-yourself face shields for healthcare workers. We address the various issues emerging with face shield production: (1) development of face shield designs and materials, (2) examination and information sharing regarding the practicality and safety of open-source designs, and (3) collaboration with local factories. Thus, we demonstrate the significance of maker contributions to COVID-19 and provide suggestions to address future challenges.

Keywords: COVID-19, FabLab, Face Shield, Japan, Maker Community.

1. INTRODUCTION: COVID-19 CRISIS AND MAKER MOVEMENTS

Since the widespread use of personal computers and the Internet, individuals have been able to access vast amounts of information for computation and communication. In addition, open design environments and various types of digital fabrication tools such as computer numerical control machines, laser cutting devices, and 3D printers have been developed, encouraging individuals to experiment and/or fabricate things they require. In this context, a movement known as the "maker movement" or "personal fabrication" has been spreading worldwide over the past decade (Dougherty et al., 2017; van Abel et al., 2014; Gershenfeld, 2007). Maker Faire, a festival of the do-it-yourself (DIY) community, has been held worldwide, including in Japan (e.g., in Tokyo, Kyoto, Ogaki, Yamaguchi, Tsukuba, and Sendai). Furthermore, as hubs of personal fabrication, "FabLabs" have been established in more than 1,800 locations in 120 countries (Fablabs.io, n.d.). The FabLab Japan Network, a voluntary community of FabLab managers and supporters with diverse backgrounds, was established in Japan in 2010; labs are now spreading to more than 18 locations, including those in Hiratsuka and Shinagawa.

The COVID-19 infection, first confirmed in November 2019, spread worldwide in 2020. Owing to the rapid spread of the infection, serious global shortages of personal protective equipment (PPE), including face shields, masks, and gowns, have occurred. To eliminate supply shortages, the aforementioned individual makers and FabLab communities responded quickly by attempting to manufacture PPE equipment in a DIY manner using digital fabrication tools, followed by publishing open-source licenses. Various design ideas have been proposed for the DIY fabrication of face shields. For example, nine different design options were introduced in a PLOS BIOLOGY review article (Chagas et al., 2020), and the Open Source Medical Supplies website shows 28 different design ideas. Examples of equipment and tools for making face shields include 3D printers (e.g., for the "Prusa Face Shield" or "Easy 3D printed Face Shield" on Thingiverse), laser cutters (e.g., for the "Proto Shield" or "Origami Face Shield"), and even scissors and staples. In addition, the open data are licensed under Creative Commons licenses (CC BY-NC: Attribution-NonCommercial, CC BY-SA: Attribution-ShareAlike), many of which are available to the public. By July 10, Prusa Face Shield had 217 remixes by 3D printer users, and the "Easy 3D Printed Face Shield" had been remixed by 82 contributors.

On the global Maker community's website, various initiatives of makers tagged as "Plan C" ("If Plan A is the government and Plan B is industry, then Plan C is for civic action" (Dougherty, 2020)) have been published since March 22, 2020. In Japan, Maker Faire Kyoto 2020 was held as an online event on May 2. During the course of five hours on Twitter, 957 works from 394 makers were presented (Kobayashi, 2020). In addition, two panel discussions were planned on YouTube. One of these was themed "What We Makers Can Contribute to the World since the COVID-19 Pandemic." The discussion was preceded by a Slack workspace "COVID-19 Makers Forum JP" set up to share ideas, with 186 makers. For example, ideas for preventing infections in the medical and welfare fields were considered on an "idea-hackathon"' day. In addition, an online survey was conducted regarding homemade masks openly available on the Internet.

However, the global FabLab network uses hashtag #FabDoesNotWait as its motto. The aforementioned initiatives were conducted after discussions with industry experts and researchers in the field of respiratory health. They have led to the development of PPE for frontline healthcare and essential workers, and helmets for continuous positive airway pressure treatments (i.e., sending air into the nasal airway). In Japan, several FabLabs are promoting efforts to create face shields using 3D printers. For example, Doyo from FabLab Hiratsuka and Kanagawa University designed a 3D model for the frame of a face shield; the model, called the "DOYO model," is being shared widely (Doyo, n.d.). The model is available as open-source data on the author's GitHub page; therefore, anyone requiring the face shield could print out the frame with a 3D printer at a decentralized lab or home, and modify it as needed.

In this study, we focus on a community of individual makers and FabLabs in Japan. This community has been working to develop and deliver face shields to healthcare facilities, while simultaneously increasing quality and quantity.

2. METHODS

To examine the development and delivery of face shields by personal makers and FabLabs, we focus on two public Facebook groups that have contributed to the grassroots construction of face shields in Japan. Both groups are organized with the aim of sharing open-source face shield designs and supplying them to healthcare workers lacking PPE. The first group is COVID-19: The Community of People Who Make and Distribute Face Shields (established April 10; 258 members). This group is mainly organized by personal makers and FabLabs; there are at least 40 members of FabLabs in Japan. The second group is the 3D PRINT FACE SHIELD (established April 13), a broad community comprising more than 1,000 members. This community makes face shields based on open-source 3D print data, i.e., the "HANDAI Frame" developed by Nakajima, a professor of Osaka University Hospital. As an open community, various actors—medical workers, designers, engineers, makers, office workers, and high school students— participate in these Facebook groups, and the community members in these groups partially overlap, sharing information and communication among them.

This study mainly concerns the former group, as it is easier to follow the detailed processes of making, modifying, and discussing face shield designs, materials, and methods for maintaining safety, in addition to addressing mass production between personal makers and FabLabs. We created a list of all posts of the Facebook group COVID-19: The Community of People Who Make and Distribute Face Shields through June 30th by sorting the posts by date, poster, design and material of the face shields, input time by 3D printer, and the personal makers' comments on these designs or materials. Meanwhile, we also organized the chronological development process of the "DOYO model" (detailed in section 1) from Doyo's posts on Facebook and his GitHub page (Doyo, n.d.). Using this approach, we analyzed the processes involved in the development of face shields in Japan.

3. RESULTS AND DISCUSSION

The structure of a face shield includes two major parts: a transparent shield and a frame to hold it on the head. The engineering requirements for the frame are as follows: (a) securely fastened around the head and (b) fitted closely to the forehead. The frame must be comfortable to wear for long periods of time. For this reason, there are possible variations in the structure. It must be non-latex if using elastic materials, but the types of materials is not significant. In contrast, the requirements for the shield concern transparency, firmness (e.g., not easy to bend), coverage of the entire face, and type and availability of materials. Therefore, in the following sections, we will focus mainly on the design of the shape for the parts of the frame and on the types of materials for the shield parts.

3.1. Designs of frame parts

In the public Facebook group The Community of People Who Make and Distribute Face Shields, members have posted several examples of designs and fabrication approaches for face shield frames with various shapes. Most of the frames were made using a 3D printer, but others were made using a laser cutter and commercial foam tape. For the structure of the frames, one method for integrating the frame and shield parts involves making three or four small holes in the shield part using a hole punch or other tool, and inserting corresponding protrusions of the frame part into the holes to assemble it in place. Another method involves inserting a shield without holes between the frame parts. To fix the frame to the head, a hook structure is attached around the back of the head and is adjusted with a rubber band. Few posts mentioned the material of the frames; it appears that biodegradable polylactic acid has been used.

In addition, several open-source face shields have been shared by Facebook. The DOYO model has been introduced as a recommended prototype, as it is well regarded by hospitals and other organizations. As a case study, we consider the situations surrounding this "DOYO model." The repository of the DOYO model was created on GitHub on March 31, and in early April, there were multiple commits, and the data had been updated. The DOYO model

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employs the method of assembling parts with holes and protrusions, and uses a hook structure for the frame. This hook structure is based on an open-source design by 3DVerkstan in Sweden with a CC BY-SA license; therefore, the DOYO model is also licensed under CC BY-SA. There are multiple versions of the DOYO model. Following the initial version, a prototype was developed that could make five pieces together, and a week later, a version was released that could provide output in half the time (31 min) of the initial version (60 min), using a 3D printer. Subsequently, in collaboration with the medical community, a version that could make up to 30 pieces simultaneously was released. Following the release of the open-source 3D data, FabLab members and makers in Japan have used this data to make frames using their 3D printers. They have created from a few dozen to a few hundred face shields and donated them to local medical institutions and other organizations. In addition, local companies have provided thousands of face shields to local medical institutions and municipalities free of charge, and domestic 3D printer manufacturers (e.g., MIMAKI and MUTO) have been providing face shields at a rate of 500 units per day to 500 units per month, using the manufacturers' own 3D printers.

3.2. Materials of transparent shield

In addition to the design, the material(s) of the face shield also appears to be an issue in creating face shields. Is the material sufficiently transparent as a face shield? Is it durable (can it be used several times)? Can it be bought easily? In the following, we chronologically show the personal makers' and FabLabs' attempts to seek and examine appropriate shield materials by tracking personal making reports and mutual communication among Facebook groups.

One issue was the use of an A4 clear plastic folder/file. In earlier stages, when people began crafting face shields on their own, a clear plastic folder was regarded as the most potent shield material, owing to its commonness and low cost. Osaka University's model, which gained broad attention to design when published, as the idea of using a common clear plastic folder for the material of a face shield was novel. Yoshioka, a Japanese designer who works globally, published a face shield design ("Easy-to-make FACE SHIELD") comprising a clear plastic sheet that is cut and attached to glasses (Yoshioka, 2020). The social design activist NOSIGNER's DIY face shield (called "PANDAID") also uses a clear plastic folder (PANDAID, n.d.). However, from the viewpoints of people who tried to make and wear them, several problems with clear plastic folders were noted. Although clear plastic folders seemed easy to obtain and could be utilized for the urgent demands for face shields, the transparency of the clear plastic folder was insufficient, particularly for medical uses that require detailed work. Moreover, clear plastic folders suffered shortages of supply on online shopping sites; thus, the price suddenly rose. This was a serious problem for making face shields in emergencies. The idea of using a clear plastic folder, therefore, had already become regarded as unrealistic by the end of April 2020.

Accordingly, the participants in The Community of People Who Make and Distribute Face Shields started working on prototypes using various types of materials, as alternatives to clear plastic folders. Although it is impossible to show them all owing to space limitations, the material types that they targeted were broad: laminated films, vinyl sheets, polyethylene terephthalate (PET) sheets, polycarbonate plates, polyvinyl chloride plates, polypropylene (PP) films, oriented PP films, cast PP films, and so on. The features of each material and its suitability for face shields became apparent within the processes of creation and evaluation

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of the aforementioned face shield prototypes. For example, a PP film is better for durability, as it is hard to break; laminated film is good for lightness and transparency; overhead projector sheets are less transparent, despite their high prices compared with other materials. Not only the functionalities of the materials were examined, but also the adequacy of alcohol sterilization for reuse, that is, which material surfaces do not fog up when wiped with alcohol.

To determine the appropriate material, the makers conducted lively discussions. In the public Facebook group, members commented on each post, exchanged ideas regarding the materials, offered advice based on their experiences, and asked for details from multiple viewpoints – price, transparency, where to obtain materials, safety, and durability. They also held an opinion hearing for healthcare workers close to them as prospective users, allowing for the handling of some prototypes, and asking for opinions regarding wear, visibility, and stability. Such mutual feedback led them to change and improve, or to promptly try new materials.

Surprisingly, however, we did not determine the flow of standardization for a material, at least in the last three months. The possible reason for this is that the selection of a material largely depends on the material's availability as well as its functionality as a shield. Because of the heavy dependency on availabilities, destinations, and purposes, it was necessary for the personal makers to discuss the adequacy of the materials from multiple viewpoints. For them, it could be said that the best material was relative. On the one hand, the indeterminacy of the best material might be the limitation of personal production. On the other hand, it was a natural and strong point of FabLab’s characteristics, that is, small production and distributed manufacturing. These efforts could be seen as demonstrating the flexibility of small production (one of the characteristics of FabLab’s work), and helped to contribute to the urgent demands of the COVID-19 problem. At least until shields ready for mass production were completed, the flexible production by personal makers and FabLabs enabled makers to deliver slightly better quality face shields to people who need them immediately.

3.3. Practicality and safety of open-source designs

In this section, we discuss the agendas that makers and suppliers of face shields confronted in the uses and embodiments of open-source PPE designs, and describe their approaches to such problems, mainly focusing on the cooperative works of the personal makers and FabLabs.

The first agenda concerns the flood of open-source designs. Many open-source designs for PPE were shared via the Internet, leading to a saturation of designs. Innumerable open-source designs require manufacturers and suppliers to inspect and select them. The FabLab community dealt with this problem of saturation using various approaches. For example, FabLab Shinagawa, Tokyo, began checking various open-source designs for face shields in early March. They made at least 10 types of face shields by printing based on open-source 3D face shield data, wore them, evaluated each design’s advantages and disadvantages (such as manufacturability, fitting, and visibility), and noted points for reform. Every report was published on their webpage (FabLab Shinagawa, March 20, 2020). By conducting verifications individually, they confirmed whether the face shield designs were practical. As FabLab Shinagawa was the group that originally attempted to create 3D-printed self-help devices by mixing digital fabrication and occupational therapy, their previous experiences enabled them to create 3D printer face shield prototypes promptly. However, there was another challenge, namely, safety in providing the PPE. Sending PPE might cause a risk of exposing the healthcare workers who use them to COVID-19 if SARS-CoV-2 is attached to the PPE. Therefore, makers must seriously consider ways to avoid infection as well as to make the PPE. To this end, it was necessary to create platforms for learning correct knowledge regarding infectious disease prevention.

In April 2020, the project "Fab Safe Hub" was started by the FabNurse project 1, Fab Lab Hiratsuka, and Social Fabrication Laboratory. This online platform aims to explore and share the ways in which makers who create 3D-printed face shields can provide PPE to healthcare workers safely. Fab Safe Hub provides information for both makers and users. For makers, Fab Safe Hub shares face shield designs, checklists for materials and inspections, and guidelines for materials and procedures for sterilization, as appropriate for 3D-printed products. In the guidelines for sterilization, for instance, it is suggested that makers must soak the face shield's frame in sanitizers while wearing masks and rubber gloves. For users, Fab Safe Hub released a sample PDF instruction manual for the face shield, including information on the precautions, assembly method, and management method. Until May 2020, there were not sufficient face shields for single use, and thus Fab Safe Hub also advised users to sterilize the shields for reuse. The information shared via Fab Safe Hub has been widely used as a reference for makers when sending face shields they have produced.

From the efforts of the personal makers and FabLabs communities for providing practicality and safety in making and providing face shields as described previously, we determined their contributions based on their utilization of their skills and know-how in digital fabrication, and on the new tasks they confronted. For example, the FabLab community could mobilize their facilities and experiences in 3D printing to respond to the serious lack of PPE. However, it was revealed that there was a limit to what they could contribute to (or based on) their existing knowledge. Based on the concepts of "Do It Yourself" and "Share It with Others" (Gershenfeld, 2012), FabLabs have generally created small devices for themselves, or, even when giving these products to someone else, have been limited to face-to-face situations. Therefore, in completely unpredicted and new situations requiring them to supply their products to unknown people, they learned that further skills and responsibilities were necessary to make and supply them safely, for example, with regards to the sterilization, explanation, and provision of the products.

3.4. Collaboration with local factories

We have described efforts to ensure the practicality and safety of DIY face shields, that is, to ensure quality. We have also discussed the advantages of utilizing a 3D printer in the decentralized production of face shields. However, one of the disadvantages of using a 3D printer is the issue of quantity. There have been attempts to print multiple pieces at a time, and 3D printer companies have collaborated to provide several hundred face shields. However, when needing more shields, a single 3D printer is often unable to handle the need for more pieces. In response, activities for increasing production with small factories have begun. As the DOYO model was an open source, it allowed users to not only download and use the 3D data, but also to modify some of the data depending on their needs. Ten days after the data was released, Doyo was contacted by a cooperative society of small- and medium-sized factories in Aichi Prefecture, Japan. Less than a week later, a mold was created based on the 3D print data and was partially modified for mass production. In addition, recycled plastic bottle caps were used as the materials for the frames. PET sheets that were donated by other chemical manufacturers were adopted as the shield material. A production system of 40,000 units per week was prepared (AnjoHearts, April 24, 2020), and more than 17,000 face shields were distributed free of charge to medical professionals across the country in Japan within approximately one month (from mid-April to mid-May) (AnjoHearts, May 19, 2020).

4. CONCLUSION

Confronted with the unpredictable crisis of the spread of COVID-19 worldwide and the corresponding shortages of PPE, FabLabs in Japan have addressed these problems by using their skills and devices. Several issues emerged from the activities of face shield production: (1) development of face shield designs and materials, (2) examination and information sharing regarding the practicality and safety of open-source designs, and (3) collaboration with local factories. This case study clarified how grassroots face shield production helped improve the supply of face shields, at least until the mass production of PPE became ready. Although the cases of the co-design and development of face shields addressed in this article are a subset of the overall activities, these activities mixed previous experiences and immediate measures, and revealed the novel potential of personal makers and FabLabs to contribute to emergencies. The strengths of individual makers and FabLabs' works for COVID-19 are based on their skills in making and local fabrication as well as on their community networks. Instead of mass industrial production, FabLabs and personal makers have continued the prompt development of face shields, along with discussions with users and medical professionals on the safety, usefulness, and accessibility of face shields. This improvisation and flexibility in making products, which are important characteristics of FabLab's small and local fabrication, have contributed to responding to the urgent needs of the COVID-19 crisis. Furthermore, these efforts to produce face shields are based on community networks between personal makers and FabLabs, allowing members to try new designs and materials of face shields, and to modify them. In particular, existing FabLabs, such as the FabLab Hiratsuka and the FabNurse project in Japan, have engaged in healthcare activities, shared their professional medical knowledge, and helped bridge between grassroots face shield production and supply to healthcare workers.

Finally, we conclude this paper with a few suggestions on some remaining challenges. Although the supply of PPE has stabilized to some degree during the writing of this article in Japan, it is not clear that the makers' role is complete. We believe that we are in the next stage, and should consider what makers can provide for the future. The first suggestion concerns inclusive design. The urgent priority in the COVID-19 pandemic was to supply PPE (including masks and face shields) to many people. However, we believe that the development of inclusive designs for various groups of people is also necessary. For example, daily measures such as social distancing and not touching things, as encouraged by governments to prevent infection, could exclude disabled people, such as visually impaired persons (Canadian Council of the Blind, 2020). It is possible that personal makers and FabLabs could flexibly create products for those who have particular needs, by taking advantage of their small production and local fabrication. Another suggestion concerns proactive measures for future crises. In addition to the current situation, it is also important to determine how to prepare for similar infections or other issues that may arise in the

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future. Although personal makers and FabLabs' struggles against COVID-19 in Japan were mainly associated with the creation PPE, their contributions are not limited to this. Considering that the recent sphere of activity in FabLabs is broader than material processing (including electronics design, mechanical design, and biotechnology), we believe that FabLabs and personal makers could diversify the extent of measures taken against crises in the future, as challenges will continue.

ACKNOWLEDGMENTS

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ENDNOTES

[1] FabNurse Projects was launched in 2015 as an interdisciplinary project based in Keio University SFC. The project aims "to employ the power of digital fabrication (FAB) to offer customized and detailed solutions for the healthcare context" by "promoting synergy between FAB and nursing as well as working both in a university context and at actual care sites" through digital fabrication. For example, they create products such as gargle basins and arm holder covers for patients and elderly people using 3D printing (FabNurse 2015).

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Open Design and 3D Printing of Face Shields: The Case Study of a UK-China Initiative

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ABSTRACT

At the start of the COVID-19 outbreak, many countries lacked personal protective equipment (PPE) to protect healthcare workers. To address this problem, open design and 3D printing technologies were adopted to provide much-in-need PPEs for key workers. This paper reports an initiative by designers and engineers in the UK and China. The case study approach and content analysis method were used to study the stakeholders, the design process, and other relevant issues such as regulation. Good practice and lessons were summarised, and suggestions for using distributed 3D printing to supply PPEs were made. It concludes that 3D printing has played an important role in producing PPEs when there was a shortage of supply, and distributed manufacturing has the potential to quickly respond to local small-bench production needs. In the future, clearer specification, better match of demands and supply, and quicker evaluation against relevant regulations will provide efficiency and quality assurance for 3D printed PPE supplies

Keywords: 3D Printing, Distributed Manufacturing, Face Shields, Healthcare, Open Design, Optimisation.

INTRODUCTION

The World Health Organization (WHO) designated "coronavirus disease 2019" (Covid-19) a global pandemic on the 11th March 2020. In March and April 2020, many countries were experiencing rapid increase of confirmed COVID-19 cases, but doctors, nurses and other frontline workers were dangerously ill-equipped to care for COVID-19 patients. WHO called on industry and government to increase manufacturing of personal protective equipment (PPE) by 40 per cent to meet the rising global demand (WHO, 2020). In some countries, the situation has become so dire that some providers are using social media and have even set up websites to obtain PPE directly (Ranney et al, 2020).

Many distributed 3D printing teams hoped to contribute to combating the pandemic. A number of initiatives of different scales have been quickly set up. Around the world, 3D printing teams in the United States first shared their design files of 3D printing masks. Therefore, the mask design of the American teams provided us with a reference. The U.S. Food & Drug Administration (FDA) teamed up with the Department of Veterans Affairs

Innovation Ecosystem and the National Institutes of Health 3D Print Exchange, to share data and coordinate on open-source medical products for the COVID-19 response (FDA, 2020). These agencies also work with America Makes that help connect health care providers and 3D printing orgnisations (Fig 1, screenshot of https://www.americamakes.us/statement-on-covid-19/).

Figure 1. America Makes' connecting healthcare providers, manufacturers and designers

The European Association for Additive Manufacturing (CECIMO) have set up networks to respond the increasing PPE demands. To optimise the time to market of PPE production, HP Digital Manufacturing Network and HP Production Partners are partnering in delivering medical supplies and devices to healthcare providers. Face shields are a major type of PPE being 3D printed. By mid-May 2020, HP has published four designs of face shields (Fig 2. Screenshot of enable.hp.com)

For example, the Avid Face Shield was developed for 3D Printing with HP Multi Jet Fusion technology. The Design for Additive Manufacturing (DfAM) face shield frame prints in a compact geometry and parts assembles into the 3D shape by placing the face shield (sheet) on the pins. The design files can be freely downloaded, modified, and improved for 3D printing, which is typical open design.

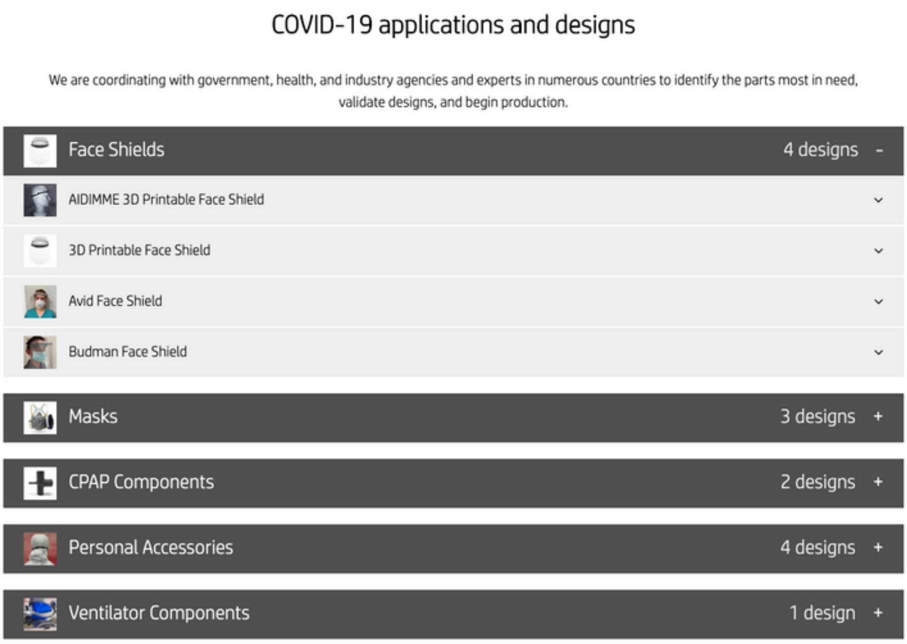

Figure 2. HP COVID-19 applications and designs (HP, 2020)

Li, S., Hao, L., Chen, Q., Zhang, L., Gong, P., Huang, Z., Huang, D., Nie, P. & Dong, H. (2020). Open Design and 3D Printing of Face Shields: The Case Study of a UK-China Initiative. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 511-524. DOI: 10.4013/sdrj.2020.133.17

Thanks for the efforts made by organisations like Hewlett-Packard, which also provided additional references to our team's design wor

1. OPEN DESIGN AND 3D PRINTING OF FACE SHIELDS

Open design (Van Abel et al., 2014) is a form of co-creation, which generally refers to the design, exploitation, and distribution of products, machines, or systems by sharing information resources. Michel Bauwens distinguishes three different dimensions of open design (Bauwens, 2009): Input side, Process side and Output side. On the input side, we have voluntary contributors and free raw materials that can be freely modified and improved (e.g., the downloadable Avid face shield design file). The process side is based on design for inclusion, with low barriers to participation, modular tasks, and communal validation of the quality and excellence of alternative solutions, equivalent to peer governance (e.g., the Sino-British multinational 3D printing design alliance to be introduced in the case study). On the output side, it creates a common, ensuring that everyone can use the final result (e.g., the 3D printed face shields and the improved design files). The common output in turn become new open free materials that can be used for the next iteration (van Abel et al., 2011).

Open design has potential value for both professional and non-professional manufacturers because it is a means of producing better products (Green and Kirk, 2018). 'Openness' means sharing solutions, processes and assets, and collecting feedback from other designers, design communities and non-designers. The entire process of open design is usually promoted by the Internet. Open design provides designers (both professionals and amateurs) with unprecedented possibilities. It challenges the definition of certain characteristics of professional design and blurs the boundary between professional and non-professional designers (Cruickshank, 2014).

Distributed 3D printing can be understood as the establishment of partnerships between 3D printing manufacturers or makers in different regions. They have different production scales and capabilities to provide products or services that can quickly respond to emerging market demand. In the post-industrial digital era, through open design and distributed 3D printing, more and more stakeholders will get the opportunity to participate in the design, manufacture and distribution of products.

Information and communication technologies and social media have facilitated open design of PPEs during the COVID-19 pandemic. Architects, designers and engineers have joined the force to help produce the much-needed face shields. In the USA, studios including BIG, KPF and Handel Architects have joined an open source project to print face shields; in Spain, Nagami Design has switched its machines from making furniture to shields; British architecture studio Foster + Partners has designed an alternative face shield that can be laser cut; Researchers at the Massachusetts Institute of Technology have developed a disposable face shield made from a single piece of plastic, which can be mass-produced and shipped flat (Shepherd and Parry, 2020).

On the 7th April 2020, Apple unveiled its design for a face shield to protect health workers fighting coronavirus (Dezeen, 2020). Its CEO Tim Cook stated, "We've launched a company-wide effort, bringing together product designers, engineering, operations, and packaging teams, and our suppliers, to design, produce, and ship face shields for health workers."

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On the same day, Nike also announced its full-face shield development in collaboration with Oregon Health & Science University, which utilised Nike-owned materials and manufacturing facilities and transformed elements of the Nike's footwear and apparel into the much-needed PPE (Nike, 2020).

These design responses to COVID-19 only reveal one part of open design, i.e., the input side, and lacks process information. The case study we are going to introduce in this paper will focus on the process side. It had delivered face shields to the UK front line workers before Apple and Nick's launch of their face shields.

2. METHODS

Content analysis was used in this case study. Content analysis is defined as the systematic, objective, quantitative analysis of message characteristics (Neuendorf 2016). The interpretational content analysis (Zou, 2006) has been chosen for this study as it is the most appropriate means of examining, understanding, and interpreting the interactive content (text, images, videos) exchanged through the social media forums created for the project.

Wechat was the host of the forum because all our participants already use this social media, and it accommodates multiple languages (in text or audio format), images, and video input. Between 24th March and 7th April 2020, 648 pieces of data were exchanged (514 text messages, 97 images, 12 videos, and 25 links). The data exchange took place naturally among a dozen core participants. The interaction covered the following key themes (Table 1) which were counted and analysed by the first author and checked by the last author.

Table 1. Key themes of the interactive content

Themes	Example	Number
Identifying needs	"Zhang：There is no unified medical standard for protective face shields. "	63 pieces
Design iteration	"Shu: It takes less time to print without the need for elastic band."	308 pieces
Examples	"Zhang: A team is also designing 3D printing protective face shields. Here is its website: https://www.thingiverse.com/thing:4236924"	79 pieces
3D printing optimisation	"Pete: This morning, I conducted a bending installation simulation on the drawing of the visor and adjusted the assembly column according to the position of the hole."	136 pieces
Distribution	"Hao: We hope to call on more 3D printing teams to use idle 3D printers to produce face shields."	21 pieces
Other (evaluation etc)	"Dong：Preliminary evaluation: easy to pack and post … "	41 pieces (evaluation 16, Likes 10, contacts 9, and other)

3. CASE STUDY

The UK-China initiative was launched by three professors (One from the UK, and two from China). Inspired by the success of the 3D printing of the Venturi ventilator valves created by the Italian 3D printing company Isinnova, on 24th March 2020 they issued a call for designers to propose PPE designs for combating COVID-19, and established a Wechat forum with participants from design, engineering, and enterprising backgrounds. They were piloting a 3D printing intelligent manufacturing and distribution alliance, with the purpose to make better use of idle 3D printing resources in response to healthcare emergencies. As the project continues to expand, an increasing number of process-related practitioners have responded to the call and joined the team (totaling 48 by the end of April).

3.1. Identifying the PPE

At the beginning, it was not clear what PPE should be produced. There were 63 pieces of text and voice data on the topic of identifying needs. Ventilators and its parts were discussed but soon the focus turned to face shields. Mrs Zhang said:" There is no unified medical standard for protective face shields." It means that the official medical institution will not ban our design work.

The threshold for satisfactory ventilator equipment production standards is relatively high which requires team members' professional medical knowledge, and it has to meet the regulations of medical devices. For this reason, it is not possible to develop new PPE equipment meeting industry standards within in a short period of time. In addition, different clinical settings may use different types of ventilators.

The team soon reached a consensus that they should apply 3D printing technology to the production of protective face shields to alleviate the urgent self-protection needs of frontline workers. Usually face shields are subject to FDA enforcement guidelines, but the FDA have relaxed their guidelines, stating that they do not intend to object to the distribution of improvised face shields as long as they create no 'undue risk' to help foster greater availability of PPE for the duration of the public health emergency. (Sarah, Flanagan, David, Ballard, 2020）

3.2. Design Process

Once focusing on face shields, the team searched for existing designs, examples and open files, and shared them (e.g., Prusa protective face shield -RC3; face shields designed by University of Bath) in the Wechat forum to allow team members to evaluate different designs and make necessary modifications. Most of the discussion also took place at this stage, with a total of 306 messages appearing on Wechat. Team members found and shared more design examples (in addition to the American design team and Hewlett-Packard mentioned in the introduction) and started their own mask design. Figure 3 shows a primitive design which was mounted on the wearer's glasses.

Figure 3. Face shield design – the first version

Li, S., Hao, L., Chen, Q., Zhang, L., Gong, P., Huang, Z., Huang, D., Nie, P. & Dong, H. (2020). Open Design and 3D Printing of Face Shields: The Case Study of a UK-China Initiative. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 511-524. DOI: 10.4013/sdrj.2020.133.17

This design was for people who wear glasses/goggles: a half open square metal bracket was used as the head support, and two screws were used to attach the face shield to the metal bracket. Users' glasses/goggle frames were to support the metal bracket above (as shown in (a) in Figure 3). The connection part was further refined, which utilised a hollow T-shaped foam to replace the mental bracket so that the face shield can be directly supported by the frame of the user's glasses (as shown in (b) in Figure 3). The advantage of this design is that the assembly is very convenient and efficient. However, the disadvantages are also obvious. Firstly, the user has to wear a pair of glasses. Secondly, the stability of the face shields is questionable because of its thin structure. Thirdly, the design does not cover the user's forehead, and the eyes are not properly protected. Therefore, this design has not been taken forward.

After comparing several open designs online, the FAB619 face shield design (files available from https://github.com/FAB619/protection-Mask--COVID-19) was deemed as most appropriate. Its design has combined the advantages of two face shield prototypes (i.e., Prusa and ENISO) and has been adjusted for easier and faster 3D printing. In addition, very detailed design, printing and assembly instructions have been provided online, what is more, the design has gone through verifications with doctors and experts. However, there were further issues to be solved for production.

Material: the first task was to identify appropriate face shield/sheet material. A4 Acetate sheets (available on Amazon) were tried but they were found too thin. PETG, PET and Acrylic (PMMA) sheets were considered and A4 acrylic (200 -250 micron) proved ideal. Initially the holes were designed to fit a Swedish hole punch (with a two-hole footprint), and later the design was modified to accommodate single hole punches as well: a universal bracket was added that fits any 6mm-diameter hole. This way the design could fit different head sizes.

Printing modification: 3D printing optimisation became necessary. The team members tried to improve printing efficiency and save printing time. The content analysis suggested that 136 pieces of interactive contents were about this theme. Some team members asked to convert the original STL file to dwg or dxf files. Some asked to modify the design to suit smaller 3D printers (e.g., diameter 100mm, and height 170mm). Vertical stacked models were designed for printing two, four or eight frames in one go (Figure 4) to improve efficiency. These modifications had reduced printing time from around 120 minutes/set to around 15-20 minutes/set.

The team also explored alternative designs, as shown in Table 2. Some have tried to combine the chosen FAB619 design and the Design C (in Table 2), i.e. plugging in the gap between the outer and the inner frames (Figure 4) to provide better protection of the eyes.

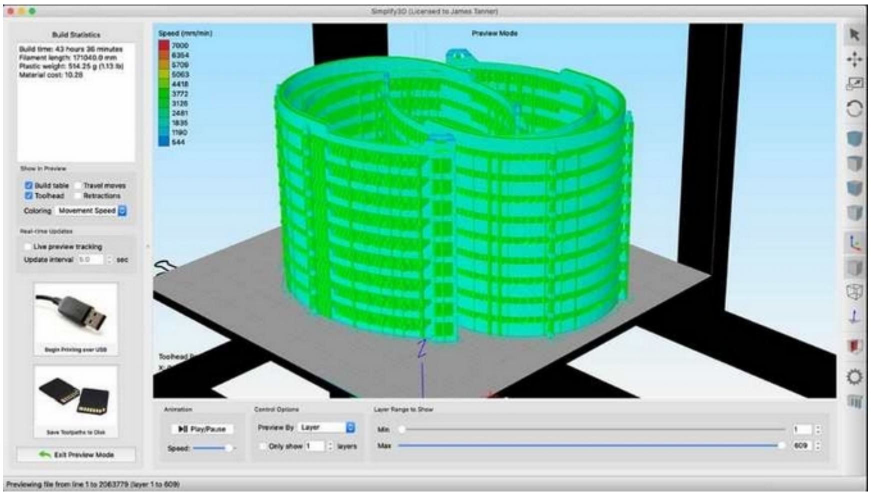
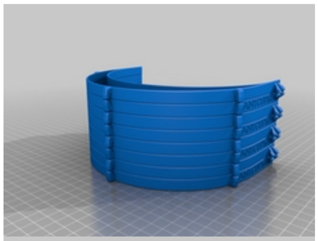
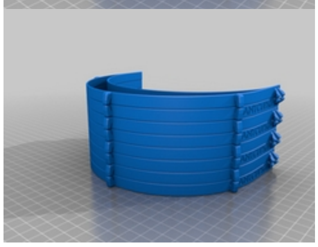
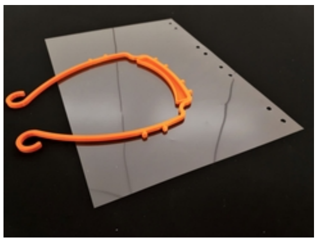


Figure 4. Multi-layer printing and layout to increase efficiency and reduce material use

Table 2. Summary of alternative designs

Designs	Source files and advantages	Images
Design A	Files available from Https://www.youmagine.com/designs/zipvisor-faceshield*.XoZFG1KyMMk.twitter) The parts to hold the sheet are very small, and they can be printed using small 3D printers. Zip ties can be used to adjust the size.	
Design B	Files available from https://www.thingiverse.com/AnycubicEurope/designs The design is stackable, and many can be printed in one go, increasing the efficiency of printing	 
Design C	Files available from https://3dverkstan.se/protective-visor/ Simple structure, quick to print and easy to assemble. With print setting guide https://3dverkstan.se/protective-visor/protective-visor-print-guide/	

Li, S., Hao, L., Chen, Q., Zhang, L., Gong, P., Huang, Z., Huang, D., Nie, P. & Dong, H. (2020). Open Design and 3D Printing of Face Shields: The Case Study of a UK-China Initiative. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 511-524. DOI: 10.4013/sdrj.2020.133.17

Figure 5. Combined new design

The original FAB619 design uses elastic materials (shown in Figure 6) to adjust the size. These have been changed to PLA plastic bands which can be produced by 3D printing as well. Therefore, all the parts except the face protection sheet can be produced directly by 3D printers. The face protection sheets can be bought in bulk from stationary shops.

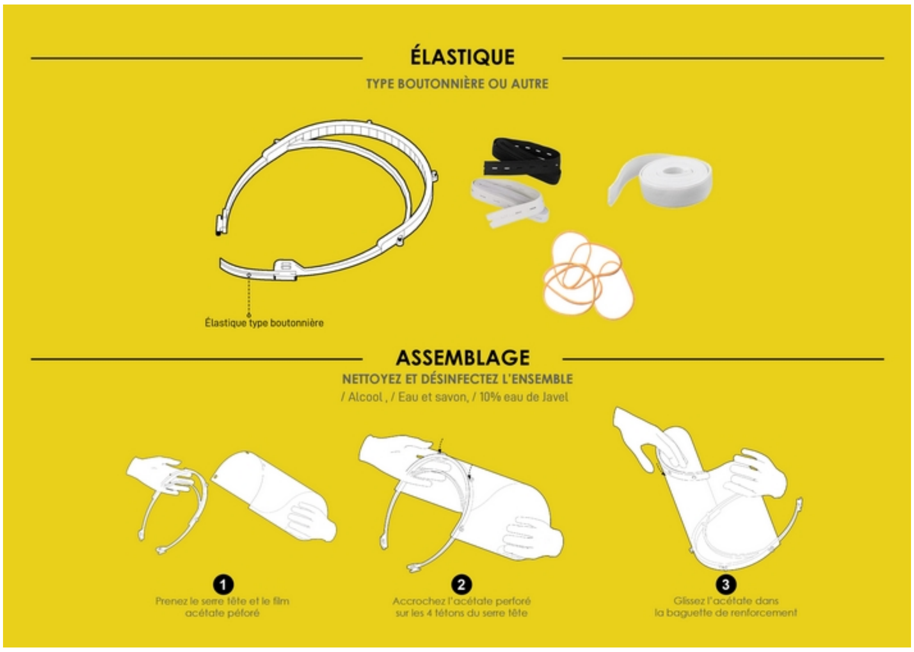


Figure 6. The FAB619 face shield design
(available from https://github.com/FAB619/Protection-Mask--COVID-19)

Further improvements include 1) adding a 3D-printed bottom reinforcement bar (simply slot in) for maintaining the overall shape and radians of the face shield. 2) Extending the length of the inner frame so as to keep a wider space between the face shield and the user's face to avoid fog. In many cases, the frame can fit the head well without the need for size adjustment, eliminating the need for the PLA plastic band. The whole set can be posted in a A4 envelope for the users to assemble by themselves (with an instruction) (Figure 7)

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Figure 7. ‘Compact’ packaging easy for delivery and self-assembly

3.3. Issues

Several issues needed to be resolved during the process.

Printing issues: In order to print as many face shields as possible, and as quickly as possible, the team had to make use of idle 3D printing resources. The Sino-British 3D printing design alliance shared their refined design as an open-source file to allow more makers with available 3D printers to join in the production initiative. The team optimised the design by adapting it to meet the varying specifications of different printers. For example, the original size of the face shield frame design is 154mmX183mm, with the thickest part being 13mm. This frame was divided into two parts from the middle, and a node was designed to connect the two symmetric parts, using a M3 screw nut. The advantage of this modification is that small 3D printers can also print the parts, leading to increased production capacity. In the meanwhile, the Alliance contacted factories with large amount of 3D printing equipment to join the force, including the Dartford NHS Logistics Center which has 200 machines that can print 24 hours a day, seven days a week. On the other hand, printing speed is critical, and it is related to the movement speed of the 3D print head, the extrusion speed, the layout of the supporting material, and the scanning path (Wang Suyu et al., 2020). Therefore, it is necessary to optimise the layout of printing materials and supporting materials, and to design an optimal scanning path to improve the efficiency of printing. The design of the face shield printing scheme has undergone a change from single-layer, single-chip printing to multi-layer, double-chip printing (as shown in Figure 4). To print 20 frames in one go (10 layers, double chip layout) will take about 43 hours, with the advantage of working continuously. However, not all the printers can meet the requirements of accuracy on top of printing 20 frames in 43 hours, thus there is a risk of failure. To solve this problem, the number of printing layers can be easily reduced for printers with less precision.

Matching supply and demand: It is important to deliver the PPEs produced to people who need them; the supply and demand match was done by collecting PPE requests from a variety of public media (e.g., Government website, health sectors’ website) and private channels (e.g., social media, email). The initial list was published at http://www.inclusivedesign.org.cn/en/covid-19/)

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In March there arose a severe shortage of PPE across the UK as the surge in COVID-19 cases resulted in a rapidly growing imbalance between supply and demand. Some doctors question the legitimacy of the PPE guide, arguing that medical workers have the right to refuse to work in the event of insufficient supply (Clare Dyer, 2020). The alliance gave priority to the supply of 3D printed face shields to nursing homes and hospitals, ensuring that healthcare workers get the necessary protection. In early April, 3D printed face shields were sent to care homes and hospitals in Cambridge, Birmingham, and Glasgow. Positive feedback has been received from frontline workers (Figure 8) , with some saying that the equipment is easy to wear and had no foam concerns (some face shield design has a foam seal on the forehead and healthcare workers were concerned about the cleanliness of the foam).

Figure 8. UK Healthcare workers' wearing the 3D printed face fields

Transportation: The Alliance also aimed to print face shields in China and send them to the UK, and appropriate transportation needed to be identified. At first, for small quantities, the team tried to send through Shunfeng Express and DHL Express. For large quantities, they tried to contact international logistics companies, expecting to find a balance between timeliness and economy. In addition, the departure place has an impact on the logistics cycle. For example, the express delivery from Shenzhen and Sichuan would arrive in about 5 days, while from Wuhan, it took more than two weeks.

Evaluation: PPEs must satisfy the requirements under the EU's PPE Regulation 2016/425 however; this EU regulation does not prescribe specific requirements for 3D-printed PPE. The team performed a heuristic evaluation of its 3D printed face shield and has prescribed recommendations for reducing potential risks (material selection, safe form, easy assembly), simplifying user instructions, and for safe usage of the product (e.g. using the face shield together with a mask, along with recommendations for hours of use: i.e. 6-8 hours for medical treatment personnel, 48-72 hours for retail personnel, and 72 hours or longer for people who are in other low-risk public environments.) On the 4th June 2020, UK Government published the guidance "3D printing (additive manufacturing) of medical devices or component parts during the coronavirus (COVID-19) pandemic" (Gov.UK, 2020),

Li, S., Hao, L., Chen, Q., Zhang, L., Gong, P., Huang, Z., Huang, D., Nie, P. & Dong, H. (2020). Open Design and 3D Printing of Face Shields: The Case Study of a UK-China Initiative. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 511-524. DOI: 10.4013/sdrj.2020.133.17

which can be used as a benchmark for future evaluation reference. It is worth noting that where facemasks are not available, healthcare personnels might use homemade masks when caring for patients with COVID-19 and might use facemasks beyond the manufacturer-designated shield life during patient care activities.

4. DISCUSSION AND CONCLUSIONS

Numerous factors have contributed to the success of the 3D printing face shield case study. At the beginning of this project, the COVID-19 outbreak in the UK was in its early stage and the National Healthcare Service was overwhelmed, while China had already passed the peak and medical supply was gradually resuming or even increasing; this had made it possible to offer help to the UK. The Alliance had brought together designers, engineers and makers from the UK and China to quickly share information and resources, thanks to the social media and the open design files online. There were ill-matched demand and supply, a lack of relevant standards and codes of conduct, and unknown legal implications. This project has provided a unique case study of open design in response to the emergent pandemic. While the process was open and collaborative, there were a lot of 'trial and error' iterations. The limitations of the case studies are summarised below:

There was a lack of medical input in the process. Healthcare professionals were overwhelmed, and the Alliance was created ad hoc and did not get input from healthcare sectors regarding the demands of PPE, recommendations or evaluation of designs in the early stage. Prototypes could not be quickly tested and validated by healthcare professionals and the match of demand and supply was largely on a 'first come, first served' basis. Due to the urgency, the face shields had to be put into use without rigorous testing. 3D-printed face shields may provide a physical barrier, but they are unlikely to provide the same fluid barrier and air filtration protection as FDA-cleared surgical masks and N95 respirators.

3D printing facilities were not readily available. Many places in the UK, for example universities, were closed because of the pandemic. Therefore, it was not easy to access 3D printing facilities. Through some 3D printing network, it was possible to identify available 3D printers, but they differ in type and size, making it impossible to use one file for all. Whilst it is possible to access a large amount of 3D printing equipment in China, timely delivery became an issue. This has made the team think about future manufacturing.

Traditionally design happens before commercial production and distribution. However, open design has enabled many stakeholders to be engaged in designing, manufacturing and distribution. Open design has made a positive impact on the production of small-scale emergency supplies, which is due to its 'distributed manufacturing' value proposition. Open design implies reconfigurable and scalable design: anyone can access the open digital blueprints and modify them to suit their specific needs. The resulting blueprint is not only user-centric, but user-led (Avital and Van Abel, 2014).

Despite the 'trial and error' approach, the project has inspired a new mode for future manufacturing. The traditional vertical value chain consists of designer - manufacturer - redistributor - consumer. Mass production took place in different regions, and then shipped to warehouses and distributed to various retail stores. There are many intermediate links in the entire process, and they are indispensable (Gebler et al. 2014; Gershenfeld 2008; Raasch et al. 2009). Open design reduces the number of links and provides designers and consumers with an open network and a direct chain (Avital and Van Abel, 2014). 3D printing is a rapid prototyping technology for constructing objects based on digital model files. This technology has the potential to revolutionise our existing traditional supply chain. It crosses the regional limitations of technology and space: whether the user is a novice or an expert, wherever they are, they can design locally and then customise and make what they want (Balka et al., 2009, Kuk and Kirilova, 2013). Open design avoids inefficiency and friction between product ideas and delivery to users, changing the way products find consumers, thus improving efficiency. Through 3D printing, users can continue to innovate based on the reuse of previously created designs (Fischer and Giaccardi, 2006). While rapid prototyping manufacturing technologies are developing and maturing, the cost of materials and time for manufacturing will continue to reduce. When utility and inexpensive manufacturing methods are combined with social media, this also means more and more objects can be produced without the help of professional designers (Cruickshank, 2014). In the future, a 3D printing distributed intelligent manufacturing model can be established to utilise Internet of Things (IoT), cloud computing, big data and other emerging information technology and public service platforms, together with 3D printing manufacturing enterprises with different production scales and capabilities in different regions, so as to provide a new mode of flexible, low cost and high-quality manufacturing system, as an alternative to mass manufacturing.

To conclude, this project has been a spontaneous response to the COVOD-19 pandemic. Open design and 3D printing have been used to quickly produce face shields for healthcare workers. The collaboration between the UK and China was organised timely and proved useful. There were some good practice and some lessons learned. Specifically, open design files need to be assessed, compared, and adapted for local printers; material, layout and design need to be optimised to achieve maximum efficiency; distributed manufacturing is promising for the future and clear specification, rapid demand and resource matching are needed, together with regulation to ensure quick evaluation. These will help improve the efficiency, quality and sustainability of using open design and 3D printing for manufacturing.

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APPENDIX

Video screenshot	Title and link
	Prusa Face Shield URL: https://www.prusaprinters.org/prints/25857-prusa-protective-face-shield-rc2 (This design is mentioned but not discussed in this study; the website has useful links to 3D-printed face shields and video links to assembly)

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Makers against Covid-19: Face shields as the international solidarity KPI

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ABSTRACT

At the first signs of the Covid-19 pandemic, the uncertainty around the global stock of medical supplies sparked a response in the DIY communities around the world. In the case of Spain, a community called Coronavirus Makers (CVM) appeared to supply ventilators and personal protection equipment (PPE) to hospitals and people in need. This paper explores the evolution of this community-driven development, detailing the patterns proposed by members of the group acting as design experts to tackle different problems. More specifically, the paper uses face shields, the most produced PPE in Spain, as a boundary object to highlight the relationships between individuals, institutions, and companies. These objects of design, being devices for medical use, must overcome validation at the technical level. Authors will also explore some of the controversies surrounding the transfer of these products from horizontal innovation networks to traditional production companies.

Keywords: community-driven development, covid-19, horizontal innovation network, maker movement.

1. INTRODUCTION

During the first moments of the Spanish Covid-19 lockdown in mid-March 2020, members of the Spanish Maker community gathered around a Telegram channel to discuss the possibility of creating a minimal ventilator in anticipation of a lack of these medical devices at hospitals across the country (Borao, 2020). Soon enough, the group grew by thousands and recognised the impossibility of having everyone collaborate in the design of a single project. Participants reorganised into different Telegram channels aimed at building PPEs and other tools against the pandemic (García, 2020). When it comes to ventilators, dozens of groups around the world started developing open-source ones (Pearce, 2020). While ventilators are of uttermost importance, it can be argued that the most replicated design, and that has put the Maker community in the spotlight, is the face shield.

The Spanish DIY communities have a large societal outreach (Cuartielles & García, in Press) which could explain why thousands of people joined this attempt to collaboratively design medical devices and PPEs (Palao, 2020). Several of the initiators of the early Telegram channel were previously involved in Clone Wars, a Spanish branch of the RepRap open-source project. This paper tries to support the hypothesis that the Coronavirus Makers (CVM) movement is the result of the technologically enhanced social fabric of Spain which brought together existing DIY cultures with volunteers from other parts of society.

The paper focuses on the challenges faced with the distributed design, manufacturing, and delivery of PPEs during the first hundred days of the lockdown of the Spanish pandemic. Being locked at home got the community to utilise personal digital manufacturing techniques: 3D printers, and electronic prototyping tools. The ease of design and manufacture of face shields made them into the main contribution generated by the CVM movement.

The production and shipping of goods was not exempt from challenges. After some weeks there was a shortage of materials, there was no freedom of movement for people or goods, and the designs for PPEs and other devices were not validated by public authorities, what hindered their acceptance by medical institutions. Paradoxically, city councils, regional officials, as well local and national security forces helped with the distribution of the PPEs to hospitals. Other sources of trouble were the never-stopping innovation and the intellectual property of the designs. Added to the multiplicity of manufacturing sources, delayed the design validation through public bodies, decreasing the outreach of the design.

2. RESEARCH QUESTION

Our aim with this article is to communicate the learned lessons that can be extracted from the process of creation and distribution of face shields in Spain. In such case, our main research problem is: what can designers and makers learn from the community driven design of the face shield, considering it to be a boundary object and even an indicator for solidarity and collaboration?

From that initial question, two secondary questions follow: which strategies can designers apply to distributed manufacturing processes? How could policy makers support DIY designer efforts to confront future crisis?

3. METHODOLOGY AND LIMITATIONS

We, the authors of this paper, got engaged with CVM's movement from its conception. Our work implies mapping the Spanish DIY culture taking the role of the participatory activist researcher engaged in the conversation while documenting the actions (Chatterton, Fuller & Routledge 2007). Our position is no secret among the community participants. In any case, we have expressed this fact openly multiple times during our data collection phase within CVM. By producing this paper, we are stepping back and temporarily taking the role of the observer. It is, however, hard for us to write about our participation in third person and have chosen the less-conventional narrator's voice for our writing.

We were actively involved in CVM, where we created a public-yet-moderated online forum for people to collaborate. When it comes to our individual contributions, we invested most of our time performing tasks from the ad-hoc governance platform created for the movement. The average workday with CVM for us could include coordination assemblies, funding decision meetings, fundraising calls, or preparing internal documents for the movement. As researchers we would meet daily to summarise the latest events and keep each other up to date. We operated as design experts according to Manzini & Coad's definition (2015, p. 45).

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4. BACKGROUND

This article builds upon aspects from distributed innovation, and the understanding of the existing ecosystem around DIY cultures in Spain. This section explores these aspects to lay a foundation for a later reflection process.

4.1. Distributed innovation in communities of practice

The Maker Movement has been portrayed by the media as a community of entrepreneurs, inventors, and creators which use every tool at their disposal to convert their ideas into physical products. According to Dale Dougherty (2011), founder of Make Magazine: "All of us are makers" which is not that far from Manzini & Coad's "we are all designers" (2015, p. 30). In most cases, these makers are presented as individuals who share their inventions with others.

According to Von Hippel (2002), these "users/self-manufacturers" can also organize as part of a horizontal innovation network:

> "user-only innovation development, production, distribution and consumption networks can flourish when (1) at least some users have sufficient incentive to innovate, (2) at least some users have an incentive to voluntarily reveal their innovations, and (3) diffusion of innovations by users is low cost and can compete with commercial production and distribution. When only the first two conditions hold, we propose that a pattern of user innovation and trial will occur within user networks, followed by commercial manufacture and distribution of innovations that prove to be of general interest."

Von Hippel's view on networks departs from the traditional producer-innovation paradigm, focused on market needs and return on investment of research and development (R&D) costs. Free innovation processes focus on collaborative evaluation, replication, improvement and sharing the results among peers so the community can learn in a virtuous feedback loop (2016). Makers often produce devices for their own use or to give them away to others, without any further commercial interests.

Authors like Hess and Pipek (2012) have categorized these initiatives as community-driven development, exploring the pre-conditions for innovation transfers to happen between communities and companies. Compared to the individual approach of Von Hippel's free innovators (2016), Maker communities work in a distributed fashion, collaborating on the creation of new devices and services using online platforms. One of the main examples of these practices is the RepRap project, that encompasses the work of hundreds of volunteers from all over the world. Next section will describe the origin of the Spanish branch of the RepRap project.

4.2. Spanish DIY communities of practice – Clone Wars

During a 2009 workshop at Medialab Prado, Professor Adrian Bowyer introduced the RepRap project to a group of 3D Printer enthusiasts, including Juan González, a robotics teacher at Universidad Carlos III de Madrid (UC3M). Juan, together with colleagues and students, streamlined the production of robots for their courses through a pedagogical narrative where each student manufactured her own DIY 3D printer. This emergent 3D printing community adopted their name of Clone Wars. The rationale is that students would replicate (or clone) their colleague's printers to make their own.

Juan González launched a video series, explaining how to assemble, setup, and operate 3D printers (González, 2012). Most printers within Clone Wars' genealogy could be traced back to the first 3D printer which was called "Madre," Spanish for mother. More than one thousand clones of printers were produced by cloning.

Clone Wars' participants gathered at events and conferences. They experimented with distributed mass manufacturing through a new format called El reto –Spanish for the challenge. It consisted in collaborative processes happening once a year open for anyone to join and produce one piece of a larger design (Penamaria, 2018). A later format, the 3DPrinterParty, originated in León (iLeón, 2016) is a yearly event that brings together 3D printing enthusiasts and their 3D printers under one roof.

Figure 1. Clone Wars 2019 Reto: Four-meter-tall statue of J.M. Amuedo, collaboratively produced from 3D, courtesy of J. M. Amoedo.

As years went by, we observed how Clone Wars' newcomers shifted interest from the building process of the machines to the possibilities offered by the printers and their software ecosystem. In words of Williams & Edge (1996), openness losses relevance in front of technological black-boxed solutions when users can do what they want (3D printing in this case). This relates to the idea of commodification of the experience of digital manufacturing and its outreach to the masses (Cuartielles Ruiz & García Sáez, in Press).

Looking at the case from the perspective of building artifacts aimed at protecting human lives, as CVM's PPEs intention was, does it really matter that they are produced in non-open machines?

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5. CORONAVIRUS MAKERS

CVM quickly reached 16.500 members. It self-organised through the Telegram social network. The community grouped around two main activities: R&D, and manufacturing. Figure 2 shows the way groups were presented on CVM's website by March 16th 2020 (Coronavirus Makers, 2020a) and their relative sizes on March 22nd, eight days after the beginning of the Spanish lockdown. Early research created during this period hints that 35% around of the respondents within CVM belonged to a Maker collective or institution before Covid-19 (Conde Melguizo, 2020).

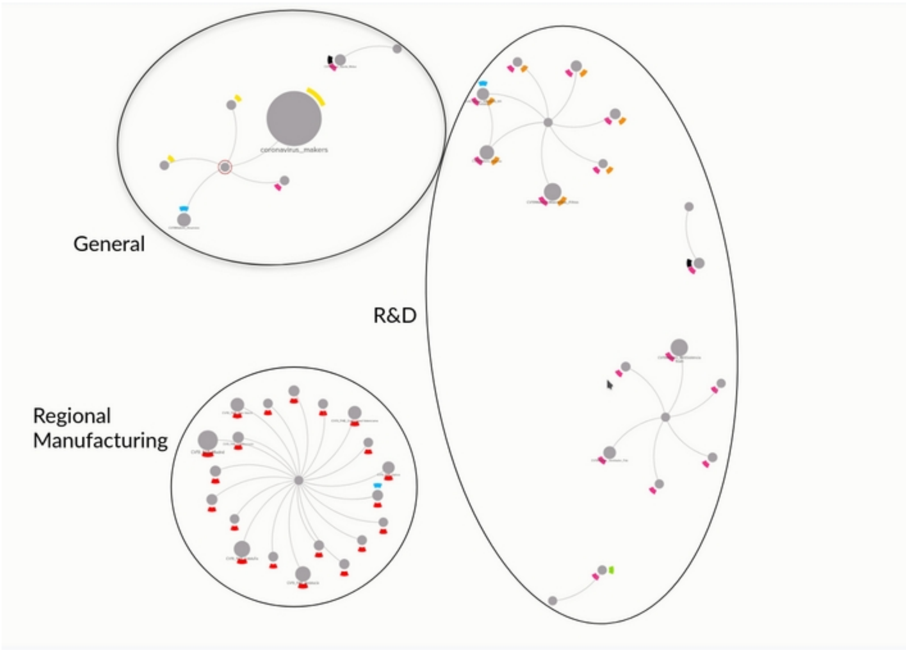

Figure 2. Emergent group configuration within CVM mapped using online tool Kumu.io from public data.

Complementing Telegram, a forum and a website were created. Realtime conversations happened on the messaging app while slower interactions happened on the forum. This dual platform configuration has been observed in other community-driven development instances (Hess & Pipek, 2012, p. 8).

Locality played a significant role in the movement's mode of operation. Raw materials came from donors all over the country, sent to regional groups that would then produce 3D printed PPEs. Community members with special permissions from the authorities picked up the manufactured goods and delivered them to hospitals, police stations, and other public bodies in need. Production groups were organised by region. Every group had their own specific Telegram channel to organize local production. Some groups even built their own logistic platforms, tailored to their needs. Working along the regional organisation units, the R&D group was also divided in smaller teams, each focused on designing specific products. A coordination group emerged, trying to couple the needs and capabilities of both R&D and the region-centric group.

During the peak of the lockdown, the regional groups had daily video conferences to discuss how to share resources, highlight the latest designs, or chat about the constant regulatory changes around medical products and devices. The R&D group met to evaluate whether to manufacture or not certain products based on the science at hand. We also set up a mechanism for accepting economic donations from companies and big donors through an external foundation to ensure there was no mischief in the handling of money.

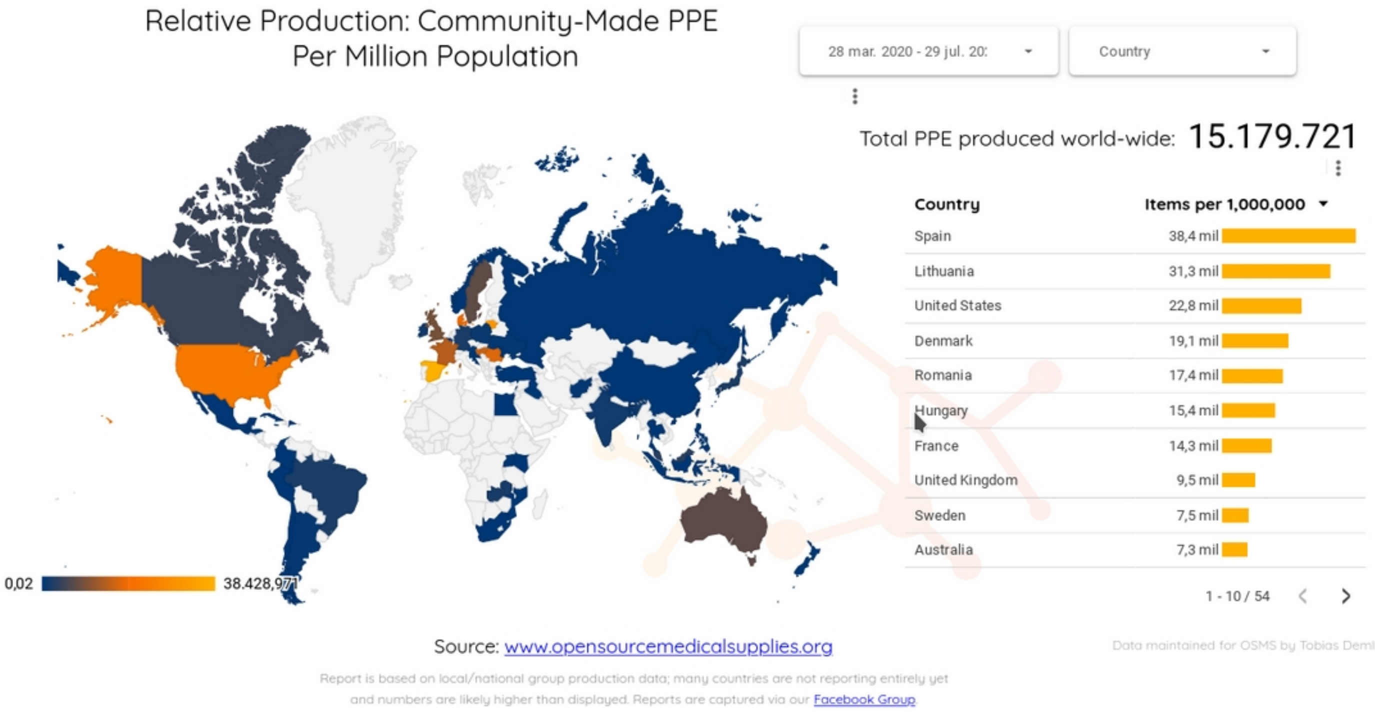

Figure 3. Open Source Medical Supplies - Relative Production: Community-Made PPE Per Million Population dashboard (Open Source Medical Supplies, 2020)

We do believe that it is this ad-hoc governance model that ensure the metrics in terms of produced (and delivered) PPEs in Spain. When comparing the data to any other country in the world, as seen in figure 3, Spain stands out as manufacturer of DIY PPEs.

6. OTHER VOLUNTEER-BASED INITIATIVES

The civic response to Covid-19 in Spain emerged from several groups, of which CVM was the largest one. Most of them had similar goals, but different means or mechanisms. In general, circumstances allowed Makers to shine, what validated the public image of the group amongst fellow citizens.

One of the most active groups was *COVIDWarriors* with more than 400 members, composed of professionals, senior managers, and patrons (COVIDWarriors, 2020). They got incorporated as a non-profit organisation on April 12th, 2020. COVIDWarriors' most important achievement is to secure funding to deploy 18 open source robots in Spanish hospitals to expand Covid-19 testing capabilities (Redacción Córdoba Buenas Noticias, 2020).

Other groups like *Frena la Curva* (2020) focused on social support and mutual aid via a geolocation platform. *Ayuda TIC* brings IT professionals together to offer pro-bono support to other initiatives, developing web services and common infrastructures. *Plataforma Makers CoVIDA contra Coronavirus*, also focused on 3D printed elements. They created 3D printed adapters for snorkel masks (Morán, 2020). Their similarities in name and goals to CVM caused a lot of confusion among newcomers and donors, with several media outlets misreferencing both groups (Compromiso Empresarial, 2020).

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7. THE FACE SHIELD: DISTRIBUTED DESIGN BY DESIGN

When CVM was getting ready to print parts for ventilators, a random spark put the focus on the production of face shields. One of the national coordinators of CVM got the request from a neighbouring nurse to create some sort of face protection to flying droplets from patients. As a result of that interaction, CVM identified the need of producing PPEs to supply healthcare professionals. He prototyped a first version to a face shield that was immediately tested on site. After sharing the design with the rest of CVM, in a matter of days, several groups were manufacturing and distributing face shields locally.

7.1. Description of a face shield

Face shields protect their wearers from flying particles of the Covid-19 virus which spread when people talk, breathe, and cough. The main protection element is a sheet of transparent and flexible plastic that is held in front of the carrier's face by means of a mechanical holder. This element has the triple function of keeping the shield straight, allowing breathing while performing any kind of daily operations with as much comfort as possible, and shielding the wearer from flying particles that could enter through the space between the forehead and the screen.

The DIY communities resorted into using CAD tools and 3D printers to produce the mechanical holders. Designs can be printed in as short as eight minutes by compromising features. The most replicated face shield is the so-called Hanoch design (2020). It considered the use of distributed digital manufacturing facilities, as well as the availability of materials, namely PLA filament for 3D printing and transparent overhead sheets.

In the early days of the pandemic, PPEs were considered single-use equipment. Over time, and due to the depletion of both plastic and overhead sheets across Spain, CVM included instructions for disinfection, reuse, and recycling with the PPEs. Some of these designs, however, did not remain static. Variations emerged based on specific validation requirements per region, materials' availability, or simply aesthetic customizations, challenging the idea of a universally valid design.

7.2. Validation

Validating a design opens the door to acceptance of the PPEs. We distinguish two types of validation: internal or external. CVM participants validated designs through discussions on chats and video conference prior to make it a de-facto standard for the community. On top of that, CVM created workflows for internal quality control of the distributed manufacturing processes. An outcome to a badly produced face shield could be the identification of a poorly tuned 3D printer. CVM groups focused in giving advice in fine tuning machines, a service also offered to newcomers. After collection from individual makers, face shields were subject to an additional inspection and disinfection before being delivered to hospitals.

External validation, on the other hand, is the official process that each one of the designs must pass either by the Ministry of Industry or the Spanish Agency of Medicines and Health Products (in Spanish, Agencia Española del Medicamento y Producto Sanitario - AEMPS). The unique designs must follow either path based on whether they will be used by medical professionals (Ministry of Industry), or by patients (AEMPS). As an example a ventilators being one of the most intrusive technologies to be used on patients, should overcome a complex test protocol designed by the AEMPS, while a face shield, being just a PPE, should be validated by the Ministry of Industry.

Given the exceptional circumstances the entire world is currently experiencing, a full set of regulations have been either relaxed or totally disregarded. Regarding the PPEs, the EU allowed importing non-CE labelled gear to accelerate the entry of new tools and protective equipment to the member countries. This applied to ventilators, masks, face shields, gloves, etc. This provoked an unexpected paradox: while there was the chance to buy suboptimal equipment, national producers had to be validated externally. As an outcome, hospital personnel would try to get any kind of protective gear — whether DIY-made or manufactured — while the hospital administration would ban the use of the 3D printed materials for lacking an official validation. At the same time, medics would fall sick and suffer personal stagnation while being forced to undergo risky work situations (Minder & Peltier, 2020; Amnesty International, 2020). CVM approached the problem by bringing all internally validated designs to pass whatever external validation process was required.

There is yet a distinction to make between regional and national validation. This is a specific problem for Spain, but it could apply to other countries. The national validation process requires testing the artifact against the existing norms at an officially appointed laboratory. To stimulate the production of the needed equipment, both the EU (International Organization for Standardization, 2020) and Spanish norms (Asociación Española de Normalización, 2020) were temporarily made public at no cost. The Hanoch face shield was designed long before the norms were made freely available to anyone, and so it was designed with no observance of the norms in mind. It just happened to be compliant at the time of testing.

Regional validation relates to the administrative division of Spain in autonomous units. While the medical competences as well as most of the security competences are handled at regional level, the state of alarm gave power to the central government to make some of the decisions (Marcos, 2020). This dual scenario complicated things for the maker community, which had no legal representation, when attempting to access any of the multiple national validation bodies. CVM decided to approach all the medical administrations in parallel.

This worked only partially. The Canary Islands' government issued a document validating the face shields presented to them by the local maker groups. In Cataluña, certain hospitals validated some of the PPEs for a subset of the medical system in the region (Part Taulí, 2020). The region of Madrid approved the use of DIY face shield and just three days later cancelled the previous order, prohibiting the use of face shields by medical professionals (Peinado, 2020).

This situation of uncertainty generated both anxiety among the medics and indignation among the members of the maker community. A final decision was made to force one of Hanoch's designs into a national validation process (Hemmerich, 2020), which completed successfully in April 2020 (Coronavirus Makers, 2020c). National validation ensured international recognition; the above-mentioned design was adopted in other countries like Argentina (Santandreu, 2020).

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Figure 4. Volunteers at fab lab Sant Cugat assemble several face shields models. There are at least three different variants of Hanoch face shield present. (Courtesy of fab lab Sant Cugat).

Unfortunately, the validation document came when most of the regional groups were calling off the action of the printing of face shields, after over a million pieces had been produced and delivered.

8. DISCUSSION AND CONCLUSIONS

Given the fieldwork synthesised above, we can conclude that this paper's research questions cannot be answered with a simple statement. The situation's extreme complexity and the speed at which events happened are our point of departure to formulate those questions. Therefore, in order to help designers, makers, and policy makers, we believe that the best way to respond is to produce a series of recommendations aimed at helping design experts grasp the power of distributed creation and manufacturing networks, and policy makers support the DIY movements of the future for them to make a difference in the crises to come. We are aware that we are not in the position of making strong generalisations of our learned lessons. However, we believe the following sections could help other designers and policy makers deal with similar situations in the future.

8.1. Recommendations for designers

Design researchers and experts should engage in the process at an early stage. There is no reason to believe that the high speed of events during the pandemic will be any different in the future. They should conceive mechanisms, whether automated or not, to synthesise the information. We used a slow platform (a forum) to slow down the high pace of a fast one (group chat over mobile devices). We did the work manually because the duration of the alarm scenario was uncertain and did not feel worth investing in developing anything. This leads to the recommendation of creating and documenting tools to monitor and synthesise public platforms to help future embryonic movements make informed decisions.

Communication, organisation, and governance are key. Once the techno-social network has been set up, the whole movement can adjust and shift focus. In the case of CVM, the network was formed around the production of ventilators. At some point, a large part of the network pivoted into the production of face shields. The initial momentum paid off, by having many groups within the community direct their efforts in different directions.

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Governance designers should assume different levels of involvement for individuals. In CVM there were thousands of participants 3D printing designs created by just a few tens of people, but all of them were considered at the same level within the movement. However, this could become the cause of arguments in terms of giving value to the different contributions. A question to ask oneself is whether it is more important to be the one creating the device, the one producing it or the one distributing. All are needed for the action to succeed.

A lax model for joining and leaving governance roles is needed to support these ever-changing structures At CVM we kept an agile approach to the forming members of the two groups dedicated to the coordination of the main actions of the group. People were excused from their duties out of exhaustion or sickness.

Care for others and oneself must be stated clearly as part of the aims of any design work. One of the most common issues was exacerbated stress. A volunteer group of psychologists offered their professional help to deal with the situation, in response to an open conversation about care and well-being in the CVM forum.

Knowledge transfer from the community of practice to the industrial fabric could generate unease among the Makers (Von Hippel, 2016). At CVM, the volunteers' efforts crashed against the reality of the industry in need to pay for materials and wages. We observed many conflicts around this topic among community members.

Design activities should focus on quick iterative loops, where feedback from those on field should be incorporated early on. There is also a need for domain experts to join the design groups. The design of face shields within CVM counted on having medical professionals involved in the testing process of early designs.

Bureaucracy should be considered only as a second step. Existing regulations for designing medical devices were left aside. Many times, they were unknown to the makers.

Do not assume existing designs as working elements. Even if there were several PPEs available as 3D designs most of them had never been tested under a clinical trial. As the CVM designs got iterated, previous models appeared repeatedly in the design sessions, slowing down the efforts to produce new designs that could comply with safety requirements and regulations. Proper versioning tools and documentation of decisions should be made as part of the process. Conflicts occurred due to not using any tools to document decisions and their rationale.

A common pattern emerges from previous recommendations, the existence of what we call weak commitments. We have observed how the creation of sets of strong rules, or strict modes or operation within CVM, either scared some participants away, or provoked conflicts within the movement. Therefore, we suggest creating room for weak commitments, allowing people to prioritize their wellbeing and personal needs in the first place.

8.2. Recommendations for policy makers

When sitting on the side of societal governance, we believe that the position taken by the UK in the creation of ventilators is a strong model to follow (Medicines and Healthcare Products Regulatory Agency, 2020). In this scenario, the government acted as intermediator between large scale manufacturers and those owning designs and processes to create more. Governments can empower those with the highest probability of success. In Spain, we –the researchers writing this article- in representation of CVM, along with COTEC Foundation, acted as middlemen between the AEMPS and over hundred inventors of ventilators at a two hours long meeting to raise any questions to the ad-hoc ventilator validation process the agency had just published (Cuartielles & García, 2020).

Policy makers should design pre-emptive responses to potential shortages of medical equipment. Basic manufacturing materials should also be considered. CVM worked for weeks thanks to the material donations from the makers themselves, but also from national companies that happened to have some stock. Eventually the stock ended world-wide.

Many European countries have never supported the DIY movements. Considering the role played by CVM, it is time to consider a larger implication from public institutions in the promotion of a societal interest in technology beyond innovation centres and universities. It would be interesting to promote transdisciplinary communities like the maker movement in schools and neighbourhoods to build a more capable techno-social fabric.

There is a need to promote public-private partnerships between small and medium enterprises (SMEs), local DIY communities, and public institutions to help the parties align in case of need. This should include clear workflows to go from a community design to a scaled up manufactured good assuring transparency and accountability at every step of the process. CVM improvised such a workflow for the face shields. SMEs in different regions ended up manufacturing injection moulded versions of the face shield designed by the CVM movement (Merca2.es, 2020). Yet another pattern could be the promotion of different solutions through competitions. An example of how this suggestion could be implemented comes from the above-mentioned case around the creation of ventilators in Spain. The COTEC Foundation curated a communication channel where many of the creators of those designs shared their status and disclosable research information (Innovadores, 2020).

8.3. Closing remarks

The above recommendations open a series of questions. From a knowledge production perspective, we cannot help asking ourselves whether a different governance model for the community would have produced a faster outcome. We would typically not consider the time dimension to be too critical when looking at distributed design, but being the case of Covid-19, time played a key role.

Face shields became a way to make visible the implication of different levels of society in the fight against the disease. Everyone wanted to be a part of this fight. From the person that bought a cheap 3D printer to multibillion companies like Nike (2020) or Apple (2020) that ended up producing face shields.

One could compare this situation with Manzini and Coad's (2015, p. 30) concept of anyone having the power to act in designer mode. Under pressing circumstances where we all are transformed into prisoners of our own homes, the uncertainty of the future and the fear for the possible consequences, made us all go into Maker-Designer mode. Everybody in the ecosystem contributed by their own means.

Finally, and reflecting upon our role as design experts, in what can be our largest contribution to the field, it is close to impossible to deal with the day-to-day of a movement by trying to apply design frameworks. We do believe that the only possible mode of operation is the one of the participatory activist researchers where design is made through

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the active participation in navigating the daily challenges of the movement. Planning is needed but it is hard to pursue when at a state of emergency. Design experts need to figure out how to balance their commitment and become part of the solution through collaboration and immersion.

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STRATEGIC DESIGN RESEARCH JOURNAL

Design in emergency scenario: project of a hand sanitizer dispenser in public transport using Design Sprint method

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ABSTRACT

In the emergency scenario generated by COVID-19 pandemic, the development of fast solutions to reduce the contagious curve can mean saving lives. Democratic access to prevention methods is essential, especially in places with high exposure to contamination and whose activities have not been interrupted, such as public transportation. This work presents the development of a hand sanitizer dispenser for public transportation and other possible locations in the urban environment, designed during an online marathon. The focus is on the development of the Design Sprint method and its adaptations to fit the remote work and other constraints due social distance. The final product was designed to be produced by 3D printing and open design, to fast distribution and replication. It fits in the bus's handrails, with some positioning possibilities and the use of PET bottles as alcohol containers. As a result, the paper highlights the particularities of agile methods for the design process at a distance and demonstrates that the process used allows for quickly responding to solutions for emerging needs.

Keywords: 3D printing, COVID-19, Design Sprint, hand sanitizer, product design, open design.

INTRODUCTION

The year 2020 brought to the world the reality of the first major pandemic of the 21st century. While medicine strives to find a cure, society undergoes a very rapid and urgent adaptation process in daily activities, prioritizing social distance as an efficient tool to combat the spread of COVID-19. The pandemic accelerated changes, in a matter of weeks, that would normally take out over years or decades. In addition to that, technologies that until then were underutilized are now part of the routine - such as online meetings and videoconferences.

Therefore, Design emerges for the creation and adaptation of products/services to this new reality. According to the definition of the World Design Organization (WDO, 2015), "Design is a strategic problem-solving process that drives innovation, generates business success and leads to a better quality of life through products, innovative systems, services, and experiences ". It is important to highlight the character of the problem-solving presented by the field of Design, introducing it as a factor that promotes a better quality of life or a fast adaptation facing this new scenario.

The focus of design projects is the human being, its complexity, and its diversity. The user is the center of the process, as a crucial factor for design decisions. There are nearly 17 million people infected by COVID-19 in the world and more than 2.400.000 in Brazil (data from July 28th, 2020, according to Johns Hopkins University, 2020). Fortunately, there are a great number of initiatives and proposals to face the pandemic.

In this context, the IFSul (*Instituto Federal de Educação, Ciência e Tecnologia Sul-rio-grandense* - Federal Institute of Education, Science and Technology Sul-rio-grandense) proposed in May, 2020 an online marathon, five days long, to motivate the academic community to develop viable and innovative solutions, with social impact, related to the production of ideas, actions, products or services facing the pandemic problematic.

Based on the event's proposal, a team of students from the LEP (*Laboratório de Experimentos em Prototipagem* - Laboratory of Prototyping Experiments) was formed, along with their supervisors, to develop a product that helps control the spread of the coronavirus. Thus, the objective of this article is to present the project of the alcohol dispenser for public transport, developed during this hackathon, and also highlight some relevant contributions on the design process carried out at a distance in this emergency scenario.

1. DESIGNING IN AN EMERGENCY SCENARIO

The incidents of the pandemic created an emergency scenario that demands project development to be fast and remotely executed. In this way, the methodology for the design process must adapt its stages, as well as the use of resources and tools to make them agile, prioritizing team interactions.

However, the main constraint imposed by this scenario was social distancing. During the hackathon, the design team met exclusively remotely. The access to the laboratories was restricted due to school instructions and the limited public transportation available due to COVID-19. In the initial stage of the pandemic, there was no possibility of face-to-face interviews with stakeholders, like drivers, passengers, companies.

These requirements initially help the team to find a suitable method. References for agile methods were sought focused on the development of a product that would solve the problem proposed in the time available. At first, it was considered the use of Human Centered Design (HCD) methodology, that begins by examining needs, desires and behaviours of people whose lives are connected to the problem situation. But the ground of HCD is close contact with users, immersion in the context and field research, which are activities that go against the proposal for social distance.

Researching for agile methods, a team member found out and proposed the Design Sprint method (DS), created by Jake Knapp at Google in 2010, which intended to guide a small workgroup through the design process in five days, same available time as the online marathon. Furthermore, in the method's website (The Sprint Book) there is a learning guide, with tools, checklists, facilitator's handbook and videos, to clarify the process to all team members in a practical way, by online and simple access.

In this context, DS seemed to be a promising alternative, as it creates a design process where a team joins efforts to answer critical questions of the product/services through design, prototyping, and testing ideas (Knapp et al, 2016). Despite the activities were elaborated to

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presencial work, the team considered to adapt the method by its focus on challenges and opportunities, agility drive and its recent creation.

The method is structured in five stages (Figure 1): first, it is made a map of the problem; second, each one sketches solutions; in the third day, it is decided which sketches are strongest; on the fourth, it is built a realistic prototype; and the last, it is tested that prototype with target customers (The Sprint Book, 2020).

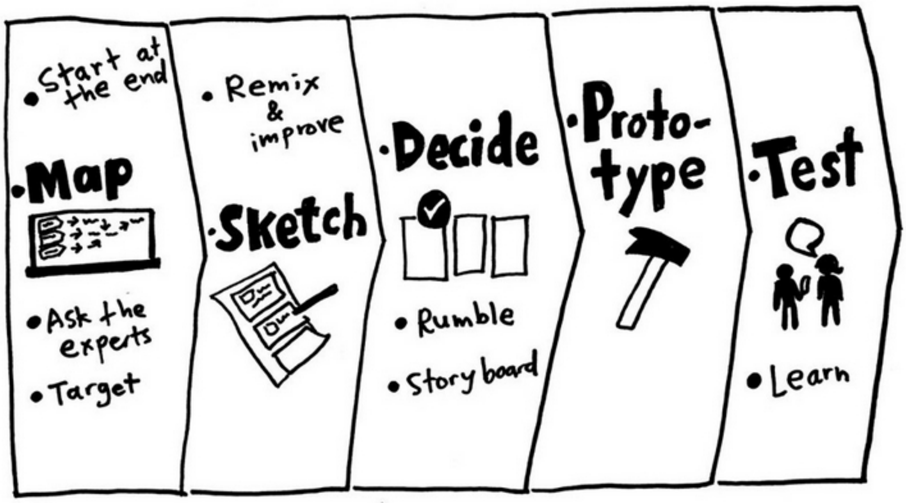

Figure 1. Design Sprint Method. (Rietch, Sprint Stories, 2018).

DS takes advantage of the creative capacity of the team in an organized way, aiming to solve the main problem in a short time. Also, prioritizes the direct and daily contact of all project members in the same physical space, without distractions and holds the main objective aligned by the team.

Therefore, this method requires simultaneous visibility of the design materials, media, annotations, photos, research data. This enhances the process of identifying patterns and synthesizing ideas among the group sharing the same space and resources.

The initial challenge was to build this integrated project space, with the entire team involved working remotely, plus the short deadline. Thereby, some decisions were quickly made to define the project space:

- All meetings were held remotely (Google Meet and Whatsapp video), with an open channel for instant and direct communication, for viewing concepts and for discussing ideas (video conference);
- Sketches, visual and research references were shared by pictures through a project management tool (Trello), to organize the creative flow in a shared-use repository;
- Prototyping should go only to virtual models, awaiting sanitary conditions to allow 3D printing of the first mockups and prototypes to test.
- All members had a stable and fast broadband connection.

Once the project space is defined, the requirement for starting the design process is to adapt the existing tools to the project constraints (time, social distancing, remote work).

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2.PRODUCT DEVELOPMENT

In the next sections, the steps and activities developed based in DS method will be presented.

2.1. Map

In the first stage, the focus was on building a foundation, sharing knowledge, understanding the problem, and choosing a target for the week's efforts. Structured conversations were held to create a schedule for the project. This allows the team to start seeking as much information as quickly as possible, avoiding unfocused conversations (Knapp et al, 2016).

On the first day, we focused on defining the design problem. Thus, information about the coronavirus pandemic was collected, generating a comprehensive mental map of the scenarios that were directly or indirectly affected. Among these, the essential services with higher transmission risks were highlighted.

One of them was public transportation, a critical area for any other sector of society that continues to operate as essential services. Public transportation systems must be considered a high-risk environment for the spread of COVID-19 due to a large number of people in a confined space with limited ventilation. In addition to that, there is no access control to identify potentially sick people and users should touch and hold to various surfaces (card machines, handrails, ratchet, door handles, in addition to the supports to go up/down and hold on during the journey) (UITP, 2020).

According to the National Association of Urban Transport Companies (2020), the June 2020 numbers on public transport shows that among the 5,570 Brazilian municipalities, 2,901 are served by organized public transport services by buses, totalling a fleet of 98,975 buses. Considering the data from the city of Pelotas, in the state of Rio Grande do Sul, the focus of the project's development, the current fleet is 210 buses and 12 microbuses, which make about 3,500 trips per day, with approximately 103,000 users daily (Pelotas City Hall, 2020).

Facing this problem, public transport was defined as the project's field. An online survey of sanitizer products for public transport was carried out. We also gathered information on the norms covering public transport during the pandemic in Pelotas City, its macro-region, and elsewhere in the world. These resulted in a brainwriting about possible problems and solutions within public transport.

Another activity suggested in the DS is "ask the experts", an interview with an external guest skilled on the topic in question to share what he knows. An online interview was conducted via messaging app with a public bus ticket collector. One of the team members questioned details about daily life at public transportation, their current and previous efforts. The main information collected was that users do not feel safe when using public transportation, and collectors and drivers feel unprotected in their work environment.

Given the information obtained in these early stages of the project, a user journey map of the activity analysis was developed to obtain an overview of the process of using public transport by bus, which also generated a risk contact map (Figure 2). From this journey map, it is possible to see the main points of contamination and to trace the route of contacts and manual touches from waiting at the stop to getting off the bus.

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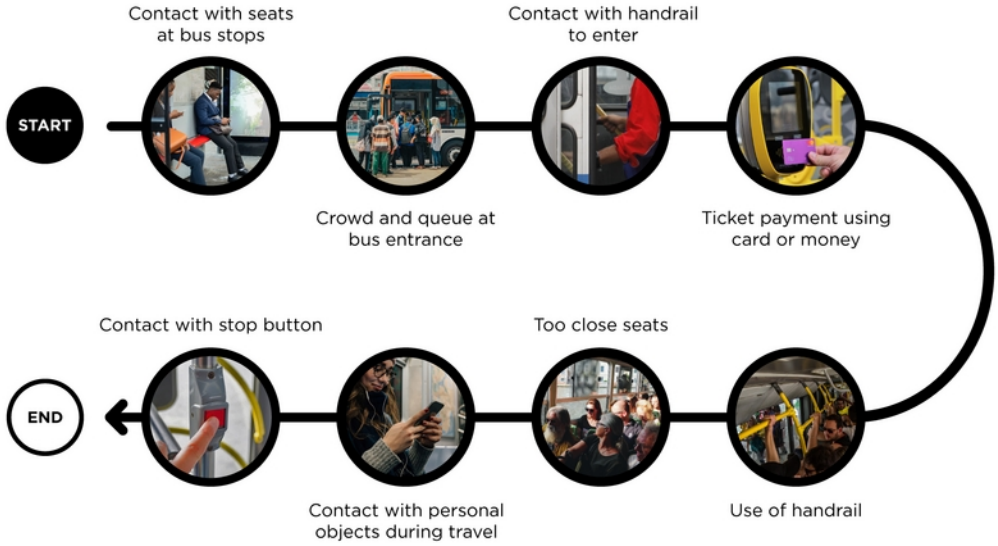

Figure 2: User journey map with risky contact points using public transport.

Through the user journey map, it can be seen that there is a high incidence of touch on handrails and buttons, which are made by all passengers. It is known that one of the main forms of infection of COVID-19 occurs in contact with contaminated objects or surfaces, followed by contact with the mouth, nose, or eyes. However, it is possible to minimize the transmission and spread using adequate and frequent hand hygiene. The WHO (World Health Organization) recommends the use of 70% ethyl alcohol for the hands asepsis, and also the cleaning of surfaces and objects when it is not possible to use soap and water.

An ongoing initiative at IFSul is the production of 70% glycerin alcohol, from the distillation of alcoholic beverages captured by the Federal Revenue, which are filled in 2-liter bottle packages (supplied by a local soda factory). Thus, combining the issue of public transport with the opportunity to obtain 70% alcohol at low cost, the focus of the project problem was reached: the development of a hand sanitizer dispenser that aims to facilitate and democratize the access and distribution of alcohol 70% in gel or glycerin within transport public, in order to minimize the risk of transmission of the COVID-19.

2.2. Sketch

The next step, on day 2, is the idealization of solutions and the generation of ideas. At this stage, the challenge was no possibility of using creation tools and strategies together. The social distance forced each team member to draw alone and share their ideas through photos and videos. In the first moment, there was no team's interference: each one drew individually, exploring possible solutions for a predetermined time. All the sketches pictures were made by smartphones, and update them to Trello management platform, allowing the discussion and sharing. Sometimes the understanding of a particular idea was not complete, which led to the need for video calls or notes and descriptions for detailing.

Some principles of the Sketch step of the DS methodology were adopted, such as: "ugly drawings are accepted", "words and descriptions are important", "it is ok to mix and improve ideas" - generate alternatives on top of existing ideas, "anyone you can draw" and "concrete is better than abstract"- creating sketches to transform an abstract idea into a solution that can be understood by others (Knapp et al, 2016). Using these tips was important to reduce the pressure and self-criticism normally found in the concept generation stage. Additionally, the freehand drawing technique was maintained to express ideas, attempting to speed up the process.

It started from the definition of a product for hands hygiene to be installed inside public transport buses, and proposals were generated freely, considering different ways of activation (automatic, with the foot, elbow), different places of installation (on the handrails, at the collector's station or the bus entrance) and forms of the container. The ideas once sketched could be explored by the group, in terms of their limitations and possibilities (Figure 3).

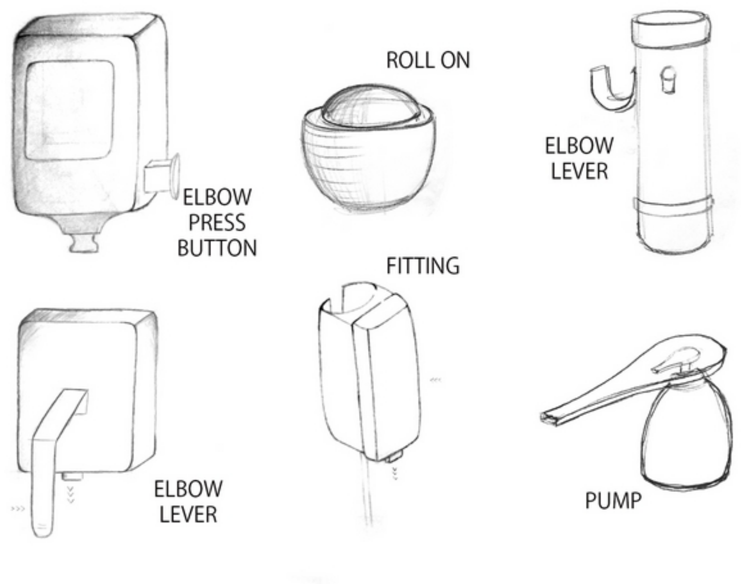

Figure 3. Pictures (made with smartphones) of some ideas from the initial sketches.

The proposals varied in several aspects and allowed the members to follow different paths. During remote meetings to discuss the sketches, one of the insights precisely pointed to taking advantage of the 2 liter PET bottles of alcohol as a container, which dispensed with the need for new packaging, directing ideas towards creating a viable support.

This definition directed the decision that the dispenser should be capable of digital manufacture through 3D printing, which would increase its replicability, feasibility, reach and speed of production. 3D printed products are not depending on industrial injection molds and streamline the testing and adjustment process. As the team has knowledge about prototyping and digital manufacturing, this requirement was considered mandatory and guided the sketch process.

Another determining point was about the distribution of the project: it was defined for the Open Design (OD), democratizing access, which concerns the ease of execution and understanding of the proposal. According to Cabeza et al (2014), open design is a way to promote innovation and social transformation resulting in a transparent, open production model, based on free, collaborative and cooperative work, deprioritizing the closed and monopolizing industrial production mode. Is a free and online way to distribute the product's manufacturing file, so that everyone interested can access and print it, replicating the solution and proposing changes. In this context "the role of the designer is radically transformed in the processes of creating and making the product, which enters a complex dimension - the dividing line between the designer, the manufacturer and the user is blurred" (Cabeza et al, 2014, p. 58).

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An OD project needs to offer the required information, in any readable format, so that it can be used, replicated, modified and redistributed by anyone. What seems important is the possibility for anyone, professional or amateur, to reproduce, optimize and customize such projects using the lesser possible number of proprietary tools and without any hidden data behind documentation (Freire et al, 2018).

Additionally, a tool proposed by DS called "Crazy 8s" was used. This tool divides a sheet of paper into eight squares, and draws a variation of the best sketch on each one, for a total of 8 minutes. After the bottle was defined as a container, there was a new session for generating ideas, now focused on meeting a series of requirements developed after these activities and classified as mandatory or desirable:

Mandatory requirements:

- Use 2L bottles as the main packaging, and other PET bottles (other brands and volumes) can be used;
- Digital manufacturing through 3D printing;
- Easy replacement of alcohol packaging (refueling);
- Adjustable height for installation on buses handrails or public metal posts;
- One-hand operation, as the passenger usually embarks carrying bags or belongings;
- Be a replicable solution in open design distribution.

Desirable requirements:

- Adaptable to different social contexts;
- Take up little internal space on the bus;
- Possibility of use inside buses or at stops;
- Intuitive and inviting use.

With the new concepts generated (Figure 4), some online meetings were held that facilitated the reconciliation and the development of ideas, which integrated two or more solutions.

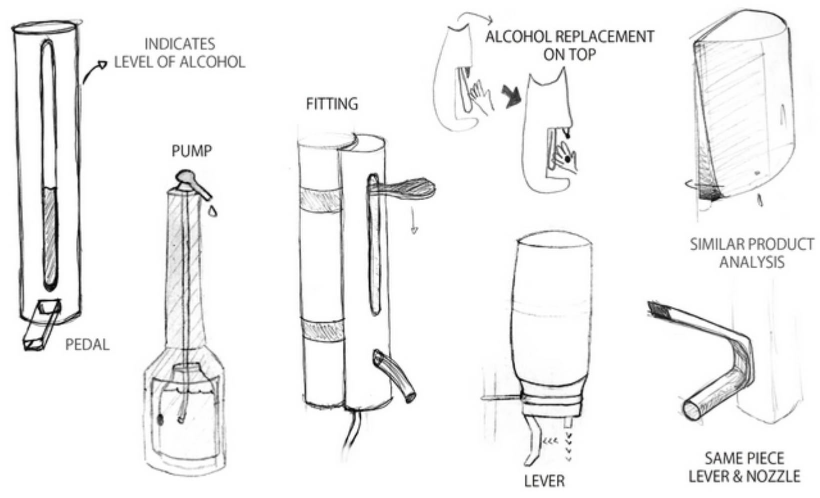

Figure 4. Pictures (made with smartphones) of some concepts from the second sketching session.

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The ideas generated in the second session showed a greater degree of detail and concern with the viability of the solution. The project requirements also served as a basis for the evaluation and decision process of the most appropriate alternative, carried out in the next step.

2.3. Decide

This stage happened during the third day when the “Decision” process was conducted. Then, the team converged the thoughts and questions raised previously into a single idea. As part of the decision on the best interface for the release of alcohol, one of the members of the group carried out an analysis of the dispenser systems of several packages and taps that he has at home, photographing the products in use, describing the hand position and the ease of activation during use (Figure 5). This task facilitated the understanding of the system and provided a sense of the size scale of the parts.

Figure 5. Analysis of the use of different dispenser systems.

In the decision-making process, instead of group debates and decisions, the DS methodology suggests to identify the best solutions: to visualize all the ideas together in the same physical space (in this circumstance, using Trello); systematic individual voting on preferred solutions; quick criticism of the solutions that were highlighted in the previous activity; and deciding vote. The winning concepts went to the prototype stage, to be evaluated in more volumetric and 3D detail.

Important decisions guided the concepts towards a smaller number of parts and ease of production, as it was understood that 3D printing and OD would contribute to achieving the goal of distribution and speed of replication.

It was defined that the dispenser should have two parts: the lower support, with the bottleneck fitting, the actuation valve, the alcohol outlet nozzle and the fixation on the handrail; and the lower support, a piece to give more firmness between the bottle and the handrail, preventing it from moving with the movements of the bus. Thus, the selected ideas were modeled three-dimensionally. They are depicted in Figure 6.

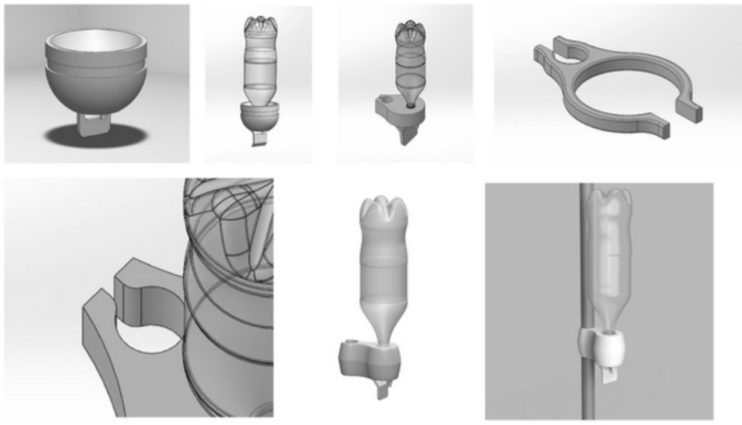

Figure 6. Virtual 3D models of solutions.

From the modeling, flaws were detected in some concepts, such as excessive sizing (which could take up a lot of space in the installation inside the bus), fragile points on the parts and fittings compatible with only one packaging model.

2.4. Prototype

On the fourth day, the developed solution ideas were prototyped. Due to the difficulty of accessing the prototype laboratory during the hackathon, they were modeled and tested digitally, using virtual 3D modeling software. According to DS, the goal of prototyping is to simulate a finished product for your customers, following a "fake it till you make it" philosophy. A realistic-looking prototype will get the best possible data from the test step (Knapp et al, 2016).

After several sketches and the virtual modeling of the concepts, we reach the final idea. The dispenser acts as a support for the bottle, providing a system that releases a specific amount of alcohol per time. It has a hanger that grabs the bottle and the handrail, offering stability. The material of the 3D printer filament is a thermoplastic polymer for fused deposition modeling, usually PLA (polylactic acid) or ABS (acrylonitrile butadiene styrene). Both materials do not react chemically with alcohol and have a good mechanical resistance, enough to support the weight of the bottle and the compression force of the actuation valve. Besides, the polymeric materials have the necessary flexibility to open to fit the bottle and the handrail, returning to the position after that. The final proposal is shown in Figure 7.

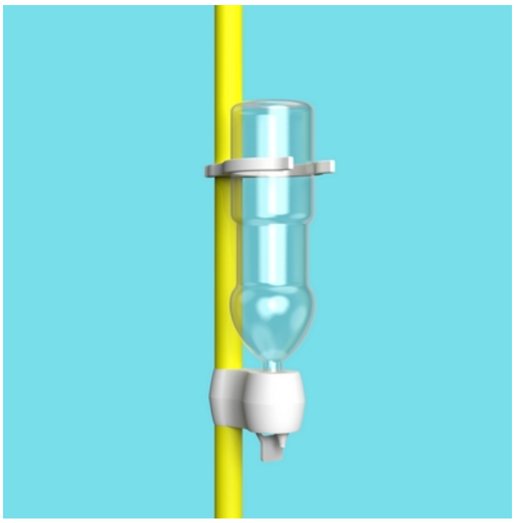

Figure 7. Digital prototype of the hand sanitizer dispenser solution.

The design has the appropriate fittings in the handrail, providing the support to the bottle, and the concern with the peculiarities of 3D printing, such as the maximum size of the print area, the need for a straight face at the base to facilitate the adhesion to the impression's start and the correct dimensioning of the parts, avoiding the excessive time of impression and material waste.

It also focused on the use of the pet bottles as main containers, but taking into account that other packaging can be adapted (based on the principles of OD). Besides, this solution can be fixed at any heights, made it accessible for wheelchair users (Figure 8).

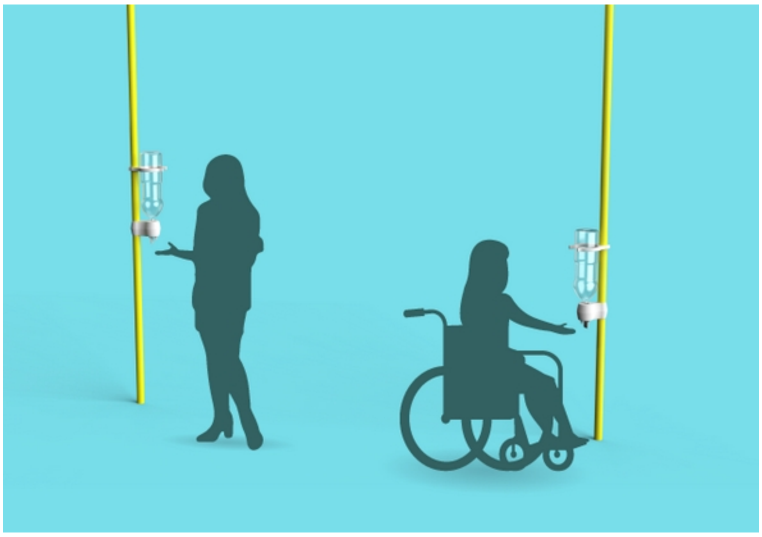

Figure 8. Digital prototype showing height possibilities for installation on the handrails.

The developed product has fittings for the bus handrails and upper support providing greater stability. The fitting also allows for installations at bus stops and it has a trigger handle to be activated by a single hand. Among the advantages of digital modeling, the project is interested in the generation of the digital distribution file for OD, exported by the same 3D modeling software, with the requirements for 3D printing. The gaps in this process are the domestic access to the software and the ability of this tool, which can severely impact the production.

2.5. Test

The fifth and final stage of the Design Sprint is Test, when the prototype is presented to customers individually. As it was not possible to execute physical prototypes, the renders were made to simulate the dispenser developed in its real scenario and scale of use, providing the impression of something real, necessary for the evaluation and testing (Figure 9).

Figure 9. Renders set in real use situations, inside public buses.

During the Hackathon, the project's deliverable documents were evaluated by a panel composed of six members from the health, information technology, and business areas, considered the project's first consumers and testers. This committee validated the proposal, emphasizing the viable and accessible solution to a real problem that is directly linked to the spread of the virus, contributing to increase the safety of those who need to circulate during the pandemic and depend on public transportation.

The project is currently in progress, now focusing on testing the internal mechanisms in 3D printing. Tests are expected to be carried out with users after the physical prototypes are manufactured. The first batch of 15 units will be installed in Pelotas city buses and put into real use, for obtaining feedback and making final adjustments to print and distribute the hand sanitizer dispenser product and files.

3. RESULTS AND DISCUSSIONS

Among the various projects received by the hackathon organization, the hand sanitizer dispenser won first place. The project awarded scholarships for the students to implement the proposed action. This result is a positive feedback that drives the development of other design solutions, also themed around the pandemic.

As a project for a latent need, it is supposed agility in project deliveries and also in production. The use of the DS methodology proved to be effective in the distribution and fulfillment of activities over the planned days.

Due to the emergency nature of the project, some of the project stages, usually performed with more depth, were shortened. In the step "map", mood boards, semantic and conceptual panels were not carried out, using this time to understand the problem, research about important subjects related and ask an expert. This results in the understanding of the basic use of urban public transport, supporting the elaboration of the risk contact map and definition of the product that would meet the demand.

In the “sketch” phase, divergent and convergent thinking allowed two sessions to generate ideas, even with reduced time. At this stage, the mandatory distance and remote work brought difficulties but also interesting results. Each member of the team sketched their alternatives individually, exposing their ideas without the influence of others, which generated an appropriate number of different solutions. After the exchange and discussion, in the second session of ideation, the drawings already presented a mixture between two or more concepts and all members felt comfortable to sketch and present.

One of the mandatory requirements was digital manufacturing by 3D printing for a few reasons: it speeds up the project in the testing and correction stage, and decentralizes production - several people can access the file and make the product, in different locations, meeting the OD proposal. We concluded that the use of OD contributed to produce a solution more viable (easy to reproduce) and economic (rational use of the material).

Logically, an industrial mass production, by polymer injection for example, is more convenient against 3D printing, in terms of production quantity, speed and cost in the final product, but the digital file allows to do product testing and adapting at any available 3D printer, at low costs and short time.

With this digital distribution, OD benefits the production of the hand sanitizer dispenser at any place in the world, a scalable product with editing capacity providing better conditions to adopt this model. The counterpart is that it depends upon technology resources and modelling software knowledge.

In the “decide” stage, the effectiveness of structured decision-making methods to the project time is highlighted. The systematic voting tools and joint contemplation of the alternatives used served to organize and externalize logical reasoning, which contributes to the agility of the activity, in addition to minimizing the chance in the choices made. The research and analysis of mechanisms, adapted to be carried out in the home environment of the members of the team, also proved to be interesting because it solved questions of product sizing and contributed with ideas to activate the dispenser. It was possible to understand and adapt mechanisms to the project, in addition to stimulating the search for similar ones in other digital sources.

In the “prototype” and “test” stages, it was possible to define the product design through digital modeling. The model allows the generation of renders that can be uploaded for viewing by the team in the project space, as well as simulating their volume and instantly checking for possible flaws and correcting in real-time. However, some requirements need the physical prototype for evaluation and test.

Therefore, the shortening of stages and activities delimited by time has speeded up the development processes, without significantly compromising the mapping of the problem, the generation of concepts, the definition of the design, and the digital prototyping. It should be noted that the composition of the project team, whether in number or plurality of areas, is a complex variable to estimate in terms of gains or losses of time in the execution of activities.

The development of remote work required adaptations of tools and the creation of a non-physical design space. Despite the Design Sprint based on the principle of a work team centralized in the same physical location and focused on a specific problem, the team was able to adapt this methodology for a remote project. It is important to note that, as well as a design method, each team configures this space according to the conditions of those involved.

Analyzing the stages of the design process from the barriers offered by social distance, these were mostly resolved through a design space with virtual tools, such as sending pictures of sketches, videos, or remote access to software modeling, which were fundamental. There were favorable conditions for the use of such tools by the members of the project team, who had minimal resources to access and manage these technologies.

Using online tools result in a huge amount of information, probably bigger than in a presencial project. All the DS steps were organized, with each team member's content, so the feedback and iteration process could occur at any time, not depending on everyone being online. This ensured freedom for each team member to organize their work schedules, creating an online collaboration cycle and provides enough information for the team, with easy access. On the other hand, a lack of structure in the project documentation can cause development failures, and this is a positive aspect for the use of a structure method.

4. CONCLUSION

This work presents the design as a problem solver in emergency scenarios. Designers have always been at the forefront of approaching the needs of the world, responding to an existing situation, and defining a solution that benefits society (Covid-19 Design Challenge, 2020).

It is expected that the presentation of the project contributed to highlighting particularities of product development in social isolation, mainly from the agile method and carrying out activities at a distance. In the same way that this solution is proposed for the specific demand of public transport, the results of each stage of the project can serve as a baseline for other developments about hygiene and the virus in this context, to bring more safety to users involved.

Some design steps were shortened, however, they presented satisfactory results. Therefore, it is understood that there is a trade-off relation within the emergency scenario, which must be considered when developing agile methodologies. In this case, a balance between design agility and amount of data, it is up to the project team to set the rule.

The article presents that it is possible to do a project without any face-to-face meeting. However, it is clear that there were not so many spontaneous changes and interactions during the activities, especially in the final stages of defining the design, when compared to face-to-face development. The manual modeling of ideas, a usual activity in product design, was also hindered by the lack of access to materials and prototype lab. As a research gap suggestion, it is possible to further analyze the differences between project activities carried out in person and carried out at a distance.

It also highlights the importance of setting a moderator to manage the project space. In this case, the supervisor teacher acted as a project manager, moderating the time of activities and dividing tasks between the team. It suggested new data research when lack of information was noted and exchange of activities when the team was not stimulated. It is possible that a lack of leadership could have a negative impact on the design process.

Should be noted that, after the end of the development phases, the DS methodology was adapted by its authors to the remote mode – The Remote Design Sprint Guide (Knapp et al, 2020) – and became available on their official website, since June 2020. However, the design of the dispenser was carried out before this publication, in May 2020, through spontaneous adaptations of DS. Therefore, future investigations can also compare the resources and tools, used and suggested, to verify patterns.

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Interactive voice response systems for informing citizens about the COVID-19 pandemic: a study on Brazil's *Disque Saúde*

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ABSTRACT

In order to slow down the spread of the coronavirus SARS-CoV-2, it is vital to adopt measures to inform citizens about preventive actions. Such an operation requires a wide-ranged system that comprises a variety of interfaces as channels between citizens and healthcare authority's information services. Amongst such interfaces, the Interactive Voice Response (IVR) systems can present benefits for informing citizens about the pandemic. Although the literature shows that IVR systems have been used for healthcare, the extent of the COVID-19 pandemic demands new examinations on the role of IVR systems on a multiplatform system for delivering information. This paper aimed to identify gaps and opportunities for the use of IVR systems to inform citizens about the COVID-19 pandemic. A case study was conducted by mapping the Brazilian Ministry of Healthcare's channels of information about the coronavirus and analyzing the Disque Saúde IVR system – a phone-based ombudsman channel - based on literature recommendations. The results showed that while IVR systems have great potential for accessibility, it is essential that all types of information are available and continuously updated for citizens. Furthermore, the vast and mutable availability of information in a pandemic scenario may be a challenge for the usability of such systems.

Keywords: COVID-19, Healthcare, Information communication, Interactive Voice Response systems, Usability, Speech interfaces.

INTRODUCTION

The coronavirus SARS-CoV-2 pandemic is causing urgent healthcare needs for populations worldwide. However, recent studies have shown the efficacy of preventive actions such as social distancing (Flaxman et al., 2020) and facemasks adoption (Stutt et al., 2020) in decreasing the coronavirus' reproduction. Thus, to encourage citizens to engage in preventive actions and mitigate the spread of the virus, governors must adopt measures to inform citizens about the COVID-19 pandemic.

Currently, with the advances in hardware and software technologies, information can be communicated through varied means and reach massive audiences. In recent years, e-government platforms – "the use of ICTs to more effectively and efficiently deliver government services to citizens and businesses" (UN, 2020) –, have been growing popular as communication channels. However, such interfaces may not be accessible for all, considering social and economic inequalities. In Brazil, for example, 20.9% of the Brazilians did not have access to the internet by 2018 (IBGE, 2020), 6.8% of the population is illiterate (IBGE, 2019), and 3.4% of the population had some degree of visual impairment by 2010 (IBGE, 2010).

In the COVID-19 pandemic scenario, it is paramount that information on preventive actions is widely available, and therefore authorities must develop strategies for informing all of the population. Meroni (2008) argues that solutions that meet social demands usually require complex and contextualized product-service-systems, rather than a single product or interface. Therefore, it can be argued that information from governments to populations should be available in a wide-ranged, multichannel system for delivering information. Such a system should comprise various devices, interfaces, and interaction channels as touchpoints between public healthcare authorities and all citizens.

Considering the need for varied and accessible channels of communications, Interactive Voice Response (IVR) systems can bring several benefits for accessibility. These speech-based interfaces can be used offline and use the auditory channel as an alternative to visual or textual information. In the area of healthcare, IVR systems have been used for several functions such as conducting questionnaires with patients, post-discharge follow-up, monitoring of health status, and providing information (Kraft & Androwich, 2012). Nevertheless, such systems need to be carefully designed to avoid user frustration (Pearl, 2016; Pieraccini, 2012).

Despite the known advantages of IVR systems, the extent of the COVID-19 pandemic is unprecedented to contemporaneity, and its impacts demand new investigations on the use of IVR systems for providing information on healthcare. A holistic approach is necessary to examine IVR systems as one of the various touchpoints between citizens and healthcare authority's information services, rather than as an isolated interface. This paper aimed to understand the gaps and opportunities for IVR systems to inform citizens about the COVID-19 pandemic, considering the broad system necessary to provide information for citizens in such a scenario. To achieve this goal, a case study was conducted on Brazil's *Disque Saúde*, an ombudsman channel created by the Brazilian Ministry of Healthcare's (MH) that has been used to present coronavirus-related information for citizens.

1. INTERACTIVE VOICE RESPONSE SYSTEMS AND HEALTHCARE

IVR systems are a type of voice interface that is "capable of understanding human speech over the telephone in order to carry out tasks" (Pearl, 2016, p. 30). IVR systems have menus structured in a branch logic format, through which users can navigate and answer questions by pressing buttons on a touch-tone keypad or by speaking voice commands (Lieberman & Naylor, 2012). IVR systems became popular by the 2000s' (Pearl, 2016), but, even nowadays, IVR systems are a tool that presents several benefits for users and developers.

Firstly, since IVR systems only require the auditory channel, complex and specific information can be presented without requiring users' visual channels (Pearl, 2016; Meeker, 2016), enabling users with visual impairments or low literacy levels to interact with the system. Secondly, voice interaction is ideal for products with small or nonexistent displays, (Meeker, 2016), and thus may be accessed from simple, familiar telephones instead of expensive or potentially unfamiliar devices such as a computer or a smartphone (Lieberman & Naylor, 2012). Voice interaction may also be easier to use than graphic interfaces since speech is intuitive for humans (Pearl, 2016; Meeker, 2016). Furthermore, IVR systems do not require a human operator, and thus are cost-efficient and can automatically collect and store data in real-time (Lieberman & Naylor, 2012). Also, IVR systems may repeat information as many time as needed (Lieberman & Naylor, 2012; Kraft & Androwich, 2012) and, because there is no human operator, some users may perceive interactions with IVR system as less threatening than a personal discussion (Kraft & Androwich, 2012). Finally, these systems can be accessed by multiple users simultaneously and are continuously available (Pearl, 2016; Lieberman & Naylor, 2012).

IVR systems have several uses for the healthcare area. Brinkel et al. (2017) showed the efficacy of a mobile-phone-based tool to collect individual disease information and offer treatment recommendations for mothers of ill children, educating parents and supporting their decision to seek hospital assistance or not. Likewise, Rigotti et al. (2017) conducted a study with post-discharge smoker patients who wished to quit smoking, and identified a positive relationship between the use of an IVR-facilitated intervention and smoking cessation, indicating the benefits of IVR systems for post-discharge follow-up. Similarly, Besse et al. (2015) conducted a study with an IVR system to monitor pain levels of palliative outpatients with cancer and observed the efficacy of the system for circumventing patients' reluctance to contact healthcare professionals in cases of high pain levels and, consequently, supporting the adjustment of their treatments.

In order to avoid frustration for IVR systems' users, interaction designers must be aware of usability recommendations available in the literature. Firstly, interactions should **minimize the cognitive load on users** (Cohen et al., 2004). Voice-based menus should not present more than five options at a turn (Pieraccini, 2012) and should allow users to select their desired option as soon as it is presented by the system (Wickens & Carswell, 2012). Frequently performed tasks should be presented prior to other options on menus, and recurrent users should be allowed to skip non-essential information (Killam & Autry, 2000). Responses should be written in plain language (Moore & Arar, 2019), and confirmation messages should use consistent wording across the system (Killam & Autry, 2000). IVR systems should not mix input methods, and voice prompts are preferred over touch-tone keypads, as users do not need to associate numbers with options (Pieraccini, 2012).

Similarly, systems must **keep interactions short**. Designers should decrease the necessary steps to complete tasks to increase efficiency (Cohen et al., 2004) and IVR systems should limit their responses to a sentence or less and decompose long answers so that users may navigate at a lower level of granularity (Moore & Arar, 2019). Furthermore, **IVR systems should keep a consistent interaction flow**. Interactions should start with a greeting, and the main menu presenting high-level information should be presented to facilitate users' access to system's features (Killam & Autry, 2000). Throughout the conversation, acknowledgments should be provided to ensure that users' commands were understood (Pearl, 2016). Users should also be able to close an interaction sequence after achieving the desired outcomes, and move on to further options (Moore & Arar, 2019). Finally, **IVR systems should prevent and handle errors**. Voice interfaces may employ confirmations – "reprompting" – as a means to minimize errors (Pieraccini, 2012, p.220), but they should not overload users with confirmations (Pearl, 2016). The system should allow users to cancel menu selections to return to previous options (Killam & Autry, 2000) or ask for a repetition of information (Moore & Arar, 2019).

Although there are studies in the literature pointing out to design recommendations and opportunities for IVR systems in healthcare, the COVID-19 pandemic poses challenges for

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implementing these systems that are yet to be addressed. Unlike other scenarios in which information is directed to a target audience, the coronavirus outbreak requires information to be delivered to all the population. Therefore, it is necessary to analyze such interfaces as one of the multiple touchpoints needed to deliver information for all citizens, as aforementioned. Also, since research on the disease is still in progress, healthcare authorities' recommendations are being developed gradually, and a large amount of data is available. Thus, it is unknown which usability issues may arise in the use of such systems in a pandemic scenario.

2. METHOD

The goal of this study is to understand the gaps and opportunities for IVR systems to inform citizens about the COVID-19 pandemic. Yin (2018) suggests that research seeking to describe or understand contemporary events in which the researcher has little or no control over – such as a new virus' pandemic - can benefit from the case study method. As before-mentioned, there are several accessibility challenges for communicating health-related information in Brazil, making the country an opportune case to be studied in the pandemic scenario. Hence, this paper presents a case study that mapped the Brazilian Ministry of Healthcare's (MH) channels of information about the COVID-19 and analyzed the IVR system *Disque Saúde. Disque Saúde* is an ombudsman channel created in 2011 by the MH that can be accessed online (chat) or through phone calls (IVR system). Due to the SARS-CoV-2 outbreak, the MH added new, voice-based features to the platform to evaluate the health condition of the population, monitor the status of symptomatic citizens, and provide information about the pandemic (Casa Civil, 2020)..

The research method comprised three steps: the identification of all communication channels available or suggested on the MH website, a survey of all information related to the COVID-19 pandemic on each platform, and an usability analysis of the *Disque Saúde* based on literature recommendations. All data was collected on May/June 2020.

The gathering of the communication channels available as MH's communication platforms started from the Ministry's main website. Hyperlinks related to the word "coronavirus" were examined, as well as advertisements about other MH's platforms outside of the webpage. The same process was conducted for all platforms examined. The criteria for accepting platforms on the analysis were:

1. The platform must have been developed by the MH. Although there are information channels available from alternative sources, it is vital that public authorities provide reliable information for citizens in a pandemic scenario. The scrutiny of further platforms is beyond the scope of this paper.
2. The platform's content must concern any type of information aimed at informing citizens and preventing the spread of the virus.
3. The information must be directed to layman citizens. Information explicitly directed to healthcare professionals was not accepted.

A total of 12 platforms were accepted for analysis (table 1). A flowchart was developed to visually represent the relationships between the platforms. Such analysis was chosen to represent the system's map and enable the identification of the information organization throughout the interfaces (table 1).

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Table 1: Description of the platforms analyzed

Platform	Description
Coronavirus website	A website linked to the MH main website dedicated to coronavirus-related information.
Tele SUS Chat	A chat bot within the coronavirus website that answers questions about the coronavirus with pre-programmed answers. It can also be used for the self-evaluation of symptoms.
Coronavirus panel	A website dedicated to presenting information about the status of COVID-19 cases in Brazil.
Interactive panel	A website dedicated to presenting information about the status of COVID-19 cases in Brazil.
OpenData SUS	A database from the MH containing various types of data, including the coronavirus-related information.
Hospital beds and supplies panel	A website dedicated to presenting information about the availability of hospital beds and supplies across the country.
Coronavirus App	A smartphone application dedicated to coronavirus-related information. It can also be used for the self-evaluation of symptoms and for finding hospitals.
Fake News webpage	A page within the MH's main website exclusive to explaining fake news on varied topics, including the coronavirus.
Prevention campaigns	A page within the MH's main website where citizens can download the advertisements from the MH' coronavirus' prevention campaigns. The page does not specify where or how the advertisements are intended to be displayed.
Fake News Whatsapp line	A WhatsApp line dedicated to coronavirus-related Fake News.
Ministry of Healthcare Answers WhatsApp line	A WhatsApp line dedicated to answering coronavirus-related questions using pre-programmed answers. It can be used for the self-evaluation of symptoms.
Disque Saúde	An IVR system from SUS – not exclusive for coronavirus-related information – in which citizens may evaluate and monitor symptoms and access information.

The second part of the analysis was the scrutiny of each information channel collected on the previous step. All information that satisfied the criteria mentioned above were categorized on a bottom-up approach and recorded on a table. As the COVID-19 pandemic is demanding the communication of varied data, the bottom-up approach was chosen so that the analysis would encompass all types of information identified, rather than being limited to previously established categories. A total of 73 pieces of information (instructions, definitions, etc.) were identified and clustered into 13 categories. An information percentage score was created to identify differences in the amount and type of information available in the analyzed platforms. For each platform, the number of pieces of information identified for each category was accounted, and then divided by the total number of pieces of information encompassed on that category (figure 2). For example, the "Coronavirus app" had eight out of the sixteen pieces of information identified in the "prevention" category. Thus, the information percentage score for the "Coronavirus app" on the "prevention" category was 50%.

As for the usability analysis of the *Disque Saúde*, multiple calls were made to identify the systems' call flow (Appendix 1-3), that is, "diagrams that illustrate all the paths that can be taken through your [voice user interface] system" (Pearl, 2016, p. 75; figure 3). *Disque Saúde's* analysis was based on the literature recommendations presented in the previous section. Such an assessment was conducted to identify which usability issues may be linked to the presentation of coronavirus-related information on IVR systems.

3. RESULTS

The flowchart illustrated in figure 1 shows a map of the analyzed MH's platforms. It can be noticed that several interfaces are used to communicate information and can be accessed from various devices (telephone, smartphone, tablet, computer). Moreover, varied types of platforms are available such as websites, the dedicated App, WhatsApp lines, and the IVR system. However, all communication channels except for the *Disque Saúde* require an internet connection to function or be installed. Additionally, the *Disque Saúde* is the only platform that primarily presents information through the auditory channel, without requiring any visual support.

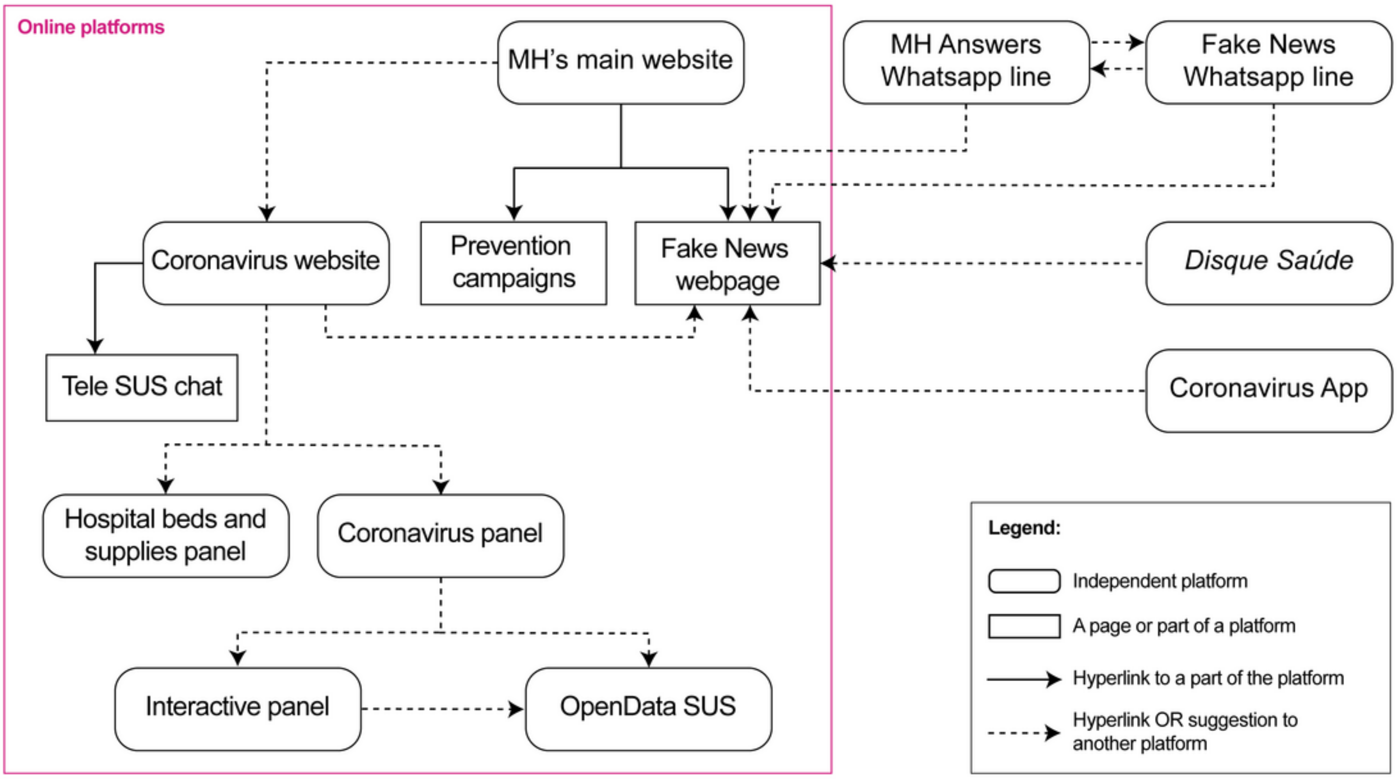

Figure 1. Flowchart containing all surveyed platforms.

Furthermore, it can be observed that several MH's webpages are used to display information about the virus (indicated by the pink square in figure 1), and there are two WhatsApp lines that citizens may contact to search for instructions. However, such an organization may spread different types of information across platforms of the same type (websites; WhatsApp lines) and confuse users about where to look for information. For example, the "Coronavirus website" is a webpage dedicated to the pandemic, but the data concerning confirmed cases are located on other websites ("Coronavirus panel", "Interactive panel"). Contrarily, the *Disque Saúde* and the "Coronavirus App" are the only MH's platforms of its type (IVR system; App) with information about the pandemic.

Figure 2 illustrates the representation of the information percentage scores, which shows how different categories of information are spread across the platforms. Overall, none of the analyzed channels of communication comprised all of the categories of information collected, showing inconsistencies in the availability of information across the interfaces. It can be observed that some platforms were developed exclusively for presenting one category of information, such as the "beds and supplies panel", which only displays information about medical supplies in Brazil. On the other hand, some categories of information are either absent or have limited availability across the platforms. Such a tendency can be verified for the “Fake News” information category. While there are two platforms exclusively dedicated to presenting this type of information (“Fake News webpage” and “Fake News WhatsApp line”), 8 out of the 12 communication channels surveyed did not display data on fake news and therefore had to address citizens to other channels, as shown in figure 1.

Figure 2. Visual representation of the percentage scores for each platform. The level of saturation of the purple color ranges from 0-100% and represents the amount of information available from the categories in each platform. White represents zero information (score = 0%) and the most saturated purple means all information (score = 100%).

It is important to point out that the heterogeneity indicated in figure 2 is also due to inconsistencies of the information on subjects across the platforms. For example, the “Coronavirus App” recommended that citizens should only wear facemasks if they are coughing or taking care of infected people. However, this information is outdated compared to other platforms, which not only recommended facemasks to all citizens, but also provided instructions for its usage. Similarly, the *Disque Saúde* and the “MH answers WhatsApp line” were the only platforms in which the chloroquine and hydroxychloroquine protocol was available.

As for the *Disque Saúde*, figure 2 shows that the IVR system does not encompass six categories of information, including basic definitions of the pandemic and symptoms of the COVID-19 disease. Also, the percentage score for all categories except “risk groups” and “treatments and vaccines” is below 100%, indicating that there are missing or inconsistent information on the interface. As represented in figure 1, the result of missing information is the need to address users to other platforms. However, switching platforms to locate information may not only be frustrating and demanding for users, but may also be unfeasible for citizens without an internet connection.

The appendix 1-3 illustrates the flowcharts of the *Disque Saúde’s* call flow. As recommended by the literature (Killam & Autry, 2000), the interaction starts with a high-level menu, in which users may choose to evaluate their health status, monitor their symptoms (if they have contacted the system before), and listen to information on other topics, including general information about the coronavirus. (Appendix 1). Nevertheless, the IVR system is not entirely in line with the literature’s usability recommendations.

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Firstly, the *Disque Saúde* does not always allow users to interrupt the system's output to select or go back to a menu option. This is problematic since it forces users to listen to all of the voice response, making interactions slow, cognitively demanding, and complicating the recovery from selection errors. Secondly, the "Coronavirus information" branch has seven options on its menu (Appendix 3), which diverges from the advised maximum of five menu options and may lead users to forget the available choices (Pieraccini, 2012). These issues are aggravated by the use of a touch-tone keypad as the input method for most interactions, making users associate options to numbers and increasing their cognitive load. Contrarily, the entirety of the "monitoring of health status" branch of the system (illustrated in Appendix 2) employs voice commands as the entry method. Although speech is the preferred input method by the literature, it is not recommended to mix voice commands with a touch-tone keypad as entry mechanisms (Pieraccini, 2012).

Furthermore, the analysis showed that some voice responses from the system were too long because of the need to provide detailed information. For example, the platform offers instructions for citizens on how to wash their masks, but all information is presented at once, which is not only time-consuming but also gives users little time to memorize or write down instructions. Similarly, some characteristics of the system may affect the interactions' brevity. In the information branch (Appendix 3), users must listen to an advertisement before being redirected to the menu options, and, after hearing a piece of information, they must answer if they were satisfied with the interaction to proceed. Such extra steps decrease the interaction efficiency.

It can be noted that many of the *Disque Saúde's* usability issues are related to the interactions' brevity or high cognitive demands for the users. It is possible to argue that the large and varied amount of information that should be displayed by the system may be the cause of such problems. Presenting information about a pandemic as large as the COVID-19's requires several types of information, as pointed out in figure 2, and may be a challenge for IVR systems.

Considering this study's results, some suggestions may be offered for the *Disque Saúde*. In the first place, for the system to function independently and maximize its potential for accessibility, it is recommended that the system should comprise all information available across the MH's communication channels, and that such data is updated continuously. Based on the before-mentioned literature recommendations on usability, it is suggested that the number of menu options on some branches is reduced, the possibility for users to interrupt system's responses is added, and support for selection errors is provided. Long information pieces should be broken down into chunks of information, advertisements should be removed, and users' evaluation of the system should be optional. Finally, it is suggested that voice commands are standardized as the input method.

4. CONCLUSION

In order to mitigate the outbreak of the SARS-CoV-2 coronavirus, it is paramount that governors provide information about the pandemic for all citizens, and IVR systems may play an important role in such scenario. Yet, an investigation is necessary to assess IVR systems as touchpoints in the complex, broad system for delivering information required to deal with a pandemic as extensive as the COVID-19's. This article presented a case study on the Brazil's IVR system *Disque Saúde,* aiming to understand the gaps and opportunities for IVR systems for informing citizens about the COVID-19 pandemic. To achieve this goal, a survey and scrutiny of the Brazilian MH's communication channels were conducted, as well as a usability analysis of the *Disque Saúde.*

Despite the limitations inherent to the case study method, some general conclusions can be offered for the use of IVR systems for the COVID-19 pandemic. As expected, including IVR systems as channels of communication can leverage the accessibility of information, especially for populations with high rates of illiteracy, visual impairment citizens, and low levels of internet connection. It is essential that IVR systems provide all of the necessary information for citizens, and that such data is consistent, reliable, and up to date with other platforms. Such homogeneity of information is important for the independent functioning of an IVR system, considering that consulting other platforms might be unachievable for some citizens, and, ultimately, may cause them to give up the search for information. Considering the urgent and unpredictable nature of the coronavirus outbreak, in which new data and recommendations from healthcare authorities are constantly evolving, an alignment of information across platforms might be challenging. This demand highlights the importance of analyzing interfaces as touchpoints of a larger system for delivering information, rather than isolated platforms, to track all the available data and homogeneously distribute such information across communication channels.

Finally, some of the usability issues identified in the *Disque Saúde* were related to the nature and amount of information to be communicated in the COVID-19 pandemic context, which includes lists, instructions, procedures, etc. Such characteristics can be problematic for IVR systems since users need to listen to several menus options, make associations with touch-tone keypad numbers, and listen to long pieces of information. However, voice recognition technologies are now capable of achieving high speech recognition rates (Pearl, 2016). Systems such as voice assistants (Siri, Alexa, etc.) already use automated speech recognition and natural language processing algorithms to fulfill a broad set of tasks for users (Pearl, 2016). Thus, the use of voice prompts as input methods can be used in IVR systems to allow users to directly ask for information about the COVID-19 pandemic, making interactions easier and faster. Interaction designers must follow guidelines on usability so that interactions are effective, efficient, and satisfactory for users, and further testing with users is necessary to identify additional usability issues.

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APPENDIX

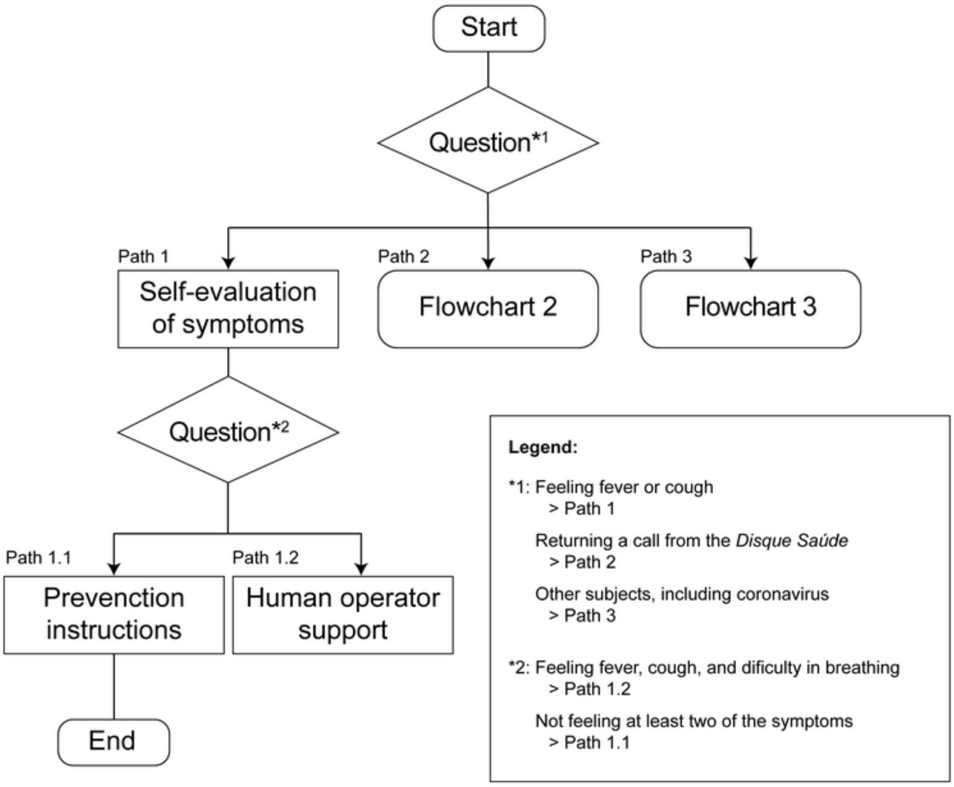

Figure 3. Flowchart of the *Disque Saúde's* call flow (part 1)

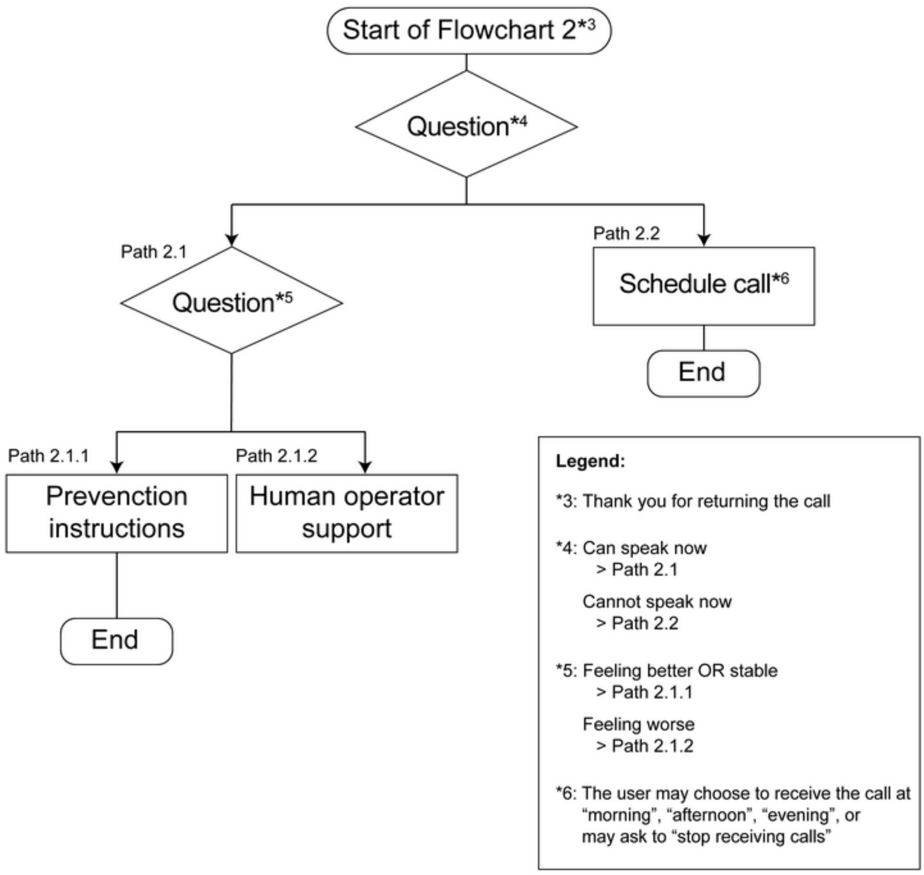

Figure 4. Flowchart of the *Disque Saúde's* call flow (part 2)

Motta, I., Lopes, J. R. & Quaresma, M. (2020). Interactive voice response systems for informing citizens about the COVID-19 pandemic: a study on Brazil's Disque Saúde. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 552-563. DOI: 10.4013/sdrj.2020.133.20

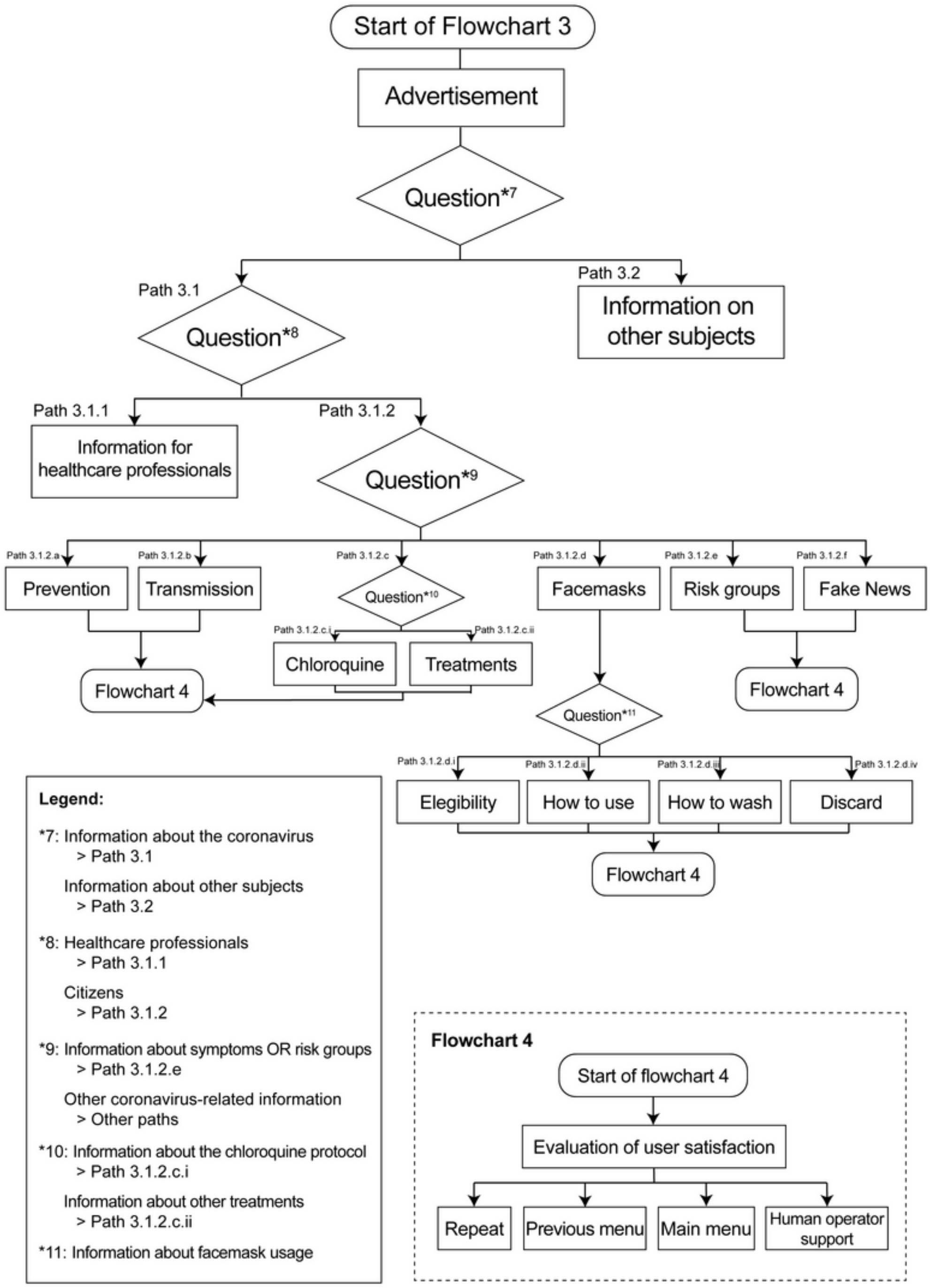

Figure 5. Flowchart of the D*isque Saúde's* call flow (parts 3 and 4)

STRATEGIC DESIGN RESEARCH JOURNAL

Towards a "Better Normal": Educational Experiences in Design in Latin America During the COVID-19 Pandemic

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ABSTRACT

The emergence of the COVID-19 pandemic has demanded the adoption of extraordinary measures of quarantine and social distancing, impacting educational institutions worldwide. Schools and campuses – which used to be spaces for social exchange – had to cease face-to-face instruction and shift to remote learning with no prior planning or training, which posed several challenges to education systems around the globe. In Latin America – responsible, today, for over half of the planet's daily COVID-19-related deaths - this scenario is even more dramatic. The diverse socioeconomic levels of the student population is a major challenge for online teaching, as institutions cannot provide computer training, equipment and connectivity to all those in need. In spite of all challenges, universities which are part of AUSJAL (Association of Universities Entrusted to the Society of Jesus in Latin America) are making every effort to offer online classes during this pandemic, since education plays a pivotal role in these countries. This paper presents a selection of Design educational experiences conducted in AUSJAL universities during this pandemic. Design educators from Brazil, Colombia, Ecuador and Nicaragua present educational methods and strategies for dealing with this critical situation. In conclusion, we discuss how their innovative and engaging teaching ideas are paving the way towards not simply a new, but a "better normal" in Latin America.

Keywords: AUSJAL, Design, Education, Latin America, Online classes, Pandemic.

1. INTRODUCTION

Since it was first detected in China, in December 2019, this novel coronavirus SARS-CoV-2 pandemic has disrupted people's lives, causing much suffering and huge losses around the globe. Over 58 million people have been infected and over 1,385.000 people have died as a result of COVID-19 worldwide (John Hopkins CDC, 2020). Although the emergence of this pandemic has undoubtedly affected every nation on the planet, each one of them – however - has been impacted in a different moment, depth and way.

As countries have been at different points in their COVID-19 infection rates, over the past months, local and national governments worldwide have established different policies and rules to deal with this pandemic. Almost all of them have decided to decree lockdowns to avoid or reduce contagion. This sudden – and quite unusual – demand for social distancing has dramatically changed life in cities and communities around the globe.

Education has been one of the sectors most seriously impacted by nationwide lockdowns. With no prior planning, schools and universities worldwide had to either suspend all their educational activities for an unpredictable length of time, or shift them to a remote, virtual, online mode. Although many institutions opted for stopping their activities, most of them requested their educators to adequate their classes and activities to this new condition. All of a sudden, both teachers and students had to completely alter their normal daily routine, in order to adapt to a new teaching-learning system. Educational spaces – which have traditionally been *loci* for warm social exchange, vivid community building and noisy personal interaction – were abruptly replaced by virtual online platforms. Having their kids or teens at home has also become an issue for parents, who were either struggling to work from home, with less privacy, or needed to leave their houses, when they worked in emergency sectors. From K-12 to postgraduate levels, every student and every teacher – and their families and institutions – had to quickly adapt to this "new normal" education system.

The negative effects of this pandemic have been felt by every nation on the planet, but in some countries or regions they have been far more severe. In recent weeks, Latin America has become a hotspot of the COVID-19 pandemic, being responsible for an overwhelming death rate, equivalent to half of the global total number (John Hopkins CDC, 2020). In spite of its effort to revert this dramatic situation, several factors - such as high rates of poverty, substantial segments of the population living in crowded cities and slums, and great percentages of people depending on informal work for their survival – have made lockdowns quite ineffective in Latin America. The pandemic continues to grow in this part of the world, exacerbating its profound social inequalities, and causing a colossal economic loss.

For being the most fundamental pillar for a nation's development and growth, education is an area of utmost importance for Latin America. Therefore, in spite of all challenges, institutions which are part of AUSJAL - Association of Universities Entrusted to the Society of Jesus in Latin America - have made every effort to avoid interrupting their students' education during the pandemic. By promoting emergency training on online teaching methods for educators and talks on how to adapt classes to a variety of virtual platforms, by lending computer equipment and providing internet connectivity and materials to those students in need, by offering counselling to students who were facing personal or family health problems – among other various emergency actions - AUSJAL institutions have managed to continue offering high-quality academic activities to their students.

In the area of Design education, however – which requires a combination of theoretical knowledge and practical skills for the creation, development, production and implementation of objects, services and systems – going online was quite a challenging task: how to quickly replace all regular, in-person classes by virtual ones? In the case of theoretical classes this was slightly more easily achievable. However, for all those practical disciplines and laboratory activities, this sudden shift to virtual posed technical and pedagogical problems, requiring the development of new teaching strategies and techniques.

This paper discusses academic challenges posed by the COVID-19 pandemic, and presents a selection of diverse and original accounts of Design teaching during this pandemic, in AUSJAL Universities. In the next sections, Design educators from Pontifícia Universidade Católica do Rio de Janeiro/ PUC-Rio (Brazil), Pontificia Universidad Javeriana Cali (Colombia), Pontificia

Universidad Católica del Ecuador / PUCE (Ecuador) and Universidad Centroamericana UCA (Nicaragua) discuss major challenges they faced during the pandemic, and present innovative educational experiences and strategies they have employed for dealing with this new social distancing situation.

2. PONTIFICAL CATHOLIC UNIVERSITY OF RIO DE JANEIRO (BRAZIL)

2.1. The invisible challenges of online teaching

For over 10 years, I have been responsible for teaching “Design Issues in Digital Media” to an average of 30 freshmen students per semester, at the undergraduate Design course at the Department of Art and Design, PUC-Rio, in Brazil. This semester, my students initial assignment was a *soundwalk*. Divided in teams, they should walk in silence around the Campus for 60 minutes, following a pre-determined route, fully focusing their attention on hearing all sounds around them. They should try not to "see", or "smell" or "feel", but just listen. They were asked to record small snippets of interesting “sounds” and transcribe fragments of conversations they heard during the walk, elements which were presented in class, at the end of the tours. As lively and talkative students, they very much enjoyed this initial “outdoors” immersive exercise, whose aim was to awaken their other senses beyond vision – which is already deeply explored in Digital Media.

That afternoon – in March 2020 - was the only time I saw my students in real life, during the academic semester. On the following days, PUC-Rio announced they had suspended all in-person activities, because of the COVID-19 outbreak. Our second class was already online, but when I started the virtual class – to my surprise – all I could see was their names: their cameras and microphones were all off. I asked them to turn them on, but they responded they didn’t feel at ease with that, and they all refused to do it.

At first, it made no sense to me: why would all my 30 Digital Media Design students not turn their cameras and microphones on, remaining “invisible” and “mute” during classes, except for a few of them who - occasionally and briefly - would turn on their microphones to ask something specific? By virtue of being Digital Media Design students, weren’t they what we call *half-digital beings*, used to all kinds of virtual adaptations, all types of interactive platforms, addicted to game interfaces, heavy users of cell phone applications and immersive media?

Since I regularly invite different speakers to talk about their experience in Digital Media, as part of my classes, the students not only had myself as a speaker, but another guest, at every class. Although this semester they very much enjoyed all talks – on topics such as Animation, Game Design, Sound Interfaces, Virtual Reality, Robotics and Artificial Intelligence, among others - and class attendance was very high, nevertheless I observed that my students found it very difficult to stare at a person talking to them, on a bright screen, for 3 hours per class, even if that person would be a different one every week. Why it seemed more difficult for them to attend 3-hour long online classes than in-person classes of that same length? It seemed they also lacked having more interaction among themselves, during our online classes.

In discussing this issue with my colleagues at PUC-Rio – as well as with my Latin American Design colleagues from AUSJAL, and also with my ACM SIGGRAPH colleagues from the VR

Educational Group – I found out that these issues were not unique to my classes, but a very generalized trend around the globe, although not yet well documented.

To better understand their reasons, I informally interviewed them, both in group, during our classes, and privately, in conversations after class. Almost all of them reported they had to share their equipment and their room space with other family members, while staying home. Because of their lack of privacy – and unwillingness to share the intimacy of their homes and family life with their classmates – they preferred to turn off their cameras and microphones during classes. Most of them attended the classes from their bedrooms – which they shared with their siblings. As for lower income class students, however, the situation was even more delicate: they mentioned having to share the computer with all family members, and they were ashamed of showing their homes. At some point, I suggested students could use virtual backgrounds, but most of them said they "did not want to show their houses, nor their faces". One of them said "he considered himself ugly, and didn't want to see his own face on the screen".

Social contagion was another strong reason for this collective behavior: even the few students who had no problem being "visible" or "audible", reported they could not go against the majority of the group. Some other facts deserve mention: a student reported her father used to attend a few of my classes, and enjoyed them very much, and another student said her boyfriend was attending a few classes too.

I came up, then, with the idea of asking them to create face masks during one of our classes, as a game-like experience. At that very initial stage of the pandemic, masks were not yet being used as a protection against contamination, in Brazil. Therefore, creating a mask had the sole purpose of covering their faces. I gave them a few minutes to create their masks, and on that class, most of them finally turned on their cameras, while wearing their paper masks, as shown in Figure 1.

That experience totally broke the ice. During the rest of the course, we coexisted very well on those new terms: I would not ask them to turn on their cameras or microphones again, and whenever they felt they needed to, or wanted to participate more lively, they would do it. All other assignments, during the semester, were adapted to fit their request for not turning on cameras or microphones, and, in spite of their "invisibility" during classes, results were outstandingly positive. Almost all students attended all classes, produced excellent work, and their grades were higher than they have ever been in previous semesters of this course, over more than 10 years.

After 35 years of educational practice in Design, during this unique semester I realized I still have much to learn. After all, as João Guimaraes Rosa wisely wrote, "an educator is not the one who always teaches, but the one who, unexpectedly, learns." (Rosa, 1970, p. 235).

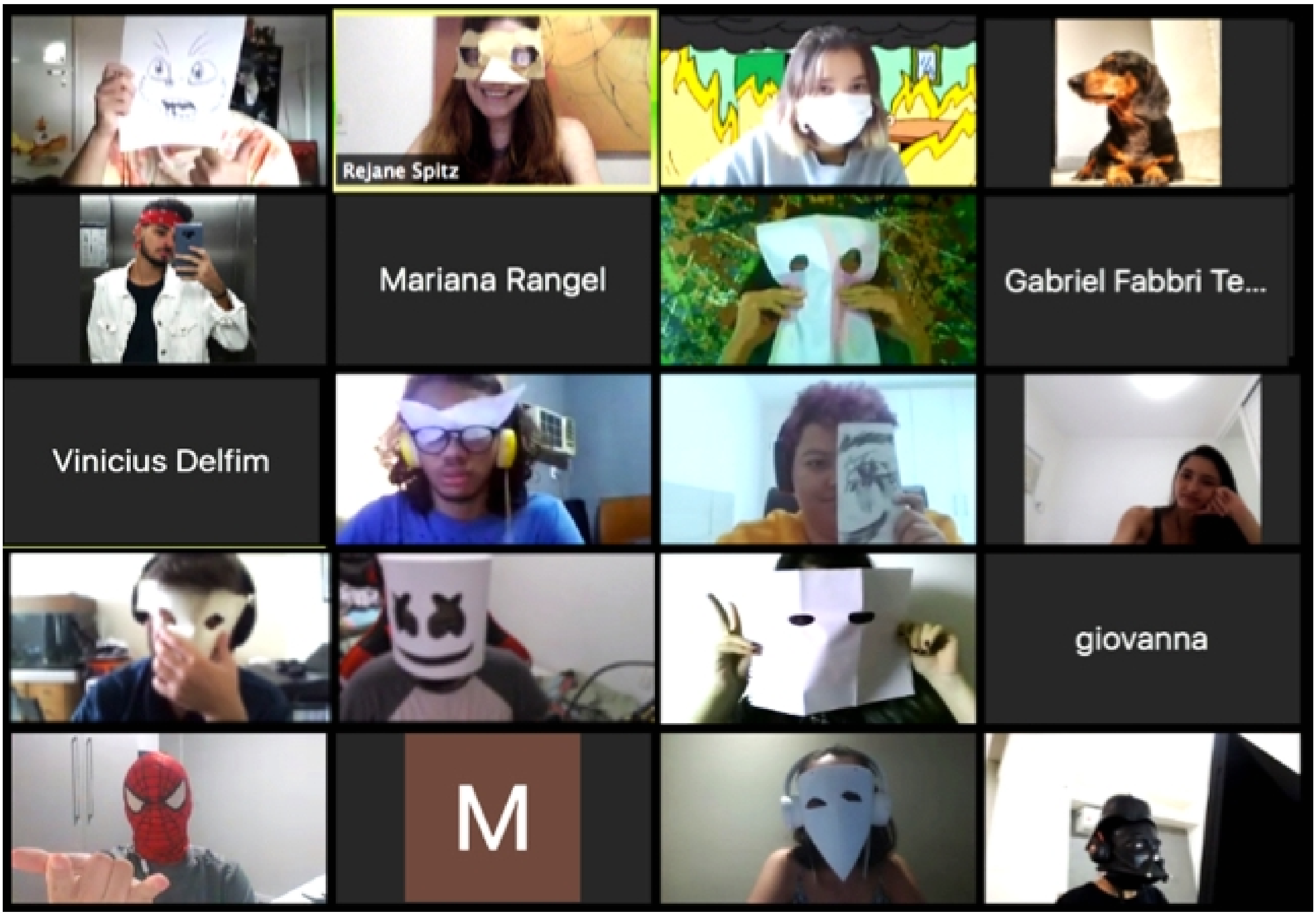

Figure 1. Face masks as a game-like experience during online classes.

3. PONTIFICIA UNIVERSIDAD JAVERIANA DE CALI (COLOMBIA)

3.1. Teaching-learning processes: the value of trust in Covid-19 times

The reflection around teaching-learning processes in design in Covid-19's times, and some paradigm shifts that could possibly be evident are key aspects of the analysis proposed in this section. Changes in terms of the ways in which these processes had been traditionally approached, as well as the emergence of new ways of conceiving relational premises among involved agents have been noticed. Since students do not have to carry out their activities physically in front of their teachers, new dynamics emerge that lean towards a greater empowerment of students in their learning processes, as well as in the management of their time and resources, which puts in a new dimension the tension between paradigms such as control vs. trust. New spaces for interaction are opened up, mediated by channels and technologies different than those that were usually used to support and monitor pedagogical processes.

In this scenario, the concept of trust becomes a fundamental factor of attention. As pointed out by Tierney (2008), trust is a fundamental cultural construct in the agent equation in higher education institutions, which is often overlooked. Still, this construct is essential to dimension the hasty response on which design teaching-learning processes have had to be restructured, especially during the first half of 2020, and which will foreseeably determine the dynamics of the coming academic periods, at least of the closest. The question is, then, if a whole process of a student on his way to achieving a result can be totally "controlled" or it can be promoted a construction exercise where mechanisms that allow the latter to become more empowered and use different resources and narratives to successfully walk the path are put through his paces, both in individual and group settings, within a framework of “solidary personalism” in the terms proposed by Žalec (2013). This alludes to “a kind of virtue ethics which stresses the importance of virtuous people for functioning of social systems and structures” (p. 66). Therefore, in addition to the fine training in the management of technological platforms, these ethical and aesthetic reflections become a fundamental context for promoting trust in situations of limited synchronous convergence. This implies at the same time for the student, the strengthening of interpretative, argumentative and purposeful competences, as well as essential soft skills, such as empathy, negotiation skills, good communication, punctuality, organization and ease of adaptation.

For this to be viable, the creation of ideal conditions for building trust, especially around the perspective of the processes that affect students, is essential. And it may not be feasible, not viable, much less desirable, to apply unnecessary controls that have been operating under conditions of transactional presentiality. As expressed by Žalec (2013, p. 66), “the idea that it is possible – by some perfect and complete control – to replace or assure such faith or trust is a dangerous illusion”. Trust becomes then a fundamental value on which to support the teaching-learning processes, above even the control systems - or at least in dynamic balance with them - and the latter are put at the service of the trust to define relational frameworks of action between agents. This makes it possible to build trust in the three dimensions proposed by Martins & Baptista (2016) in the dialectics of organizational learning that allow changes, integration and finally institutionalization.

The innovation and autonomy filtered into the new normality displace the patterns of intense and persistent contexts to which our students were accustomed. Living environments, capable of developing trust as a system of exchange, both in synchronous and asynchronous spaces, are interrelation scenarios that were otherwise difficult to perceive in the in-person course. In fact, the control of the general educational system has undergone a change towards a new relationship between teachers, institution and students. The plural spirit experienced on face-to-face should be recovered and migrated to the online space. If a learning session is still a plural forum, it is not understandable why this should change. All dialogue is based on a process of trust and must leave out prejudices and stigmas of irrational control.

Open to all new formats, ideas and thoughts born of divergence and innovation, the pandemic allows us to observe the shortcomings of resources, experiencing in this work in process that future place(s) that cannot be conclusive but inclusive. In the change, we lose in securities but win in explorations. Spaces, as Manzini (2018, p. 74) points out, in which we all design and that make contemporaneity an unprecedented fluctuating ethical-aesthetic luck.

The tension between trust vs. control management, is also in this present-future an amplification of our movements, words and relationships, that can be traced, recorded, reproduced and even become conclusive proof of daily activities, expanding a host of new experiences for both teacher and student.

The new space for interrelation within the university setting reveals psychosocial and emotional situations, that in the face-to-face sphere perhaps went unnoticed. Covid-19 is not going to erase the university; ‘to innovate is to dialogue with tradition’, and when this is well done, essential features of the educational tradition that are valid are rediscovered. Instead of suppressing them, they should be improved and consolidated.

4. PONTIFICAL CATHOLIC UNIVERSITY OF ECUADOR (PUCE) - (ECUADOR)

4.1. Collaborative digital platforms for academic leisure

During the last months, several governments decided to decree a lockdown to avoid people's physical contact as part of the efforts to fight against SARS-CoV-2 (Dunford et al., 2020). Consequently, most of the educational institutions developed digital strategies to adequate their academic programs to this new condition. In addition to teaching and learning problems, social distancing introduced some new difficulties to our everyday lives. For instance, some authors (Hackeo Cultural, n.d.) mention the dangers of exacerbating individualism; similarly, Byung-Chul (in Renduele, 2020) explains the disappearance of rituals as an isolation problem. Some authors have highlighted collaboration as one of the main characteristics in digital communities (Jenkins et al., 2009; Mao, n.d.). Howe (2006) defined these practices as crowdsourced manifestations revealed in different formats (e.g. crowdbuying, crowdthinking, crowdcreating, among others). Nevertheless, Lara (2014) mentions the importance of a trigger to initiate the collaborative process. Hence, this project aimed to set a virtual multiplayer space for the community of the FADA-PUCE (Faculty of Architecture, Design, and Arts - Pontifical Catholic University of Ecuador) to encourage the participants to spend time together out of the academic program, with the excuse of reconstructing the FADA's building virtually.

FADA´s block (bloque FADA, original name) was set in Minecraft: Education Edition. Minecraft is a 3D multiplayer sandbox game that allows users to navigate the virtual space. The game invites players to modify the environment through the arrangement of cubes in the space, users have access to a huge variety of materials, that allow the players to create amazing structures. Minecraft has also been used in a variety of ways besides the game, for instance: urban planning (Rosenberg, 2019), virtual concerts (Alexander, 2020), or school graduation ceremonies (Peters, 2020).

A set of elements were designed before inviting the community to the meetings: (i) a brief manifesto to explain the project, (ii) instructions for downloading the application and learning how to play, (iii) and a privacy policy to inform about collecting data mechanisms. The document was hosted in a public place on the internet and shared through publications through social media and mailing. A Facebook event was created and nine dates were appointed within April 2020. About 100 people participated in the project among students from architecture, design, and arts; several professors and program´s directors joined as well, and even the dean played with the community in FADA block (Fig. 2).

Figure 2. FADA block (https://bloquefada.github.io)

Everyone cooperated to rebuild the place from their memories, since the usage of architectural blueprints were not allowed. Nonetheless, some reported the use of photographs, google maps, and street views to refresh memories, others said that they played with someone seated next to them to remember the place together. Participants were always encouraged to talk with each other in Minecraft´s chat, however, the logics of communication varied from session to session. For instance, some groups organized their building process through the chat, while others talked about casual topics. A few of users used the chat to enable other new communication channels like telephone calls, discord, or zoom. Finally, a website was designed to share the world template with the community and explain the experience. Later, the template was edited in Blender and uploaded in Hubs, a virtual web platform by Mozilla, to add new layers of multimedia information and to create the final exposition of Graphic Design and Products Design programs.

4.2. More creativity, less scarcity

The mandatory use of virtual tools during the pandemic's confinement led to the appearance of new applications. Those previously misused applications in the classroom, in one way or another became novel co-participatory borders. The Design Career at Pontificia Universidad Católica del Ecuador in response to the pandemic, revitalized the Design teaching processes from all the possibilities that virtualization offers to higher education. These new learnings accompanied by the need to act against the global emergency led to rethinking the design projects that were established at the beginning of the semester, to use emerging products for a society that respond to various scenarios affected by COVID-19.

The intention in the Careers of Graphic Design and Product Design classes focused on sensitizing students about the contributions of Design that can be built from home and with the material resources available. The Projective Design methodology incorporated new digital instruments in the classroom, and favored the development of proposals with a global scope. As a result, it led to creative contributions, sustainable and linked to the new way of living and coexisting of people. As relevant examples, a lamp that helps to emotional well-being, an ergonomic table for telework, a solar dehydrator, personal protective equipment, and interactive micro-stories that show the new reality through games (Fig. 3).

Figure 3. Examples of projects devised by Design students during the pandemic

Thinking of a "new better" in Design teaching processes leads to an adaptive practical maturation of all the possibilities that digital tools harbor, such as e-learning platforms, inverted classrooms and Open Source software.

During the pandemic, the Design teaching practice has been dealing with highly emotional challenges in and outside the classroom; therefore, creative, accelerated, exploratory, and practical learning with scarcity-based thinking was adopted to overcome the issues of new normality. This vision revitalized the relationship between emerging technologies and manual techniques as a complementary practice in Design teaching. Hence, a considerable variety of open-source technologies were used in the concept phase, exploration activities, and verification processes, giving greater emphasis on the meanings and narratives. These strategies prompted a quick response from teaching and an immediate adaptation to various tactics such as microlearning, co-participation, resourcefulness, and flipped learning.

In this way, Design acquired a new look at the world as a resilient and edifying discipline that transgresses traditional educational models in academic institutions. Any Design action

Spitz, R., Gonzáles, J. R., Ugarte, S., Álvarez, A., Abril, X. B. & Idiáquez, J. M. (2020). Towards a "Better Normal": Educational Experiences in Design in Latin America During the COVID-19 Pandemic. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 564-576. DOI: 10.4013/sdrj.2020.133.21

transforms the world, and the creation through scarcity will enable students to present empathetic, socially inclusive and globally impactful solutions.

5. CENTRAL AMERICAN UNIVERSITY (NICARAGUA)

5.1. *Rara avis*: the experience of migrating to full online education

Universidad Centroamericana (UCA) is *rara avis* among the rest of universities migrating to fully online courses, as it was forced to do so when, all of a sudden, its San Ignacio de Loyola Campus, in Managua, had become unsafe during the unparalleled social crisis that exploded in April 2018. This took place two years before the COVID 19 pandemic – which, for the second time, required UCA courses to go online.

In 2018, for the initiative of a full online university – which was called Academic Virtual Cycle, or CAV 2018 - we applied Design Thinking to design our migration to full online learning. We redesigned our value proposition, used Business Model Canvas to analyze our Career Business Model. We also created *personas* - the so called Z generation – to learn how they would interact with ICT and used that information to redesign the learning experience. The main handicap was the fact that very few of our teachers were certified as Virtual Tutors in an online training program. Borges (2005) states that for a virtual tutor to be successful, he or she must have been a virtual student before. Teachers must experience the anguish, confusion and desperation of their students during an online course due to the lack of empathy from teachers. Furthermore, an AUSJAL publication -which reported the findings of research conducted in 13 of its 30 universities in Latin America - recommended that, in order to be effective, the training of Virtual Tutors has to be done online (AUSJAL, 2012)

In the pursuing of international support for UCA sustainability, AUSJAL launched an innovative initiative for the CAV2018 through which Volunteer Teachers donated their time to work as Virtual Tutors in courses offered in the CAV 2018 to UCA students. In response to the call, 6 teachers from 3 Jesuit universities worked successfully together with Nicaraguan teachers. They came from University of Córdoba, Argentina; IBERO of México City and UCA of El Salvador. This was an outstanding act of solidarity, and UCA achieved an extraordinary expertise in e-learning methodology, with more than 400 courses served during the CV 2018.

Our experience with the Volunteer Teachers of AUSJAL universities during the CAV 2018 was our fire baptism, so we were in a better position to confront the COVID-19 pandemic. During the first semester of 2020, due to our previous experience, we obtained satisfactory evaluations in most courses. We were able to design and successfully execute learning projects involving more than one subject or specialty, as was the case of Marketing Fundamentals, Branding, Web Design and Graphic Communications Theory (Fig. 4). Interdisciplinary projects are part of the concept model of our Graphic Design program. The "new normal" for our Graphic Design Career will be a value proposition of a learning environment that seamlessly integrate online and physical interaction activities.

Spitz, R., Gonzáles, J. R., Ugarte, S., Álvarez, A., Abril, X. B. & Idiáquez, J. M. (2020). Towards a "Better Normal": Educational Experiences in Design in Latin America During the COVID-19 Pandemic. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 564-576. DOI: 10.4013/sdrj.2020.133.21

Figure 4. Covers of Learning Objects (LO) developed by students and teachers at the Universidad Centroamericana.

COVID 19 added a new layer of complexity to the academic life. We implemented permanent coaching and empathy to better address the anxiety and stress among students and teachers, which commonly arise during online courses. This guaranteed a rewarding online learning experience with few desertions. We also applied innovation using User Experience Research to get insight on our student´s online learning experience and, therefore, improve our efficiency. Certifying all of our teachers as Virtual Tutors was an important asset during the pandemic. Finally, we used a Business Model Canvas tool to turn our business model into an Online and Blended Learning based one. This strategy has helped us face consequences of the political crisis and the "new normal" that we are living in pandemic times.

We feel that the pandemic opens a tremendous opportunity to accomplish AUSJAL´s Strategic Plan 2019-2025, and consolidate a powerful network of 30 universities alongside Latin American region, now that all of those universities went online simultaneously. AUSJAL will become a powerful Latin American university, offering high quality online programs in graduate, postgraduate and doctoral programs, all triggered by the pandemic. Crisis are opportunities.

6. CONCLUSIONS

Considering that the COVID-19 pandemic is far from being over, it urges to ask: in case lockdown policies are necessary to be maintained for a longer period of time, what preparations should educational institutions make? Unfortunately, this possibility is not a mere conjecture. Although recently some countries around the globe have gradually started to release some of their lockdown measures and social distancing policies, according to research conducted by the Massachusetts Institute of Technology in 84 countries, the worst is yet to come: without a medical breakthrough, the total number of COVID-19-related

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deaths keep growing at scary rates, and by mid 2021 "well over 90% of the world's population will still be vulnerable to infection—more if immunity turns out to be transient." (The Economist, Jul 4, 2020).

As Latin America continues to report an increasing number of new coronavirus cases and related deaths, most institutions have already notified their students they will not reopen their *campi*: some will remain completely closed, while others – as in the case of AUSJAL universities - have already decided to continue offering online classes to their students, over the next academic semester.

We don't know how long this pandemic will last, or how devastating their effects will be for Latin America. Still, we must prepare for such an uncertain, unpredictable future, in which we might either need to suddenly lock ourselves down at home once again, to prevent a new contagion outbreak, or – as a result of the emergence of new effective drugs, tests and vaccines – may soon reestablish our social proximity and reopen our schools and universities. In any case, it is important to consider the lessons we have learned during this odd pandemic semester, and better adapt our academic content to a more virtual lifestyle – as this seems to be the new trend of education, in most societies.

As highlighted in the United Nations' Policy Brief *The Impact of COVID-19 on Latin America and the Caribbean* (United Nations, July 2020), recovery from the pandemic in these extremely affected regions should go beyond short-term emergency actions, aiming at "building back better" - with more social equality, greater respect for human rights, as well as great concern for environmental and sustainability issues.

In conclusion, as discussed along this paper, educators are devising innovative strategies for teaching online, and getting ready for a whole new set of pandemic challenges. In this critical scenario, Design education in Latin America has a pivotal role, since it can help building back a post-pandemic society that is not just better - but far much better.

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Design, Education, and the Online Tech-Pandemic

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ABSTRACT

Amidst the COVID-19, the use of technology in the learning environment was no longer a matter of choice. Forced by circumstance, educators had to adapt in order to see the academic year through. While for some, already used to an online modality, it was business as always, for others was the start of a journey through unfamiliar territory. This study inserts itself in such context. It presents and discusses results gathered through an online questionnaire about the perceptions and personal experiences of design educators in Higher Education (HE) caught in this move from in-class face-to-face onto online teaching. Objectively, it portrays how this shift impacted their ability to teach, the compromises made or alternatives sought, and views towards a more technologically enabled future in HE. From a more extensive reliance on Learning Management Systems (LMS), changes in the learning environment, and perspectives of near-future uses of Virtual Reality (VR) in distance education, this study covers uses of technology but also the identification of pain points influencing the overall experience, as well as positive perceptions and significant changes made to the learning environment.

Keywords: Design, Higher Education, Online Pedagogy, Technology.

1. OUTLINE

This study involved HE professionals from the broad field of design and their recent experiences with online teaching due to the COVID-19. It begins by identifying and reviewing published literature to determine and clarify the state of the art regarding distance education, specifically in the online form. This first part follows with a brief overview of the ways technology is changing the learning environment, influencing pedagogy, and the teacher's role. Together, these two provide background to the study. Moving forward, past the methodology, and after presenting results, it concludes with a short resume and discussion involving the most relevant findings and their influence on the teaching, learning, and practice of design.

2. TEACHING FROM AFAR

Distance education, online education, and e-learning are common concepts, however, their definition is not entirely consensual. Sun and Chen (2016) faced a similar dilemma in their literature review when the search string "online education" revealed an association with, or being synonymous of, twelve other terms which, for their paper, they accepted as being “sufficiently synonymous” and used interchangeably throughout (p.160). Other authors, such as Moore, Dickson-Deane, and Galyen (2010), disagree but defining clear boundaries in their work was somewhat challenging. Unclear boundaries are one reason for their non-standardized use in literature, but there are others. The author's country of origin, or local context in which the term is used, is likely to exert influence in the way it is later applied in literature, leading to consequent disparities. For instance, Simonson, Smaldino, and Zvacek (2015) note that online education applies exclusively to HE, e-learning to distance education in the private sector (e-training), and virtual education refers to distance learning in K-12 education (online public schools in the USA and Canada). However, their view on e-learning does not match Hubackova's (2015), whose account makes specific references to its use in HE, in European countries. Another reason may be time; the meaning of each term doesn't remain static to its passage. Variables of different natures (e.g., political, historic, pedagogic, etc.) keep mutating their meaning to keep them aligned with current views. Consequently, this also changes their use, and sometimes denomination; this was the case with the term e-learning, whose origins are rooted in Computer-Based Learning (CBL).

Distance education is the broad, inclusive term. At its heart is the concept of separation of teacher and student, but, for a mode to qualify as such, it has to fulfill three main conditions. The first is distance, which can be of the geographical type, or distance in time; second, it has to enable a channel between teacher and student that allows two-way communication; lastly, it has to integrate an education institution (Simonson, Smaldino & Zvacek, 2015). Online education is then a form of distance education, which utilizes the online medium, and can occur in either synchronous or asynchronous form. The first involves teacher-student interaction in real-time, while the second allows participants to complete self-paced web-based tasks, without live interaction. Asynchronous online education (e.g., a standalone package of instructional material with no face-to-face contact with a teacher or other students) is thought to be the essence of e-learning (Klein & Ware, 2003). The combination of asynchronous online education (hereafter referred to as e-learning) with in-class teaching is known as blended learning. A term also interchanged often in literature with hybrid learning or mixed-mode learning, all of which synonymous (O'Byrne & Pytash, 2015).

3. STAGE PERFORMERS AND LEARNING ORCHESTRATORS

Online education has gained more attention over the years as instruction actively migrates from conventional forms (e.g., books, face-to-face lectures) to computer-based media (e.g., podcasts, educational games) (Mayer, 2019). Several studies have discussed the advantages and disadvantages of online modalities (Hameed, Badii & Cullen, 2008; Hammad, Hariadi, Purnomo, Jabari, & Kurniawan, 2018). Arkorful and Abaidoo (2014) note key factors such as access to a large amount of information, discussion through forums that help eliminate barriers that may hinder participation, and enable self-pacing via e-learning. In contrast, Hameed, Badii, and Cullen (2008) refer to the lack of social interaction, the need for pre-existing digital literacy, and a tendency to be suitable only for students with robust independent learning and motivation skills, which constitute a subset of the student population. Literature supports that a combination of modalities is a better approach and more inclusive of student needs, which has contributed to the rise of blended learning (Wedgwood, 2012).

Merging online components into an existing course, or offering the latter solely online, requires planning. Designing for online means is different from designing for in-class, so what may work in a traditional face-to-face environment won't necessarily do online

(Driscoll & Carliner, 2005). Doing so requires revising the pedagogical framework, — teaching and learning sequence, methods, assessments, etc. as to weave the features of the new medium into a thread leading to the fulfillment of the learning outcomes. In short, integrating online components changes the way instruction is provided by using technology to achieve better learning outcomes, or a more effective assessment of these outcomes, or a cost-efficient way of widening the learning environment (Mayes & de Freitas, 2013).

Learning Management Systems (LMSs) have become central to the day-to-day teaching and learning in many institutions, providing several features that go beyond traditional forms of teaching spaces and standalone technologies (McPherson, 2016). The system is online, available to the community, and enables a multitude of interactions between students, teachers, and support staff. To those who teach, it allows access to tools whose affordances facilitate not only information sharing and subject administration but also task or activity setting for student involvement. The number of resources and features available to both teachers and students, and the tendency for a more technological learning environment, are increasing a move away from lecturing onto more flexible models. Teachers are now having to choreograph content, context, and tools, with both skill and purpose, making them less of stage performers and more of learning orchestrators (Cronje, 2016).

Technology may afford new learning opportunities, but these are still contingent on personal beliefs. The duality, where some see technology as a threat and others as an opportunity, is still common in education (Ertmer & Newby, 2016). Making use of it or not, however, does not influence the ability to teach. Understanding the subject and having the skill to deconstruct a topic into meaningful and manageable concepts is what's genuinely fundamental (Hokanson & Hooper, 2004). Technology is also unable to reproduce the complex teacher-student relationship or effectively transmit all aspects of the proactive, pedagogical engagement of a good teacher (Simonson, Smaldino & Zvacek, 2015). More than technology, and critical to the process, is the capacity of the people involved in orchestrating the learning experience. While these may employ tools technology enables, their use alone will not guarantee the pedagogy or instruction's success.

4. METHODOLOGY

During quarantine, the use of technology in the learning environment was pivotal. Reliance on it has led to a massive experiment involving teachers from broad demographics, who suddenly had to move online to continue teaching. This study aimed to characterize the experience and perceptions derived from this event, particularly from HE academics in areas related to design. Objectively, it sought insight into:

- The level of familiarisation with different forms of technology
- Trade-offs between in-class and online modes; noticeable changes in the learning environment and student learning
- Experience of teaching solely through online means
- VR and perspectives on its applicability to HE

Primary data was gathered through means of a questionnaire, available online during May in 2020. A total of 27 questions, composed of multiple-choice, scaling, and open-end questions, were developed and divided into four parts, as set in the following section. A link to the questionnaire was distributed by email to an education-related personal contact network and the PhD-DESIGN JISC mail list. It got a total of 74 respondents, from which 39 answered entirely. A summary of results is present in the section that follows, which, although it cannot be generalized, can characterize perceptions on online education and its pedagogy.

5. RESULTS

5.1. Demographics

Respondents are within the 25-70 plus age range; the majority is within the 35-49 threshold (61.5%). Gender wise, female respondents outweigh others (57.89%). In design fields, most are from product or industrial design (22.08%), architecture (14.29%), interaction, and user-experience design (12.99% each). About teaching in HE, only 17.95% indicate 0-4 years of active practice; the largest groups are in the 5-9 and 10-14 interval, each at 25.54%. Most are involved at undergraduate (42.03%) and postgraduate (40.58%) level, with 17.39% at the doctoral level.

5.2. Familiarization With Technology

Familiarity, assumedly, enables a quicker adoption of other existing forms of technology with similar features or workflows. Desktop computers or laptops (84.21%), smartphones, and digital tablets (64.91%) rank highest in confidence levels. Less common are wearables and smart home devices, with 49.12% and 36.54% indicating no experience. The lesser-known is VR or Mixed Reality (MR), where 63.13% indicate no experience, against 3.51% who position themselves at an advanced level. On the software side, respondents are most comfortable with web services such as email or search engines (78.95%) and text editors (80.70%). Data processing, social media, and communication or learning spaces show an average proficiency level across the sample.

5.3. Perceptions of Online Education

Before COVID-19, traditional contact teaching was the standard form of delivery (69.88%), followed by blended (25%), and online (2.74%). Once quarantine and social distancing periods started, online peaked to 88.10%, blended lowered (10.71%), and contact teaching recessed to 1.19%. Although not asked to specify the online form, the choice of the channel provided clues. Zoom.us (34.78%), Microsoft Teams (21.74%), and LMS features (14.49%) were the top picks, and the first two occur in the synchronous form. In the option "others," respondents added: Youtube, Slack, Github, Exam.net, Vimeo, Dropbox, and Jitsi. However, in most cases, the channel was defined by the institution (27.27%), not the practicioner. When the choice was theirs, contributing factors included institutional or colleague endorsement (17.17%), affordances or features such as user-friendly interface (16.16%), and built-in options such as screen-share or record (14.14%). Participants added “choosing channels familiar to students” or not blocked in some countries (e.g., Google applications are blocked in China). 68.95% indicated that their institutions provided training to teach online but only 42,86% attended; 26.19% knew about it but chose not to, and 30.95% indicate having had no training before or after moving online. Regarding prior use of LMS features, to track or assign work online, 61.9% reported active use, against 19.05% who had not considered it before;

4.76% deemed it unsuitable to their subject and did not elaborate. 9.52% indicated no access to an LMS.

Teaching online required changes in the pedagogy. In general, respondents note the development of activities to be accomplished online (22.90%), the redesign of teaching materials and assignments (19.08%), and the development of videos, podcasts, or other resources to share with students (18.32%). The option "None, my subject or materials didn't require adjustment" got 0.76%. In the comments, two respondents added, "I made a list of podcasts and write on how to use podcasts on design education" and "adapted the methodology to assign in-class evaluation moments." The assessment was a general cause of concern; the lack of control over the environment was the most worrying factor (21.51%), followed by technology familiarity and limitation of means (16.13%). Respondents also reported "lack of significant interactions," "difficult to know what students learned," "bad internet connection," "limited means to make and test prototypes and models," "students with caring responsibilities, and other complicated circumstances are at a disadvantage," "explanations of assessment not as easy, text-only means students are challenged by English," "it's far more draining working online / having real-time communication mediated through a screen."

Moving online in limited time led to compromises. Had circumstances been different, and if given time to plan, could each of the taught subjects (assigned to the respondents) be delivered solely online to the same standard as in-class? Respondents were asked to indicate their answer on a 1-12 point scale, where 1 stood for "extremely unlikely" and 12 "extremely likely." The 1-5 interval added to 72.22%, from which scale point 1 alone got 22.22%. Interval 6-10 received no responses, marker 11 got 19.44%, and 12 only 8.33%. All answers are summarized below in Figure 1, and Table 1.

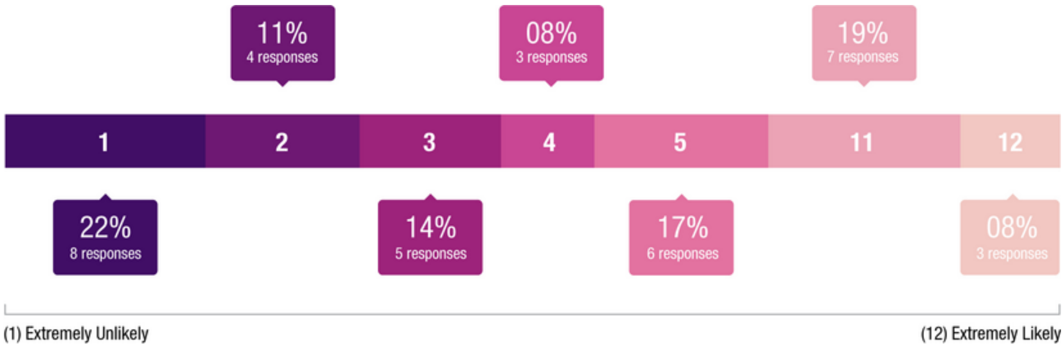

Figure 1. Likelihood of in-class taught subjects being delivered online to the same standard

Table 1. Statistical complement to Figure 1

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
(1) Extremely Unlikely: (12) Extremely Likely	1.00	12.00	5.47	3.96	15.65	40

Regarding the online learning environment, respondents were provided with a series of statements focused on student behavior changes and perceptions about teaching. They were then asked to classify each as unnoticeable, lower, same, or improved. Each of the eight statements and corresponding results is shown in Figure 2, located on the next page. The most noticeable results show a lower ability to "read" the room when discussing specific topics (77.14%), fewer opportunities for spontaneous in-class teaching (67.5%), difficulty in developing meaningful connections with students (60%), and lower participation or communication in class (45%). The most prominent “improved” results were 27.5% and 26.47%, with the first referring to student engagement with content, and the latter regarding students providing the practicioner with teaching or module related feedback.

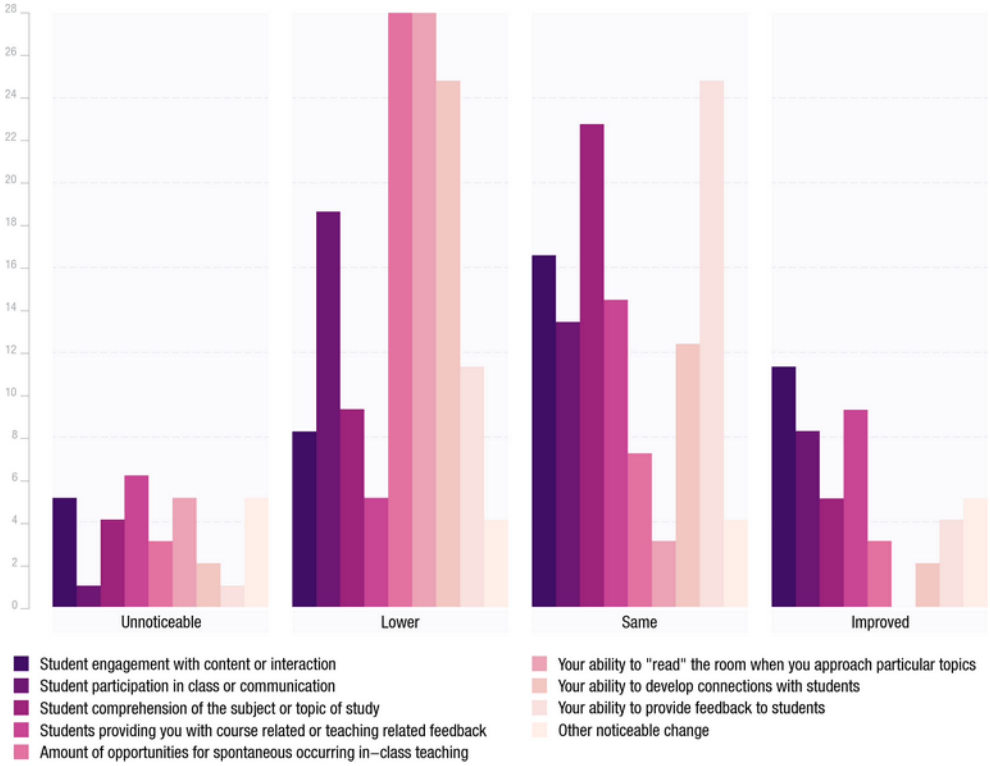

Figure 2. Perceptions about the online learning environment

To further substantiate prior results, respondents were asked to qualify their impressions through a five-point semantic scale composed of 13 polar adjectives or reactions. "Isolating," "separates me from people," and "alienating" scored the highest. "Dull/captivating", "effective/ineffective", or "pleasant/unpleasant" were neutral.

Table 1. Polar adjectives used in the questionnaire five point semantic scale, and results obtained

Polar adjective	++	+	-	+	++	Polar opposite
Active	20.51%	15.38%	28.21%	23.08%	12.82%	Passive
Individualized	17.50%	32.50%	25.00%	20.00%	05.00%	Collaborative
High-level autonomy	20.51%	23.08%	30.77%	15.38%	10.26%	Dependent
Pleasant/attractive	07.69%	05.13%	48.72%	23.08%	15.38%	Unpleasant/Unattractive
Effective	12.82%	15.38%	46.15%	15.38%	10.26%	Ineffective
Motivating	10.26%	10.26%	41.03%	25.64%	12.82%	Demotivating
Engaging	07.89%	13.16%	34.21%	34.21%	10.53%	Unappealing
Isolating	33.33%	23.08%	25.64%	12.82%	05.13%	Connective
Practical	05.13%	23.08%	35.90%	23.08%	12.82%	Impractical
Simple	05.26%	13.16%	42.11%	28.95%	10.53%	Complicated
Brings me closer to people	02.56%	07.69%	23.08%	35.90%	30.77%	Separates me from people
Alienating	10.53%	39.47%	34.21%	13.16%	02.63%	Integrating
Dull	18.42%	10.53%	47.37%	15.79%	07.89%	Captivating

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5.4. VR and HE

Enquiring about VR shows that most respondents are only slightly aware of the technology (46.15%), and 33.33% familiarised. When it becomes the discussion subject, 47.37% thinks about it in the semi-immersive class, 34.21% considers fully-immersive, and 18.42% in the non-immersive. The semi-immersive class is also the most interacted with (33.33%), followed by fully-immersive (27.08%). 16.67% have never experienced VR, regardless of purpose.

Concerns about technology are broad. Price and difficulty in implementing are the most significant (20.45%), followed by VR sickness (12.88%), lack of support (12.12%), and content dependency or relevance (11.36%). Four respondents added "workload prep," "I teach physical computing and design studios, so the application is not that relevant," "not effective unless VR is the subject," and lastly, "VR is a display technology and a current and recurrent hype looking for an application; it's not pedagogy or education." When asked about using VR in the future, in any class, integrated into their subjects, responses dwell between "no" (43.59%) and "not sure" (35.90%); "yes, I plan or expect to use VR in the future" obtains 17.95%. One responded highlighted that the choice of using VR may not be personal but institutional instead. However, given the opportunity, most respondents are willing to learn or use VR in teaching (55.88%); 32.35% remain undecided, and 11.76% wouldn't. The follow-up question asked if their department had considered integrating VR into the program, as a tool for teaching and learning; the response was mostly negative (80%); however, few are integrating (11.43%), and others are now discussing it (8.57%).

6. DISCUSSION AND CONCLUSIONS

With an increasing number of educational systems moving online, and at a much faster pace than before, a change in traditional teaching was imminent. In parts of the world where the existing technological infractured allowed it, transitioning online meant updating pedagogy and redesigning instruction to ensure learning outcomes. Synchronous teaching was complemented with asynchronous learning. Reliance on LMS increased, and assignments were adjusted to fit the medium; all led to a rise in student engagement with content. Utilizing a combination of venues or channels to provide access to information expanded the learning environment and provided fertile ground to test new possibilities. There were, however, two critical downsides. The first was in the form of human connection; the screen-mediated relationship severs the meaningfulness of a teacher-student relation. This loss has broad ramifications, among which the disabling of functions such as the ability to recognize or identify tell-tale signs of student needs or unrest. The second is assessment, which is equally important as a measure of teaching efficacy and student learning. The lack of control over the environment and limited means is concerning, but other elements influence it and are harder to identify or address. These include the home environment and personal responsibilities of each student (e.g., caring responsibilities), time zone and level of proficiency with the language of instruction (e.g., international students), and access to physical resources or communication channels. These are new challenges tied to particular independent contexts, which are now unique and harder to grasp. So, even though educators could deliver their subjects online during this period, it's hardly the same as before. In-class teaching is still seen as enabling more teaching and learning opportunities and closer human connections; the benefits, both at an academic and personal/social level, are various and unmatched by technology, thus far.

Continuing online will influence and exert change on design education; success derives significantly from a social nature that's now compromised. More responsibility is imposed on the student; learning turns into a lonely experience removed from the benefits of a social environment (e.g., group work, peer-learning), and geographical displacement impairs community building. These, and others above-mentioned, will need consideration as they impact everyday practice, especially among first-year students where bonds or relationships between them have yet to form. Researchers have looked for alternatives, and some have found limited success in interactions through social media networks (Schadewitz & Zamenopoulos, 2009). Other possibilities may include VR and Multi-User Virtual Environments (MUVEs). These afford opportunities for embodied social presence, immersive experiences, hands-on activities, and experiential learning (Fedeli, 2011). Features such as these could enable a richer online education experience in design areas but, work in this direction, specific to design and relying solely on distance teaching, is still scarce. The study results suggest an openness to learn and use VR in the future, in the learning environment and, considering the present conditions, the time might just be right for further research and development towards it.

Results and conclusions of this study cannot be generalized. They can, however, provide with an overview of the difficulties and resolve of some HE educators from the broad field of design, in certain contexts, and how they are adapting this new normal as a consequence of the COVID-19 pandemic. This is relevant to note because the responses gathered indicate of a pre-existing and dependable technological infrastructure, with internet access, which is unlikely the case everywhere. Some countries or regions, where also different cultures or teaching and learning practices exist, will likely be dealing with this change very differently. Having this said, it would be exciting to research other solutions taken in effect, in different parts of the world, during this period, and contrast them according to context. Such endevour would provide a broader and more holistic understanding of how different educational systems around the world reacted during this period, and the adaptions made. Such research would allow to establish a baseline to contrast or relate future changes with, in a post-pandemic future.

ACKNOWLEDGMENTS

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Looking through the window: emotional experiences of Instagram users in isolation

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ABSTRACT

The impact of COVID-19 pandemic on the health and wellbeing of people around the world has become an important research topic. Even for non-essential workers, social isolation has drastically changed people's lives and habits. Considering that our daily lives and habits occur largely through the intermediation of products and services, social isolation may have drastically changed people's relationship with the products and services surrounding them. Thus, social media apps like Instagram have become crucial sources of information, social connection, and entertainment for the socially isolated. This article investigates the role of social media applications in people's daily lives in isolation, based on the analysis of their emotional experiences. To this end, an exploratory study was carried out with 13 users in social isolation, based on diaries in which they reported the experiences they had through the Instagram platform from June 15th to June 29th. Results showed that Instagram had brought predominantly positive experiences to its users; however, negative emotions related to an excess of information and content consumption were also relevant. The results and conclusions of this work can be considered in future investigations about parameters for developing digital products that aim to reduce negative experiences and anxiety.

Keywords: Covid-19; Emotional Experience; Social Media; Emotional Design; Diary Study.

INTRODUCTION

The presence of social media apps in our daily lives has grown expressively throughout the last decade. As products, social media apps like Instagram, Facebook, and Twitter have the premise of facilitating and enhancing social connections, personal expression, and entertainment just with a few taps. According to the mobile consulting firm App Annie, in 2019, people have spent nearly half of their mobile use time on social and messaging apps (App Annie, 2020). However, the negative aspects of the heavy use of social media have been widely discussed in books (Lanier, 2018; Sampson et al., 2018; Tettegah, 2016), media articles (Harris, 2016), and research works (de Koning, 2019), such as psychological dependency, undermining of face-to-face interactions, and other potentially harmful consequences. Other works also discuss the positive side of consciously using these products to connect with friends and family, express yourself in new ways (Wood et al., 2016), enhance social connections (Clark et al., 2018) and have access to content people would not normally find in other sources. In the context of social isolation, social media apps have gained special importance as a product in people's lives. They have become one of the only ways of staying in touch with friends, family, and getting information about the world around us. Like any other product, the intensive interaction with these apps has the potential of influencing socially isolated individuals' emotions and wellbeing, which are already being heavily influenced by the ongoing of the COVID-19 pandemic worldwide.

The connections between emotion, experience, and wellbeing in human-products have been actively discussed over the past years. The experience conveyed by any product is a complex structure in which cognitive processes, actions, and emotions come into play, with the emotional aspects having a crucial role (Hassenzahl, 2011). After the episode of interacting with any product or service, people tend to evaluate the experience as “good” or “bad”, depending on their goals, concerns, and personal beliefs (McCarthy & Wright, 2004; Hassenzahl et al., 2013). It is important to note that the emotional aspects, product meaning, and aesthetic elements, are the main components of an experience (Hekkert, 2006; Desmet & Hekkert, 2007). The convergence of emotions, aesthetics, and meaning is connected to the potential that products have of negatively or positively influencing peoples’ happiness (Hassenzahl et al., 2013). In that sense, through its emotional experience, any product can intentionally or not influence the wellbeing of its users in various intensities.

At the present moment, most people around the world have had their daily lives, concerns, emotions, and wellbeing heavily affected by the global pandemic. For individuals in isolation, the internet and social media apps have become their main source of information, social connection, and entertainment. Since this type of product has assumed such a crucial role in the present moment, the following study aimed to investigate the role of social media apps in the pandemic context, focusing on the Instagram platform. The Instagram app was selected because of its diverse functions, serving as a social, business, and entertainment platform. Through the exploration of this problem, we aim to raise hypotheses on what are the true roles of social media apps in crises, and how can we design products that actively promote its users' wellbeing and happiness in this context.

1. ADRESSING EMOTIONS IN HUMAN-PRODUCT INTERACTION

1.1. Emotions in Experience

Our interaction with products is not made of prescriptive and static communications. After interacting with any product or service, users tend to recollect a "story" of what happened and how to assign positive or negative aspects to it (McCarthy & Wright, 2004; Hassenzahl et al., 2013). Kahnemann (1999) defines “experience” as a thread of emotions, thoughts, and actions, separated from the immediate moment that they have occurred. The emotions elicited over the course of interaction are one of the main aspects of how a user evaluates their experience with a product. Desmet and Hekkert (2007) and Hekkert (2006) discussed that specific layer of experience under the term of product experience. The Product Experience can be understood as the overall affective aspects that arise from interaction between people and products. That includes the sensorial levels (aesthetic experience), the meaning (experience of meaning) and the emotions and feelings (emotional experience). It is important to note that all three layers work together to convey an experience, as it can be observed in figure 1 (Desmet & Hekkert, 2007).

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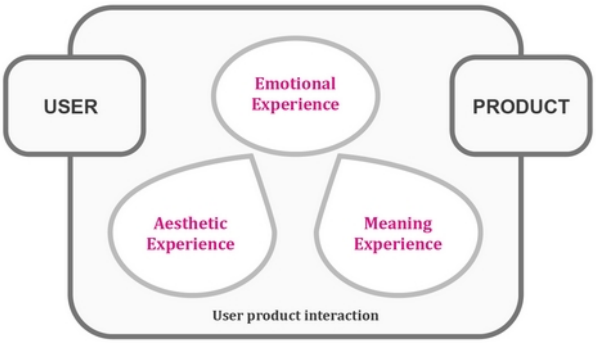

Figure 1. Framework of Product Experience (Desmet and Hekkert, 2007).

Regarding the emotional experience, emotions in interactions are consequences of how people appraise aspects of the product, defining them as positive or negative for their concerns and wellbeing. A demonstration of the Basic Model of Product Emotions can be seen in figure 2 (Desmet, 2003).

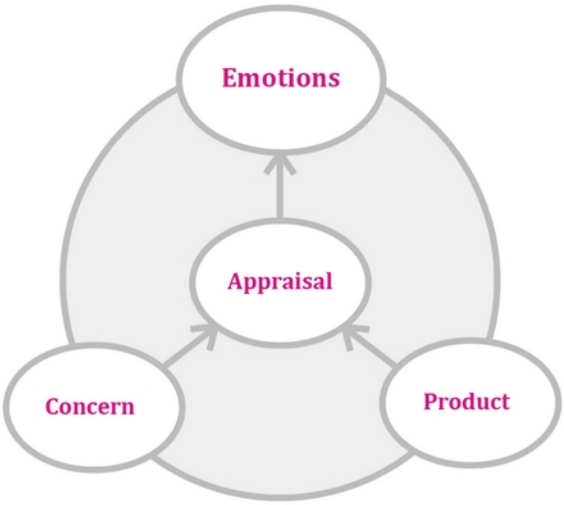

Figure 2. Basic Model of Product Emotions (Desmet, 2003).

In the context of the emotional experience, an appraisal is what mediates products and emotions. That mediation is the main reason why people can have different emotional reactions after interacting with the same product (Desmet, 2003). Understanding of the components of an emotional experience is crucial to the present work, given its multilayered nature. Social media apps are complex products where multiple concerns and motivations coexist. Because of that matter, we understood that the presented models would provide an adequate exploratory analysis of such an intricate subject.

1.2. Classifying product relevant emotions

Drawing from previous research on cognitive emotion models and appraisals, Desmet (2003) proposes a multilayered model of product-specific emotions. The model establishes a direct link between types of appraisals and types of emotions. In that sense, the model is considered multilayered because it addresses the social, aesthetic, and functional aspects of interaction with products. Based on five appraisal types (novelty, motive/compliance, intrinsic pleasantness, legitimacy, and challenge & promise), five types of emotions can be elicited: Surprise, Instrumental, Aesthetic, Social, and Interest emotions. A representation of the model can be seen in figure 3 (Desmet, 2003).

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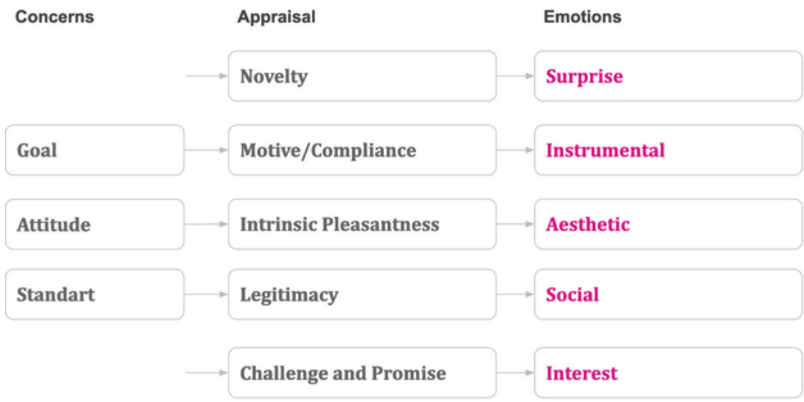

Figure 3. Model of Product Emotions (Desmet, 2003).

Surprise emotions are elicited when some aspect of the product or experience is considered unexpected by the user. On the other hand, Instrumental emotions are related to our goals and expectations while using a product. The Aesthetic emotions are elicited by aspects of a product that affect our senses and generates an attitude of "liking" or "disliking" a product. Social emotions are related to our expectations of how “the world should be” or how “others should behave”. Interest emotions are linked to stimulations (or lack thereof), like challenges or promises that the product evokes. For example, if a user opens Instagram intending to find new meat-free recipes (their goal, a type of concern), they might be delighted to find what exactly they had in mind (which then would be an Instrumental emotion). They might even feel happy and validated because other people share their concerns about meat consumption (which would be a Social emotion). In that sense, the model addresses not only the emotion itself or its affective aspect, but also where does it come from in the experience of using a product.

In light of the diversity of functions that Instagram offers, and the multilayered nature of an emotional experience, the model proposed by Desmet (2003) was considered ideal for the scope of the present study. It is essential to note that this model was designed with physical objects in mind. For that reason, we have considered not only the app itself but also the content it delivers to its users. Since content sources at Instagram are curated and prioritized by the app itself in different ways, we considered that the final result could also be studied as a product-specific aspect.

2.METHODOLOGY

To analyze the participants’ emotions and concerns, we have used the structured Diary Studies method, paired with a previous survey. The Diary Study is an option for collecting data in situ, providing a holistic, self-reported view of experience (Baxter et al., 2015). The chosen method is also versatile enough to be done remotely, which was crucial in the isolation context. The method consisted of calls on the Instagram platform itself, with diary entries crafted as Instagram Stories, where participants could interact without leaving the application. This format makes it less likely that users delay or skip submissions, and is considered ideal for real-time collections (Baxter et al., 2015). Both the survey and Diary entries were designed to collect a closed set of variables: affective indicators, emotions, and concerns that arise from the experience of using Instagram, and how their daily Instagram use has changed during the isolation period.

2.1. Method structure and procedures

The previous survey sent to all participants inquired three questions: Question 1 asked, "For how long have you been practicing voluntary social distancing, going out only for essential activities (buying food, drugstore, emergencies)?". Question 2 asked users to rate how much their Instagram use was during isolation by an increased or decreased scale of -2 (Sharp Decrease) to +2 (Sharp Increase). The last question (Question 3) inquired what were their main motivations while using Instagram in their social isolation period. Participants could select up to three (3) options out of nine (9). The results of the previous survey would provide some important context for analyzing the results of the following step.

Regarding the Diary study entries, the first question (Q1) inquired, "How did you felt using Instagram today? You can link specific pictures or posts you may want to share. If you did not use this feature today, you can skip the entry." Q1 had subsections for each of the four main content sources at Instagram: Feed, Stories, Live Transmissions, and Explore tab. The second question (Q2) inquired participants their main motivations for publishing content today (provided if they have published any content). The purpose of these questions was to overview the emotions, goals, and concerns that aroused from the experience of using Instagram and the affective aspects of their experience (positivity or negativity). The Diary entries for these questions, formatted as Instagram Stories, can be observed in figure 4.

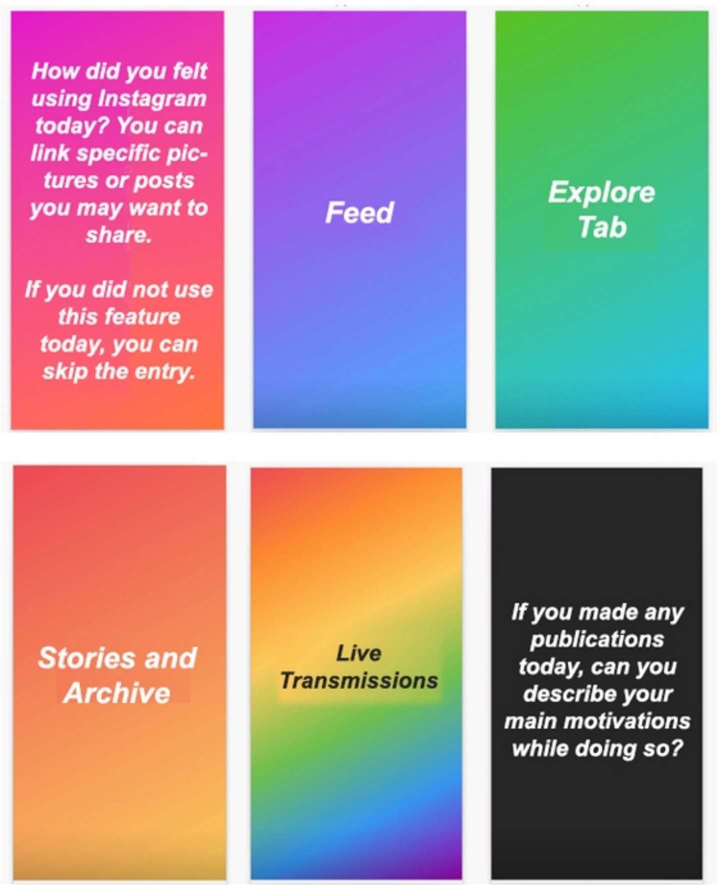

Figure 4. Diary entries formatted as Instagram Stories.

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The third and fourth questions inquired: “Report using this scale how Happy (Q3)/Aroused (Q4) did you feel while using Instagram today”. These questions would be used to collect the general affective aspect of their experiences, composed both by pleasure and arousal. These questions were answered using an app native slider, supported by a 5-level scale for Pleasure and Arousal, with a corresponding emoji for each level.

The Pleasure and Arousal sliders were inspired by the work of Bettella and Verschure (2016) that creates the "Affective Slider", which is a digital and self-reported tool to communicate affective aspects and emotions (Bettella & Verschure, 2016). Given the format of our study, there were considerable limitations for the implementation of the Affective Slider, which is more suitable for webpages. One of the goals in designing the study was that the participant did not have to leave the Instagram app to answer the entries. Because of that matter, we have decided to construct a slider and scale using Instagram Stories' native features, while keeping Pleasure and Arousal as components of affective aspects.

The five emoji were selected based on answers provided by the participants before the first entry was sent, via a preliminary survey about emojis and meaning. We have asked the participants to select the three (3) emoji that best communicated each of the following emotions: Pleasure; Displeasure; Arousal and Disinterest. We have decided to adapt "Pleasured" to "Feliz" (Portuguese for "Happy") in the Pleasure slider because we considered that other translations to Portuguese would not convey the same message in the desired intensity as "Feliz" would. For the same reasons, we have decided to use "Empolgado" (Portuguese for "Excited") for the Arousal slider in Portuguese.

In the following question, participants were asked to rate on a scale of 1 to 5 how each emoji represented these emotions for them. The results of both sections were combined using the average of each emoji's scores, resulting in a 1 to 5 level emoji scale for Pleasure and Arousal. The results were used to create the Diary entries for these questions, formatted as Instagram Stories with sliders, as it can be observed in figure 5.

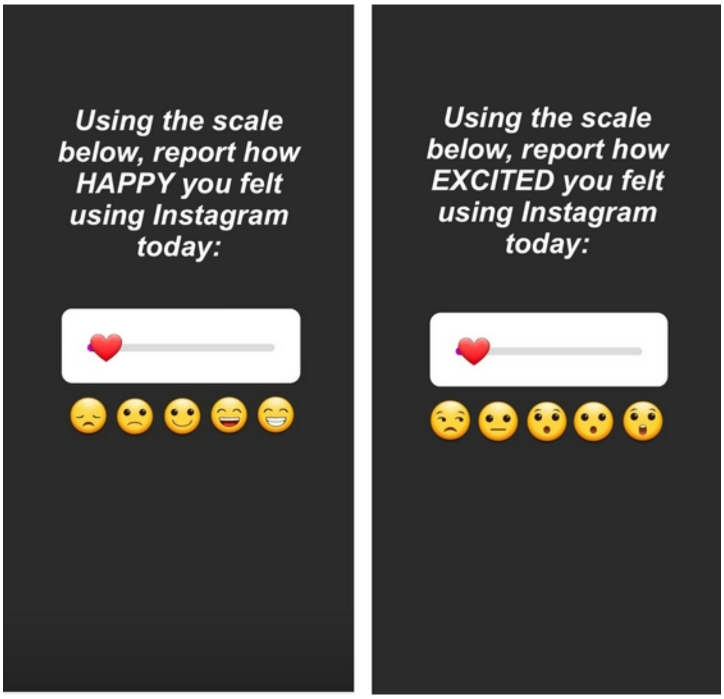

Figure 5. Diary entries for Pleasure and Arousal as Instagram Stories with native sliders (translated for English).

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We have selected a convenience sample of fifteen (15) individuals for the Diary Study. The participants needed to fulfill two criteria: (1) using the Instagram app at least two times a week; (2) having been in social isolation due to the COVID-19 outbreak for at least a month, before their first day of participation. The Diary entries were sent via Instagram Direct for each participant, in the evening, for two weeks. Two (2) participants had dropped off from their participation before the first entry was concluded. The participation rates ranged from

3 days (21,4%) to all 14 days (100%) by the end of the study, where any number of answered questions in that day was considered a valid Diary entry. The final qualitative and quantitative results allowed us to overview which types of emotions and concerns were most significant for users of the Instagram app during their social isolation times, as well as a look at their Pleasure and Arousal tendencies while using the platform.

2.2. Result Analysis

The text entries were analyzed by classifying reported emotions in the Model of Product Emotions (Desmet, 2003). We have considered associated reasons (appraisals and concerns) to infer what type of emotion was being reported. We have also classified emotions in positive and negative ones, considering the context in that they were expressed, and the reasons presented by the participant.

We have converted the slider answers of participants to numbers from 1 to 5 using an image editing software. Using the resulting numbers, we have calculated the median for "Pleasure" and "Arousal" for each participant. Subsequently, we compared the median values to the tracked emotions and purposes.

At the end of the study, we had a pool of 210 emotions expressed across 269 different text entries, 106 Pleasure reports, and 104 Arousal reports. These results are analyzed and discussed in the next section.

3.RESULTS

Before considering the Diary Study outcomes, we have overviewed the Preliminary Survey results, which would give us a first look at the participants' goals and habits of using Instagram in their isolation period. Most of the participants (66,7%) reported that one of their main goals when using the Instagram app was to “get a distraction”. The following goals were Entertainment (60%), Communication with family and friends (53,3%), Self-expression (46,6%), and Information in general (40%). The least reported goals were Developing new skills (13,3%), Information spreading/Seeking information about the pandemic (6,7%) and Spreading information about the pandemic (0%).

To start examining the overall emotional experience of participants with Instagram, we have classified all reported emotions into ten groups, where each emotion type (Surprise, Instrumental, Aesthetic, Social, and Interest) had "Positive" and "Negative" subgroups. The distribution of those groups can be seen below in figure 6 and figure 7.

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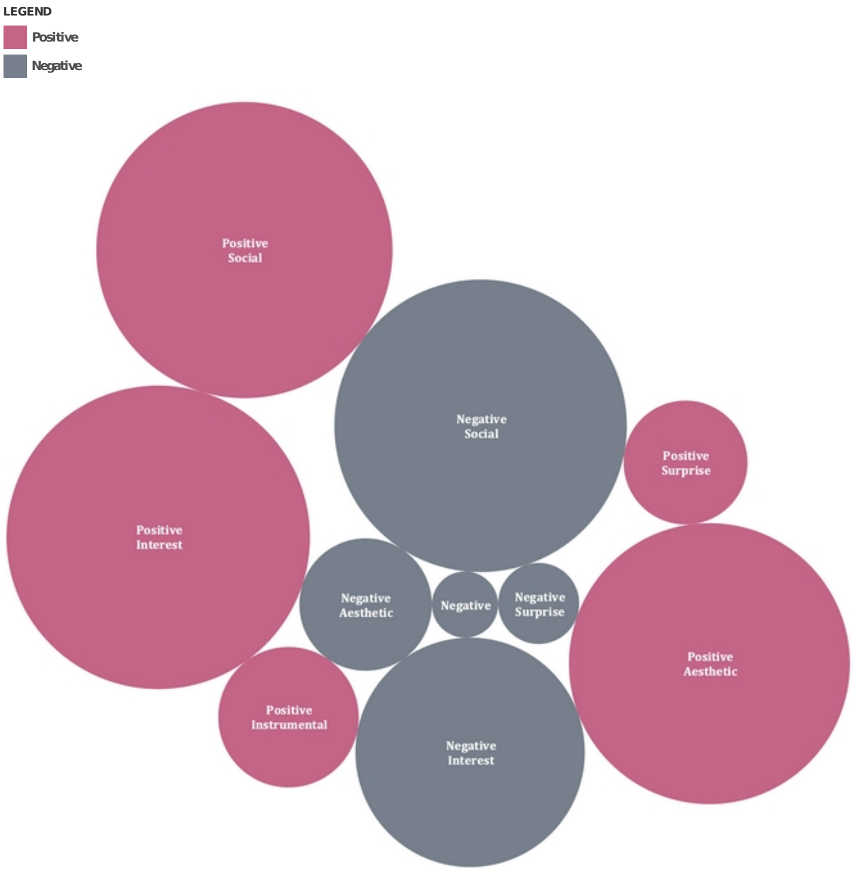

Figure 6. Distribution of reported product emotions by type/affect in a bubble chart.

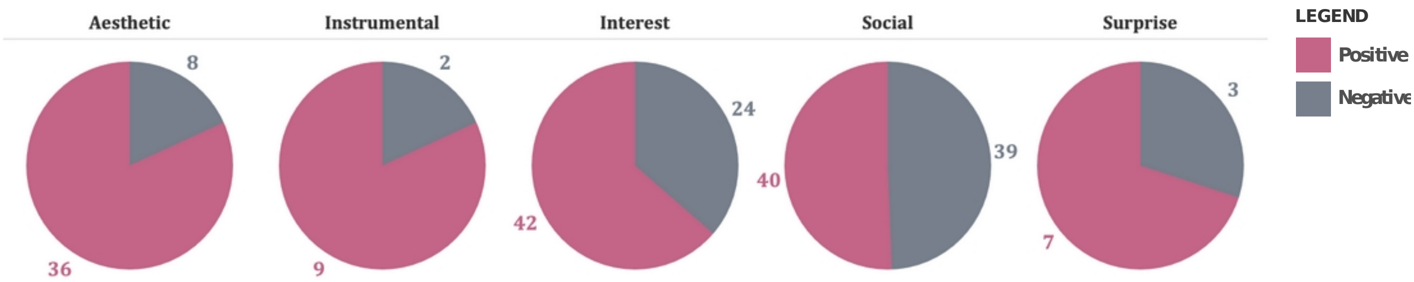

Figure 7. Distribution of reported product emotions in pizza charts by type.

Observing the first two charts, we can note that Positive emotions were most dominant across the participants, with Positive Interest emotions being the most occurrent group (42 in 106 reports). Positive Social (40) and Negative Social (39) emotions were the second and third most expressive types. Social emotions were the only group where Positive and Negative emotions demonstrated a similar number of reports. Aesthetic, Instrumental, and Surprise emotions shown a predominance of Positive emotions in general.

The majority of Negative emotions were related to the disregard of social isolation norms by others and to political events, which would normally fall under the Social emotion type. Some examples are "anger", "indignation", "irritation" and "disdain". As for Positive emotions, the most occurrent reasons were being able to check up on friends and family or remembering pleasant moments with them. We initially thought of "Nostalgia" and "Saudade" as inherently Negative emotions. According to the Lexico dictionary, “Saudade” can be translated as “a feeling of longing, melancholy, or nostalgia that is supposedly characteristic of the Portuguese or Brazilian temperament” (Oxford University, 2020). After considering the context where those emotions were reported and the concerns behind them,

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we have discovered that they were not necessarily unpleasant for all of the participants. A portion of these reports was associated with encountering pictures taken before the pandemic and were linked with pleasant feelings, such as "hope" and "happiness". Although there is some discussion on whether Saudade has a positive or negative component associated with it, for the scope of this study, we have decided to consider what other feelings came along to make the decision. "Inspiration" was also a very occurrent feeling that was often found alongside Aesthetic emotions. Many participants reportedly used the app to seek inspiration and pleasurable themes like animals, art, and decoration.

Another type of Negative emotion that was recurrently reported was Negative Interest. Reports like "Boredom", "Anxiety", and "Melancholy" were very occurrent, often associated with the dullness of repetitive content being delivered through the Feed, Stories, or the Explore tab. Almost half of the participants said that they felt "entertained" or “distracted” after using Instagram. We have considered these to be Positive Interest emotions since the most occurrent goal for using the app amongst participants was "just for distraction" (66% of participants).

We have also correlated the emotions affectivity to the reported alteration of use frequency, and the resulting chart can be seen in Figure 10. However, it must be considered that frequent users will tend to report more emotions as well. Considering that fact, we have also analyzed the median Arousal and Pleasure tendencies for each frequency alteration group.

Although all frequency groups have reported mostly positive emotions, the groups “sharp decrease in use” and “sharp increase in use” had a greater predominance of Positive emotions, as we can see in figure 8.

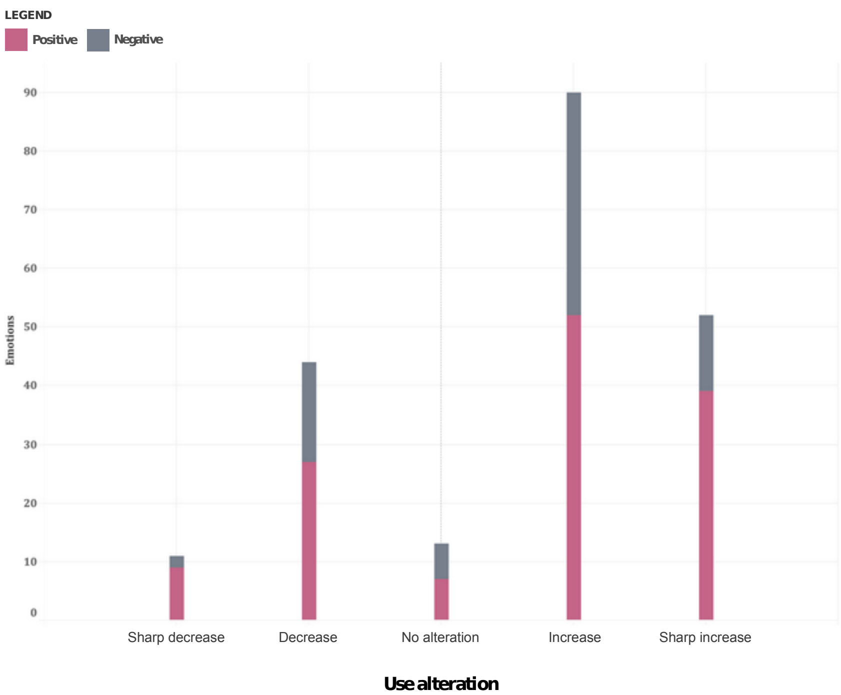

Figure 8. Emotion affectivity by frequency of use alteration groups.

As it can be observed in figure 9, the Pleasure medians ranged between 2.4 and 3.0 in the five use alteration groups. The group “sharp decrease in use” has tended to demonstrate more Pleasure than other groups (median of 3.0). However, groups 1 and 2 (increase and sharp increase in use) have slightly higher Pleasure tendencies.

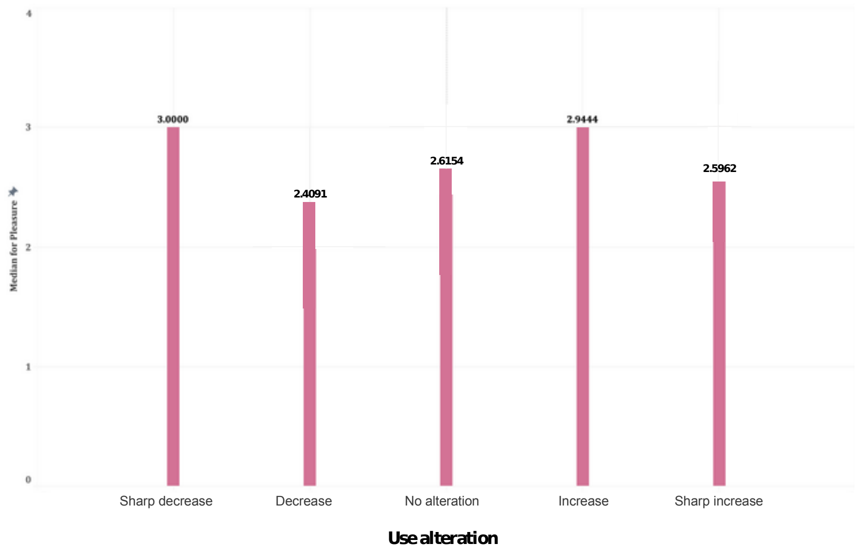

Figure 9. Median for Pleasure by frequency of use alteration groups.

Considering the Arousal tendencies by frequency of use alteration group in figure 10, we can observe that the group "decrease in use" tended to feel more Aroused than other groups. The Arousal medians in the five groups ranged from 1.5 to 2.5 by the end of the experiment.

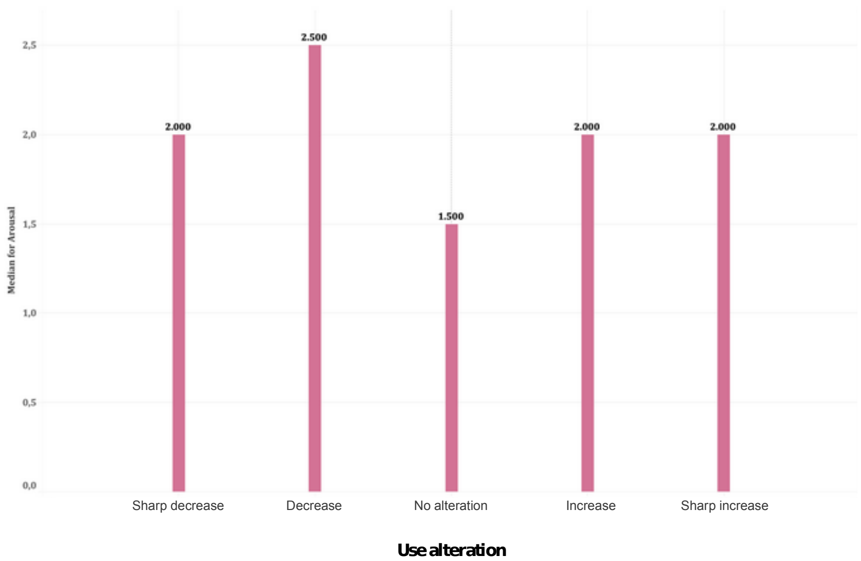

Figure 10. Median for Arousal by frequency of use alteration groups.

4. DISCUSSION AND CONCLUSIONS

In this work, we have explored aspects of emotional experiences in the interaction with the Instagram app, considering the context of the COVID-19 pandemic in Brazil. Observing the results, it can be stated that most participants have reported more Positive emotions than Negative ones. Despite variations of proportions between respondents, none of them have reported more Negative emotions than Positive ones. However, even with the predominance of Positive emotions, the Pleasure tendency of the group was still around 2.5 out of 5.0. We must consider the expressiveness of each participant in this case. Aside from that, the Positive emotions were frequently associated with being able to check up on friends, colleagues and family ("a warm sensation seeing my friends' smiling", "Quite happy to see old videos of me and my friends", "Felt informed after seeing how my friends are doing"), or with pleasurable content like domestic animals, art and news that they consider being good ("I've felt delighted with so many cat pictures", "Inspired to see so many talented Brazilian

De Paulo, B., Damazio, V. & Quaresma, M. (2020). Looking through the window: emotional experiences of Instagram users in isolation. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 586-598. DOI: 10.4013/sdrj.2020.133.23

female artists"). That reinforces the hypothesis that isolated individuals already had the habit of using Instagram before the pandemic. The product represents an efficient means of keeping in touch with dear ones and with the world outside.

Nevertheless, often the same type of content that brought participants Positive feelings, depending on the context and how it was presented, conveyed Negative ones as well. While keeping themselves informed about their friends, some participants reported feeling overwhelmed by notifications or repetitiveness of content ("Felt bored seeing the same pictures taken from the same angles and monuments again and again", "So much information, I don't remember what I saw", "Overwhelmed by all that repetitive content"). Negative emotions related to excess and repetitiveness of content represented 15% of all reported emotions. Considering that, it can be hypothesized that the way Instagram delivers content to its users can convey them anxiety for never feeling "done" with all the information it presents. Recent work in psychology research associates frequent social media use to mental exhaustion and stress (Sriwilai & Charoensukmongkol, 2016; Thomée et al., 2007). Field specialists like Tristan Harris (2016) have elaborated on how most content feeds are designed to keep people from leaving and reconsidering their consumption (Harris, 2016). In the context of social isolation due to the pandemic, Gao et al. (2020) examined the correlations between mental health problems and social media exposure during the COVID-19 outbreak in Wuhan, China. Their findings report that the general population is combating an "infodemic" in parallel with the pandemic (Gao et al., 2020). This "infodemic" can be described as the excessive amount of information isolated people expose themselves to on a daily basis. Although the present study has a different scale and purpose, we can formulate that the repetitive, "never-ending" way Instagram presents its content can intensify the same feelings of exhaustion and stress.

Elaborating on content, we have observed that the most and least frequent users reported proportionally less Negative emotions than the intermediary frequency groups. This observation raises the hypothesis that a frequent user has more opportunities for understanding how to curate their content, limiting topics, and people that can bring them negative emotions or unpleasantness. A non-frequent user can either have already curated their feed or stay in the platform enough time to fulfill a set of tasks and then leave. Therefore, we raise the question of how social media apps can provide efficient tools for users to control their content consumption. We can observe the contradictions between Positive emotions and Pleasure/Arousal reports in the study. Some participants reported their observations on how, despite talking about pleasurable emotions in their text entries, they did not feel complied to report higher pleasure/arousal levels in the sliders. Therefore, we can question if all the positive experiences Instagram has conveyed to the participants are healthy and positive for them in the long run.

Considering all observations, we can conclude that Instagram has brought mostly positive emotions to the participants, based on how it was a tool for communication, information, and entertainment. For isolated individuals, television, video-on-demand, and social media apps were important ways of keeping in touch with the world and with friends and family. However, users still have to be aware of their content and information consumption to avoid unhealthy states of mental exhaustion and stress, especially in the isolation context. According to the World Health Organization, in a post-pandemic world, "regarding what is happening during this pandemic for people, [...] mental health will be a problem in general," (World Health Organization, 2020). In the light of the present moment, it is relevant to discuss how can designers and other decision-makers provide tools for users for rethinking their content consumption and usage in a healthy, self-conscious, and autonomous way.

5. FUTURE WORK

Given the exploratory scope of the study and the current scenario, we concluded that the Instagram Diary Study was an efficient technique for collecting insights and raising hypotheses on the emotional experiences of isolated individuals in the pandemic. Although some participants were more talkative and engaged than others, we were able to carry satisfactory participation rates throughout the fourteen days of study. For future work using this format, we recommend pairing the Diary Study with other user research methods, like interviews, aimed to remove any biases and test hypotheses. Considering that the Diary Study and interviews provides subjective and self-reported data, it is also relevant to combine these methods with objective emotional response measuring tools. Some examples include Eye tracking, Galvanic Skin-response (GSR) and EEG headsets (Schall, 2014). We intent to run broader studies around the same research problem and evaluate other product emotion models for that matter. In the future, an emotional experience model regarding digital products or social media apps specifically might be a research goal.

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STRATEGIC DESIGN RESEARCH JOURNAL

Mexico City's Quarantine Narratives and Underlying Values for Future Urban and Domestic Design

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ABSTRACT

This paper explores the construction of quarantine narratives as they relate to the design of everyday public spaces and domestic artifacts in Mexico City. The interdisciplinary research studies the government-led health campaign and exposes pre-existing urban design problems further accentuated by the crisis. In parallel, the paper presents an online survey in which photographs and texts of domestic objects are analyzed alongside artistic exhibitions and events that uncover individual needs and aspirations. Finally, the paper identifies a set of collective and distributed values for Mexico City's New Normal to be materialized locally at the urban and product design scale and discusses the potential of narratives as a design tool.

Keywords: design narratives, quarantine design values, interdisciplinary analysis

INTRODUCTION

Mexico City's demographic, social and economic contrasts pose serious challenges for controlling the COVID-19 pandemic, and offer fertile ground for the conception of new narratives. What can design learn from quarantine narratives, and what implied values will influence the design disciplines in the near future?

The research methodology begins with the examination of graphic content used to deliver public health slogans, norms and recommendations. Local news stories, labor and transportation statistics, and mapping techniques were employed to crosscheck the official public messaging against real urban conditions. Photographs of personal domestic objects that gained significance at the onset of quarantine and accompanying texts were collected through an online survey and analyzed through the generation of a word cloud and object categories. The study of performance art, artistic work and exhibitions that specifically spotlight domestic objects in their storytelling further inform the interdisciplinary research. The authors conclude that narratives serve as a valuable research tool for conceptualizing design futures.

1. COVID-19 PANDEMIC IN MEXICO CITY

Initial cases of COVID-19 appeared in Mexico towards the end of February 2020 (Gobierno de México, 2020). The Secretary of Health officially decreed quarantine measures a month later closing down all non-essential services (Gobierno de México, 2020). With more than

21,581,000 inhabitants, Mexico City ranks as the fifth most populated city in the world (United Nations, 2019). The city's vulnerability to the pandemic, however, is not only due to its size but a combination of cultural, economic and urban design factors that pose serious challenges for effectively carrying out safety measures.

According to Mexico's National Institute of Geography and Statistics, more than half of workers in Mexico City belong to the informal sector and labor in precarious conditions (INEGI, 2015). Peer-to-peer informal businesses and services include small street shops, street markets and street vendors. In other words, a significant portion of economic activity takes place in public space and hinges on physical contact and proximity. This high-risk sector of the population lives on a day-to-day basis, with no social security or safety net and no option to work from home.

Not only does the public nature of this population's workplace pose a threat, but also the congested mode and long hours spent commuting in public transportation. Mexico City is one of the top most congested cities in the world according to the TomTom Traffic Index. The congestion level for 2019 was calculated at 52%, which translated in 195 extra hours spent in traffic per year (TomTom, 2020). Centrally concentrated places of employment draw workers living in the periphery or in the neighboring state. The periphery-center mobility pattern reflects an uneven distribution of affordable housing near places employment (Fig. 1). Extensive daily commutes to and from the city, translate into an average travel time of 2-6 hours daily in overcrowded subways, buses, and *peseros* (collective taxis).

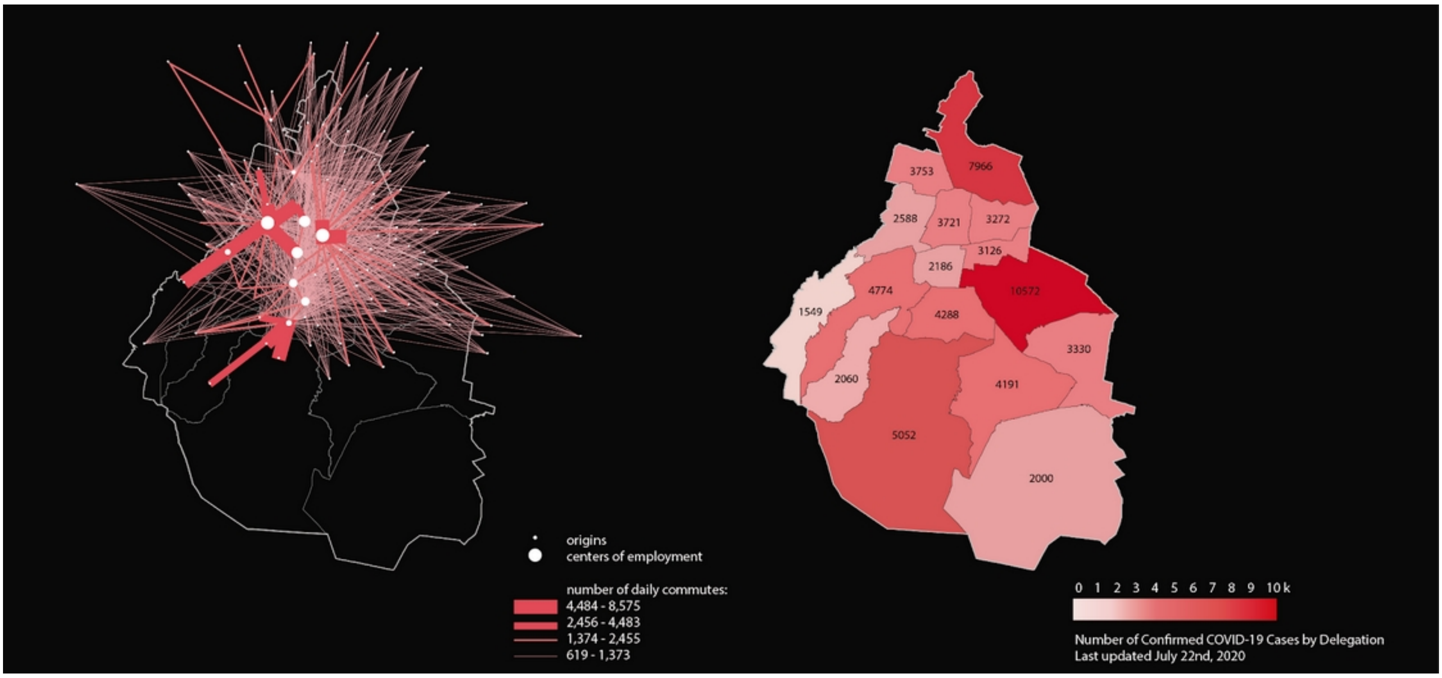

Figure 1. Left: Mexico City workers' daily commute. (González, 2018) Right: Number of Confirmed Covid-19 Cases by District. (Gobierno de la Ciudad de México, 2020)

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The family-oriented and traditional nature that characterizes Mexican culture adds another layer of complexity to managing the pandemic. For example, regardless of the health emergency and strict government issued stay-at-home orders, several Mexico City residents left home to buy flowers and presents on Mother's Day. To avoid the agglomeration of crowds and another peak of infections, authorities shut down one of the largest flower markets, *Mercado de Jamaica*, days leading up to May 10th. The strategy notably backfired given the rush to slash prices to sell all merchandise, which only attracted more crowds in the days leading up to the shutdown (Gómez, L. 2020). When assessing risk and benefit, a pressing need for economic survival as well as social, religious and cultural expectations largely factor in as reasons for interrupting quarantine.

2. MEXICO CITY´S NEW NORMAL AND THE QUARANTINE MODULOR

The Mexican government's spokeswoman for social distancing, a female superhero clad in pink spandex with arms stretched out, popularizes safety measures through media outlets. “Susana Distancia,” a play on words meaning “your safe distance,” combats the invisible enemy by modeling responsible conduct in public spaces. Her super power? When she extends her arms, a 1.5 meter diameter bubble magically appears that keeps coronavirus away, a super power any citizen can tap into.

Figure 2. Susana Distancia. (Gobierno de México, Secretaría de Salud,2020)

Susana Distancia, however, is more than an effective communication tool, she is the new measure of all things. Leonardo da Vinci’s Vitruvian Man transmitted the principles of order and proportion, values that strongly shaped Renaissance design and its materialization. Centuries later, Le Corbusier’s Modulor, a man with an arm raised to measure 2.20m, reconciled standardized dimensions and a bold modernist vision. In the history of design, the reinvention of the “ideal body” has played a fundamental role in imagining new models of living that are submitted to material constraints (Picon, 2020). In the age of coronavirus, health constraints are reshaping our interaction with our material world and our design values.

On June 1st Mexico City’s government devised a gradual plan towards a *nueva normalidad* (new normal) following its own "traffic light" system in which red signals maximum quarantine measures. As a part of this strategy a graphic campaign was designed with guidelines for different public spaces, such as the *tianguis*, an open street market where vendors sell produce, grains, clothing and other items. Immediately following the reopening of the city center’s shops and tianguis, an overflow of visitors poured onto the streets with a large disregard for safety measures prompting new closures (González, 2020). In the photographs capturing a day in Mercado de Jamaica, the new normal looks quite similar to the old: the eerie affinities disrupted by a cloud of face masks. A closer analysis of existing architectural typologies and urban design reveals stark contradictions between what officials decree as safe and what is physically possible.

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Figure 3. Left: typical day in Mercado Jamaica (IMER Noticias,2020). Right: a Sunday in nueva normalidad in Mercado Jamaica (Severiano, 2020).

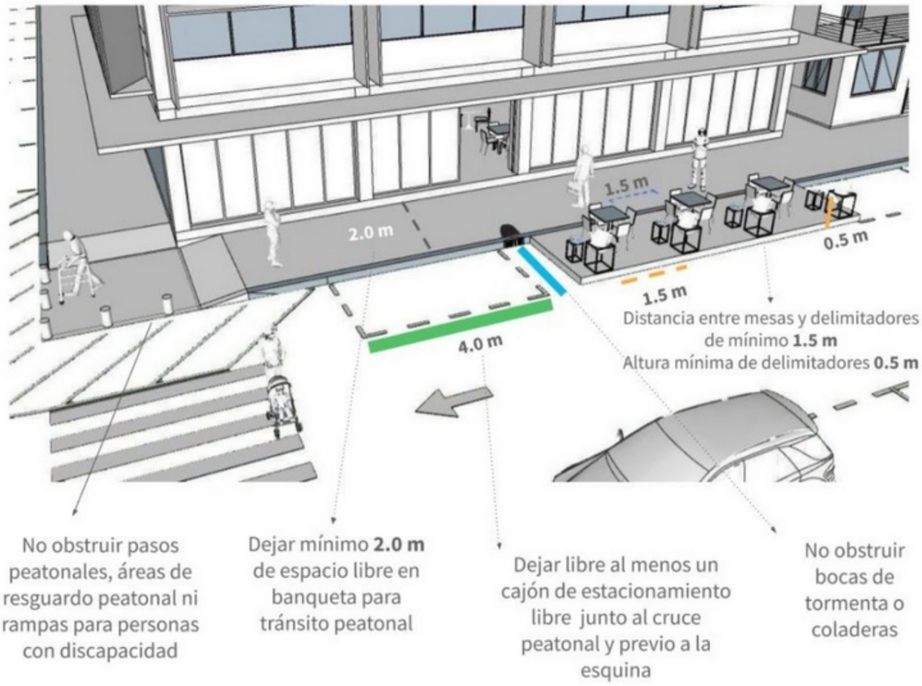

Figure 4. Street corner illustration for restaurant social distancing guidelines. (Gobierno de México, Secretaría de Movilidad, 2020)

As part of the strategy for reopening restaurants, local government issued a set of guidelines permitting restaurants to operate in public sidewalks and parks in order to increase capacity from 30% to 40% (Secretaría de Movilidad, 2020). The illustration used to outline the rules for safely spacing furniture outside depicts a bird's eye view of a fully accessible street corner, complete with a 2m wide sidewalk and a clearly marked crosswalk (see Fig. 4). This game board only exists in a few major avenues of the richest neighborhoods of Mexico City, excluding the majority of restaurant owners from playing by the rules. Furthermore, to officially condone the invasion of public space is ironic given that the regular informal occupation of streets, sidewalks and parks for private economic gain is already standard practice in Mexico City.

For example, streets leading up to the largest wholesale market for produce in Mexico and in the world, *Central de Abastos* (CEDA), either do not have an accessible width to maintain social distancing or are intermittently interrupted by physical barriers ranging in their degree of permanence including construction, light posts, trees, planters, tarps, parked cars or even arcade machines (see Fig. 5). Located in the delegation of Iztapalapa, one of the poorest delegations in Mexico City (CONEVAL, 2015), CEDA already has reported more than

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500 COVID-19 cases (Argüelles, 2020). Considering the lack of accessible urban design and basic services such as running water for carrying out the simple task of washing one's hands, it is no surprise that Iztapalapa is a hotbed among delegations for coronavirus, leading the charts with more than 25,952 confirmed coronavirus cases and 2,255 deaths as of November 2020 (UNAM, 2020) (Fig. 1).

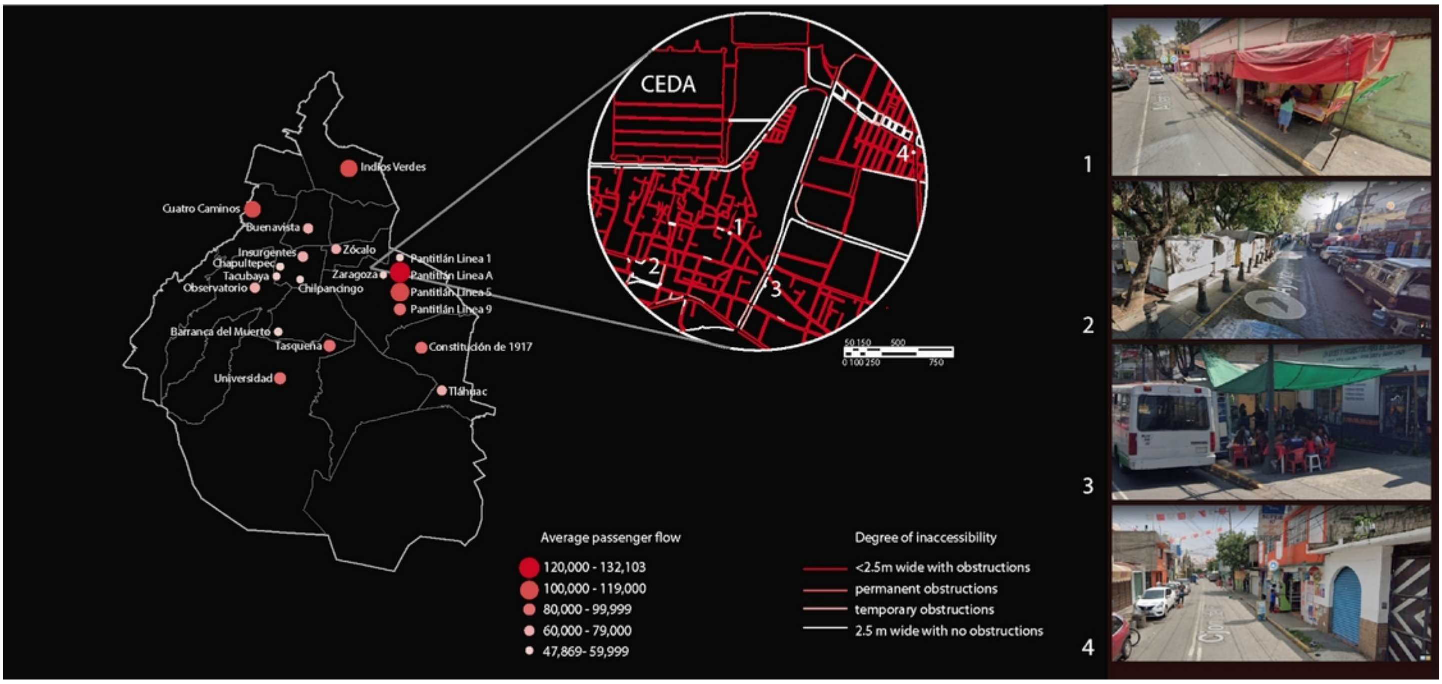

Figure 5. Left: Quarterly average passenger influx April-July 2019 in the busiest Mexico City metro stations. (Gobierno de la Ciudad de México Metro, 2019) Right: The obstruction of public sidewalks leading to the Central de Abastos. (Google Earth Images, 2020)

The inaccessibility of the streetscape is an extension of the high-contact and hostile nature of the public transportation system. As part of the new safety measures in the metro systems, authorities demand users to use facemasks, keep safe distancing, and refrain from talking (Ramírez, 2020). The compressed spaces and excessive amount of users generate crowded funnels that forcefully interrupt safe distancing. Furthermore, the most frequented metro stations in Mexico City physically coincide in most cases with the most marginalized delegations (Fig. 5). Similar to the informal commerce variable, delegations whose higher dependence on public transportation and time spent in these modes of transport present higher contagion rates (Merodio and Ramírez, 2020).

Figure 6. Users of the metro system in Mexico City on June 1st 2020 (Castillo, 2020). Right: Sign instructing passengers to avoid talking (García, 2020).

The grave disconnect between what health authorities demand of the public and what is spatially possible in places of work, leisure and transportation in the public sphere

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underscore the fragility and overwhelming deficiencies of existing urban and architectural design models in Mexico City. Prevalent inaccessibility, inequitable distributions of services, and the ambiguous definition of public space in spite of the overwhelming reliance on it for economic survival, reflect design structures on the brink of collapse. The same design principles that historically participated in the marginalization of populations, now present life-threatening health hazards to the most vulnerable.

In early July, the Secretary of Health introduced Susana Distancia's "health squad," one for each traffic-light phase of the pandemic modeled after women minorities: an elderly woman, a woman with a disability, an indigenous woman, a queer woman (Proceso, 2020). The superheroes sport their own color costumes and accessories and each one informs the public of the strategies for fighting off the specific perils associated with their phase. Susana Distancia and her allies reflect a clear push towards social inclusion, accessibility and tolerance and a much needed change in the cultural understanding of what strength and courage look like in a country deeply plagued by femicides and machismo. In response to such an ambitious agenda, resilient design typologies must materialize at every scale to support and reflect shifting cultural values.

3. ESSENTIAL DOMESTIC OBJECTS AND DISTRIBUTED VALUES

Home, a place where one can comfortably leave the superhero costume and face mask at the door, has become the designated "safe haven" by the government stay-at-home order *quédate en casa*, (Fig. 7) first instituted on March 23rd. According to a national newspaper survey, the number of people staying at home dropped from 71 to 64% between April and June (Moreno, 2020). For those who can afford to stay at home, the long ongoing quarantine has created opportunities for creative interactions with domestic spaces and objects.

Figure 7. Stay at home government ad. (Gobierno de México, Secretaría de Salud, 2020)

In the Mikhailovsky Theatre dancers video (Hosie, 2020) gone viral at the onset of worldwide quarantine, a ballerina floats across the room in arabesque, gracefully stirring her cooking pot before gently placing it on the dining table; another dancer playfully bourres around a cutting knife, fanning herself with a large dinner plate. The body's masterful engagement with kitchen utensils beautifully captures the underlying paradox of quarantine: a surprising newfound imaginative freedom afforded by a state of confinement. In Mexico City, ingenuity extends to the spatial dimension, and no domestic territory is left unexplored. In *sueños de azotea* (rooftop dreams), an artistic performance created by Tránsito Cinco Artes Escénicas, artists defy gravity with circus acts while performing quotidian activities such as hanging laundry out to dry: "In that (rooftop) ambiance of ropes, knots, bed sheets,

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pipes, antennas and wash basins, different actors escape confinement with their creativity" (Palapa, 2020). The theatrical narratives invite an audience to view these domestic objects and spaces with fresh eyes.

Perhaps less elegantly yet in an equally inventive way, common people are heroically engaging with the material and spatial limitations of quarantine. The home doubling as office, daycare, gym, and classroom breeds uncomfortable overlaps and frictions that lead to a redefinition of our relationship with our domestic universe. These intense juggling acts strip away preconceived affordances and reveal the essential qualities that have us clinging to certain objects.

Figure 8. Left: Pandemic *Lotería* submitted for Design in Quarantine. (Gonzales, 2020)

According to Mexico City residents, which key artifacts are essential in quarantine? To gather insights the authors launched an online survey during the last week of June and first two weeks of July 2020, in which Mexico City transitioned from a "red phase" of maximum alert, to an "orange phase." The survey asked Mexico City residents to upload a picture of an object that had become significant to them during quarantine and include a small text explaining their meaning. The survey collected 119 replies from respondents ranging from 19-78 years of age.

Results are analyzed by generating a word cloud in which words are scaled depending on its rate of recurrence. *Trabajar* (work) is the word used most often, followed by *me_ayuda* (helps me), *familia* (family), *tiempo* (time), *contacto* (contact), *día* (day) and *nuevo* (new), among others. The word *trabajar* is employed for reporting the usefulness of an object in relation to maintaining a job and an income. The word *me_ayuda* describes objects seen as helpers, as comforting elements, or as a way to help achieve something. The words *tiempo* and *día* signal a heightened sensitivity towards the passing of time, and the construction of a habit or ritual. *Contacto* is used for objects that permit communication with loved ones, that draw one closer to nature or to note prolonged physical contact with the object itself. The word *nuevo* describes new pastimes, carving out new spaces for productivity, new modes of working or staying in touch. Descriptions range from objectively stating needs the chosen object satisfies to thoughtfully sharing a discovered appreciation or affection for the object.

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Figure 9. Word cloud generated with texts of the respondents

Domestic objects or artifacts have been studied and categorized before, a methodology that leads to understanding the affective properties of objects. In “the power of things” (1990) and “Fieldwork in the living room: an autoethnographic essay” (1994), Riggins classified domestic artifacts based on the categories of symbols in Goffman's theory (1959). Some categories Riggins proposed were esteem objects, occupational objects, alien use objects, social facilitators and time indicators. Another example of categorization used was that of agency and mode, to distinguish between an active and passive use of objects: objects to be handled or objects to be contemplated. In design, the topic has been studied by product semantics (Krippendorff and Butter, 1984; Krippendorf, 2006), emotional design, (Norman, 2004) design for positive emotions (Desmet, 2012), design for pleasant experiences with products (Ortíz Nicolás, 2014), positive design (Desmet and Pohlmeyer, 2013), product attachment (Mugge, 2007) and slow design (Strauss and Fuad-Luke, 2008; Grosse-Hering et al, 2013). Desmet (2012) used a survey where product images were included to categorize products based on the emotions they evoke. The categories he proposed were the following: object-focus (emotion provoked by a product's appearance, including taste, tactile quality, sound, and fragrance), meaning-focus (association of a product with a person, event, or a product symbolizing values or beliefs), interaction-focus (products to fulfill a need or achieve a goal), activity-focus (products that enable or facilitate an activity), self-focus (products used as a social identity, self-identity) and other-focus (interactions facilitated or influenced with other people by products). Whereas previous authors have created their own classification of domestic products to guide designers in identifying target emotions in their design process, local context must be considered.

In a worldwide pandemic, it is easy to generalize the stay-at-home experience; affective relationships with objects, however, are nuanced and specific to urban settings, individuals and their personal narratives. These relationships are especially fluid in these unstable times as new routines emerge and our use of domestic objects intensify. The analysis of the uploaded images, therefore, beseech a categorization based on the descriptions to understand new patterns. Some categories are based on exact words used by respondents, while other categories are created by deduction from the comments. Many objects fit in two or more categories depending on the text submitted.

The chosen categories are: contact (mostly laptops, tablets and phones to stay in touch with others, the outside world and for working); escape (natural objects such as a hanging plant-frame or potted plants, comfortable objects such as a lounge chair or recliner and artifacts used for distraction such as a video game console); comfort (objects that appeal to the senses like a scented candle, a wine glass, coffee or tea cup; remembrance (items like a cross or baby footprint); (re)commence (objects associated with starting a new activity or taking up an old pastime, such as a crochet needle and ball of yarn, a cooking stove, a telescope, an easel for painting, a guitar or a pencil and paper); perform (objects connected to work and productivity such as a blackboard for planning, post-its, headphones to concentrate); ritualize (objects that are mentioned in connection with a time of day and a ritual, like a coffee cup that ensures a "happy morning" or a metal cone for pour over coffee in which time is dedicated to its preparation) and aid (helpful objects that accompany the person every day, like sandals or books, and objects that assist in staying healthy like a face mask or a bike to move around without risking contagion).

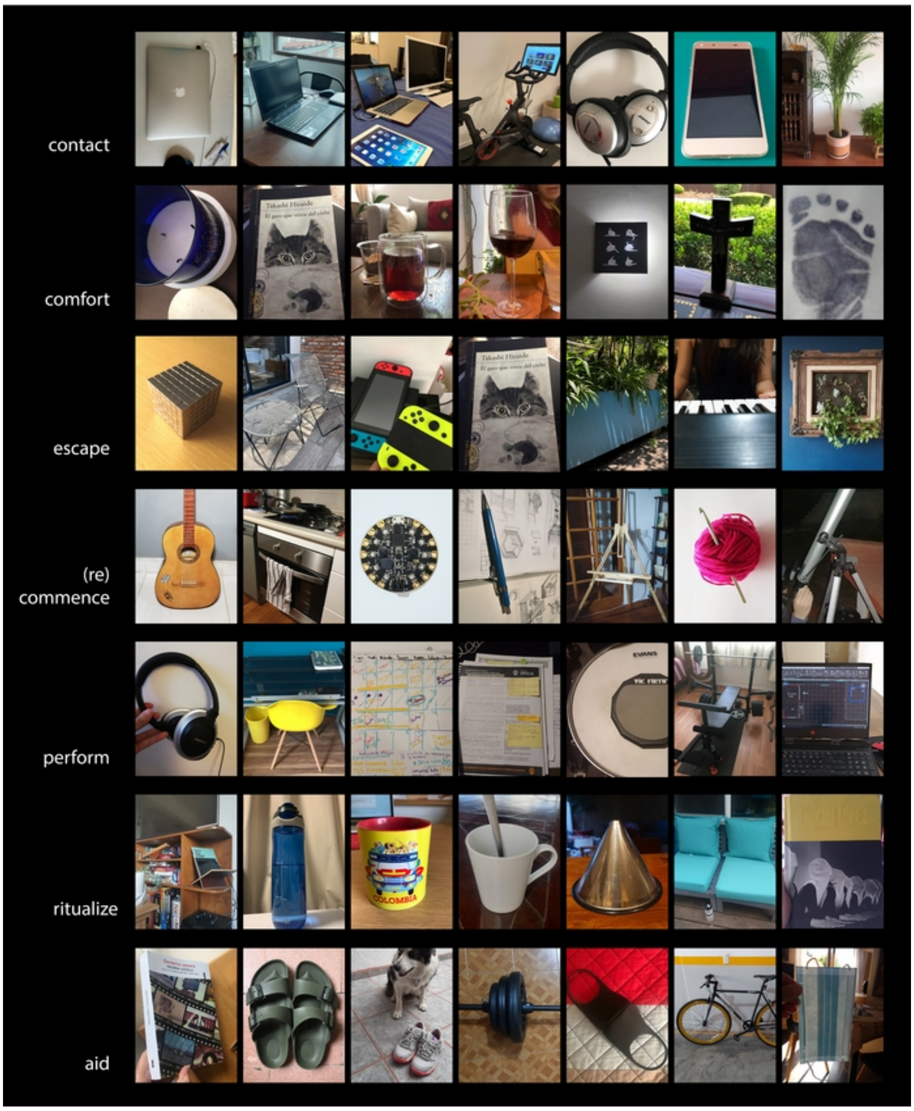

Figure 10. Object images uploaded by respondents and corresponding categories.

Delgado, M. & Sattele, V. (2020). Mexico City's Quarantine Narratives and Underlying Values for Future Urban and Domestic Design. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 599-613. DOI: 10.4013/sdrj.2020.133.24

The findings and object categorization can contribute to previously mentioned design research on affective properties of objects and product attachment in connection with the "domestic new normal". Studying the characteristics of the objects chosen can be helpful to understand the essential characteristics for coping and thriving. For the participants of our study, these objects have gained new emotional meaning and value, and the analysis of the responses offer weak signals of changes in home living that will have to be considered by the design disciplines.

In parallel to the research presented here, an initiative by the *Museo del Objeto del Objeto* (MODO) in Mexico City, called *Los Objetos del Confinamiento* (Objects of Confinement), asked the public to upload objects to their webpage with a story. The personal reflections offer perspectives into the dreams, joys and challenges of individual households and reveal how old objects are imbued with rich new meaning. A *papalote* (traditional Mexican kite) transports one author back to a sunny day in her childhood hometown and fills her with hope of one day flying the kite again with family. An electric juicer is a symbol of the family's business and the pressing need to leave home daily to keep the family business afloat: "There is no choice...if you get sick, it's over, but if you stop working, it's also over." For another author, a pair of slippers acts as two trusted companions, faithfully present while he eats, does house chores, kills insects, assists video conferences, drinks whiskey, dances and goes to bed. Finally, a woman describes her ritual of making lemonade and being deeply moved by the news of rising cases of domestic violence on the radio; the lemon squeezer serves as a reminder that home is not a "safe haven" for everyone[1].

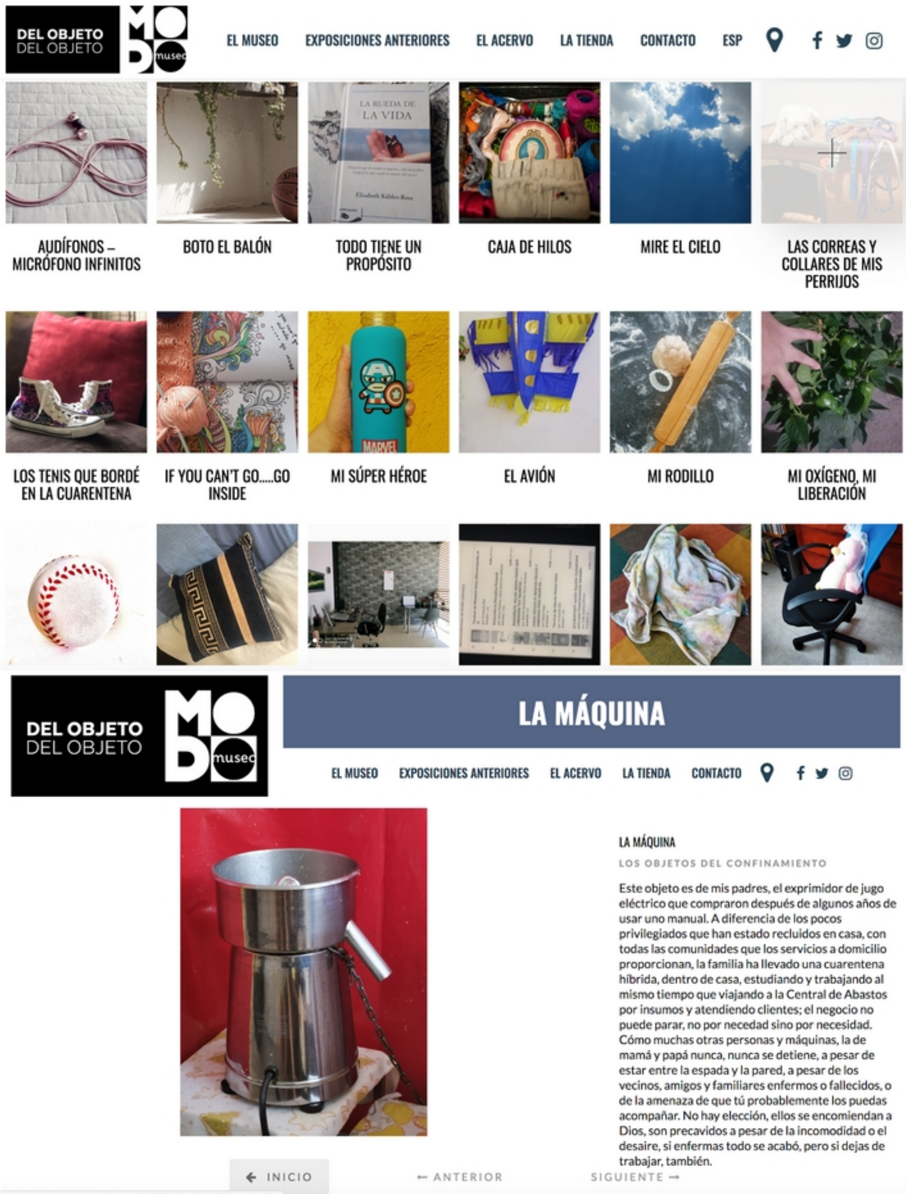

Figure 11. Above: Online exhibition curated by the *Museo del Objeto del Objeto* (MODO) entitled *Los Objetos del Confinamiento.* Below: Example of object and story exhibited (MODO, 2020).

Delgado, M. & Sattele, V. (2020). Mexico City's Quarantine Narratives and Underlying Values for Future Urban and Domestic Design. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 599-613. DOI: 10.4013/sdrj.2020.133.24

4. CONTEXTUALIZING DESIGN VALUES

Through the study of COVID-19 narratives generated in Mexico City a new set of instrumental values surface for driving future design in the public and private domains. In relation to public space, the authors identify an overarching narrative crafted by the government that tasks individuals to act "heroically" by practicing safe distancing and staying at home. Existing urban design coupled with the economic and cultural context, however, render this new normal a fantasy at best for the most vulnerable populations. The narrative's incompatibility with reality underscores a dire need for new design values to be implemented at the urban scale. The collection of personal narratives reflect a transformation and/or intensification of use and meaning assigned to ordinary domestic objects. They also uncover parallel realities, some of which contradict the government's vision or instructions: home is not safe for everyone, and not everyone can work from home. Nuanced perceptions, needs, worries, and struggles reveal personal conflicts that can signal the emergence of new design values.

The following table summarizes the design values identified in the research of the top-down and bottom-up narratives. Each row represents a category or type of value instrumental in the present and near future: the left column lists design values relating to urban space and the right column proposes principles relating to a domestic context within that specific category.

Table 1: Mexico City design values for quarantine and the new normal

	URBAN	DOMESTIC
Accesibility	Physically accessible	Digitally accessible
Interaction	Inclusive	Mediating
Centralization	Decentralized	Centralized
Productivity	Productive in the exchange of goods and services	Productive in the exchange of information
Perception	Visual and low-contact	Highly sensorial
Circulation	Highly choreographed	Spatially overlapped
Rituals	Conducive to safe health rituals	Conducive to meaningful personal rituals
Collective vs. individual	Supportive of collective cooperation	Supportive of individual expression

Urban space must be physically accessible, inclusive, decentralized, productive in the exchange of goods and services, visual, low-contact, highly choreographed, conducive to safe health rituals and supportive of collective cooperation. Designing with these principles in mind can help ensure a better environment for controlling the pandemic while allowing the informal sector to generate an income. The authors believe that the design of public spaces in Mexico City that properly safeguard the health of a growing informal sector while securing their productivity is paramount.

On the other hand, the domestic realm has acquired new meaning for those who can work from home. The home doubling as office, school, gym, etc., depends on efficient communication with the outside world and an intense interaction between household members. Therefore, domestic environments should be digitally accessible, mediating, centralized, productive in the exchange of information, highly sensorial, spatially overlapped, conducive to meaningful personal rituals and supportive of individual expression. For

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architects, product and service designers, this means a new way of conceptualizing the home in order to diffuse tensions and compromise between so many conflicting needs.

Furthermore, if new design models emerge in the domestic space and prove resilient post-quarantine, they can have positive repercussions in the urban sphere and vice versa. For example, the home office and the decentralization of urban activities could help mitigate some of the major traffic problems and long commutes that Mexico City has faced during the last decades as discussed in the first section of this article. Less time spent in traffic translates to more time spent on meaningful personal activities at home. The shift in the strong emphasis on mobility towards recreational uses of public space could lead to more investment in public parks, bike routes and pedestrian friendly projects.

Although this research was carried out at the macro and micro scales, the conclusions highlight the strong interdependence between both worlds. The neat separation between spatially distributed functions has collapsed, and design disciplines can no longer afford to work in isolation. Spaces and products must inform and complement one another to bring about coherent design strategies that negotiate the collective and individual in a post COVID world. The role of the designer is to imagine future worlds, a process that necessitates the use of new analysis tools that lead to a holistic understanding of how our urban and domestic worlds are intimately intertwined.

Given that the aim of this paper is to create a highly contextualized framework for informing future design in Mexico City, the design values that were identified cannot be generalized and applied to other cities. Following steps for this research should consider expanding the range of design disciplines and applying the methodology to other metropolises. Follow-up research should study whether the proposed values persist even after quarantine measures are lifted. This paper contributes to ongoing research on how design can learn from the construction of narratives during crises in urban settings.

ENDNOTES

[1] The number of calls reporting domestic violence during the month of March 2020 increased 70% in comparison with March 2019 (Consejo Ciudadano para la Seguridad y Justicia de la Ciudad de México, 2020).

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HETEROTOPIA WORK: Correlation Between the Domestic Built Environment and Home Offices During COVID-19 Confinement

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ABSTRACT

The new COVID-19 context has transported work to a domestic setting. These new locations, heterotopic, do not always adequately respond to user needs. This paper explores the relationship between the domestic built environment and certain elements that shape it, the perception, emotional state and productivity of the users. A pilot case study was carried out with 11 volunteers who evaluated their home offices for seven work days using physical environment tools, two tests -fixed data and daily evaluation- . Also, environmental parameters of the territory were monitored. Among the main findings, we observed that the perception of size does not relate to actual size; a balcony is associated with happiness and calm. We have verified how biophilic elements promote well-being. Happiness and calm are related to hight and low levels of lux. There is a tendency of happiness associated with collaborative tasks, and calm with individual ones. This article opens up a path for exploratory research on resilient situations in which physical barriers force people to seek creative solutions and offers tools to empower users. Current trends in data-driven design and teleworking support research proposals like this one, with a focus on well-being, productivity.

Keywords: Built environment, COVID-19 confinement, Emotions, Home office, Perceptions, Well-being

INTRODUCTION

The interaction between the built environment and human beings is based on the exchange of information via the distinct physical environment parameters of the surroundings and human beings. As creative disciplines, design and architecture enable an efficient configuration of one's environment to improve and support full well-being for human beings at all levels. These physical-environmental parameters must be controlled to ensure that they are within people's comfort ranges and to promote well-being and quality of life as their consequences and effects can actually impact health (Barrett, Barrett, and Davies, 2013).

The current COVID-19 pandemic is rapidly reconfiguring the way spaces are inhabited as a result of measures such as confinement, social distancing, and the reduction of movement. Moreover, studies are already being carried out that link physical environmental aspects with the virus, such as contamination levels and the spread of the disease (Centre for Research on Energy and Clean Air, 2020).

The measures taken by various entities and governments have produced a complete physical barrier during this period for all citizens, in which their work life has been restricted to the domestic sphere. This other, improvised work space, created by necessity, coincides with Foucault's (1967) concept of heterotopia, or heterogenous spaces in social and cultural terms due to the search for juxtaposition, combining different components, discontinuities, and the hybridization of various incompatible spatial elements within a real space, creating a particular microcosm (Martin et al., 2015; Çalışkan, Ribeiro and Tümtürk, 2020). A real place in which incompatible spaces are juxtaposed (García Alonso, 2014).

The above refers not only to the space itself, but also to the multiplicity of experience and aesthetic judgment through communication technologies (Vattimo, 1992), terms that encompass these "other" workplaces and their relationship with the people who inhabit them.

By the end of 2021, 25-30% of the workforce is expected to work from home several days a week (Global Workplace Analytics, 2020) and 75% of CFOs expect to transfer former on-site employees to remote work following the COVID-19 pandemic (Gartner, 2020), making it necessary to understand the compositions and configurations of these domestic spaces with a view to ensuring solid performance from and the well-being of their inhabitants.

The inequality present in terms of different housing formats and qualities is a reality, as is the fact that not everyone has access to quality space, especially due to the cost of living in large cities.

In terms of well-being, quality includes good natural lighting, thermal and acoustic insulation, resistant and toxic-free materials, placement in relation to the sun's path, and size, not only in terms of square meters, but also cubic meters. These characteristics do not always depend on the end user. However, there are other elements that do depend on the user, which can help and contribute to well-being, such as aspects regarding biophilics, aesthetics, maintenance, and the choice of healthy products insofar as chemicals such as textiles, leather, agglomerates, and so on are considered. All this influences the perception that people may have of their own spaces and their physical and psychological health. Some reports on trends are already attesting to certain points of tension in home offices, such as a lack of space, nature deficit, physical health and hygiene issues, and simultaneous video calls within the same space (Trends Club by Cenfim, 2020).

This is why empowering users with knowledge about this topic is a necessity, as is understanding what these parameters mean, what value they have, how they affect people, and how they relate to one another, not only on a physical level, but also on an emotional level. This empowering can be achieved through simple, easy-to-use everyday technology tools such as mobile phones.

Although emotions are a complex dimension for human beings, there is evidence and literature that make it possible to classify them to distinguish one from another (Abella Garcia, Clèries Garcia, and Marco-Almagro, 2020). One way is through the arousal-valence model, which frames emotional experiences in two terms: valence –positive or negative affective quality– and excitement –how relaxing or exciting the information is– (Rubin and Talarico, 2009).

The objective of this pilot study is to explore the relationship between the domestic built environment and certain elements in its configuration, the perception and emotional state of users, and their performance –types of activity and cognitive aspects– during COVID-19 confinement. Furthermore, it aims to contribute to the processes of obtaining scientific data that may impact project processes, ergonomics, and design guidelines focused on well-being.

Within the context of the current crisis, this study has unfolded as a resilient research case study in which the available resources and the barriers due to the situation are a driving and innovative force for creating interesting research methodologies with everyday elements to collect data.

1. METHOD

To achieve the objective set out for this article, an exploratory pilot case study was developed and applied in three countries: Spain, Sweden, and Chile. In order, to explore the possible differences and check that this methodology can be used in different contexts, as a response to the globality of the problem.

The participants included 11 volunteers -7 from Spain, 3 from Chile and 1 from Sweden-. Eight of whom were women and three of whom were men, between 25 and 65 years of age. All of them live in an apartment located in different cities. As this research was a pilot study in an emergency context – with uncertainty about the duration of lockdown – the sample is small but enough to validate the methodology used and extract some conclusions about the topic.

The tools used consisted of: a fixed data sheet, DS1, and a daily data sheet, DS2. The first provides information corresponding to the parameters, such as: form, biophilia, artificial lighting, colors, and predominant materials, among others.

Heterotopia DATA SHEET 1
WORK FIXED DATA

Participant name	Occupation

Parameters	Sub-parameters			Perception							Emotion				
					1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
FORM	Overall size			Small						Big					
		YES	NO												
	Terrace or balcony			Small						Big					
		YES	NO		1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
BIOPHILIA	Nature views			A few						Several					
	Plants inside home			A few						Several					
ARTIFICIAL LIGHTING	Color temperature	WARM	COLD								Calm	Happiness	Disgust	Sadness	Neutral
	Space1														
	Space2														
	Space3														
COLORS		NAMES			1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
	Space1			Colorless						Colorful					
	Space2														
	Space3														

MATERIALS	Which material do you like the most or attracts your attention most in your space?	

TEMPERATURE	Do you have air conditioning?	YES	NO

		YES	NO		1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
WORK	Have you ever teleworked before?			Sporadically						Constantly					

Figure 1. Example of DS1 fixed data sheet.

In contrast, the daily evaluation sheet, DS2, facilitates evaluating data from the environment, such as lighting (lux and type of lighting), noise (dB), and temperature, as well as activity and certain cognitive aspects such as creativity, productivity, concentration, and general satisfaction.

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Heterotopia DATA SHEET 2
WORK DAILY DATA

Participant name		Occupation	

DAY 1

Time:		Space nº:	

Parameters	Sub-parameters			Perception							Emotion				
					1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
LIGHTING	Data measured (lux) with the app			Low						High					
		YES	NO												
	Artificial light on?														
		DIRECT	INDIRECT												
	Light type			Low glare						High glare					
					1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
NOISE	Data measured (dB) with the app			Low						High					
					1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
TEMPERATURE	If possible data measured (ºC)			Cold						Hot					
					1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
SMELL				Good						Bad					
					1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
ACTIVITY	Individual			A few						A lot					
	Social / Meetings			A few						A lot					
					1	2	3	4	5		Calm	Happiness	Disgust	Sadness	Neutral
COGNITIVE ASPECTS	Productivity			Low						High					
	Creativity			Low						High					
	Concentration			Low						High					
	General satisfaction with your work			Low						High					

Figure 2. Example of DS2 daily evaluation sheet.

On both sheets, all the data is linked to perception on a scale from -2 to 2 (1 to 5) (Likert, 1932) and emotional states are categorized according to the Arousal-Valence graph (Rubin and Talarico, 2009):

- Calm: only calm.
- Happiness: surprise, adoration, admiration, fun, love, satisfaction, interest, sympathy, aesthetic appreciation, and curiosity.
- Disgust: anger, envy, horror, angst, disgust, fear, anxiety, and shame.
- Sadness: empathetic pain, boredom, confusion, and nostalgia.
- Neutral.

Mobile apps were used to measure lighting in lux and noise in dB.

Finally, a daily atmosphere monitoring sheet for the territory was used, with data on temperature, relative humidity, and air quality. These data were obtained from online platforms[1 2].

1.1. Procedure

An explanatory presentation is made to the participants and they are asked to carry out the following actions:

- Read the instructions in the project presentation dossier.
- Read and sign the informed consent form.
- Download the Noise and Lighting Evaluation Apps and try them out.
- Fill in form 1 (DS1).

- Send a photograph of each domestic workplace.

The data sheets are shared through the cloud platform.

1. The day after receiving everything requested for the first phase, the daily evaluations of the domestic workspaces with the DS2 sheet begin, for seven business days. Participants are told the most appropriate hourly ranges to take measurements in order to have greater information regarding their performance during the day.

2. Because the forms are completed online, and to avoid subsequent changes in the information provided, the previous day's data sheet is saved in pdf format the day after each evaluation.

In parallel, general data on the physical environment parameters of the different spaces were monitored twice daily, at 10:00 am and at 6:00 pm in each participant's local time. Finally, we requested that the participants compare their regular office space with their home workspace based on the same parameters.

It is worth noting that this study was carried out during different seasons, spring in Europe and autumn in South America.

2. RESULTS

2.1. Spaces, elements, and materials

Materials such as wood, leather, slate, ceramics, and textiles stand out. The most significant colors are in hues of beige, gray, black, yellow, maroon, green, and terracotta.It is worth mentioning that the material participants liked or were attracted to most was wood, with six different evaluations. It may be for this reason that a greater trend was observed in the use of wood, a material that has positive characteristics that affect people's well-being (Nyrud, Bringslimark and Bysheim, 2014).

We observed that dining rooms, living room sofas, dedicated home offices in some cases, and, in only one case, a bedroom with an element used as a provisional desk were the main spaces and objects used in this case study (see Figure 4).

In general, people tend to prefer places near windows (Park et al., 2018), and as seen in this pilot study, some of the participants strive to work in places that are near windows, either due to the views or natural light.

Figure 3. Moodboard of materials and colors in the spaces.

Figure 4. Moodboard of elements, materials, and colors by space.

2.2. Correlations of interest

The correlations of interest that have been analyzed in this pilot study are:

- Form – sizes and the existence of an external space – and productivity.
- Biophilic aspects – views of and having plants – and creativity.
- The color temperature of the lighting and the participant's opinions.
- Each participant's prior experience with working from home and their general satisfaction with it.
- The parameters of the environment over time – acoustic, visual, and thermal.
- Lighting and creativity.
- Individual activity in relation to social activity.
- Cognitive aspects as a whole –productivity, concentration, creativity, and general satisfaction–.
- Data on the space related to temperature, relative humidity, and air quality.

In all cases, parameters and behaviors alike are associated with perception and emotional states.

2.2.1. Form and productivity – biophilia and creativity

The size of the homes evaluated varied between 45 m2 and 130 m2, with an average of 80 m2. As can be seen in Figure 5, the average perception of size was 0, neither large nor small, and the predominant emotions were calm and happiness. The form and distribution of interiors in office buildings makes workers feel greater satisfaction in smaller, controlled spaces (Park, J. et al., 2018). Comparing this information with the data obtained in this study, the perception of size may be less relevant as our research involved private spaces.

In addition, all participants had a terrace or balcony, producing happiness and calm above all. Size was perceived as neutral, with a tendency towards small. Average productivity stood at 0.68, which can be attributed both to size and to having an outdoor space.

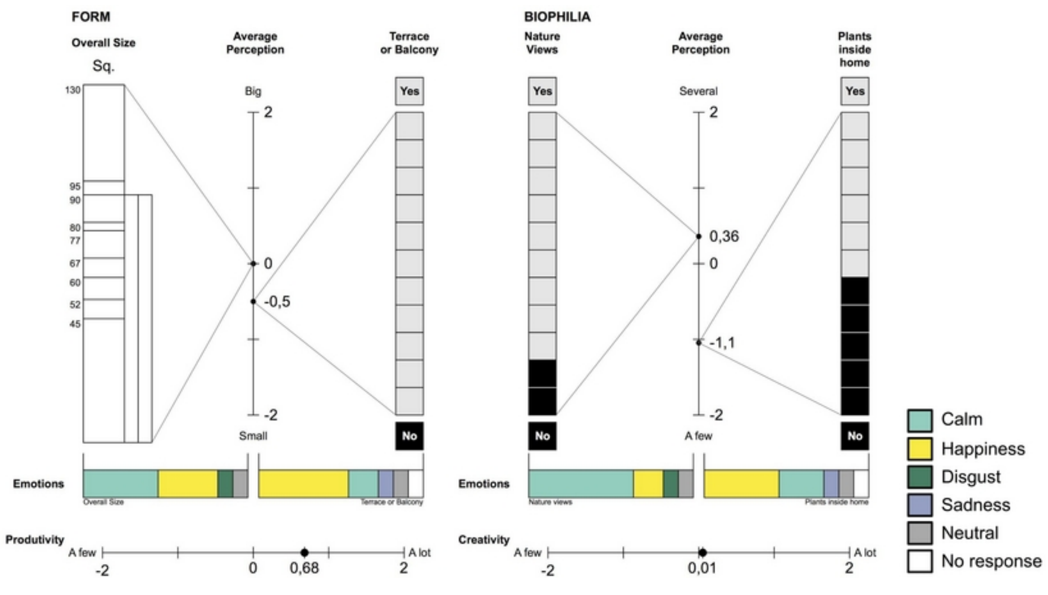

Figure 5. Form and productivity - Biophilia and creativity

There are studies that show that biophilia and the addition of natural elements in indoor spaces can lead to positively valued changes in cognition and emotion (Grinde and Patil,

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2009). Regarding these biophilic aspects in the current study, nine cases present views of nature, which primarily produce calm and, to a lesser extent, happiness, which are perceived as sufficient, standing at 0.36.

Six cases with plants inside the workspace were observed, perceived as few with an average of -1.1. Plants inside a home caused happiness and calm (see Figure 5), this is related to studies showing that indoor plants have been determined to provide psychological benefits (Bringslimark, Hartig and Patil, 2009). These parameters are correlated with creativity, averaging 0.01, falling within a neutral position.

2.2.2. Teleworking and satisfaction

People who had previously teleworked defined their house as a home: a place of safety and rest that provides them with greater concentration because they have fewer distractions.

Nine participants had previously worked from home, although only sporadically, with a perception of -0.54, which caused a simultaneous sensation of calm and happiness, and occasionally neutrality. General satisfaction with work tended to be high, perceived at 0.66, teleworking allows for task-based flexibility depending on one's mood, which directly affects productivity (see Figure 6).

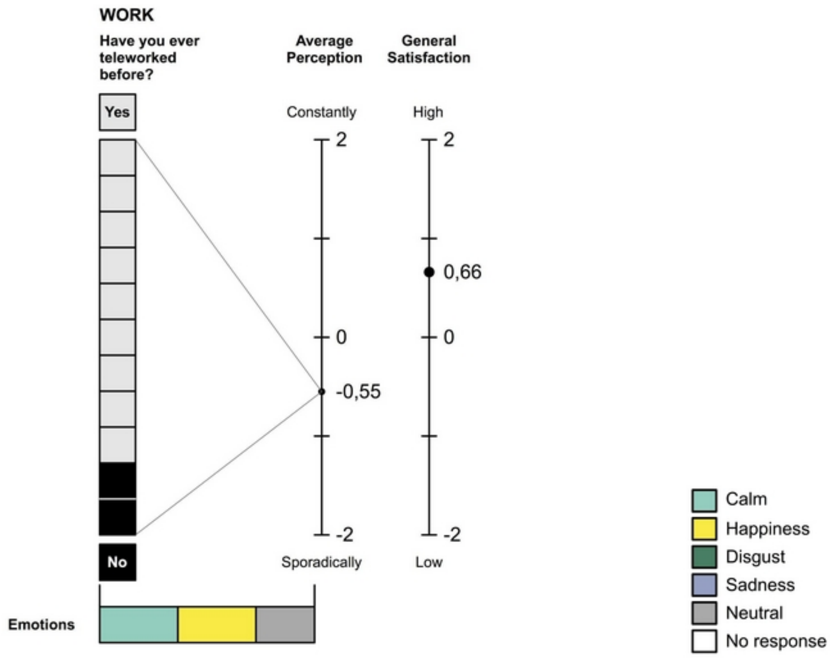

Figure 6. Teleworking and satisfaction.

2.2.3. Physical environment parameters over time

This study evaluated the following physical environment parameters from every domestic space –interior–: noise, the level of lighting on the work space, and the temperature. The evolution of the data over the seven days of the study is shown below (see Figure 7).

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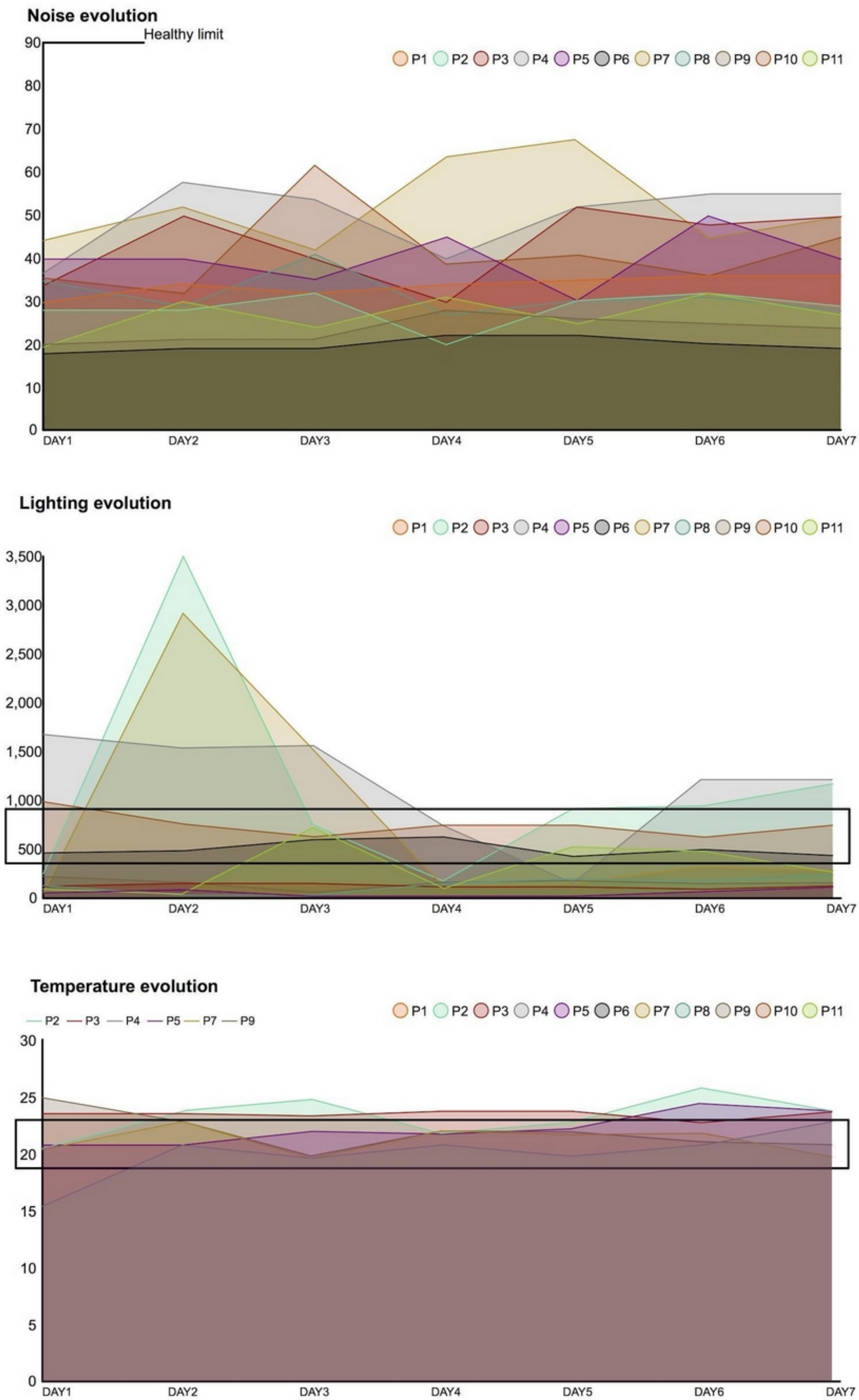

Figure 7. Noise –dB–, lighting –Lux–, and temperature –ºC– over time per participant in their domestic space.

The average for noise stood at 35.61 dB, with a minimum of 19.85 and a maximum of 52.28.The limit shown on the Figure 7 is 90 dB, based on OSHA criterion (OccupationalSafety and Health Administration , n.d.). Perception stood at -0.7, with a trend towards little, which caused a great deal of calm followed by a neutral state (see Figure 8). In general, noise limits

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usually address hearing protection, without considering data on sounds and well-being. Acoustic comfort is one of the most complex issues, as simply being below the established level is not sufficient: other factors such as frequency, vibrations, impacts, and the nature of the noise or sound have an influence (Lercher, 2019).

Regarding lighting, it had an average of 474.38 lux, with a minimum of 56.85 and a maximum of 1,146.14 lux. As seen in Figure 7, the comfort range is between 500 and 1000 lux (Lillo, 2000), as presented outlined in black, revealing that there are many cases that are below and many that are above what is recommended. Average perception tended towards a lot, at 0.42, and caused calm at 6.5, happiness at 3.5, and disgust at 1.

As to color temperature, all participants except one have warm artificial light for color temperature. Warm light mainly produces emotions of happiness and calm, although they also coexist with emotions of neutrality and disgust.

Only six participants had a tool to measure temperature, and the data provided varied between 16 °C and 26 °C with an average of 22.6 °C. Perception stood at 0.16 with a high tendency, and related emotions were calm and neutral, followed by happiness (see Figure 8). Thermal comfort is one of the most widely analyzed phenomena in terms of well-being associated with space (Chaudhuri et al., 2018; Huizenga et al., 2006). This study found no imbalances with this parameter, due to the seasons of the year in which it was carried out.

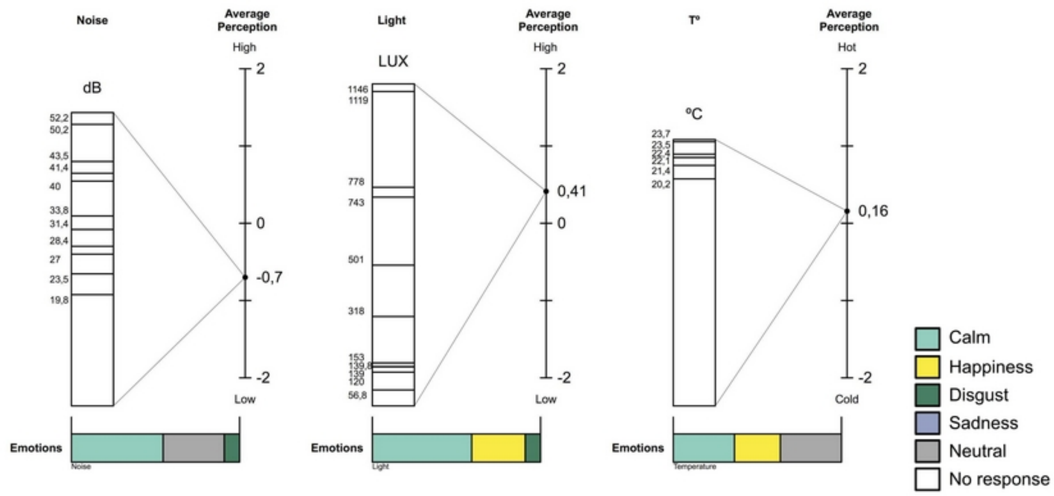

Figure 8. Noise –dB–, lighting –Lux–, and temperature –°C– perception and emotion.

2.2.4. Noise and concentration

When relating noise and concentration, the correlation coefficient is -0.37, and we observed the following trend: at low noise levels, the level of concentration is higher (see Figure 9). In general, noise is always considered as a distractor and as a pollutant in communication.

2.2.5. Light and creativity

There is no correlation –the correlation coefficient is equal to 0– between the average lighting level, 474.3 lux, and the perception of creativity, -0.03 (see Figure 9). However, there are articles that do associate low lighting with greater creativity.

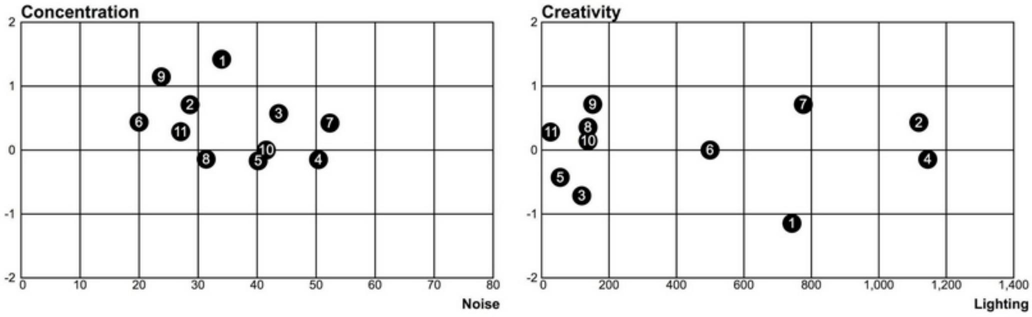

Figure 9. Scatterplot between noise –dB– and concentration; light –Lux– and creativity.

2.2.6. Activity in general

Individual activity trended towards high, with an average of 0.705, a maximum of 1.71, and a minimum of -0.28. It was rated as follows: 7 calm, 2 happiness, 1 disgust, and 1 neutral.

Social activity fell in a more in a neutral zone, with an average of 0.003, a maximum of 1.28, and a minimum of -0.71. In terms of values, this activity produced: 7 happiness, 3.33 neutral, 0.33 calm, and 0.33 disgust (see Figure 10). Social aspects are very important in the development of work activity. However, the confinement situation has caused, on one hand, that people achieve more calm in their individual tasks and on the other, value more those social moments -when these are in balance regarding the working day-.

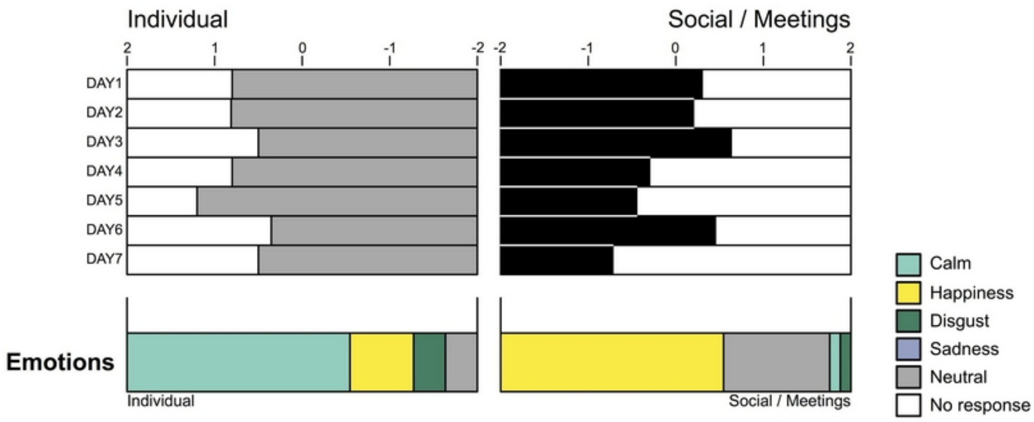

Figure 10. Individual and social activity and associated emotions.

2.2.7. Cognitive aspects

Productivity had a tendency towards high, with an average of 0.67, a minimum of 0.28, and a maximum of 1.28, associated with happiness, calm, and disgust. Creativity had a tendency towards low, with an average of -0.038 and extremes falling at a maximum of 0.71 and a minimum of -1.14, associated with calm, happiness, neutrality, and sadness. Concentration was observed with a high tendency at an average of 0.415, a minimum of -0.14, and a maximum of 1.42, associated with happiness, calm, neutrality, disgust, and sadness. Finally, general satisfaction had a tendency towards high, with an average of 0.622, a maximum of 1.71, and a minimum of 0.14, associated with happiness, calm, neutrality, and disgust (see Figure 11). This general satisfaction can be linked to an increase in both concentration and feeling productive, which is associated with states of calm and happiness, leaving the creative aspects and their more neutral emotional response on a more secondary level. This coincides with those previously stated regarding being in a familiar space where various parameters can be controlled by the user.

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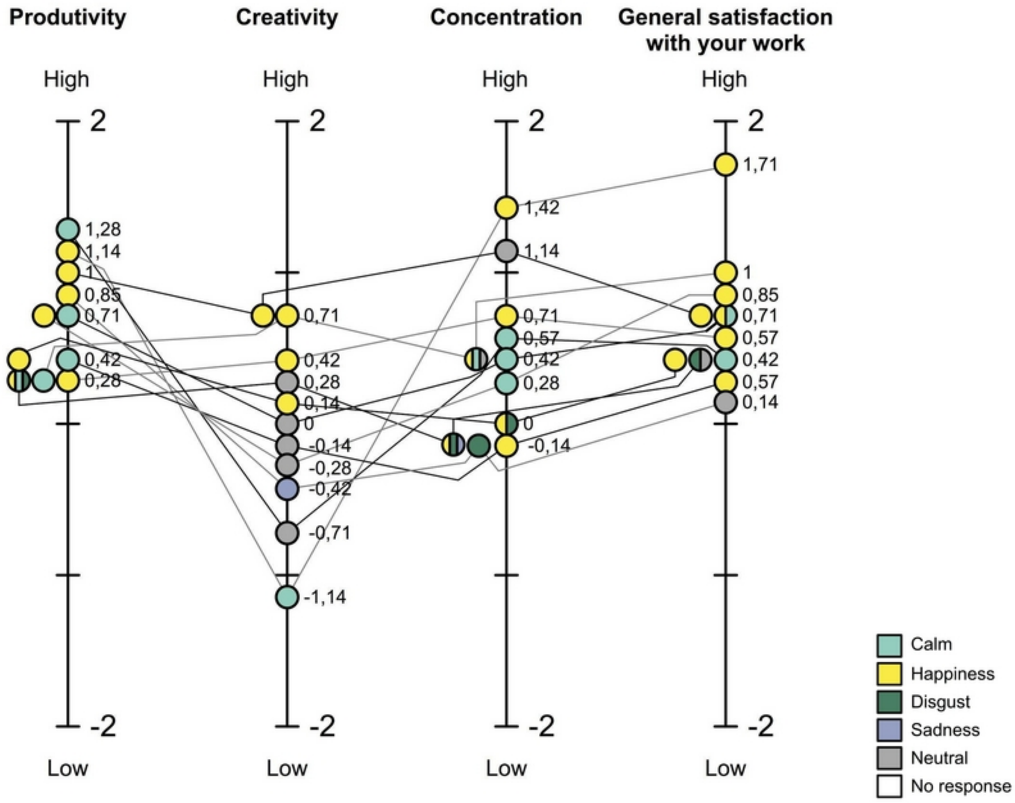

Figure 11. Productivity, creativity, concentration, and general satisfaction.

2.2.8. Environmental parameters of the territory

As to the environmental parameters of the territory monitored relating to temperature, relative humidity, and air quality, the evolution of the results over time can be seen below (see Figure 12).

As two measurements were taken for temperature, at the beginning and at the end of the day, the averages have been plotted. Both in Spain and Chile, the temperature remained between 14 °C and 25 °C. However, in the case of Stockholm, Sweden, a drop from 15 °C on the first day to 5 °C on the fifth day was observed.

Regarding relative humidity, greater variation was observed between locations, with Santiago and San Felipe, Chile and Stockholm, Sweden the most irregular. In both Chilean locations, the relative humidity exceeded the lower limit of the comfort range, between 30 and 40%.

Air quality was found to be a healthy constant in nearly all locations, except Santiago, Chile, which presents a visibly high value, reaching a CAQI (European Common Air Quality Index) figure above 80, bearing in mind that between 0 to 20 is very low, 20 to 60 low, 60 to 80 medium, 80 to 95 high, and 100 very high. The other locations were below 40.

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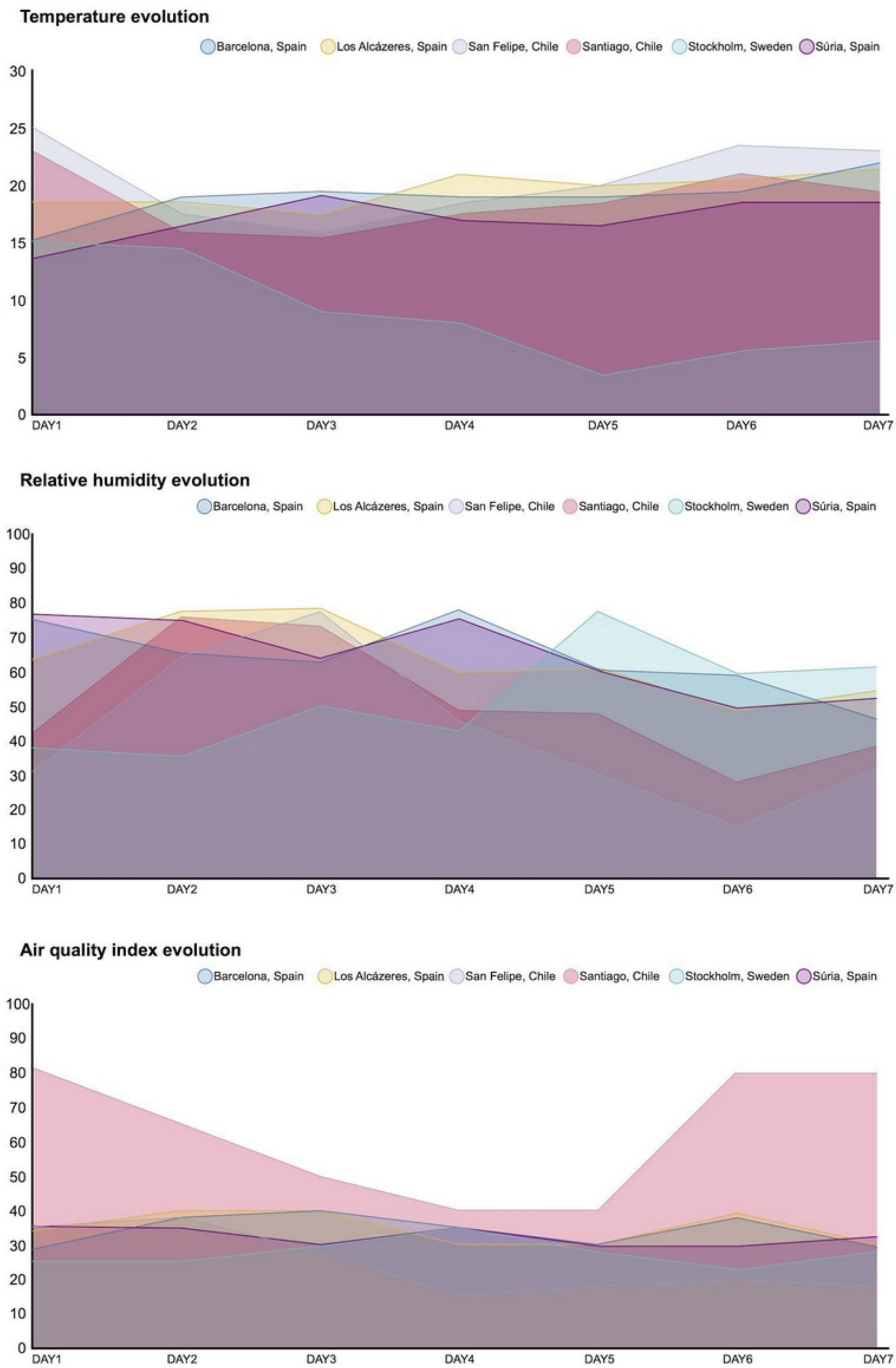

Figure 12. Location monitoring of temperature –dB–, relative humidity –%–, and air quality –CAQUI–.

3. DISCUSSION

3.1. Parameters, perception, and emotion

In this study, it is observed that in domestic environments, spaces are configured to the taste of the users and ergonomic aspects are not considered in a large majority of cases. On the other hand, the opposite occurs in workspaces, spaces are more neutral, less personalized, but more ergonomic.

Within these preferences, materials play an important role, apart from the scientific evidence (Zhang, J. et al., 2018; Kobetičová and Černý 2017), there are different platforms and design

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guidelines (Healthy Materials Lab, n.d.) to help professionals select materials that have healthy characteristics and promote well-being. These include: chemical components, textures, colors, among others (Friendly materials, n.d.; Mears et al., 2017).

For example, it has been proven that the use of wood in hospitals promotes faster recovery for patients and the psychological well-being of healthcare personnel. Moreover, there are types of wood that contain chemicals that help stabilize blood pressure and have an aroma that promotes restorative experiences (Matsubara and Kawai, 2014).

Although materials are one of the fundamental elements in the configuration of spaces, form and size also play an important role in perception and well-being. Symmetry, connectivity, and openness are involved in user experience, which has a direct impact on psychology (Ergan, Shi, and Yu, 2018). These more spaces of refuge, concentration, and intimacy should be one of the characteristics to be reinforced for the design of new workspaces –from large offices to collaborative coworking spaces– (Newsham, Veitch and Charles, 2008). Since they contribute to well-being and productivity, as seen in this study. In addition to materials and form, biophilia has become an increasingly used concept within spaces. Even though all participants' homes had a terrace or balcony, few had views of nature and almost half did not have indoor plants. In order to reinforce those healthy spaces, there are guides that help choose plants according to their benefits (Frély, 2013) and also guidelines for designers and architects on biophilic design patterns (Ryan, C. et al., 2014; Browning, Ryan and Clancy, 2014).

The same phenomenon happened with natural lighting. Apart from providing light, natural lighting ensures that people's bodies are in balance with the circadian cycle, which is how the body responds based on the time of day and the color temperature of the light (Stone 2009; Viola et al., 2008). Since proximity to windows is important in space design, it should be avoided settings that limit it, and strategies should be promoted to control unwanted effects such as glare/reflectance. Caution should be exercised, depending on the location and the orientation of windows, as an increase in direct sunlight can produce an increase in heat, and thermal discomfort. For the above, there are strategies (Khandelwal, Schenning and Debije, 2017; Shahzad et al., 2016), which help to control these effects. As can be seen in this paper, another important phenomenon is noise, and the noise data measured were always below the limit. However, there was a variety in terms of the perception of noise, what causes it, and how it affects, above all, concentration: on days with greater noise, lower concentration was observed. Acoustic comfort is one of the most complex issues, since it is difficult to control in different situations –both open/diaphanous workspaces as well as in the urban environment– which ends up affecting the domestic space and specific activities of concentration and virtual meetings.

Finally, air quality is a topic of great interest, especially in connection with the study of various diseases such as asthma, allergies, and even cancer and COVID-19. It is a more complex parameter to measure specifically, although there are various stations that allow us to understand the air quality of a given location, as evaluated in this study. However, these parameters are more of a regular feature than people understand, especially in a domestic environment that can be detected through HEPA's filters (Mousavi et al., 2020) and controlled by means of paint, the choice of objects, and maintaining the space free of toxic substances, although such information needs to be better disseminated (Healthy Materials Lab, n.d.).

3.2. Heterotopia and other Covid-19 consequences

The COVID-19 pandemic has served as a driver for rethinking offices and promoting telework, as well as the role that these spaces will have following lockdowns (Julià, 2020). Architecture depends on lived social contexts (Till, 2009), and the current situation has brought the home office to stay (Global Workplace Analytics, 2015). Therefore, heterotopic spaces have been created (Foucault, 1967) that present advantages such as user empowerment, comfort, and better productivity, but at the same time, such spaces have points of tension that remain unaddressed (Trends Club by Cenfim, 2020). Porphyrios (1982) calls "heterotopic sensitivity" formal, considering the spatial organization that includes juxtaposition and the combination of different components and discontinuities in spatial composition, taking the works of Alvar Alto as an example in this approach and considering heterotopia "a category of design methodology."

In this study, see figure 4, different types of spaces have been observed – shared, comfortable, located based on natural light, and with technologically relevant elements that have been adapted at times to manage coexistence and simultaneous meetings. The colors they present –light and harsh tones, wood, orange, blue, black, and gray– have more life and are less neutral and aseptic compared to traditional offices.

The participants underscored the importance of natural light, temperature, noise, air quality, and view parameters as essential and relevant, confirming what science asserts, and all of these at home were more highly evaluated when compared to offices. In the other spaces – the Home Office– there is more natural light and exterior views in the various rooms, which encourages temporary settings and enables better alignment with the circadian rhythm. The temperature was more pleasant, as it could be regulated in a personal and non-centralized manner, and greater ventilation of the spaces was possible, which improved the perception of air quality. Regarding noise, spaces were shared in many home offices, and headphones were necessary for isolation within the context of confinement, as multiple and simultaneous video calls had to be dealt with.

Moreover, connectivity also led to greater stress and a loss of the sense of the work day and holidays. Recent publications coincide with the opinions of the participants, who stated an increase of two hours, or 38%, more work hours on average during confinement (el Economista, 2020). Another consequence of constant connection is the so-called Zoom Fatigue (Sklar, 2020). All of the foregoing has directly affected the work experience in recent months and has placed value upon the elements necessary to promote well-being in the workplace. Emotions influence experiences and subjective well-being, and are also a source for understanding people's use of spaces. We observed how domestic, personal, and family situations later have a direct impact on work, especially in such a complicated context. In addition, some of the participants mentioned the difficulty of choosing a group of emotions related to any of the parameters, evidencing the need to support emotional intelligence and encourage learning about it from an early age.

4. CONCLUSIONS

Under normal circumstances, people spend between 80 and 90% of their time in indoor spaces (Demattè et al., 2018; Statistics, 2008). However, with the confinement measures currently in place, this figure has reached 100% in many locations, mainly within the domestic context.

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This study highlights how people are able to creatively adapt their environments to be comfortable while remaining productive. This adaptation is due to the subjectivity of well-being and comfort, which depends on each individual. This makes it necessary to deliver tools that empower and control their environment in a healthy and humanly sustainable way.

It is striking how the various participants perceived size as neutral, although the dimensions did present a significant difference. This shows that the participants placed more importance on the combination of other parameters such as natural light, temperature, noise, ventilation, and views as elements that improve their cognitive and emotional experiences.

An increasing number of everyday tools allow us to make measurements. Beyond being ways to obtain data, they have become an opportunity for users to juxtapose and combine the elements in their own spaces based on their well-being.

This research aims to open a data-driven path to contribute to the present-day search for the creation and adaptation of suitable workspaces to promote well-being and productivity in the new normal situation resulting from the COVID-19 pandemic.

ACKNOWLEDGMENTS

The authors would like to thank ELISAVA, Barcelona School of Design and Engineering, University of Santiago, Chile (USACH), and International University of Catalonia (UIC).

ENDNOTES

[1] https://weather.com/es-ES/

[2] https://www.meteoblue.com/es/tiempo/outdoorsports/airquality/

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Design as a positive stimulus in a Brazilian hospital environment

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ABSTRACT

The new coronavirus pandemic has put healthcare professionals, patients, and family members under pressure and stress, causing mental health issues, especially in the healthcare community. Studies show that a positive environment plays an important role in the well-being of individuals, impacting the physical and psychological security of people. This article presents a project developed for the Hospital de Clínicas de Porto Alegre, that through graphic interventions softened the effects of combating COVID-19 for the healthcare staff and patients throughout the pandemic. The project is detailed and the discussion presents the main points considered in the process of decision making. Results show how design can play an important role in helping, not only the Covid-2019 pandemic but also in making hospitals more hospitable places.

Keywords: COVID-19, Environmental design, Evidence-based design

INTRODUCTION

The 2019 novel coronavirus is highly contagious and its incidence has increased exponentially World Health Organization (WHO). Although authorities must focus on prevention and control, the mental health of people, especially the medical community, must also be addressed (Ornell et al, 2020, Shigemura et al, 2020; Zhenyu Li et al, 2020; Li et al, 2020). A study published in 2008 about the 1995 Kikwit Ebola outbreak (Hall et al, 2008) shows that to ensure a sustained effort to provide care, staff needs to be protected physically and emotionally.

The severe situation is causing mental health issues for frontline health professionals such as anxiety, depressive symptoms, insomnia, anger, and fear (Li et al, 2020; Kang et al, 2020; Zhu et al, 2020). A study developed by Zhang et al (2020) with 1,563 medical staff members found that more than one-third of the participants suffered from insomnia symptoms during the COVID-19 outbreak, indicating that interventions among medical staff are needed.

WHO states that the measurement of health and the effects of health care must include not only an indication of changes in the frequency and severity of diseases but also an estimation of well being. On the other hand, the collapse of the Brazilian public health system was a challenge long before the pandemic (Oliveira et al, 2020), already putting medical staff under pressure and directly impacting mental health in adverse situations.

So, how could a design project help to improve the frontline health professional's quality of life during the COVID-19 pandemic? A study developed in 1998 at the Johns Hopkins University identified 1,219 articles describing investigations into the impact of environmental elements on health outcomes (Rubin et al, 1998). The report indicated that

80% of the most rigorous studies found positive links between environmental characteristics and health outcomes (Ulrich, 2000b; Rubin et al, 1998). Ulrich (2000b) also found that design approaches in architecture and signs that make wayfinding easy to promote positive well being.

The existence of positive environmental stimuli plays an important role in the well-being of individuals who work in and access the hospital. It is important that workers and patients have experiences that capture the subconscious attention, transporting them psychologically and allowing time for reflection and mental distance from stress-generating situations (Laumann, Gärling, & Stormark, 2001).

Aiming to contribute to the frontline of COVID-19, Tecnopuc, the Science and Technology Park of the Pontifical Catholic University of Rio Grande do Sul, offered the services of its laboratories for companies and the public sector. In that context, the Hospital de Clínicas de Porto Alegre (HCPA) started a partnership with Tecnopuc Crialab, the creativity laboratory of Tecnopuc, to work on interventions in the hospital environment that helps health care staff and patients throughout the COVID-19 pandemic.

This article presents how graphic interventions made in the hospital environment can soften the effects of combating COVID-19 for the health care staff and patients throughout the pandemic. The hospital's challenges that are addressed relate to the well-being, physical and psychological security of people. A pilot project that was carried out seeking to meet these challenges is described, and based on the observation of positive results from its implementation, the expansion of the design project to new areas of the hospital is described, highlighting how the design project's interventions met the hospital's challenges.

1. THE HCPA AS A REFERRAL FOR COVID-19

The HCPA is one of the main pillars of public health care service for the state of Rio Grande do Sul. The HCPA dedicates 88% of its infrastructure to the public health system and is responsible for 18.5% of the ICU beds available for the population of Porto Alegre.

The HCPA is a reference in highly complex care for patients with COVID-19 in the city of Porto Alegre, and faced with the pandemic, is under additional pressure. In response to the current situation, the hospital has expanded the number of available ICU beds, increased the number of staff, and reorganized its infrastructure and operation. The hospital has also fostered initiatives that promote the well-being and engagement of employees to maintain the excellence of the services provided. In this regard, positive environmental stimuli was acknowledged as a feasible promoter of well-being in individuals who work and pass through the hospital. It is important that health care workers and patients have experiences that capture their subconscious attention, which allow time to reflect and that transports them psychologically, allowing mental distance from stress-generating situations. In this specific regard, HCPA faced new challenges (Figure 1) that motivated this design project.

(1) Due to access restrictions within the hospital, it was necessary to rethink and inform the public about new movement patterns throughout the hospital, thus encouraging the use of stairways to avoid crowding and the unnecessary use of elevators.

(2) Besides reducing the number of visitors and patients, it was also important to communicate new policies that make the hospital spaces safer and prevent the spread of the virus. Such policies were related to managing the use of common spaces, discouraging gatherings of groups, and indicating appropriate social distancing.

(3) The workload of health professionals has increased, so actions were taken to boost morale, such as providing break rooms for resting and recharging.

(4) Health professionals, patients, and visitors' fears and risk awareness changed the hospital's climate, which by nature is already ambivalent, to a heavier, more apprehensive environment.

Figure 1. HCPA's challenges.

Considering all that, the design project presented in this article focused on creating interventions in the hospital's physical space to address these main challenges, aiming at maintaining the well-being, physical and mental safety of the medical staff, employees, visitors, and patients.

2. THEORETICAL BACKGROUND

Healthcare is not separated from the environment in which it is delivered, as the space and organization of buildings affects the healing process (Horsburgh, 1995). Therefore, scientists argue that the hospital environment can influence not only the well-being of patients, but also the healthcare professionals. To Shumaker and Pequegnat (1989) and Ulrich et al (2010), poor design can directly and indirectly affect the delivery of healthcare, creating a stressful environment. A stressful environment can further threaten patient health, and can impair the ability of the healthcare professional to give efficacious treatment and attention to the patient (Shumaker, Pequegnat, 1989).

The first studies about the relationship between the environment and its health effects were conducted during the 1960s. During the 1980s these studies focused specifically on healthcare environments, especially hospital buildings. In 1993, healthcare and design professionals that believed design could improve patient healing through scientific knowledge founded The Center for Health Design (CHD) in California, and have made progress in evidence-based understandings. The researchers focused on healthcare design to reduce the stress of patients and healthcare professionals, improving safety and productivity (Berry, et al., 2004; Alfonsi, Capolongo, & Buffoli, 2014; Ulrich et al., 2010; Zimring, Joseph, Choudhary, 2004).

As medicine and other health sciences moved toward evidence based practices, design moved to be guided by research and user experience. As a result, the mounting scientific

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evidence brought international awareness to healthcare facility design and that certain environmental design strategies can promote improved outcomes (Ulrich, 2001), bringing a new research field called Experience Based Design (EBD) to the discussion. “EBD refers to a process for creating healthcare buildings, informed by the best available evidence, with the goal of improving outcomes'' (Zimring, Joseph, Choudhary, 2004). According to Zimring, Joseph and Choudhary (2004), EBD is not about nicer hospitals, but about designing hospitals that provide experiences of caring and safety, and still help patients get better and healthcare professionals do their jobs better.

Later, the concept of EBD was expanded to Experience Based Co-design (EBCD) to emphasise the collaboration in the process. According to Tsianakas et al. (2012), EBCD’s approach is to understand how healthcare professionals and patients interact with the healthcare service, that in major cases are hospitals. So EBCD focuses on improving healthcare services, combining co-creation and user experience to identify improvement priorities that reflect the experience of healthcare professionals, patients, and their families (Donetto, Tsianakas, Robert, 2014).

According to Ulrich (2001), healthful experiences like social support and pleasant distraction became important considerations in creating new healthcare facilities, and the reduction of infection or disease risk exposure should not be the only requirement. The emphasis on functionality and pathogenic conception of disease has often produced healthcare facilities with environments that seem factory-like, being stressful instead of creating environments that calm patients or otherwise address their psychological needs. (Ulrich, 1991, 1992, 2001; Horsburgh, 1995).

Looking at all research and findings in health design, Ulrich (1991, 1999, 2000a, 2001) brings the Theory of Supportive Design as a proposal of design directions to promote improvements on patient outcomes. The Theory of Supportive Design proposes that healthcare environments have a relationship with improved outcomes by reducing stress (Ulrich, 1991, 1999, 2000b, 2001). Ulrich (2001) proposes a guideline for designing supportive healthcare environments: (1) foster control; (2) promote social support; and (3) provide access to nature and/or positive distractions (figure 2). The importance of these strategies in hospitals is explained, as they served as theoretical foundations for the design project at HCPA.

FOSTER CONTROL

Feeling in control can help patients better deal with stress, and loss of control can affect medical outcomes (Evans and Cohen, 1987; Taylor, 1979; Ulrich, 1991, 1999). One study found that patients in hospitals with good information systems were more self-reliant and made fewer demands on hospital professionals. Additionally, patients with less information classified the hospital less favorably (Nelson-Shulman, 1983-84).

Many hospitals know the importance of wayfinding systems, but it is difficult to solve this problem with a fragmented approach. An orientation system needs to provide an integrated system, with easy-to-understand elements that can guide unfamiliar people (Zimring, Joseph, Choudhary, 2004; Carpman, 1993). Evidence suggests that wayfinding design should combine a building structure that is cognitively comprehensible (main entrance, main hallway, high visibility of major services) (Baskaya, Wilson, Ozcan, 2004; Weisman, 1981; Werner, Schindler, 2004) with information along the way (easy-to-understand signage system) (Carpman, Grant, Simmons, 1983; Levine, Marchon, Hanley, 1984; Wright, Hull, Lickorish, 1993).

(a)

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PROMOTE SOCIAL SUPPORT

A healthcare environment should support family presence and social interactions to reduce patient stress, in order to increase satisfaction and to improve medical outcomes (Bay et al., 1988; Chatham, 1978; Happ et al., 2007; Hendrickson, 1987; Mason, 2003). Besides that, some research has indicated that social interaction and support can be increased with comfortable waiting rooms and lounges (Ulrich, 1991, 2000a, 2000b; Zimring, Joseph, Choudhary, 2004). For Ulrich et al. (2010) a healthcare organization that wants to support family presence must incorporate quiet waiting rooms with comfortable group seating to receive them.

In a study about family presence, Happ et al. (2007) realized that patients who survived critical illness reported that involving family in the process was important. Patients in this study rated social support as important for reassurance, comfort, and peace of mind.

(b)

PROVIDE POSITIVE DISTRACTIONS

According to Ulrich (1991, 1999, 2000b), positive distractions are environmental and social elements capable of improving moods and avoiding stress. Humans have a predisposition to elements that recall human faces, music, nature, or comedy and laughter (Ulrich, 1999; Ulrich et al., 1991).

To improve the environment, positive distractions can divert the attention of patients from stress and negative emotions. Positive distractions stimulate emotional well-being for patients and improve their psychology. (Ulrich, 1991; Ulrich, 2008). Studies support the use of nature elements to distract patients and reduce stress. This kind of distraction can be done through outdoor gardens, indoor plants, and window views of nature as well as indirectly through artwork and other visual displays of nature scenes (Ulrich, 1984).

(c)

Figure 2. Guidelines for healthcare environment design: (a) Foster control (b) Promote social support (c) Provide positive distractions.

3. THE PROJECT

Aiming to meet HCPA's challenges related to the well-being of its clinical staff and patients, HCPA called for a pilot project. This first initiative was titled the "Affective Wall", as graphics were developed and put on a wall within the radiotherapy unit (Figure 3). Workers and patients were involved in the creative process through electronic and printed surveys asking for words that evoke feelings of comfort, which gave rise to the contents used in the graphic and multimedia interventions that were created. With the survey and some conversations with stakeholders we defined elements, colours, and strategies to achieve the best results. Besides that, the proximity to medical staff and patients was kept to guide the project and the strategies to improve outcomes. More than turning the building nicer, the project focused on enhancing the experience of being and working in the Hospital. In addition to seeking to create a better experience, the project tried to involve patients and medical staff in a co-creation to improve the health care service and make the work in a controlled area friendly.

(a) (b)

Figure 3. Affective Wall: (a) Graphic intervention (b) Intervention applied

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According to HCPA, "Healthcare professionals and patients are going through difficult times. Understanding their esteem, belonging, and safety needs is crucial to propose more changes in their lives - even if it is about a change in the environment in which they work". The concept of affectivity was defined as a premise for the design and has influenced the decisions made throughout the creative process.

Positive responses to the "Affective Wall" prompted new areas of the hospital to request similar interventions. An extensive study looking for theoretical and visual references was carried out to guide this new phase of the project. The research focused on visual and non-visual signs in order to collect input and generate insights that supported the design process and oriented graphic designs. Thus, the research provided the basis for choosing elements that would contribute to the positive perception of the environment, and to the well-being and comfort of patients and professionals.

HCPA's budget is mostly committed to medical supplies and staff for the pandemic. As a result, a low-cost material with a simple installation process was needed. Vinyl stickers are easy and fast to apply and are easily sanitized. Through low-cost graphic interventions, moments of pause and inspiration were cultivated, spreading messages of warmth, gratitude, and emotional support, as well as reinforcing the newly-adopted organizational procedures due to the pandemic.

Colors, fonts, illustrations, and casual verbal and visual language were used in order to make each environment more pleasant. The visual concept was built based on geometric shapes, with universal and quick understanding by the observer. A set of elements were created, considering the needs of different users regarding the hospital environment and assigning different functions to each shape (Figure 4).

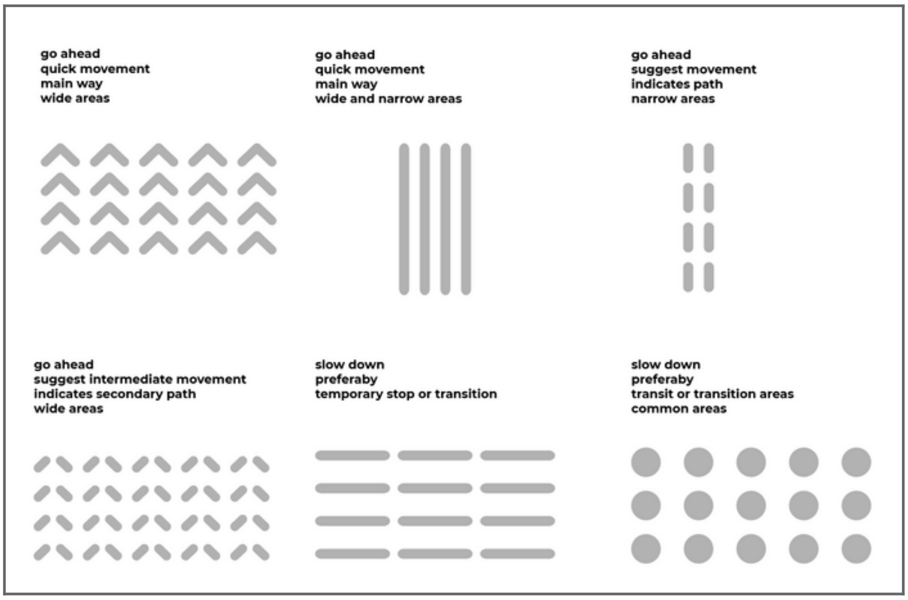


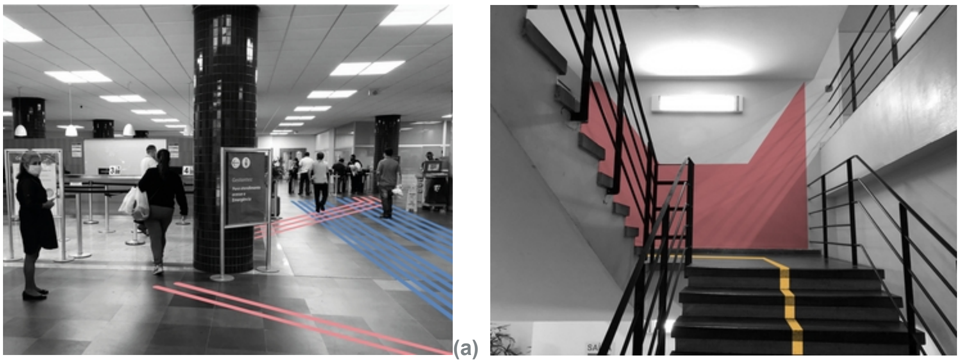
Figure 4. Set of elements / signs.

Using different colors (Figure 5) added to the creation of signs which were used on floors and walls, helping in orientating and also positively distracting people. In the graphic interventions that use words two fonts were selected: a sans serif and a handwritten one (Figure 5). The first font intends to highlight the precision of the work done by health care professionals, and the handwritten font represents their human and dedicated service.

Figure 5. Colors palette and fonts.

The first challenge was related to moving around hospitals, as they are notoriously busy places that receive heavy traffic on a daily basis with no sequential logic of services. Lack of information can make the experience confusing and disorienting for a person. A properly executed orientation ensures that visitors always know exactly where they need to go and how to get there, helping them to stay calm, and feel safer.

Besides the basic orientation problem, proposing new ways of moving while encouraging people to use the stairs was needed. To meet that, a signaling system was developed (Figure 6). The shapes and elements created were organized in a way to help people move within the spaces in an intuitive and safe way. The new visual language was created to work with the current signs that already exist at the hospital, without mischaracterizing or compromising the essential information available.



(a) (b)

Figure 6. Signaling system: (a) Floor (b) Stairs interventions.

The second challenge was related to the need to make people and spaces safer in order to prevent the spread of the virus. To meet this challenge, new ways of using common spaces, discouraging the formation of groups, and helping people to respect the mandatory physical distance were thought of. Casual and playful graphical approaches highlighted specific spaces for meetings, incorporating proper social distancing (Figure 7). Also, in waiting areas such as elevators, specific spaces were defined.

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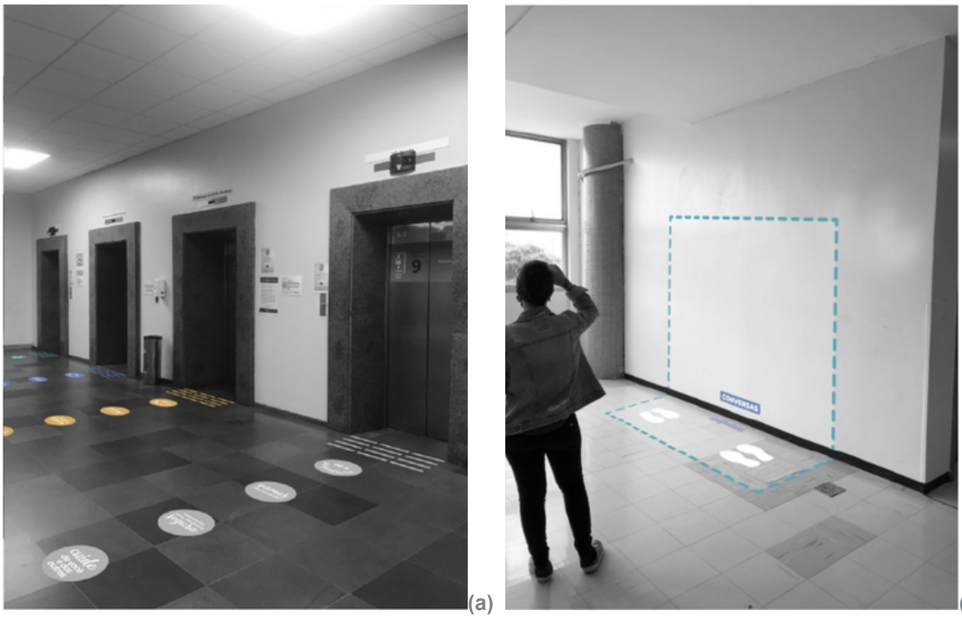

(a) (b)

Figure 07. Floor signs. (a) Meeting areas (b).

For the third challenge, the use of the common areas of the hospital were modified because of new procedures against COVID-19. As the workload of health professionals has expanded, providing a source of motivation and gratitude became imperative. To meet this demand, interventions were proposed for the available resting spaces to calm, welcome, and inspire people. These resting spaces were little used before the pandemic, but because of the hard working shifts they were revitalized with applications of colors and shapes making them more pleasant to use (Figure 8).

Figure 8. Revitalized spaces.

Finally, the last challenge is directly related to the hospital climate. Hospitals, by their very nature, engender a disconcerting atmosphere. The pandemic exacerbates this situation due to its uncertainty and risk which affects physical and mental health. Using design to meet this challenge was one of the most difficult points of the project. At a time when all efforts are focused on healing, finding an alternative way to bring comfort to people was the main goal.

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Words of affection were inserted in the circulation windows of patients and family members (Figure 9). In the areas of the common use of employees, positive messages were inserted (Figure 9) and at the hospital entrances and exits, welcome messages were applied (Figure 10). In addition, in the Radiotherapy Unit, the sector that originated the development of the project, a new "Affective Wall" was created, this time in the waiting room, focusing on messages for patients (Figure 11). Finally, also in the waiting room, a children's area was created bringing more interactive elements (Figure 12).

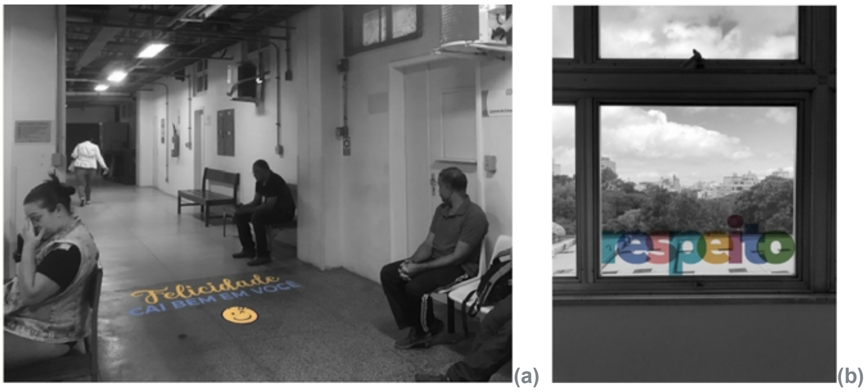

Figure 9. Supportive words on the floor and windows: (a) "happiness looks good on you" (b) "respect".

Figure 10. Welcome and farewell messages: (a) "have a nice work" and "you are unique" and (b) "have a good rest".

Figure 11. Affective Wall at the waiting room.

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Figure 12. Children's area.

For the printing and application of the stickers, we found partner companies that donated the needed material. In this paper we have presented simulations of this project in order to protect the privacy of the people and spaces of the hospital during this difficult time. Due to the high rate of occupancy and human circulation, it wasn't possible to photograph the spaces.

4. DISCUSSION

The challenges of developing a design project for a referral public hospital for the treatment of patients affected by COVID-19 are countless. Projects like this involving two institutions (Tecnopuc Crialab + HCPA) tend to be time-consuming and very bureaucratic. The imminence of the pandemic and the urgence of minimizing the effects in society helped make the project much more agile and a priority for both institutions. Also, the Hospital has a budget that is mainly committed to medical supplies and staff, so the project must be low-cost and simple. We also tried to minimize the need for physical interactions in the Hospital, so just a part of our team has done a technical visit to know the building and make notes. Besides it, the COVID-19 impacted the idea we have about social support. We needed to look at the new procedures of care in the pandemic, and make the social interaction happen without physical contact or agglomeration. Therefore, one of the requirements of the project was to think beyond the present, and make a project that will be useful in a future after the pandemic for the Hospital.

Ulrich (1984, 1991, 1992, 1999, 2000a, 2000b, 2001, 2008) is perhaps the main reference regarding discussions about the hospital environment and its impact on people. The three strategies proposed by the author were the basis for the development of this project and helped in the decision-making process with the many stakeholders involved.

For Ulrich (1991, 1999, 2000b) fostering control is related to the feeling of being in control. In addition to the studies that indicate the importance for medical staff to feel in control due to the nature of the work (Teikari, 1995; Shumaker and Pequegnat, 1989), in times of pandemic, this point gains even more importance. Considering the intense workload that overloads health professionals, thinking about the design project as a way to give autonomy

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for people to move around in the hospital, without depending on others, is already a positive result of the project. Thus, seeking to address the issue of fostering control, the signage for the stairs were created, as well as indications of social distancing in the elevators and floors, both for general circulation in the hospital and those focused on the medical staff.

Ulrich's second point (1991, 2000a, 2000b) relates to the role of design to promote social support. This point was addressed differently for patients and employees. While the medical staff is highly informed on how to act in adverse situations of the pandemic by training and protocols, patients and visitors often do not know how to act. With this in mind, specific areas for doctors, family members, and patients to talk were graphically represented, encouraging the expected behavior in an unconscious way, making the issue of necessary social distance lighter and more playful. For the medical staff, decompression areas were created, with a series of interventions presented in the results of this article. Lastly, the pilot project, the Affective Wall, also applied in other areas of the hospital, offers messages of support and welcome, promoting social support.

Finally, positive distraction, the third point recommended by the author (Ulrich, 1984, 1991, 1999, 2000b, 2008), was achieved in the interventions at the entrance and exit of the hospital, on the walls of units and in the various messages and directions within the areas of decompression. These areas of decompression were designed to be places for rest and relaxation for the medical staff.

In the face of a global pandemic, with uncertainty and an unclear perspective of what the future holds, the need to remain calm and the attempt to feel some control become more important. Considering that, all initiatives related to improving the well-being and mental health of people on the front lines of fighting the pandemic are fundamental.

Studies (Zimring, Joseph, Choudhary, 2004) relate the physical environment to results in four areas: reduce staff stress and fatigue, and increase effectiveness in delivering care; improve patient safety; reduce stress and improve outcomes; and improve overall healthcare quality. The wayfinding project and the interventions developed at HCPA sought, through design, to meet these four areas, with initiatives developed in different areas and sectors of the hospital.

A stressful environment can, over time, make individuals emotionally and physically ill. In addition, a high turnover of healthcare professionals has been attributed in part to stress, which reduces the quality of care for patients (Pardes, 1982). In this regard, the improvement of the work environment is related to the physical and mental health of patients, medical staff, and family members.

Also, patients are more vulnerable considering that they are ill or in need of care, whereas the nurses' role is to care for others and to manage crises. Patients and nurses spend different amounts of time in hospitals, and have different abilities to leave. Patients can't leave the hospital, but usually stay for short periods of time, while nurses can leave after their shift, but obviously stay working at hospitals for years (Shumaker, Pequegnat, 1989). This was an important aspect to be considered in the project as it influenced the use of colors and elements that would not make the space tiring or too distracting or fatiguing, either for patients who spend a lot of time in the same place, or for health professionals who are in the hospital for long periods of time.

The positive impacts of the design project on the different hospital ambient will be perceived even after the end of the pandemic, reinforcing the role of design as a promoter of psychosocial support for healthcare professionals and patients (Figure 13).

"The positive impact of the project was not restricted to the interventions made in the environment. Employees started to take more care of the premises. They first organized the kitchen, then the cabinets, and then they standardized all communications displayed in the Unit."
(HCPA physician)

"I feel very motivated. Everyday I see something new in the environment. And I feel everyone is happier."
(HCPA technician)

"The graphic interventions are cheerful and bright, adding happiness to the Hospital's ambient."
(HCPA nurse)

"Other coworkers come spontaneously to our Unit to take pictures in front of the graphic interventions. And I know these are spread in many WhatsApp groups and social media."
(HCPA technician)

"The effect of the Affective Wall was almost a catharsis. People got united to do other positive stuff in the environment."
(HCPA head of unit)

"It was good to be involved in the decision process. Although it might have turned the hole process more difficult for the designers, we felt responsible for the changes in the environment."
(HCPA nurse)

Figure 13. Staff testimonies.

5. FINAL CONSIDERATIONS

The project developed for HCPA has potential for expanding to more areas and sectors of the hospital, and even other health institutions. The use of vinyl adhesives allows for both the creation of the product and the artwork to be developed within Tecnopuc Crialab, without the need for other professionals. Because it is a cheap material and simple to apply, the involvement of suppliers for the installation of the project is also reduced, bringing agility and cost reduction to the process.

The novel coronavirus pandemic was the first stimulus for the project, but the end result goes far beyond meeting the immediate needs of the pandemic at the hospital. All the interventions and pieces created are timeless, and at the end of this most critical period, they can remain in the hospital and continue to play a fundamental role in the daily lives of patients, family members, and employees.

Often the hospital's medical team is unaware of the potential of design as a transforming tool of the work environment, thus project opportunities are lost. Because of the pilot project we could see the potential of the role of design as a positive stimulus in the HCPA hospital environment. In this sense, design can play an important role in helping, not only the Covid-2019 pandemic, but also in making hospitals more hospitable places for those who have to and chose to be there.

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Reacting to the Emergency by Opening Perspectives: Design-Driven *Knit Therapy* as an Adaptable Tool to Answer the Change

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ABSTRACT

When the COVID-19 emergency has raised, the entire world had to stop, adapt, and face the challenge. The article reports the reaction undertaken with an ongoing project that in February 2020 was experimenting with the therapeutic effects of knitting on patients. The project, driven by scientific international studies, was bringing the intervention of designers on the topic with experimental pilot actions, designed and led by designers on-field, that were going on inside the hospital environment when the emergency changed the scenario, limited the environment, shifted the eye on a new, wider target of healthy people. Observing the new scenario and the initiatives risen on social media the designers involved in the ongoing project made knitting a tool to help individuals spending the forced time at home in meaningful ways. The project took a new perspective and evolved into a social media campaign, proposing virtual workshops for a better living in emergency times. The two projects, on-field and online, showed knitting to be a meaningful solution not only for healthcare but also for the daily life of people, and outlined how designers and a design-driven approach can act and react on the product-service creation, improvement, consolidation, and communication.

Keywords: inclusive fashion, knit therapy, knitwear design, participated workshop.

1. BACKGROUND RESEARCH. THE PILLARS OF KNITTING AS A BENEFICIAL ACTIVITY FOR PERSONAL HEALTH AND SOCIAL INNOVATION

Knitwear covers today a wide industrial sector of made in Italy, fastly growing in these recent years, and thus became a domain of interest for scientific research in industrial design. While some branches of research are strongly linked with the industrial soul of the sector, we cannot forget that knitwear has its origin as an ancient manual work, barely homemade (Affinito et al., 2017). Therefore, design research is still investigating this aspect and the evolution of knitting as a craft: from being a solitary activity at home, hand knitting has become a social activity, made in groups and in public spaces; from being considered a hobby, it is being recognised as a side-therapy for the wellbeing of people.

1.1. Why knitting

The idea of using a craft for helping people coping with diseases is more ancient than people think, and the concept of knitting as a therapeutic activity started to be structured in 2005, when the physiotherapist Betsan Corkhill started to purpose knitting as a useful activity to answer the need, in healthcare, of a whole-person care approach (Corkhill, 2014), namely "the coordination of health, behavioural health, and social services in a patient-centred manner with the goals of improved health outcomes and more efficient and effective use of resources" (Maxwell et al., 2014). Such an approach would be a beneficial solution not just for the patients, but for the healthcare system in general, especially regarding the costs.

The first conference about therapeutic knitting was held at Bath's Royal Scientific and Literary Instruction Institution in 2012, organized by Corkhill herself and by Professor Dieppe (Corkhill, 2012). The starting points were the idea of the healthcare systems being economically unsustainable, and the will to find side-activities to be paired with traditional medical therapies. Many other scientists have analysed the topic, reporting knitting as a practice that fosters benefits on a personal level, helping the individual to live moments alone without the perception of loneliness but with the idea of a positive solitude, but also as a tool for people to integrate (or re-integrate) into sociality in a more serene and valuable way, regaining that social identity and purpose in life that too many times can be lost throughout a lifetime.

If compared with other crafts, knitting is suitable to a wide range of environments, including clinical ones: preparation and cleaning are simple, the required equipment can be inexpensive and occupies a small amount of space, work can be unravelled and the material can be reused (Corkhill, 2014). Low space occupation also involves portability, with important implications for individuals who use this activity to manage anxiety. Lastly, knitting is largely accessible: really few medical conditions prevent people to knit, and this is also valid for any age range, any social, educational, and cultural background: an important factor when considering integration.

1.2. Health and social benefits

When analysing the health benefits of knitting, the first thing to consider is the physical activity itself, which is a "bilateral, rhythmic psychosocial intervention" (Corkhill, 2014, p. 30). On a chemical level, studies report that repetitive rhythmic movements induce the release of serotonin (Hart, 2008) and therefore knitting is proved to have soothing effects (Jacobs, Fornal, 1999) and to "elicit the relaxation response [...] a state in which heart rate and blood pressure fall, breathing slows, and levels of stress hormones drop" (Knit for Peace, 2017, p.8). In this perspective, knitting can be considered an effective side treatment to cure depression (Corkhill, 2008) and eating disorders (Clave-Brule, Mazloum, Park, Harbottle, Birmingham, 2009), to break additions and to manage phobias, bipolar disorders or disruptive behaviours, particularly in children (Duffy, 2007). Repetitive patterns of movement are also used by physiotherapists and neurologists to treat chronic pain (Corkhill & Davidson, 2009) and brain injuries, such as strokes (Corkhill, 2008). These findings have implications also for those who suffer from memory problems, as a tool to intervene in the early stages of the illness or as a preventive method: knitting showed influence on the reduction of the onsets of cognitive impairment, dementia and Alzheimer (Geda et al., 2012). Other research shows how knitting can be used to treat Post Traumatic Stress Disorder, as Corkhill explains:

> It's believed that in PTSD troubling thoughts and memories cannot be filed away securely and, as a result, remain vivid in the sufferer's brain causing torment and flashbacks. Knitters who suffer from PTSD tell that the act of knitting slows down these cycles and enables them to process their troubling thoughts" (2008, p.3).

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The social aspect of knitting is then equally important and becomes crucial in the modern society where levels of loneliness, particularly in certain age ranges, have become so high to generate the term "chronically lonely" (Knit for Peace, 2017), and where isolation is proved to be correlated to decrease in health (Perissinotto et al., 2014), physical illnesses and cognitive decline (James et al., 2011), together with higher levels of depression, suicide (O'Connell et al., 2004) and premature death (Marmot, 2010). This is not only a problem for the population but also an urgent need for the sanitary system, which will see a constant increase in costs: loneliness was indeed defined a "major public health concern [...] devastating and costly" (Knit for Peace, 2017, p.17). Fighting loneliness is therefore a necessity for the entire healthcare system, particularly in countries, like Italy, where healthcare is public.

Spending free time doing activities like knitting represents a rewarding occupation not just to fight loneliness but also to fight the self-perception of uselessness that can strongly affect self-worth in a society where being always productive is fundamental. Moreover, knitting stimulates creative thinking, imagination, flexibility, which then are spontaneously applied in other aspects of life besides the knitting project, and positively affect self-managing, problem-solving, and goal setting. While a knitter's mind understands to deal with the difficulties of the single knitting project, people also learn how to "respond in more resourceful, innovative ways" (Corkhill, 2008, p.8) to the inevitable complications that occur in life.

1.3. The role of design

The difficulties in the recognition of this kind of research have been mainly linked to a more qualitative than quantitative nature of the data gained from the experimentations (Bissell & Mailloux, 1981), that represented an obstacle for the validation and acceptance of the practice in the medical and scientific world. When dealing with design research, qualitative data are a valuable tool to enrich the theoretical base through meaningful stories of life, recovery, integration, regained self-identity and sociality rather than through numerical amounts. Starting from the research activity ongoing at Politecnico di Milano in the field of knitwear design, and from the interest in deepening the investigation around knitting as a therapy, the research project reported in this paper searched for an answer to the question about the role of designers when they act in a domain that lies in between quantitative scientific data and the qualitative aspects of crafts. Designers became link activators (Fagnoni, 2018) tackling the design of new processes going beyond the logic of large-scale planning, proposing more economically and socially sustainable models, experimenting with more flexible relationships with public administrations. Therefore, it was clear that intervention had to be done not only to construct a more consistent scientific theoretical base, but also on the communication level.

2. ACTION RESEARCH INSIDE THE HOSPITAL

The literature review highlighted the existence of a promising ongoing theoretical validation process, yet still not accompanied by a sufficient on-field application. Most of the concrete initiatives in promoting the whole person care approach are led by charities active in hospitals, but their work is based on volunteering and suffers from a lack of funding, research structure, skills, and resources to build long-term research projects or programs. These premises evidenced the opportunity for the field of design to give its contribution, not in creating new medical evidence, but in understanding the opportunities of intervention in the sector with a design-oriented approach to act on side of charities association by improving the structure of the activities, their communication, the patients' involvement, and the evaluation of results.

This was the purpose behind the pilot session of knit therapy workshops in hospital Papa Giovanni XXIII in Bergamo (Italy) –in collaboration with the voluntary organizations Gomitolorosa and Associazione Oncologica Bergamasca– aimed at creating a format to be scaled and applied to other realities with a long-term prevision.

2.1. Design and co-design: new methodologies for generating innovation

Why should design take an interest in medicine and science? The concept is linked to cross-fertilization, as:

> The capability to build connections and to coordinate different multidisciplinary actors throughout the development of new products has always been a winning characteristic of the design profession. (Conti & Zanolla Mancini, 2014, p.73)

The project is also driven by co-design, an approach that "enables a wide range of people to make a creative contribution in the formulation and solution of a problem" (Chisholm). Within co-design, the role of designers becomes the one of facilitators, where they are not anymore just researchers and makers, but also teachers and moderators. The social role of culture creation is integrated in a meaningful way with the fundamental role of education. Co-design was chosen as a way to act also for its affinities with therapeutic knitting: with co-design stakeholders become co-creators during the innovation path, and this shift to a proactive condition that resembles the one found with patients in whole-person care. The holistic approach to health reflects a holistic approach to design processes, with not only ideological but also practical implications (e.g. cost reduction). The direct participation stimulates social innovation and behavioural change, translated into the fundamental pillars for social development of solidarity, empathy, tolerance: the result is a progress towards a inclusive society which can be participated by everyone.

2.2. Scenario analysis and structure of the project

The research applied the design-driven approach to on-field experimental activities, through the participation, for several months, in the charitable knitting campaign Viva Vittoria in Bergamo. The collaboration with organizations and experts enabled a direct engagement with the local community of volunteers, and allowed a critical interpretation and further re-elaboration of the ongoing practices inside the hospital.

The project, focused on the product/service creation, improvement and consolidation and on its communication for valorisation and promotion, was articulated on four levels:

1. Design and implementation of a promotional campaign (Fig. 1).
2. Knowledge (with a dissemination plan for the existing scientific evidence).
3. Design proposal (composed of a promotional campaign and three pilot events, whose results were analysed and progressively refined towards the creation of a format applicable to new scenarios).

4. Training (where the designer trained the operators to make them autonomous on a long term prevision).

(a)

(b)

Figure 1. *Knit therapy* promotional campaign, hospital Papa Giovanni XXIII, Bergamo, February 2020.

Each of the three workshops in the design proposal phase had a first short phase of knowledge sharing, followed by the core part of the event that consisted of experimenting with knitting as a therapy with the mediation of the designer. This core part was loosely structured, to allow in-depth discussion and to vary and expand according to the participants, their interests and knowledge.

Being the research aimed at developing evidence-based contribution, the need for procedures for data gathering was identified as crucial. Due to the nature of the research – already supported by quantitative scientific data that are not an intervention ground for the designer– and of the investigated subjects, qualitative data were here privileged to elicit personal inclinations, suggestions, problems, and opinions of the interviewees. Data were gathered through two surveys, one released before the activity, to understand the level of knowledge about knit therapy and the expectations before participation, and the other at the end, to evaluate the impact. Both the surveys were filled by 100% of participants (WS1: 12 participants; WS2: 8 participants; WS3: 9 participants). The structured questionnaires with clear questions and answers were then analysed together with the records taken by the designer-researcher during the workshop sessions themselves. The audio records, that captured a big amount of other data and information spontaneously emerged with the conversations that typically arise in a knitting circle, confirmed what stated in the surveys and expanded the quality of information. The main results of the twofold analysis are briefly resumed in Figure 2.

Question	Result	Attendants' quotes
Reasons for knitting	Creativity; calmness; concentration; satisfaction in learning (particularly with easy schemes); seeing the outcome; having a goal; distracting from negative thoughts; wearing what is created; tactile sensations and colors;	*"I think that it makes me feel very happy, time flies"* *"I like to see how fast you can achieve results. The complicated methods become usual and very rewarding!"*
Reasons for participating in *Knit Therapy*	Curiosity on the topic; desire for amusement; captivating flyers; workshop agenda;	(Other reasons) *"Helping others in learning the stitches"*
Perceived benefits during the workshops	Relaxation/calm; reward; distraction; creativity; fun/diversion; improved memory; gratification; chit-chatting; socializing; compassionate attitude; recall of memories; freeing the mind;	*"Despite the presence of many people I was able to grow apart from the environment and think about my next travel"* *"I think my brain produced a lot of happy hormones when I saw the results"*

Figure 2. Qualitative data analysis: resume of results

2.3. Results

The qualitative data gathered confirmed what is reported in the literature, particularly regarding the benefits perceived while knitting (calm, concentration, satisfaction, having a goal, distraction), which also confirmed how knitting is not only about the product, but also about the process. Attendants affirmed never having previously encountered a similar project and this showed the innovative soul of knit therapy, at least in Bergamo hospital. Participants also declared that a fixed presence of the initiative would be positive.

In general, the workshop structure and execution were successful: the initial introduction which then continued into a friendly discussion while knitting presented effectively and reliably the benefits studied in literature. The workshop was also a moment of social bonding, and the exchange of knowledge among the participants allowed new perspectives to take shape (Fig. 3).

(a) (b)

Figure 3. *Knit therapy* workshops, hospital Papa Giovanni XXIII, February 2020: (a) some attendants are already knitting/crocheting, while others are filling in the pre-activity survey (b) session with patients and visitors in the waiting room of the Oncology ward.

2.4. Future perspectives

As mentioned, the goal of the research was to intervene with a design-driven approach as a facilitator, to improve the recognition of a valuable practice also from a scientific standpoint; to add new knowledge to the existing scientific one, considering the qualitative aspects when dealing with the whole-person-care approach; to create a concrete link between these knowledge and people; to act towards the promotion of the whole-person-care approach, by designing pilot actions as a scalable format, event for a further institutionalization within the Italian healthcare system.

Conti, G. M., Motta, M. & Micheli, M. (2020). Reacting to the Emergency by Opening Perspectives: Design-Driven Knit Therapy as an Adaptable Tool to Answer the Change. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 646-657. DOI: 10.4013/sdrj.2020.133.27

The first question that can arise in this perspective may regard the economic level: how could a public healthcare system dedicate resources to an activity that is still in the process of its scientific validation to be institutionally accepted? The answer lays in voluntary organizations: hospital Papa Giovanni XXIII alone counts 45 operative voluntary organizations, that during the workshops firstly attended as normal participants and soon shared their interest in making the activity a stable program. From them came the proposal to have volunteers taking charge of the project, that with their stable presence inside the hospital could become the facilitators after being trained by the designer.

Regarding the structure, the analysis of the pilot workshops validated them as a possible format to be applied in other realities with similar features. The involvement of stakeholders will be fundamental for organizational, promotional and costs reasons. Lastly, each workshop could become, through data collection and analysis, an incubator of research to furtherly test the existing theoretical evidence on the therapeutic benefits of knitting, as requested by scholars and researchers.

3. PLOT TWIST: COVID-19

During the implementation of the pilot workshops, the COVID-19 pandemic exploded, in February 2020. Italy was the first widely hit country in Europe and Bergamo hospital was in the very heart of the emergency. Being all the resources dedicated to Covid-19 and due to national regulations, the workshops in Bergamo hospital were temporarily suspended.

The emergency gave a further confirmation on the necessity, within the Italian healthcare system, of initiatives linked to the whole person care: in fact, despite knit therapy could not be inserted in the pandemic discourse as a solution, what can be observed is that the pandemic made clear how the public healthcare systems need support, particularly on the economic level, re-highlighting the whole person care approach as a valid cost-reduction strategy. A better costs management will stay as one of the main topics in the healthcare discourse also after the end of the emergency, and new solutions for cost reductions will be fundamental. Therefore, knit therapy, as other whole-person care practices, will not anymore be a possible solution, but a more and more needed free of charge side-strategy for a general better management of the costs for normal daily functioning and in preparation for possible future emergencies.

But this promising perspective had to wait. The emergency situation caused the Italian country, as many others in Europe and worldwide, to be put by governmental dispositions in almost total lockdown: people were asked to limit their movements to fundamental reasons, to prevent the infection as much as possible; hospitals became dangerous places with no admittance except for serious reasons of medical assistance necessity; homes became the places where people were spending their lives.

3.1. Scenario update: new contexts, new targets, new languages and channels

In a situation in which individuals had to stay home, new solutions immediately started to raise, particularly on the web, with the aim of helping people to live quarantine in a more serene way. Among the others, on social networks were born initiatives like virtual workouts and yoga lessons, cooking tutorials, jam sessions and many others, usually accompanied by the hashtag #IORESTOACASA (like the English #STAYHOME). On Instagram were also created profiles properly dedicated to proposing options to spend time at home. Among the others, an account that had a good response was the profile @mysweetquarantine, created by some Italian influencers.

Observing the evolving situation on the web, and motivated also by the forced momentary stop of the pilot project in the hospital, the knitting discourse had to find its place in the newly born situation, identifying in craft a possible solution for facing situations of not only fear, anxiety, negative thoughts, sadness but also boredom, inactivity, excess of free time and all the conditions brought by lockdown times. Launching knit therapy on social media was also identified as an opportunity to analyse how this practice could have been embraced by a target which was completely different from the one of the pilot project in the hospital. In addition, the online project could also test how a discipline like knitting, which is still today strictly linked to ideas of analogical tools, would fit into the hyper-modern language of social media.

3.2. Structure of the project: translating physical activities into online proposals

In line with the mentioned #IORESTOACASA campaign, the #IOLAVOROAMAGLIA campaign was launched, with people invited to post on social media pictures of themselves knitting, with the hashtags #iorestoacasa and #iolavoroamaglia.

The campaign was not only addressed to those who were already used to knit, but also to new possible crafters, who therefore were invited to take up the new hobby. A tutorial for beginners was posted together with the campaign, to guide people that were willing to try but still not able to knit. Even if a large number of tutorials can be found on the web, a new one was designed ad-hoc, to give an image of reliability, to engage the public and to build a stronger connection with the designer through learning by looking at her knitting rather than observing some unknown hands self-searched on the web.

After a first initial positive response, the project went on with the creation of knit therapy virtual workshops, made through the tool Instagram Live Video. The idea of proposing live workshops was a consistent link to the workshops in Bergamo hospital and allowed an additional analysis on how a face to face in-presence proposal could transform, forced by unchangeable external factors, into an online live event. Once again, the adaptability of knitting to different environments, situations, and targets reported by the literature could be tested. The workshops were scheduled on a weekly appointment and lasted for the entire period of lockdown in Italy, from March to May 2020.

The live virtual workshops evolved the structure of the workshops in the hospital:

1. Online promotional campaign on Instagram and Facebook (Fig. 4a)
2. Introduction: the designer explained what the knit therapy is about, its benefits and why it could be a meaningful solution for spending time during lockdown.
3. Hands-on activity: the author showed how to knit, with new small projects every time (Figs. 4b and 4c)
4. Empowerment: some profiles of artists and activists who use knitting in innovative ways were suggested to participants, to further deepen their knowledge about the

craft and at the same time to help them to overcome traditional stereotypes linked to the commonly perceived image of knitting.

5. Feedback collection: the participants were asked to express their opinion and post or privately send pictures of the work they had done.

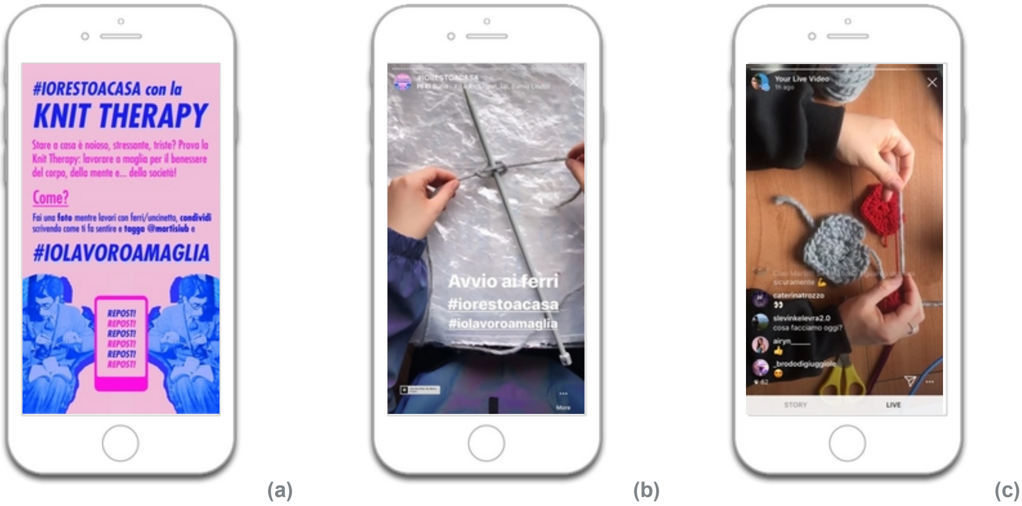

Figure 4. #IOLAVOROAMAGLIA social media campaign: (a) online flyer (b) screenshot from beginners tutorial (c) screenshot from *knit therapy* live virtual workshops.

3.3. Results: new digital perspectives for therapeutic knitting

The users' reaction to #IOLAVOROAMAGLIA campaign was immediately positive, not only in the number of posts and reposts but also in the interactions and topics of discussion that it fostered. Users posted pictures of them knitting with the hashtags #iorestoacasa, and #iolavoroamaglia, and reposted the campaign on their profiles, and shared the initiative with their followers. Some people wrote to the author to share their feelings and the benefits they perceived while knitting. Some others asked for more information about knit therapy, while some wanted to know where they could buy the material. Some respondents were people known by the author and already part of her followers, while others (particularly in a second moment) were not among the initial followers and got informed about the campaign through the mentioned reposts or through other users.

The #IOLAVOROAMAGLIA campaign was a successful initiative for the Instagram platform, with a solid response through reposts (154 reposts), interactions (over 4000), and participation in the live workshops (average of 40 participants per workshop). Another interesting evidence is that, despite knitting is usually perceived as an old-fashioned craft for elderly people, it instead emerged as suitable and adaptable to digital media, social media and to their targets and trends. This aspect is not new, since knitting websites and blogs have been existing for years, but what emerges here as an innovative observation is the fact that this adaptation, to be truly successful, should be done by also renewing and improving the visual and communicational language knitting has, under a design-driven perspective.

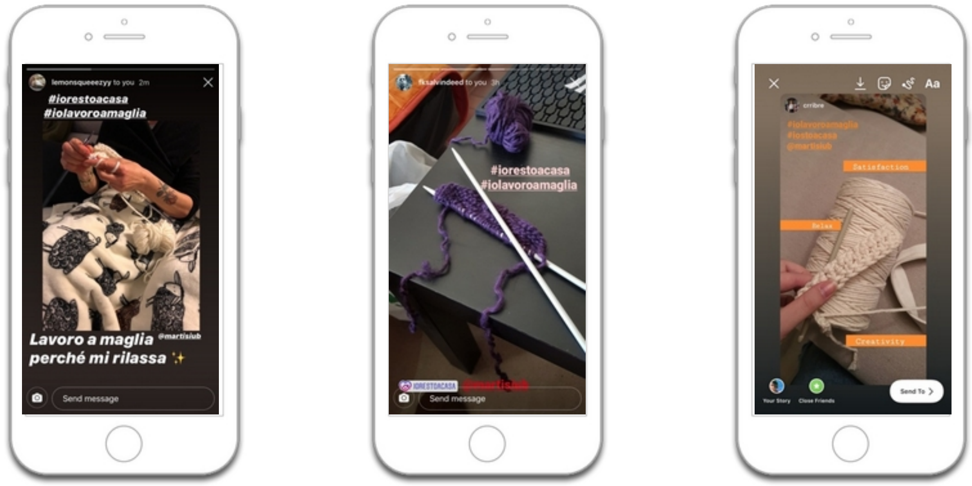

Figure 5. Users' reposts for #IOLAVOROAMAGLIA social media campaign.

4. CONCLUSIONS

The first aspect that emerged from the project and from the plot twist made necessary due to the Covid-19 pandemic is that emergency transforms the contexts: the places where people used to take care of their health were not accessible anymore, while homes changed from being the place of spare time to the place of everything, and healthcare became something that can be done at home. Moreover, the emergency transforms the target: being limited in everyday life has consequences to people, and knitting, which has always been something delegated to certain moments of life and to certain age/gender categories, now comes as a cure for social isolation and mental health accessible from a wide public.

In this perspective, the role of designers becomes fundamental, not anymore only as researchers side to side with scientists and doctors, but also ass creators of a design-driven strategy which is able to innovate both on the service and on the communication level. As it was done in this project, design and co-design can in fact be new methodologies for generating innovation, in a holistic approach to design processes which is able to reflect the holistic approach to health carried on by whole-person care. In this process, the designer must become a directly involved actor, where closeness, contiguity and engagement are fulfilled through daily shared experiences with the other figures involved, whether physically or digitally. The co-design of a format of knit therapy events in the hospital revealed the importance of these conditions, but design was also necessary for the creation of ad-hoc information and visual language, which become fundamental both for a better conveyance of the scientific theoretical evidence, aimed at a higher validation within the scientific discourse, and also as a way to a wider audience and target by exploring the potential knitting has if applied on social media, not only as an amusing proposal, but again also as a physical and psychological beneficial support, both in emergency situations and in normal life conditions (Fig. 6).

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	Need	Target	Channel	Communication strategy	Main role of designer
ON FIELD (hospital/normal conditions)	*Whole person care* for patients, visitors and workers	Middle-aged women/men (core part of hospital users)	**Knit Therapy** physical workshops in presence	Promotional campaign inside the structure, scientific knowledge sharing during workshops	Product/service **creation, improvement, consolidation**
ONLINE (emergency conditions)	*Whole person care* for everyone in lockdown	Adolescents, young adults, middle-aged women/men (core part of social network users)	**#IOLAVOROAMAGLIA campaign** and **Knit Therapy live virtual workshops** on social media	Posts, reposts, live videos, online tutorials, personal interactions via direct messages	Product/service **communication for valorization and promotion**

Figure 6. Comparisons between project on-field and project online.

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STRATEGIC DESIGN RESEARCH JOURNAL

"OPER.TEN" Transform Emergency Now! Facing Covid-19 with Open Innovation and Human Centered Design

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ABSTRACT

The paper presents "OPER.TEN", a ten days program that hybridized Human Centered Design (HCD) with Open innovation (OI), developed in response to the Covid-19 pandemic. The program adapted an HCD methodology to face the challenges of designing during a pandemic, such as relying on remote interactions only. The article presents methodological challenges as well as tools and methods developed to overcome those challenges. OPER.TEN, Transform Emergency Now! is a hybrid methodology that relies on HCD and OI tools and principles. OPER. TEN ensures fast implementation of the results involving stakeholders of the territory with implementation capacity. The final network involved Universities, Companies, Municipalities, and Government. After the design phase, three of the four solutions were successfully implemented. Results report how to hybridize an HCD with OI to push rapid implementations.

Keywords: Covid-19, Coronavirus, Open Innovation, Human Centered Design, Case Study

INTRODUCTION

The Covid-19 pandemic demonstrated how helpful Human Centered Design (HCD) responses are, in understanding the worldviews and ecosystems for users (White et al., 2020). More specifically, Design Hacking demonstrated their central role in creating our future individual, community, and social ecosystems (White et al., 2020). Against a pandemic, speed is crucial, and open innovation (Chesbrough, 2003, 2019) (OI) helps to empower the human capital distributed around the world to launch rapid testing of possible solutions (Chesbrough, 2020). This article aims to show "OPER.TEN", a program that links university, industry, government, public, and the environment to push fast implementation. The program methodology hybridizes an HCD approach with OI. The approach also includes suggestions to overcome problems that the design team had to face during the pandemic (e.g., keeping relationships virtual). As a result, the program was able to rapidly produce testable solutions concepts that have been successfully implemented to tackle the pandemic challenges.

1. THEORETICAL BACKGROUND

1.1. Human Centered Design (HCD)

The term "human centered design" has evolved over time and can be seen in the international standard ISO 9241–210, which describes "approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques". According to ISO 9241-210, every HCD process should be based on the following principles:

- The design is based upon an explicit understanding of users, tasks, and environments;
- Users are involved throughout design and development;
- The design is driven and refined by user-centred evaluation;
- The process is iterative;
- The design addresses the whole user experience;
- The design team includes multidisciplinary skills and perspectives.

Giacomin (2014) notes that the engineering-based concept of HCD as the science of human use and interaction with objects or services has, with time, given birth to a very complex network of different approaches. Those approaches have in common the attention to human meanings and behaviors, that can be resumed in a paradigm that "is based on the use of techniques which communicate, interact, empathize and stimulate the people involved, obtaining an understanding of their needs, desires, and experiences which often transcends that which the people themselves actually realized" (p. 610). Sanders (2008) gave an adequate representation of the ongoing transformation from the "design for" to the "design with" mindset with her evolving map of design practice and design research. She focused on "People Centered Innovation" as a cluster that included participatory design and user centered design methods, halfway between research-led and design-led approaches. We can resume this as a field of action in which multidisciplinary experts interact with stakeholders and users, stimulating each other during a research process that applies participatory methods and applied ethnography to identify issues and problems otherwise invisible, co-design solutions, and test it through fast prototyping. According to the ISO 924-210, the HCD approach aims at designing a solution that meets users' requirements through a structured process, as shown in Figure 1.

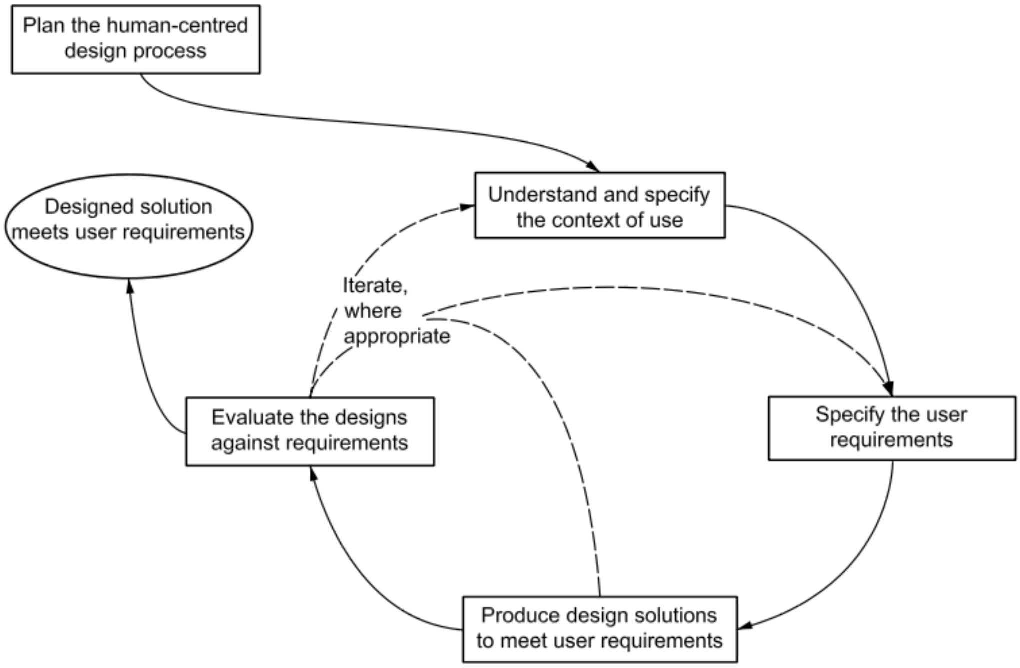

Figure 1. The HCD process (ISO 9241-210).

The HCD process lifespan depends on various factors, such as the number of design iterations that allow understanding the needs of the people involved in the research, empathizing with them, and then developing a tested solution concept. However, based on the authors' experience, on several case studies (e.g., the IDEO field guide to human centered design[1]), and assessments on the duration of each HCD phase (Maguire, 2001), the HCD process duration is measured in months.

1.2. Open Innovation (OI)

In the management literature, OI is defined as "*a distributed innovation process that involves purposively managed knowledge flows across the organizational boundary*" (Chesbrough and Bogers, 2014) (p. 3). With a broader perspective, OI is described as a shift from the traditional closed innovation paradigm (where organizations have full control of their knowledge and do not cooperate to innovate) towards open models of collaboration (Gassmann and Enkel, 2004; Enkel et al., 2009). In those models, organizations acknowledge the value of external competences and know-how and choose to exploit both internal as well as external ideas. These open models of collaboration include many actors who gained increasing importance in collaborating with firms during the OI era, such as Startups, Spin-offs, Venture capitalists, Employees, Lead users, Individuals, Inventors, Innovators, and, among all, Universities. In particular, since the diffusion of the Technology Transfer Offices, university efforts to commercialize science have evolved (Kochenkova et al., 2016), and new pathways are emerging, such as the spin-off creation based on research results (Munari et al., 2016), crowdfunding of entrepreneurial projects (Meoli et al., 2019), and an interesting novel approach relates to the activation of OI initiative (Enkel et al., 2009). Over the years, several companies have used Hackathons (Mohajer Soltani et al., 2014) and other OI forms to generate creative ideas (Dahlander and Wallin, 2020), involving universities in their programs. In particular, the typical Design Hackathon process lasts from 1 to 3 days, focusing on developing an idea through rapid prototypes (e.g., sketches, digital interfaces, mockups), as shown in Figure 2.

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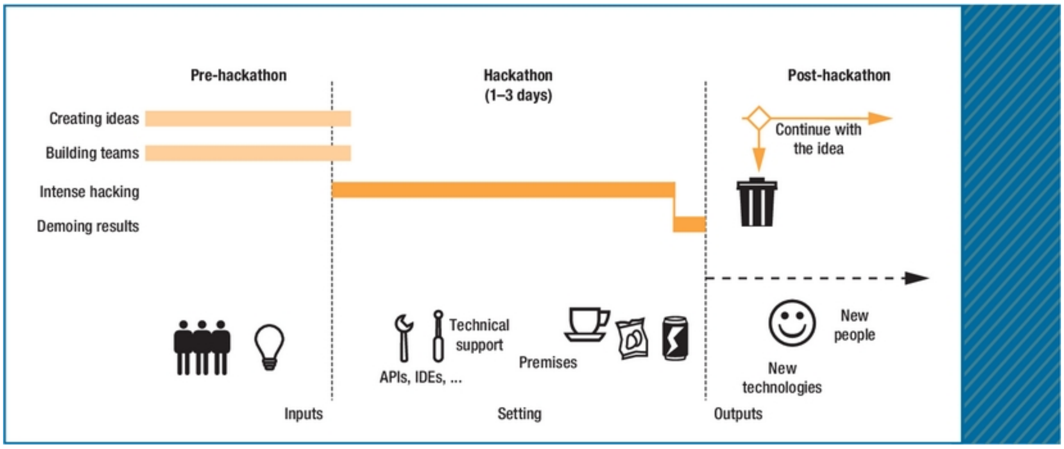

Figure 2. The typical hackathon process (Page et al., 2016).

In these short-term and intensive events called hackathons, participants aim at developing working prototypes as a possible solution to a beforehand well-defined problem (Mohajer Soltani et al., 2014).

1.3. Universities initiatives based on OI and HCD related to Covid-19 emergency

In these times of crisis, Universities launched several OI and HCD initiatives. For instance, Emily Carr University of Art + Design proposed "Together Vs. Virus"[2], a country-wide online hackathon for people of all backgrounds. Many of the San Diego Bay area universities participated in the alliance who promoted "D4SD"[3], a huge event based on design and design thinking to address difficult civic challenges in San Diego. USC has organized "USC Technology Innovation Bootcamp 4HS: Fighting Covid-19,"[4] a 3-weeks program for selected high-school students to develop new solutions to fight the wide range of challenges from the Covid-19 pandemic. That program includes topics of HCD, Customer discovery, Creative business model development, Engineering prototyping, Agile methodology, and Communication to investors and technology managers. MIT launched an OI initiative based on the rapid development of open-source low-cost ventilators[5]. The University of Pisa, together with the Italian Institute of Technology (IIT), carried out a project - called LHF connect - which allows hospitals to build their proximity robot providing the instructions and the software needed following an open-source model[6].

2. METHODOLOGY

Among all the OI forms, the Design Hackathon approach has recently been hybridized with HCD to overcome the problem of obtaining technologically impressive solutions that lack a deep understanding of the problems from the users' point of view (Taylor and Sherman, 2020). According to this perspective, in the middle of a severe pandemic, it was necessary to "humanize" Hackathons and speed up HCD efforts to deliver fast implementations.

OPER.TEN[7] (Transform Emergency Now! 10 days for a change) is a program that links university, industry, government, public, and the environment through multidisciplinary teams of students. OPER.TEN links OI and HCD approaches (as described in chapter 1) to take advantage of the synergy of both: in facts, users, stakeholder, and experts have been asked to cooperate in the research and to design the development of solutions to four

Mincolelli, G., Cocchi, N., Dosi, C. & Vignoli, M. (2020). "OPER.TEN" Transform Emergency Now! Facing Covid-19 with Open Innovation and Human Centered Design. *Strategic Design Research Journal*. Volume 13, number 03, September – December 2020. 658-668. DOI: 10.4013/sdrj.2020.133.28

challenges related to the phase 1 of the Italian Covid-19 emergency. Private and public organizations and companies patronized the four challenges.

Table 1: Innovating the design process: a synergy between HCD and OI

	HCD	Hackathons	OPER.TEN
Duration	Months	Days	Weeks
Focal activities	Research	Ideas development	Implementation
Outcome	Tested solution concept	Working prototype	Human Centered viable solution

Companies and organizations' involvement has been considered a critical factor in developing design solutions that could be fastly implemented. The ten days lasted from March 25th to April 5th, 2020. OPER.TEN was promoted and powered by OPER.SPACE, the OI center of the University of Bologna, in collaboration with Almacube, the incubator of the University of Bologna, and Almalabor, the digital fabrication and coworking space of the University of Bologna. The program involved multidisciplinary teams of students from three Universities in the Emilia Romagna region (the University of Bologna, the University of Modena and Reggio Emilia, and the University of Ferrara), who are alumni of OPER.SPACE's OI programs. Each team was supported by a design thinking coach – namely, experienced innovation design professionals who work at the OPER.SPACE OI center - and had the opportunity to rely on a network of professors, experts, and professionals related to the three Universities. The main actors involved throughout the program are described in Table 2.

Table 2: Actors involved in the OPER.TEN program

Team	Network involved	Main responsibilities
Design teams	MSc students	Design activities (see Table 3)
Teaching team	Design Thinking coaches	Students recruitment, Identification of possible partners, Methodological support, Process and output guidelines
Referent professor	An expert academic in the field of innovation management	Coordination of the program
Support circle	Professors, Companies, Municipality, Start-up connected to the University network	Feedback during presentations

The teaching team conducted preliminary research carrying out interviews with 20 stakeholders involved in the front line fighting Covid-19 (e.g., doctors, nurses, government officials, politicians) that led to 30 different challenges that were ranked and chosen for relevance and cognitive proximity to university students. Selected challenges were four, one for each team:

1. How might we support senior citizens who live alone and are currently experiencing isolation due to the lock-down, being more connected to other people, and doing physical activities without leaving their houses?
2. How might we minimize the risk of infections within supermarkets and grocery stores?
3. How might we help parents in lock-down to entertain and spend quality time with their children while dealing with their current smart working routine?

4. How might we enhance citizens to practice remote activities during the lock-down to be connected, informed, and keep up with their professional and educational path?

The table below presents the program's structure designed with an HCD approach and adapted from Hackathons (Mohajer Soltani et al., 2014) as a ten days Design Thinking marathon.

Table 3: OPER.TEN process structure

Day	Design activities	Goals of the day	Suggested tool for the design team (HCD tools - regular; OI tools - bold)
1	Kick-off	• Project and team set-up • Understand the design context in terms of actors involved, products and services already on the market, and innovations and initiatives in the field of the challenge • Identification of users' problems	• Desk research • Actors map • **Map of existing company assets** • **Benchmark of existing solutions** • Users interviews • Online surveys
2	Research and need definition	• Identification of the most relevant need of the main stakeholders • Identification of opportunity areas	• Stakeholders interviews • Users and experts' interviews • Personas • User journey map • Stakeholder map
3	Challenge definition and design space exploration	• Definition of the challenge reframed • In-depth research of the context	• Collaborative sense-making • Desk research
4	Ideation and prototyping	• Wider generation of ideas • Test of the ideas	• "How might we" questions • Brainstorming • Rapid prototyping (e.g., sketches, digital interfaces, mockups) • User test with stakeholders
5	Ideation and need refinement	• Need refinement • Definition of the concepts • Test of the concepts	• Prototyping • User test • **Impact and feasibility assessment**
6	Milestone	• Present the concepts to the teaching team and available partners • Select the quicker concept to implement • Definition of an action plan to implement the concept	• Presentation • Feedback analysis • **Gantt** • **List of experts, skills, and resources needed**
7	Prototype iteration	• Further development of the selected concept • Plan a system prototype test	• **List of constraints for features to build** • System map
8	Concept refinement and communication	• Definition of the user experience • Definition of the communication strategy • Test of the prototype	• User journey • **Technical blueprint** • **Communication strategy tools**
9	Implementation	• System definition (e.g., skills, resources, timing, materials) • Definition of an implementation roadmap	• **Roadmap of implementation** • **Resources map**
10	Final presentation	• Presentation of the outcome	• **Handover to organizations**

2.1. HCD methodology for Covid-19

The HCD approach reported in Table 3 was adapted to face Covid-19 challenges, such as the fact that the design team could not meet users for interviews or observe them in the context. The teaching team developed a vademecum for remote design research and cooperation to ensure a homogeneous and significant effort by all the teams and reduce coordination time. It provided tips and online tools suggestion like the following:

- Communication channels: a Slack team workspace for real-time written communications between team members. A shared Slack workspace, "Ten tutti", to link useful material or contacts. A Slack teaching team channel for any doubt/need/proposal to be addressed to the whole T-team. A Slack inspiration channel to share insights and ideas with other teams.
- Interaction with users, stakeholders, experts, companies, and organizations: Google meet for interviews and focus groups; Google surveys for the evaluation of contextual factors, needs, scenarios, concepts. A shared list compiled by the University of relevant professors and experts to be contacted. A shared list of users ready to be interviewed in different fields. Access to University, Almacube, and Almalabor website and social media to communicate the program and test ideas and solutions with the crowd.
- Visual cooperation and co-design: Google docs, Google Jamboard, Miro for System map, User journey, Service blueprint, Roadmap of implementation, System and Resources map.
- Time management: to ensure standard working hours, a Google sheet in which each team member marks the slots of working hours on the project and the slots in which he/she will be available on Slack so that the other team members have no qualms about contacting him/her.

2.2. OI for faster implementation

Innovation is often measured in terms of expected costs, but in the middle of a severe pandemic, all these issues are far less critical than the capability to deliver a solution sooner (Chesbrough, 2020). The first OI effort involved stakeholders from the territory. To facilitate involvement, the design effort was presented as a hackathon, as it is one of the most renowned OI methodologies that recently gained popularity among companies to test new products and generate new ideas (Rosell et al., 2014). The design team had to keep in touch with an extensive list of stakeholders and possible champions from the territory. The teaching team created the first list of significant stakeholders while defining the challenge, and the team had to expand it, leveraging word of mouth and personal connections as a snowball. Moreover, to ensure implementable solutions, for each challenge, the team, in accordance with the coach and program coordinator, had to identify a stakeholder (e.g., a company or a public body) that could have enough resources to bring the final solution to life.

Table 4: OI activities of OPER.TEN

Day	OI activities
1 to 5	• Identify possible stakeholders of the territory • Engagement of key stakeholders in the project to get their commitment to participating, through interviews and email • Involvement of stakeholders as users of the participatory design efforts • Involvement of the stakeholders' organizations during the milestone in the audience to give feedback (e.g., as representatives of their company and not only as individual participants)
6 (Milestone)	• Feedback from the involved stakeholders regarding the intermediate design results. In particular, the teaching team asked the involved organizations to support the design team by listing other experts, skills, and resources needed
7 to 9	• Involvement of the stakeholders in activating possible test cases with the participatory design approach. This is to speed up the design team's testing capabilities

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Day	OI activities
	• Involvement of the stakeholders to comment and support the design team in developing the designed solution implementation roadmap. This makes the implementation roadmap not only a generic roadmap but a roadmap that could be implemented by some actors of the territory
10 (Final presentation)	• During the presentation, make a clear call to action, clarifying what is needed to bring the designed solution to life

After the end of the final presentation, to guarantee a real social impact, the design team (or the coach) worked for some other days with the identified partner to transfer the knowledge and support the partner in becoming the implementation champion. To do this, the design team prepared an implementation roadmap with the selected partner. Once the organization involves a larger circle of employees for the implementation phase, the design team helps the company team to go through the implementation roadmap so that the solution can come to life.

3. RESULTS

In the middle of a pandemic such as Covid-19, the most relevant variable that should be considered to analyze an innovative intervention's impact is its rapid implementation. Either the solution is implemented now, or it makes no sense to pursue it. The OPER.TEN program was designed to quickly implement solutions to help people in dealing with Covid-19 and 40 days after the completion of OPER.TEN three of four solutions were implemented (Digitali e Uguali[8], Esci i nonni[9], Kit-Insegna). We report, as a reference for readers, cards presenting the implemented solutions in the Appendix. To succeed in this, the program identified challenges relevant in the Covid-19 scenario and suggested codesign online tools to the design teams, so that an HCD approach could be implemented despite social distancing. It was the first time that design teams (and coaching and teaching teams) had to question the effectiveness of many of the traditional field research and co-design tools because of the covid contextual factors. Empathy, which is such a precious result of direct interaction between people and designers, was not anymore achievable in the usual way. The availability of online communication and cooperation instruments has been crucial for the development of OPER.TEN. All the people involved in the HCD process have participated in the experimentation of new forms of remote collaboration for each of its steps. This experiment's results have produced enough data, insights, and ideas to grant the development of a design solution implemented for a significant part. The prototyping for co-creation and test phases can be considered the hardest to be developed, mainly when the design solution encompasses physical devices. Teams focused more on the system design definition and the concept proposal of service models prototyped and tested through visual examples or storytelling. The codesign online tools applied can be considered useful and practical but still insufficient to completely substitute direct interaction. However, the proposed methodology has been demonstrated to be an excellent way to involve users, stakeholders, experts, organizations, and companies in what Sanders (2008) calls the People Centered Innovation process. The program reported suggestions to hybridize the HCD approach with an OI approach, to successfully leverage the territorial and network resources during the design and implementation phases. Those resources proved incredibly helpful during the implementation phase by unlocking territorial resources and local networks to enable fast implementation of the proposed solution. For example, the Digitali e Uguali team was able to access a city association (AUSER), the School district Office, a teacher of a school (IC5), and a family with a child in need to test the full service of a donation of a computer to a student within one day. Even if this is a preliminary result based on a few case studies, we believe that the OPER.TEN programs could also contribute to empowering other Human Centered Design Open Innovation efforts to face the Covid-19 pandemic, and – more generally - to shed light on OI bundled with HCD as a process that should be taken into consideration to address complex social challenges in emergencies.

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ENDNOTES

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[3]https://d4sd.org/

[4]https://viterbiinnovation.usc.edu/community/usc-technology-innovation-bootcamp-fighting-covid-19/

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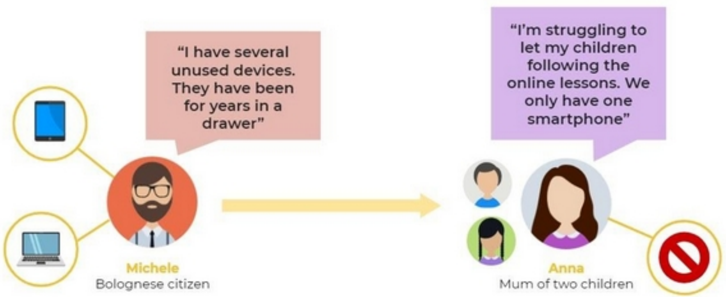
APPENDIX

Table A: Digitali e Uguali

Digitali e Uguali

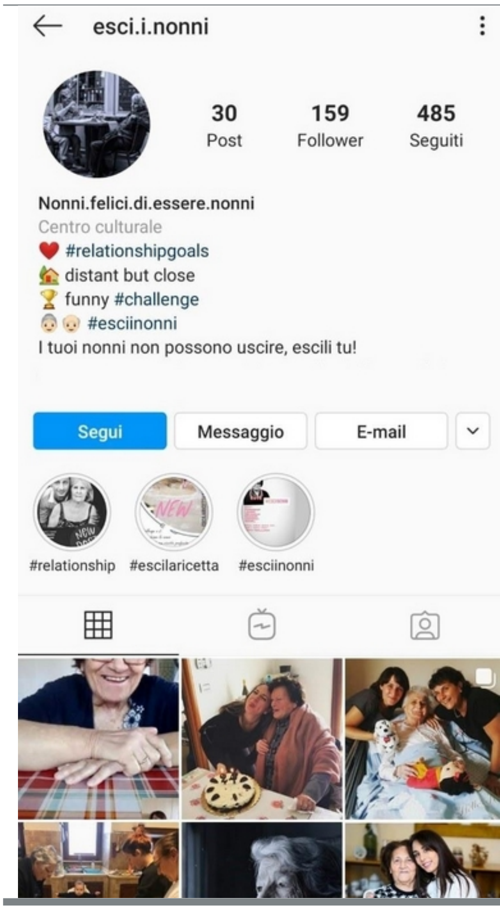
ISTAT, the Italian National Statistic Office, pointed out an issue regarding one-third of Italian families that do not own digital devices (personal computers, smartphones, tablets) in the middle of a pandemic. This matter of fact leads these families in isolation and brings difficulties in adapting to the new remote practices. Incredibly, only one in four Italian children have the instruments they need to take part in education from their homes' safety. Thus, the design team carried out a survey collecting 85 answers highlighting that 45% of families own unused devices, whose 63% is still working. The survey also figured out that 53% of families that own unused devices are willing to donate. To test these results, the design team developed a prototype, asking the reached families to donate their device, which led to the identification of 20 smartphones, 11 personal computers, and six tablets ready to be donated. As described by the design team itself, the emergent design context is shown in the figure below (Source: OPER.TEN final presentation).



Thus, the design team prototyped and implemented a system to connect Michele (the donor) and Anna (the beneficiary). The design team helped Michele in backing-up, resetting, and sanitizing, partnered with Auser, a courier service that delivered the device and helped Anna correctly set the personal computer donated in terms of first access and use of equipment. The team went through a specific learning process that helped them figure out most of the problems needed to be addressed to design and implement such a system. To sum up, the design team probed people's participation through a survey and prototyped the whole service by delivering one laptop to a child by the end of the project. The developed solution is a digital platform - called Digitali E Uguali to connect people who have surplus devices with children who need them to attend remote school lessons. The project involved two institutions acting as developers for the online platform (Yoox Net-A-Porter Group and the Municipality of Bologna) and a logistic partner to collect and transport the device (Auser). The platform has been active online since the 8th of May, which means just 33 days after the end of the process. The CEO of Yoox Net-A-Porter, the partner company engaged during the program, stated, "We have already donated hundreds of laptops ourselves. I invite you as individuals and businesses to donate via the platform".)

Table B: Esci i nonni

Esci i nonni



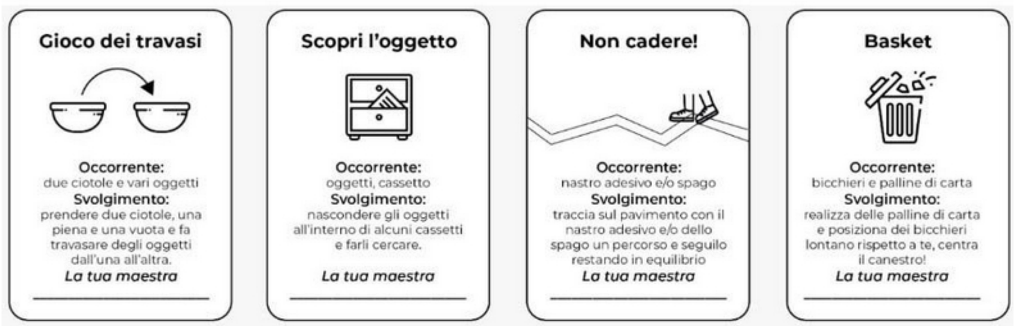
In Italy, according to the Health Ministry, the mortality rate for people between the ages of 80 to 89 due to the Covid-19 pandemic was 42,2 %. This matter of fact led older adults in isolation since their families decided to buy groceries and medicals for them in order to avoid the risk of contagion. According to the expert psychotherapists interviewed by the Design Team, "The main problems concern being alone but also feeling alone", especially for the self-reliant seniors that have their interests, such as "playing cards with friends, performing gentle exercises, making a cake for someone". Thus, the Design Team decided to focus on this category of seniors performing several rounds of interviews. What wowed the team was that many of them learned how to use mobile phone applications to make video calls, especially to feel closer to their nephews.

On the other hand, the research highlighted the nephews' trend of posting on social networks pictures with their grandparents. To foster this relationship, the Design Team came up with the solution concept Esci i nonni, which aims to collect stories about grandparents' personal life. The solution goal is also to switch from seniors' common perception as a category of frail care-taker people to "grans" as caregivers and source of knowledge and wisdom. The initiative was tested through a social campaign on Instagram, where nephews were asked to publish instant-stories about their grans. The campaign prototype #escinonni has collected over 300 followers in a few days and has incremented the time that nephews and grandparents spent on video calls. The developed Instagram page has now reached 159 followers, and 30 different posts of 30 different life stories have been published.

Table C: Kit-Insegna

Kit-Insegna

During the Covid-19, half of the Italian children (53.53%) experienced more significant irritability, intolerance to the rules, excessive tantrums and requests, and still one in five mood changes (21.17%) and sleep problems including difficulty falling asleep, agitation, and frequent awakenings (19.99%). This emergency led to many difficulties for their parents, especially those who started working from home during the lockdown. In particular, Internazionale emphasized the difficulties children need to face due to the lack of a vis-a-vis educational program, which affects their parents. One of the main redundant issues relates to the number of homework teachers provide to children: "Last week, my son was requested to fill 40 boards!". After different rounds of interviews, the design team discovered that this problem concerns teachers' difficulties in communicating with children and managing the development of remote activities. Besides, according to the expert psychologists interviewed by the Design Team, children "need to maintain contact as directly as possible with their teachers". Thus, the Design Team ideated a support Kit for teachers who take care of the growth of children aged 3 to 6. The Kit aims to facilitate teachers in using communication tools and support parents with well-defined educational activities, which positively affects their workload, providing a better family organization.



Designing with communities of place: the experience of a DESIS Lab during COVID-19 and beyond

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ABSTRACT

Social distancing, lockdown, and the consequent intensification of online interactions brought by Covid-19 are raising new questions for design theory and practices. The lack of physical or face-to-face interactions blocked the design activities developed in public spaces. The article aims to share a DESIS Lab experience to overcome these limitations and continue in a contactless way. Firstly, a literature review introduces the Lab's theoretical and methodological approaches; then, a process started previously to the pandemic outbreak is presented, called *My Neighborhood*. It happens in a neighborhood in Rio de Janeiro, called Grajaú, with face-to-face activities developed in a public square. Secondly, a new initiative prototyped after the pandemic outbreak is described. *Grajaú Collab* is an online mapping that identifies micro-businesses and volunteers in the neighborhood. The Lab's theoretical and methodological approaches provided the orientation and adaptability to stay with the local community under the pandemic. *My Neighborhood* has moved online and generates *Grajaú Collab*; however, both remain closely referred to the neighborhood's physical space. Online and offline modalities become two complementary sides of the same open-ended learning process and, in the future, the lab team can restart offline and face-to-face participation in the neighborhood as a continuum of the same *infrastructuring* process.

Keywords: Design for Social Innovation, Infrastructuring, Placemaking, Service Design.

INTRODUCTION

Safety protocols used to reduce risk during the COVID-19 pandemic, such as social distancing and lockdown, forced millions to take different forms of online sociality and contactless interactions. This process blocked all activities based on face-to-face encounters in public spaces, including design initiatives for social innovation.

Rio DESIS Lab gathers students and researchers to explore how design can reinforce social innovation processes in Rio de Janeiro. It is a member of the DESIS (Design for Social Innovation and Sustainability) Network. The Lab was involved in *My Neighborhood* process when the pandemic arrived: it is a series of initiatives prototyped or improvised by members of Rio DESIS Lab, residents and other stakeholders in the neighborhood of Grajaú, Rio de Janeiro for more than one year. It is a mutual learning process with residents on design for social innovation and placemaking which includes regular encounters to identify shared felt concerns to be worked out in a transformational way.

Grajaú is a neighborhood in the North Zone of Rio de Janeiro and is renowned in the city for its green areas, composed of tree-lined streets, squares and a park bordered by the Grajaú's Forest Reserve. It is also one of the few planned neighborhoods in the city, built in the early decades of the 20th Century. It became 'residential' between 1925-1930. However, it is not composed of standardized buildings; the planning action was concerned with the development and design of land use. Like many other city areas, it includes social inequality and spatial segregation: the neighborhood comprises four different slums, and residents from different socioeconomic backgrounds coexist. It looks like an isolated small city for residents and, for this reason, it was a good starting point for *My Neighborhood*.

However, in the social isolation scenario brought by COVID-19, *My Neighborhood* process was abruptly interrupted, and the Rio DESIS Lab team find themselves pressured to devise new ways to continue. The pressure did not come from external actors; it was a commitment with the residents and a need to stay with them through a difficult situation. Some Lab members reside in Grajaú and helped by bringing updates of the situation in the neighborhood.

The Lab has indeed reframed its activities to continue in a contactless way. The next paragraphs unfold the theoretical and methodological approaches followed by the Rio DESIS Lab in *My Neighborhood* – which started with offline and face-to-face activities in a public square - and how the process has continued online after the pandemic outbreak and generated a new initiative, the *Grajaú Collab*.

It is not my objective to evaluate or discuss the results of the two initiatives, but instead to describe, analyze and discuss how the Rio DESIS Lab continued to participate in the neighborhood processes in a contactless way. The shift from offline to online activities required by the pandemic brought about new opportunities instead of limitations and reinforced the initial *My Neighborhood* process.

The paper is structured as follows. The first session presents the theoretical approaches followed by the Rio DESIS Lab when working with design for social innovation in the city's neighborhoods; this session ends by describing *My Neighborhood* under these theoretical lenses and detailing our research and design challenge. The second session presents the methodological approach followed by Rio DESIS Lab in *My Neighborhood* and *Grajaú Collab*. The third session presents the situation of *My Neighborhood* process when interrupted by the pandemic, how *Grajaú Collab* started and its features. The final sessions analyze and discuss the findings.

1. THEORETICAL APPROACH

Some keywords, and related theoretical approaches, has guided the activities of the Rio DESIS Lab team in the neighborhood.

1.1. Design for Social Innovation

Cajaíba-Santana (2014) states that social innovation "is always related to collective social action aiming at social change," and it aims to bring up "social change that cannot be built upon the basis of established practices." It is also essential to consider its transformative character: "what underlies the path of social innovation is not a social problem to be solved, but the social change it brings about" (p. 3).

Design for social innovation is a constellation of design activities aimed at supporting social change processes, based on the recombination of existing resources to achieve socially recognized goals (Manzini, 2014). When applied to social innovation, design practices recognize the "ontological immateriality of the phenomenon" (Cajaíba, 2014, p. 44). It led us to focus on services as objects of our design practice, which are developed collaboratively as prototypes (Hillgren et al., 2011) or improvisations.

We must avoid fast and superficial approaches. A positive social change takes time. It includes improvements in human and social conditions and significant alteration in behavior patterns and cultural values and norms, yielding profound social consequences.

1.2. Places, small-scale and relationships

There is a large body of literature on placemaking, place-making, and placemaking (Matteo-Babiano and Lee 2020; Lew, 2017). I use the term placemaking inspired by some definitions in the literature (e.g., Schneekloth and Shibley 1995, Hes et al. 2020), but adapted to our focus on interpersonal relations, collaborative approaches, and *infrastructuring* – aspects that guide our steps on design for social innovation. It indicates a broad set of practices that seek to care for and transform places *together with* the people in them.

Two concepts, the sense of place and community participation (Kalandides, 2008), are at the center of our definition of placemaking. The first connects placemaking to processes of sensemaking in design (Cipolla, 2017). The second to processes of co-design (Corcoran et al., 2017). Here, the design approach to placemaking indicates small-scale updates that can increase the overall health and vitality of a neighborhood (Kahne, 2015).

This definition led us to focus on the primary purpose of *My Neighborhood* as a placemaking process: continuously prototype different initiatives to nurture meaningful relationships between people and spaces. The aim is to improve the overall quality of life referred to residents' needs and desires through meaning-creation (adapted from Hes et al. 2020). "Space provides the canvas on which meaning and identity can be affixed and contested, and the characteristics of the place also shape people's attachment to the place as well as their relationship with others" (ibid p. 280).

This focus on relationships (Prakash and Spinelli, 2016) and the articulation of multi-stakeholders (Djalali et al., 2019) on placemaking processes do not undermine the integration with the natural environment or the role of economic aspects.

The term placemaking may refer to destructive practices (Hes et al., 2020) that include marginalization processes, gentrification, and private developers or state agencies focused on placemaking processes to legitimize profitmaking or urban redevelopment projects. I use the words placemaking, hoping that the previous paragraphs adequately defined the design approach adopted, which is also related to Yi-Fu Tuan (1977, 1974) and Hassam Zaoual (2003, 2006). The first describes how an undifferentiated space becomes place: it happens over time based on interpersonal relations, and the latter calls designers to respect existing cultural processes.

1.3. Service design, social innovation and places

Placemaking processes may include perspectives on service design when requiring "professionals who provide services in order to enable local communities to propose

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alternatives that may counter redevelopment" (Huang and Roberts, 2019, p. 2). However, service design practice on the Rio DESIS Lab requires an accurate description when related to placemaking.

Service design has grown as a multidisciplinary, human-centered, holistic and iterative approach, focused on creating new interfaces for value co-creation to meet people's needs and stakeholders' goals (Secomandi and Snelders, 2011). For us, service design plays a role in our view of placemaking – detailed in the next paragraphs - by providing processes and tools to connect people, organizations, communities and their resources in new partnerships (Wetter-Edman et al. 2014) constituted through an open-ended and collaborative design process. Within this context, it is more suitable to consider what Kimbell (2011) defined as designing for service, which "is seen as an exploratory process that aims to create new kinds of value relation between diverse actors within a socio-material configuration" (p. 42). The author, echoing Manzini (2011), suggests that "what is being designed is not an end result but rather a platform for action with which diverse actors will engage over time" (Kimbell, 2011, p. 45).

Design for Social Innovation brought to service design (or designing for services) the definitions of collaborative and relational services. The first notion came to light when research (Manzini, 2007) identified types of service interactions that have been called collaborative services in social innovation cases (Manzini, 2008) on which all participants are active co-producers of commonly recognized benefits. This analysis also led to the identification of a particular form of interpersonal interaction in services known as relational services (Cipolla, 2004; Cipolla and Manzini, 2009; Cipolla, 2012), where participants are not only collaborative but also relate with one another in an intensely interpersonal way.

1.4. *Infrastructuring*

Designers and design labs who find themselves involved with social innovation processes may consider *infrastructuring* (Björgvinsson et al., 2010), and this was the case of the Rio DESIS Lab team.

It is an approach that comes from participatory design tradition that differs from project-based design. It is an open-ended design process where diverse stakeholders can innovate together: "the activities that are carried out are aimed at building long-term relationships with stakeholders in order to create networks from which design opportunities can emerge" (Hillgren et al., 2011, p. 169).

Infrastructuring indicates that "a more long-term engagement could contribute differently, especially when it comes to the implementation phase and to having a real impact" (Hillgren et al., 2011, p.180).

1.5. The *broken city* of Rio de Janeiro and the agonistic approach

The process of placemaking culminate in shared decision-making. This may be difficult when democratic practices are restricted. The ways "people give meaning to places may even stand in stark contrast to each other. Local communities do not always have to be homogeneous, and they do not always coexist harmoniously" (Kalandides, 2018, p.150).

Social inequalities are deeply felt by residents in Rio de Janeiro and expressed with the term "broken city" (Ventura, 1994). It describes the fracture of the city, with the increased

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distance between "hill" (favelas) and "asphalt" areas: each space and corner in the city, if not gated, includes tensions between residents. Therefore, it is evident that social interactions in public spaces involve political struggles for space, and this defines who is 'in-place' and who is 'out-of-place' (Cresswell, 1992, Matteo-Babiano and Lee, 2020).

Therefore, placemaking processes in Rio de Janeiro can consider agonistic democracy, which "does not presuppose the possibility of consensus and rational conflict resolution, but proposes a polyphony of voices and mutually vigorous but tolerant disputes among groups united by passionate engagement" (Björgvinsson et al. 2010, p. 48).

1.6. Hybrid-communities of place

There is a recognition that contemporary placemaking is "by necessity 'digital' due to the ubiquity of the smartphone and the Internet" (Toland et al., 2020, p. 271) and, in times of COVID-19, is a requirement. The constitution of place that emerges "under the 'digital condition' is less about geographical propinquity and more about imaginative and affective engagement and selective affiliations. It is increasingly delaminated from defined sites and communities, although they can often increase awareness about, and affinities for, specific localities (p. 271).

Manzini (2020) proposed a specific working hypothesis for design, a strategic orientation for the processes of placemaking motivated by the social distancing during the pandemic: the notion of hybrid-communities of place. It is "a system of digital relationships which, once the virus is over, could be capable of evolving and moving into the physical world" (Manzini, 2020, p. 3). It means "to cultivate in the digital space only (or at least mainly) relationships in-between 'neighbors.' That is, in-between a well-defined and localized group of interlocutors" (Manzini, 2020, p. 3).

1.7. Design and research challenge

My Neighborhood reflects the theoretical approaches presented before.

It is organized as an *infrastructuring* process to explore possibilities to prototype different collaborative and relational services as *platforms for action* to nurture placemaking and social innovation processes in the neighborhood. It is an open-ended and mutual-learning process developed between the Rio DESIS Lab members and residents on Grajaú.

It is a *design for social innovation* initiative when it seeks opportunities to support existing and new social change processes in the neighborhood.

It is a *placemaking* process that seeks to care for and transform the neighborhood through small-scale collaborative practices and nurture meaningful relationships between people and spaces.

Grajaú has tensions as part of the *broken city* of Rio de Janeiro. There are aspects related to social inequalities that cannot be ignored (and are impossible to be ignored) in a neighborhood that includes four different slums and where residents from different socioeconomic backgrounds coexist. This critical aspect lies underneath all past, present and future activities in the neighborhood.

These theoretical approaches were guiding the participation of the Rio DESIS Lab team in the neighborhood processes. They defined a set of values and possibilities for our involvement.

However, the pandemic outbreak brought the following design and research challenge: how a design team (Rio DESIS Lab) could reframe an offline and face-to-face *infrastructuring* process in a neighborhood, to continue online, without losing its previous values and possibilities?

Rio DESIS Lab team produced an initial answer to this challenge, described in the next paragraphs.

2. METHODOLOGICAL APPROACH

This session presents the methodological approach followed by Rio DESIS Lab to participate in *My Neighbourhood* and *Grajaú Collab*.

The process followed by Rio DESIS Lab members in *My Neighbourhood* unfolds the concept of inclusion (Cipolla and Bartholo, 2014). Inclusion means to nurture the designer's relation with his or her own context of life. It provides a stimulus for activities 'where you are' to transform your own situation. *My Neighborhood* and *Grajaú Collab* teams include students that are residents in the neighborhood of Grajaú. It was not a requirement, and few of them are. All team members are stimulated to be multipliers and expand positive ideas and experiences in their own neighborhoods, now as students or later as residents.

The methodological orientation adopted by the Rio DESIS Lab team was inspired by the critical participatory action-research - CPAR (Kemmis et al., 2014), combined with design phases under a dialogical approach (Cipolla and Bartholo, 2014). CPAR is considered a social and educational process for all those involved: residents, students (some also residents) and professors. It is a self-formation and learning process mediated through practices.

The focus of the CPAR is "to make changes in our own situations to enact more satisfying, sensible and sustainable ways of doing things" (p. 68). *My Neighborhood* started – as recommended by CPAR - as a process that gathered the Rio DESIS Lab team around a question: how to transform the neighborhoods in Rio de Janeiro through design? It moves the group to build up opportunities for other conversations in two different areas in the city. From this point, the group decided to get closed to a specific one (Grajaú). There the CPAR process continued in the interplay with residents.

Two features of CPAR are well-aligned with the theoretical approaches presented before:

- "the recognition of the capacity of people living and working in particular settings to participate actively in all aspects of the research process";
- "the research conducted by participants is oriented to making improvements in practices and their settings by the participants themselves" (Kemmis et al., 2014, p. 4).

My Neighborhood runs continuously as an open-ended process that includes two cycles of four months per year (March to June and August to November), which follows the academic calendar of the UFRJ (Universidade Federal do Rio de Janeiro). It started in the first semester of 2019.

Action research works well with the process of *infrastructuring* (Hillgren et al., 2011): both do not perform a well-defined plan. However, it is possible to describe a sequence of steps - that performs a spiral of "self-reflective cycles" (Kemmis et al., 2014, p. 19) of CPAR - for each cycle, as described below.

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- **Planning a change**: each cycle starts with planning a (small) and unpretentious change for the neighborhood to be defined in a participatory way, involving students, residents and a local partner. An initial program of activities is defined.
- **Acting and observing the process and consequences of the change**: continuous improvisations and adjustments occur during the cycle when performing the initial program. The process is registered in reports and includes photos, images (including print screens when online) and other related communicational materials. The original aims and program are continuously discussed and can be reframed. Adjustments are defined in weekly meetings.
- **Reflecting on the process and its consequences**: activities and results are analyzed to plan a new cycle. The analysis does not encompass evaluation in terms of failure because there is no rigid planning or expectations: it is a mutual learning process between participants.

This process continues in new cycles "- re-planning; - acting and observing; - reflecting, and so on..." (Kemmis et al., 2014, p. 19). It is an open-ended process on which each cycle produces insights to start a new cycle in an open-ended process.

The first two cycles of *My Neighborhood* happened offline and face-to-face. The role of our *students-residents* in Grajaú was vital in the first two cycles while connecting with other residents.

The third cycle would follow the same direction, but the pandemic outbreak reframed it, and *Grajaú Collab* emerged. The same methodological approach guides both initiatives.

3.FROM *MY NEIGHBORHOOD* TO *GRAJAÚ COLLAB*

The next paragraphs present the first two cycles performed by *My Neighborhood* in 2019 with the only aim to present the situation of the process when interrupted by the pandemic.

Next, I describe the third cycle and the process that gave rise to *Grajaú Collab*, including how the phases of CPAR were performed and enable the team to continue active in the neighborhood.

3.1.*My Neighborhood*: situation

The process completed its first two cycles in the second semester of 2019, and the plan was only to visit the main public square in Grajaú (Praça Edmundo Rêgo) on the weekends. The aim was to create new situations in the square to nurture conversations between residents themselves and the Rio DESIS Lab team about the neighborhood. It included:

- casual conversations with passersby with the loose aim of forming an initial group of co-participants (figures 1 and 2);
- work out what is happening in the shared setting (the neighborhood) to identify a possible shared felt concern (figure 3);
- identify, feel and perceive the current sense of place among residents in Grajaú (figure 4).

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Progressively the team started to propose specific prototypes (small-scale updates in the public square) as invitations for the passerby to gather and start conversations. It included invitations to residents:

- to gather around a breakfast table;
- to join collaborative boards that display personal stories, memories and the history of the neighborhood;
- to join collaborative boards that display opinions about the quality of life in the neighborhood, preferred ways of mobility and other issues;
- to play games with their children (hopscotch, adapted football, soap bubbles, slackline);
- to a 3D printer exhibition and presentations about maker culture, both as stimuli to talk about desirable futures (initiative *GrajaMaker*).

The group also identified in the neighborhood of Grajaú existing social innovation initiatives, some of which Lab members got involved. We established a partnership with members of a collaborative housing called Casa Anitcha, that have been very active in Grajaú since 2008. Every month they organize a well-known festival and market called "Let it go" to promote sustainable values and practices in Grajaú. The Lab team worked in the festival, got involved in the local urban garden, and started interacting with some local micro-entrepreneurs.

The prototypes worked well, and the Lab team became a regular and recognizable presence in the square. Experiences were registered along the way, reflected and considered as input for a new cycle for 2020, with some shared concerns in the neighborhood identified and organized.

However, the process was abruptly interrupted on March 13, 2020, when the university closed its doors to contain the spread of COVID-19. All gatherings in public spaces were progressively restricted or prohibited, including all *My Neighborhood* activities. The plan for 2020 was to continue and refine the previous prototypes, to invite an initial group of co-participants to develop a small practice around specific concerns identified in the last cycle and increase conversations with residents through social media.

Therefore, the Rio DESIS Lab team was unable to start this new cycle as planned. After a short period of recovering, the team began to think about a new cycle for *My Neighborhood* process.

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Figure 1. Activities in the public square as opportunities for conversations: slackline (Rio DESIS Lab – archives, *My Neighborhood*).

Figure 2. Activities in the public square as opportunities for conversations: learning game about recycling; (Rio DESIS Lab – archives, *My Neighborhood*).

Figure 3. Work out what is happening in the shared setting (the neighborhood) to identify a possible shared felt concern: collaborative board about resident's perceptions and attitudes about the neighborhood (Rio DESIS Lab – archives, *My Neighborhood*).

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Figure 4. Identify, feel and perceive the current sense of place among residents: collaborative board about Grajaú's history and memories (Rio DESIS Lab – archives, *My Neighborhood).*

3.2. *Grajaú Collab*: a new cycle

Rio DESIS Lab has continued its activities online since the beginning of the COVID-19, with two regular weekly meetings and parallel activities developed by its members. If the theoretical and methodological approaches adopted by Rio DESIS Lab provided the guidelines and strategic orientation for *My Neighborhood's* activities, the lockdown and social distancing measures stopped the process. New questions emerged: how could we continue activities intensively connected to interpersonal interactions performed on a specific space (a square in the neighborhood)? How could we continue the ongoing process of *infrastructuring* (Hillgreen et al., 2011) and more: how could we voice solidarity with other residents in the neighborhood and be useful during the pandemic?

My Neighborhood started a new cycle for the pandemic phase by following CPAR. This cycle is detailed below, organized by each phase.

***P*lanning a change.** A micro-entrepreneur referred to a DESIS Lab student - who resides in Grajaú - how she faced a relevant drop in sales due to COVID-19 restrictions. The entrepreneur is well-known among Lab members for providing food during *My Neighborhood* activities in the public square. The student also observed that residents were also facing barriers to offering volunteer services in the neighborhood during the pandemic due to mutual distrust. The team decided to propose a contribution to change this situation.

Acting and *observing* the process and consequences of the change. *Grajaú Collab* started to be developed as a mapping process to locate micro-businesses and volunteers in Grajaú. Residents can explore the area through the map to find small producers and suppliers, service providers and volunteers available in the neighborhood (figure 5). Participants fill a form to indicate the activities or help being offered and their specific location on the map. The initiative aims to facilitate new personal connections (i.e., volunteers offering to do grocery shopping for the elderly) or enable residents to discover new local suppliers for everyday products and services (i.e., local producers of bread, cakes, crafts, or local classes of yoga).

Members of a collaborative housing initiative (Casa Anitcha) are developing a complementary currency to run in the neighborhood, called NIT, and there is the possibility to include the currency in the *Grajaú Collab* process.

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***Reflecting* on these processes and consequences.** *Grajaú Collab* becomes a virtual unfolding of *My Neighbourhood*. Grajaú is the focus: those listed in the map are residents or are doing business and volunteering activities there. Until now, the map includes around 100 pins. Few volunteers joined the mapping process (less than 5). The mapping process comprised a survey about the conditions of working and volunteering activities in the neighborhood, composed by few questions. A small group answered (25). The team organized and sent the results to all participants. The proposal was to create for us (DESIS team) and residents an opportunity for reflection about the initiative and situation under the COVID-19 restrictions.

The results of this CPAR phase revealed many opportunities to define a new cycle for the *Grajaú Collab* process; they are:

- progressively include more categories in the map to reflect the diversity of activities in the neighborhood: collaborative activities (such as urban gardens) and initiatives (such as cultural performances), beyond entrepreneurs and volunteers who were the first to answer the invitation and join the map;
- propose new invitations and explore possibilities to expand the map, to cover excluded areas in the neighborhood, particularly the favelas;
- the team could create opportunities for online conversations about what is being learned in the mapping process and generate new possibilities for co-designing processes in the neighborhood.
- produce a series of webinars with experts on challenges faced by micro-entrepreneurs (such as the use of social media for business purposes);
- actions, services or events to stimulate residents to "buy local";
- actions, services or events to stimulate mutual trust between residents to favor volunteering activities.

The cycle finished with a report produced by the Rio DESIS Lab team and a new cycle is being planned for 2021.

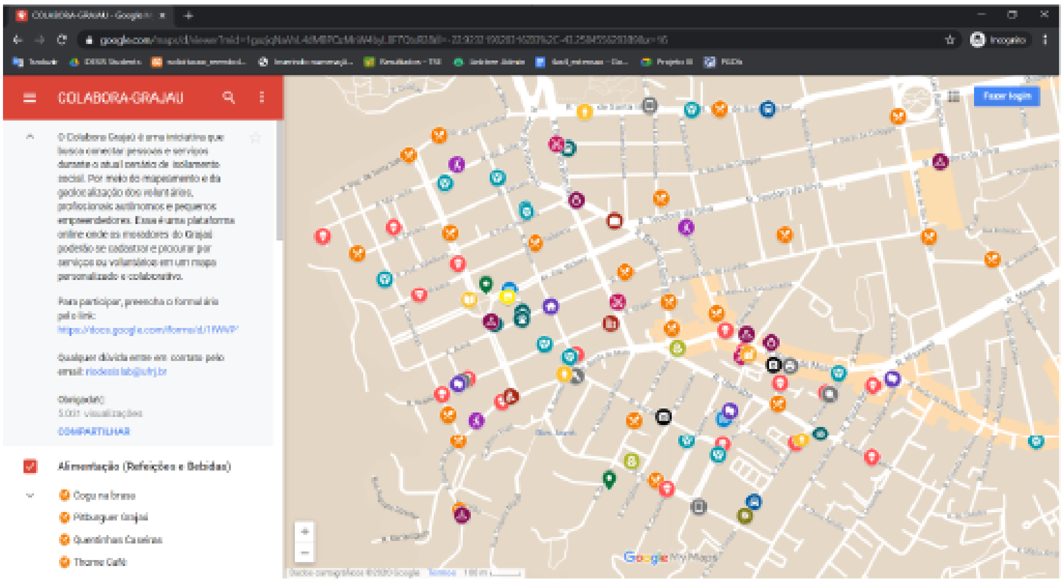

Figure 5: *Grajaú Collab* (Google Maps)

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Figure 6: Examples of posts to disseminate map's features and clusters on social media

3.3. Technological and communicative features

The team decided to develop Grajaú Collab as a platform for action in the neighborhood. The process includes free and easy technological resources:

- invitations to participate in the mapping process sent to resident's groups on Facebook and Instagram;
- a Google Form used to invite participants to self-report their small-business and volunteering activities;
- a Google Form also used in the survey process;
- a Google Map created to include and organize the information by adding pins in the neighborhood map (figure 5);
- a dedicated link (http://www.desis.rio.br/mapacolaboragrajau) created to enable easy access;
- posts on social media (on the residents' groups on Facebook and Instagram) to disseminate the map, its thematic clusters (e.g., food providers, health services) and the results of the survey (figure 6).

3.4. Other initiatives

Rio DESIS Lab members also engaged in initiatives to provide quick answers to the pandemic. It included:

- let our 3d printers available for the networked production of personal protective equipment (PPE);
- develop a fundraising campaign for university hospitals (@doeufrj);
- start a communication campaign on social media to disseminate good news, practices and examples of social innovations, to inspire citizens and promote positive attitudes and initiatives under the pandemic outbreak.

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4. FINDINGS AND DISCUSSION

The theoretical and methodological approaches followed by Rio DESIS Lab when participating in *My Neighborhood* and *Grajaú Collab* helped to continue connected to the neighborhood under the pandemic. Below I describe how each theoretical and methodological feature played a role.

Hybrid-communities of place (Manzini, 2020) provided the idea to move DESIS Lab activities online but stay connected to the physical area of Grajaú. *Grajaú Collab* can be integrated - in a post-pandemic phase - to the activities developed in the main public square and create a continuum between online and offline processes.

Infrastructuring (Hillgreen et al., 2011) provided the view of a long-term and open-ended design process. It was beneficial in times of crisis, such as COVID-19, on which previous knowledge and interpersonal relations are essential to identify new possible initiatives such as Grajaú Collab. A continuous learning process and a web of interpersonal connections allow the rapid identification of ongoing issues and explore new responses.

Inclusion (Cipolla and Bartholo, 2014) provided the idea to include students who are also residents of Grajaú in the My Neighborhood process. It helped the team to stay connected to the neighborhood under COVID-19. One of the students reported the neighborhood's situation, which led to the decision to start the *Grajaú Collab* process.

Service Design as designing platforms for action (Kimbell, 2011) provided the idea that the interruption of our visits to the public square in Grajaú did not mean to stop *My Neighborhood*. It guided the team to move online and prototype a platform for action, the *Grajaú Collab* as an invitation for residents to connect in the view of potential new actions and partnerships in the neighborhood.

Critical Participatory Action Research - CPAR (Kemmis et al., 2014) provided to the Lab team agility to quickly turn back to the observation phase and re-plan the third cycle under the pandemic. Two main aspects are relevant. Firstly, the process that results in *Grajaú Collab* did not involve residents in its conceptual phase, only the ones in the Lab team. Secondly, the Lab team quickly prototyped *Grajaú Collab*. From now on, only residents can make it useful and meaningful by accepting invitations for new initiatives related to the map or by developing it autonomously. Otherwise, it will be progressively deactivated. Secondly, the participation of residents in the research process, as recommended by CPAR, is being developed. We are exploring the possibility of introducing a complementary currency in the *Grajaú Collab* process, together with Casa Anitcha. It is a new perspective for us all and helps to strengthen the relation with an important stakeholder.

Placemaking (Kalandides, 2008) provided the idea that prototyping with residents small-scale updates in the neighborhood and creating opportunities for interpersonal encounters could increase the neighborhood's quality of life through meaning-creation. The lab team used to visit a public space in Grajaú, with many possibilities for interpersonal encounters and conversations. Now the process started online in *Grajaú Collab*. Still, there is much to be learned on nurturing interpersonal relationships and a sense of place in a contactless way. The online map that reflects the Grajaú's physical space is promising. It can progressively include the connections and relations between residents and nurture a sense of place.

The *broken city* (Ventura, 1994) was not considered until now in *Grajaú Collab*. The face-to-face activities of My Neighborhood in the public square, as a physical space of transit, included considerations about interpersonal connections or frictions between residents and passersby from different social-economic backgrounds. Prototyped activities in the public square revealed these tensions. Now, in the online map, such tensions are still to be revealed.

Open-ended and participatory design process (Hillgreen et al., 2011). This orientation led the Rio DESIS Lab team to a discussion – still open - if residents should drop pins directly on the map - to indicate their position and information - or not. The DESIS Lab team learned about an open collaborative map in Brazil that was erased and decided to mediate participation in the map to avoid risks. Information from residents and local providers was collected in a Google Form and included in the map. This decision was not easy, and it is not final. It is a new step in the learning process about limits and possibilities for design practices. The COVID-19 emergency undoubtedly moves the DESIS team from a fluid and experimental open-ended process towards a more project-based process in *Grajaú Collab*.

5. CONCLUSION

The main answer to this challenge was to move online but stay closely related to the neighborhood's physical space. This idea guided the team to quickly prototyped a new initiative – *Grajaú Collab* as an invitation for residents. Rio DESIS Lab team has invited residents or those developing neighborhood-focused activities to the mapping process and is intermediating their participation in the map. The COVID-19 emergency pushed the Lab team towards a more project-based-approach, but the focus on the neighborhood's physical area helped the team to continue the *infrastructuring* process. The online and offline processes are now considered two complementary sides of the same open-ended learning process in the neighborhood. This orientation helped the Lab members to stay connected to the neighborhood's situation and demands when an extensive digitalization of everyday processes - promoted by social isolation and lockdown – result in the multiplication of platforms for different purposes, but without specific territorial references.

The Rio DESIS Lab's theoretical and methodological approaches helped to provide answers to our initial research and design challenge, and also the orientation and adaptability to stay participative and active in the neighborhood. They allowed the *infrastructuring* process in Grajaú to continue.

The online map reproduces the physical space of the neighborhood, but users can include locations and relations. It is a simple but promising platform for collaborations and conversations between residents and nurturing a sense of place.

Despite the personal challenges brought by COVID-19, the Rio DESIS Lab members got involved in *Grajaú Collab*, which has deepened our connections with the neighborhood.

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Design amid Emergency

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ABSTRACT

This article presents the process for the "Design of services under the COVID19 emergency social protection plan", drawn up by a team of researchers and designers from Porto Alegre in collaboration with the Porto Alegre City Government, and directed at the provision of essential benefits to homeless and other vulnerable people during the pandemic. The process was developed in an unprecedented way for the designers involved: without prior notice, within very short time frames and completely remotely, using only digital platforms. As such, the process was developed to respond to the emergency and amid the emergency. In this regard, the objective of the article is to discuss how to design amid emergency. The experience was guided by the methodological principles of action research and research through design. In addition to presenting the design results: these being solutions aimed at the short, medium and long term, this article highlights the need, even in these circumstances, to aim for the prizing of difference, the suggestion of alternative views, social innovation, the systemic transformation of society and sustainability.

Keywords: Cities, COVID19, Emergency, Social Innovation, Strategic Design.

1. INTRODUCTION: DESIGN FOR EMERGENCIES AND DESIGN IN EMERGENCIES

Design and emergency are terms that have often been connected to each other by design culture. Usually the relationship carries with it design's contributions to facing emergency situations, such as those related to natural disasters or wars, and the consequent humanitarian crises they generate. The designs in question are drawn up *ex-ante*, in preparation for possible emergencies, such as those submitted for the so-called "Housing for all" ideas, promoted in 2008 by Triennale di Milano, which summoned designers, architects, engineers and other inventors for the challenge of designing an emergency housing module (Irace, 2008). Additionally, there is the possibility for designs drawn up *ad hoc* and *ex-post*, to tackle the effects of a specific calamity, as is being demonstrated currently by the proliferation of designs aimed at facing the COVID19 health crisis and its socio-economic effects. In this regard, see, for example, the "Design Emergency" initiatives, developed by Paola Antonelli and Alice Rawsthorn (2020), or "Design for Emergency", developed by Sara Colombo and Paolo Ciuccarelli (2020). In order to explore the relationship between design and emergency, in addition, there are also interesting cases of speculative design (Franzato, 2011, Dunne, Raby, 2013), which, in a way similar to science fiction, survey for apocalyptic scenarios, or even pandemic or post-pandemic scenarios, as in the case of the "In case of emergency" exhibition (Brunswick et al., 2017).

The aforementioned initiatives focus especially on the results of the design process, as repeatedly occurs when design is exhibited to industry operators and to the general public, not on the process itself. The resulting artifact, design, prototype or product is shown, with the aim that the perceptions of the presented design processes may reverberate throughout the discourse of design and society as a whole, or even may be continued to be reproduced. The design processes allowing for the achievement of such results are less demonstrated. Such processes are worked on in the context of criticism and the development of design methods. There is wide-ranging literature on emergency design, inquiring into the dynamics of emergencies, describing their contexts and, lastly, suggesting topics deserving of attention in order for existing design methods to be applied to this challenge, such as user-centred design (Frishberg, 2005), co-design (Liegl, 2016), design inspired by biomimetics (Trotta, Valdés, 2016), participatory design (Del Gaudio, Franzato, Oliveira, 2016), universal design (Gjøsæter, Radianti, Chen, 2018), social design (Farrington, 2019), and others.

The distinct situation in which the design community finds itself today in confronting COVID19, however, may allow for another approach to the criticism and development of design methods. Globally, the pandemic has limited most, if not all, human activities, including design, while giving rise to an extreme need for design in order to reshape these same activities and to devise solutions to the new problems we are facing. In other words, we must design amid and for the emergency. This has already occurred in participatory design or social design, especially as part of work necessarily situated within critical contexts (Del Gaudio, Franzato, Oliveira, 2016; Farrington, 2019), but the criticality that we are experiencing is definitely unprecedented for design, as well as for any other area. The purpose of this article is to discuss how to design amid emergencies, amid this emergency.

This article critically discusses a co-design experience that we developed to assist the City Government of Porto Alegre (Brazil) in its actions to combat the health and socioeconomic crisis brought about by COVID19. The "Design of services under the COVID19 emergency social protection plan" project sought to reconfigure the benefits distributed by the city to its population in vulnerable situations, to reinforce and expand their positive impacts through paths connecting up the different support networks and to create short, medium and long-term solutions meeting the needs of these people. The designing was undertaken by the authors, professors at a university with a campus in Porto Alegre, together with a group of students, professional designers and City Government employees. It involved a synchronous and asynchronous co-design process, as part of a network and was necessarily carried out remotely.

Both the design and this article were drawn up amid the emergency. The acceleration of processes and the urgency of implementing relevant solutions have become part of our present time. From the beginning, we were aware that we had never designed with such urgency and that, precisely for that reason, the experience could become the subject of investigation. Despite this, we were forced to leave aside the specification of a formal and structured research and design strategy and we made the decision to rely on organic and distributed reasoning, guided by the methodological principles of action research (Thiollent, 2005) and research through design (Jonas, 2007). At the end of the experience, we planned to reflect upon the design process that emerged. Such approaches were justified by the unprecedented characteristics of design developed without sound planning and within a very short time frame, which was hands on with a focus on social innovation. We knew that only by designing would we learn how to deal with these design circumstances and we hoped that our learning would contribute to the advancement of the design method, when necessary to design amid emergency.

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We recorded the experience through a field diary and the collection of design results throughout the process. Based on these materials, this article continues with the reporting of the experience, its analysis and discussion.

2. THE “DESIGN OF SERVICES UNDER THE COVID19 EMERGENCY SOCIAL PROTECTION PLAN” PROJECT

The time dimension is important for the design approach, so we will underscore it. On 05 May 2020, the University received a request for design assistance from the Porto Alegre City Government’s Office of the Innovation Director (http://www2.portoalegre.rs.gov.br/inovapoa/default.php?p_secao=1358) to contribute to the development of an emergency social protection plan. For two months, the city government’s team had been working to identify the number of people in need of assistance in the city and the social protection requirements they needed to meet. The team reached a point where it needed a method that would speed up the development of proposals and that would prioritize the views of the people to be assisted, rather than the procedural limitations of the city government. Within design culture, the Innovation Director sought answers to the crisis, alternative and creative visions, and perspectives that would clarify the complexity of the necessary actions. To accept the challenge, we needed to assemble a team of volunteers, willing to contribute to the common good, in the development of a risky design proposal, as there were no agreements formalized between the City Government and the University, nor resources to pay for the work of the designers. We contacted students, teachers and professionals who had already demonstrated themselves to be sensitive to the social problems caused by COVID19 in the city. After 13 days of work, on 18 May 2020, we presented the design results.

In the briefing section, the City Government estimated that more than 135,000 people were at risk and would need access to social protection services and benefits. The challenge posed initially was to identify people and find ways to deliver the benefits to them. It is worth noting that, at that moment, the city was already imposing social distancing, many small businesses were starting to face bankruptcy, if not closure, and unemployment was growing. Another important feature is that the low-income population in the city of Porto Alegre has difficulties accessing the internet as a daily source of information, whether due to technological and financial issues or due to functional illiteracy.

On 11 May 2020, we had a team of 14 people, including professors and design students from different educational backgrounds, at the undergraduate, graduate and master’s levels, willing to respond to the call of the city government. Strategic design (Franzato e Costa, 2017; Freire, 2017) was the methodological approach that connected the team, combined with social innovation as its desired effect (Franzato et. al, 2015). The cause was what motivated the volunteer designers to move forward with their work. We devised a design process as part of which those involved participated remotely, with a high level of autonomy so that, in just one week, they could present an initial solution proposal to the city government.

We chose certain platforms to enable the synchronous, asynchronous and remote design process. “Trello” was the platform chosen for the organization of the project, since it made it possible to organize the different tasks performed by the team members, allowing everyone to always access the information, updated in real time. “Google Draw” was the platform

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chosen for co-creation activities, and "Google Drive" as a repository for the material produced. We held synchronous meetings through videoconferencing platforms, such as "Teams" or "Zoom". In addition, we created groups on "WhatsApp" to exchange quick messages and brief the group on the challenges encountered throughout the processes. We also used "WhatsApp" to conduct interviews with people in need of assistance, in order to collect data that was essential for the project. In fact, in Brazil the application is used by the population very extensively, because, due to agreements with telephone companies, the use of data for this application is generally free.

As a collaboration strategy, we created pairs and trios, bringing together people with complementary skills to work. They started with an immersion in the context, to understand what was happening in the city. Based on this immersion, we developed a counter-briefing. According to Zurlo (2010), counter-briefing consists of a redefinition of the briefing, adjusting it based on the critical and dialogical vision that designers develop when interacting with the design context and the proposal requested by the organization. Counter-briefing should direct the design team towards devising proposals that meet the needs of everyone involved in the problem situation. In the case of the project under analysis, the counter-briefing activity was evaluated as decisive, since the initial request had only been outlined by the Innovation Director, given the urgency and novelty of the challenges faced. Next, we started identifying pain points, that is, risks and obstacles related to protection services (Osterwalder et. al, 2014) and defining personas (Stickdorn et. al, 2018) who represented the diversity of people facing an emergency situation in the city and their suffering. In a very fluid way, due to their aptitude and degree of familiarity with the techniques used, the team members engaged in assorted tasks, taking on different roles throughout the process.

In addition to the online meetings of the design team, validation meetings with professionals from the Porto Alegre City Government were held, as well as constant conversations and exchanges between the person in charge of the project at the city government and the design team. Certain scheduled deliverables have already been submitted and others are in progress, considering the iterative design process involving quick adjustments, as challenges arise, and action guidelines are defined.

2.1. Briefing and Initial Collection of Relevant Information

From a macro perspective, the challenge presented by the City Government of Porto Alegre is very similar to that of most cities faced with a pandemic: finding quick ways to ensure the survival of people in vulnerable situations and preventing more people from becoming vulnerable due to resulting socio-economic impacts. However, we understand that each challenge has its organizational, legal and cultural particularities, which completely change the way of approaching and solving different problems.

The briefing presented by the city government was: "design a path for users to receive social benefits with more efficient and faster delivery", through a video conference held through the "Zoom" platform on 8 May 2020.

Our starting point was to collect with the City Government representative the information available about the services and benefits that are being distributed to the population in need, since they have a lot of secondary data. As such, it was possible to reach an initial understanding about the difficulties of implementing and distributing these solutions, as well as preliminarily determining the number of and characterizing the project's target group. With this in mind, the development of solutions for people in vulnerable situations (for example, unemployed people, the homeless, street vendors, informal workers, recyclers of recyclable waste) was defined as the focus of the project, these people sometimes being unknown to the public administration and, therefore, not registered to receive any type of benefit. With cash inflows that, in most cases, do not even reach 100 dollars a month, these people were already in a very critical situation and, amid the pandemic, their material conditions have worsened considerably. A fundamental point was to understand who these people were, in what situations they lived and how they could be found by the government in order to receive the benefits.

From the preliminary analyses, we defined as counter-briefing the structuring of a collaborative network to expand the possibilities of production and delivery of benefits, development of emergency solutions capable of guaranteeing the survival of these people in the short term and long-term solutions capable of sustaining a better quality of life for this population with a focus on enhancing local businesses and stimulating the regeneration of the social fabric.

In this way, we were able to broaden the vision of the initial briefing in two main aspects: the structuring of a network and the development of solutions from a long-term perspective with attention given to sustainability.

2.2. Contextual Immersion: Key Challenges and Pain Points

Based on the premises and counter-briefing, the group established different lines of contextual investigation. We will describe the aspects surveyed and the main results.

We selected certain profiles of the possible target groups mapped and the main players involved locally to conduct in-depth interviews, with the objective of understanding the context and developing personas that would make it possible to understand their points of view and main difficulties. We interviewed:

- Homeless and other vulnerable people.
- Community leaders;
- City government professionals;
- Professionals from FASC (http://www2.portoalegre.rs.gov.br/fasc/), a foundation in the City of Porto Alegre focused on the development of social assistance and citizenship projects, therefore, working directly with people in vulnerable situations;
- Volunteer workers with independent projects in support of these people;
- Entrepreneurs whose companies perform some type of social work.

The construction of personas (figure 1) allowed the design team and city government professionals to realize that, behind the number of 135,000 individuals in an at-risk situation worsened by COVID19, there were real people, with specific needs and difficulties. The development of personas and narratives about their day-to-day lives sensitized the designers and other professionals into producing design solutions for the investigated aspects.

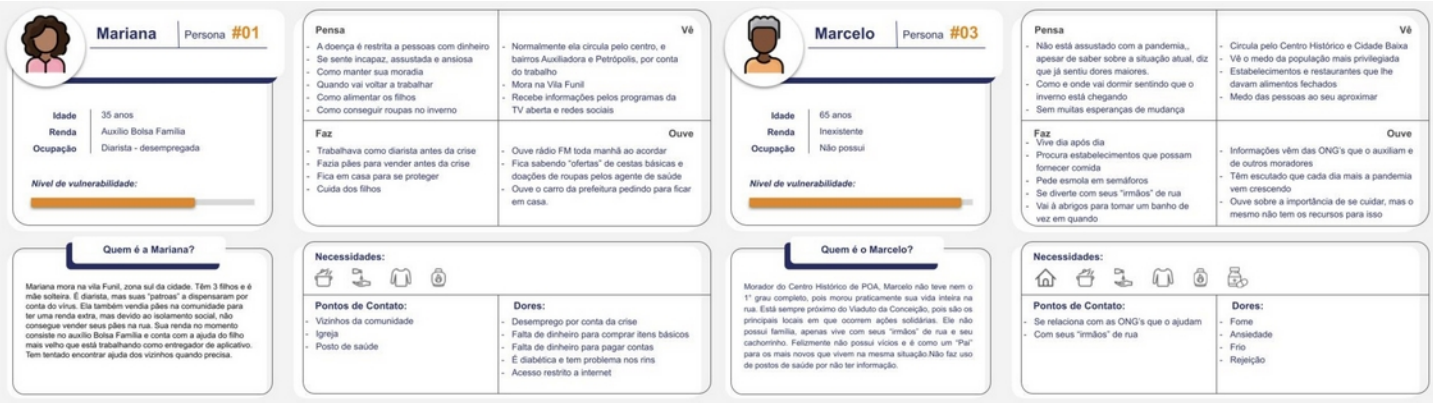

Figure 1: *Personas*

The study of secondary data on target groups, interviews and *personas* led us not only to understand the criticality of these peoples' living conditions, but also the great challenges of their battle to access benefits, including:

- Lack of knowledge of available benefits;
- Impossibility of recognizing themselves as a beneficiary, because of their marginal place in society;
- Inaccessible registration processes for benefits due to technological reasons or access to technology;
- Difficulty concerning urban mobility in seeking benefits in physical form (food and hygiene products, for example).

Alongside the in-depth interviews, seeking a systemic view of the social reality locally, we mapped out several non-governmental initiatives, launched by NGOs or citizens' collectives, which existed before the pandemic or were created by them to deal with it. We cross-referenced this information with the existing city government maps, in order to understand where the biggest gaps in the city were. In this way, we produced our first design output that we labelled as the Solidarity Map (figure 2). The map is intended to geo-locate the drives that are making a difference in the city, giving them visibility and making it possible to assess their spread. From this standpoint, it was possible to identify the areas that were not yet served in order to allocate the City Council's limited resources to them.

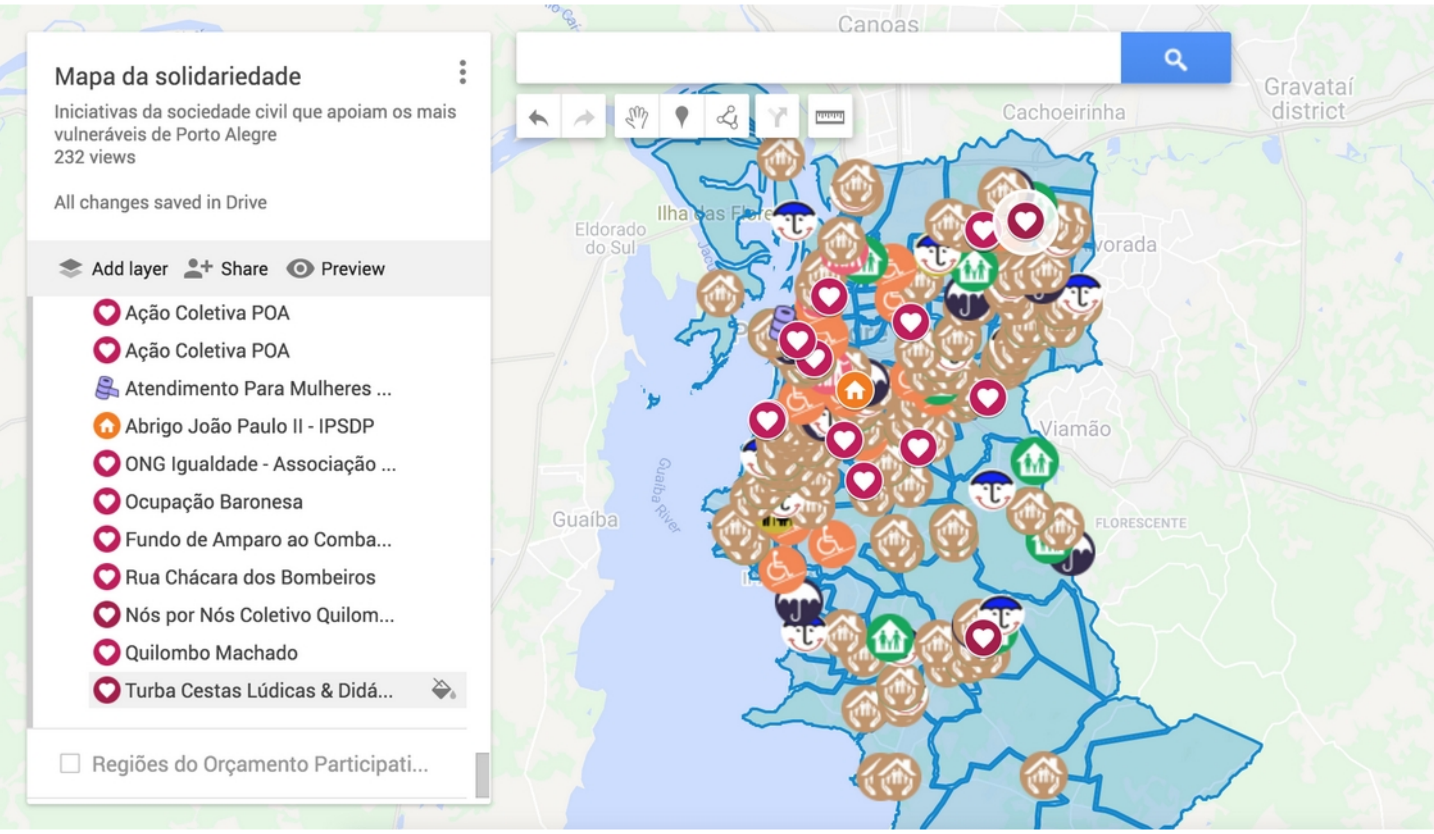

Figure 2: Solidarity Map, which shows the spread of different types of projects in the city map

The syntheses and paths designed thus far have pointed to the important challenge of reducing bureaucracy in the processes of registering people in the city government system and receiving benefits. Still, given the scope and extent of the crisis, it was necessary to think of short, medium and long-term alternatives in order for these people to have access to quality food, clothing and housing in order to stay healthy. Lastly, it became evident that there was a need to increase the reach of benefits to a greater number of people and the ways of accessing these benefits.

2.3. Partial Design Solutions

In the transition to the development of solutions, we first defined important values for their development:

- Resolution of urgent problems, keeping in mind the need to transform the system;
- Redefining of the centre-periphery polarity in the city;
- Valuing of the different forms of knowledge production;
- Recognition of already existing practices and promotion of new practices for social interaction, allowing for population autonomy to be created.

In this direction, we established that solutions should be developed based on design coalitions (Manzini, 2017) bringing together the government, civil society, universities and local businesses. We identified short, medium and long-term solutions, identifying them with three verbs - respectively, feed, nourish and transform -, which will be described below.

To organize the three types of solutions, we designed a first flow, still under construction, which shows the necessary steps and arrangements that we propose in order to implement the distribution of benefits in more comprehensive and powerful ways.

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In parallel and subject to constant iteration, we built a visual map, synthesizing the design opportunities. In the middle of figure 3, there is the name of the map: Possible Cities | Porto Alegre – New deals. In the second circle, there are the pillars around which opportunities are assembled, based on the emergency drive generated by the pandemic: food, shelter and protection, structuring of partner networks, sustainable or renewable energy, new economies and sanitation services. The first three pillars are the ones chosen for the continuity of the project. In the third circle, there are already existing solutions, linked to the pillars, which can serve as benchmarks. In the fourth circle, there is a mapping of possible actors that can be triggered in order to develop and implement design opportunities.

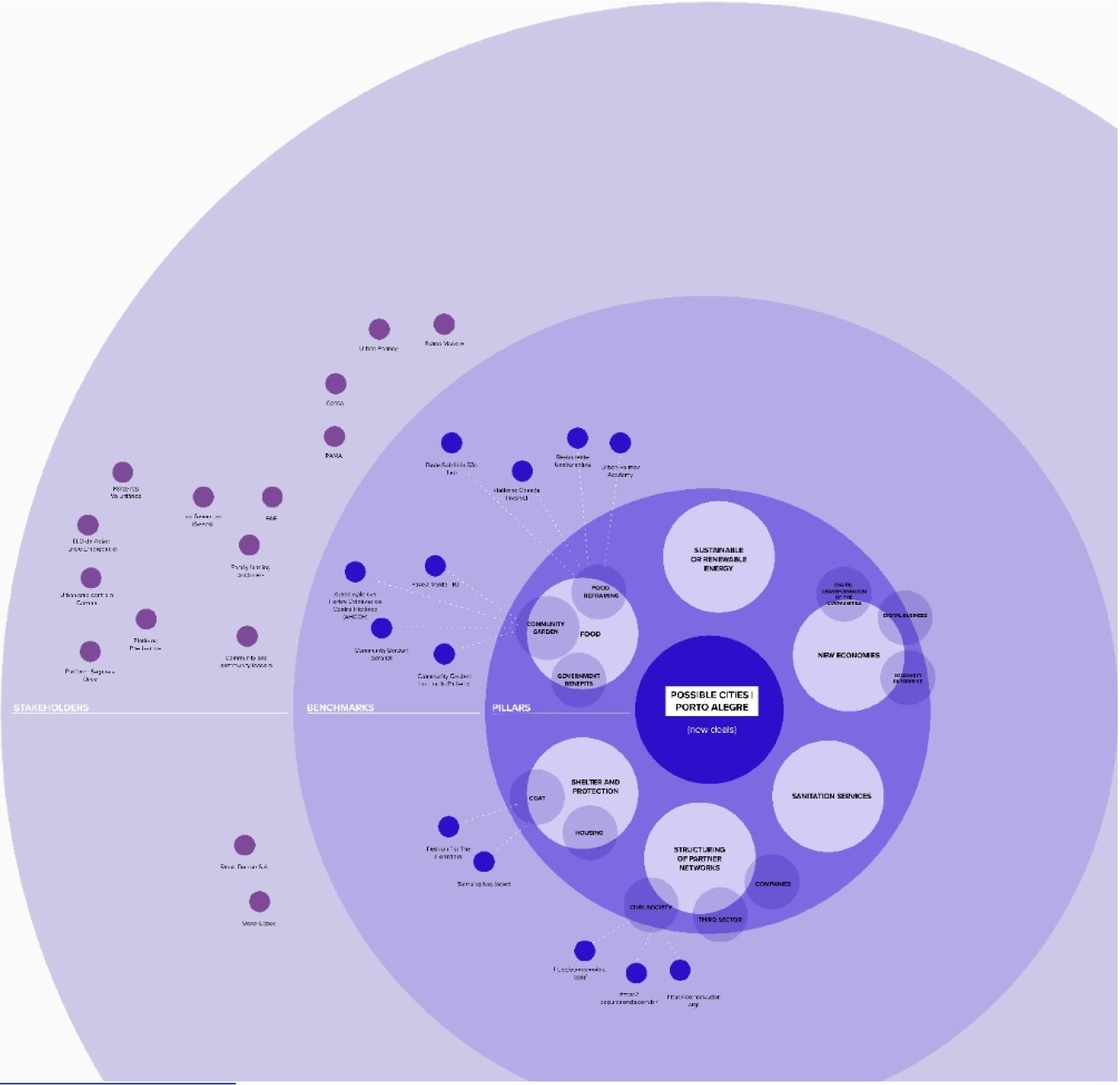

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Figure 3 – Map of Possible Cities | Porto Alegre

2.4. Feed (short term: emergency and survival)

This type of solution seeks to improve the quality of actions that are already underway. The intention is to streamline so that the modes of production and distribution of clothes and food can reach people in need of assistance, without them having to travel or form crowds in queues, with the potential for the dissemination of COVID19.

The first solution developed relates to the distribution of ready-made foods, using produce from local producers. The solution involves the initiation of the solidarity map initiatives by the city government itself, for production and distribution. This solution was designed for people who live on the street and are unable to cook their own food. The idea is to create dedicated spaces to intensify distribution, enabling people from civil society to support the project according to their possibilities, through financial support, the donation of produce, the cooking of meals or the distribution of meals.

The second solution developed relates to the setup of mobile points for distributing warm clothes and baskets with food for people who have a home and the ability to cook their own food, so as not to give rise to crowding. The solution envisages the registration of beneficiaries on-site. Implementation of the solution depends on community leaders who have a greater understanding of the needs of their communities and greater reach.

2.5. Nourish (medium term: transition to good living)

This type of solution has a more permanent and medium-term characteristic, impacting people's lives in a more sustainable way, promoting their autonomy and providing assistance for responding to crisis and emergency cycles.

The first solution developed is aimed at homeless people who, by choice, choose this way of life, thereby respecting their identity. To protect them during the city's winter, the solution seeks the distribution of what they need, such as sleeping bags too, in alternative to the infrequent and insufficient distribution of warm clothing in the coldest periods of the season, with temperatures that can drop close to zero degrees, or during bad weather. This solution envisages the triggering of communities of seamstresses and players in the textile industry as a source of skills and resources, based on an open design and distributed manufacturing platform.

The second solution developed is aimed at creating urban gardens for the production of quality food, so that fresh and nutritious food can reach the population in a more accessible way. For this, it is necessary to enhance the urban gardens that already exist in the city and value this agriculture and food culture. To this end, the solution provides for the development of partnerships with actors in family farming and other local producers, to form communities capable of producing food close to their homes.

2.6. Transform (long term: new forms of city life)

These proposals focus not only on homeless people and other people in vulnerable situations, but also on the low-income population who, during moments of intense crises such as COVID19, fall below the poverty line, becoming unemployed, losing their homes and even losing access to food. Outside of the scope of the work of coping with the emergency situation caused by the pandemic, these were not true solutions and were presented only as suggestions for the City Government.

The first one suggests the setup of solar panels at the homes of low-income communities, thereby making it possible to reduce living costs, since electricity bills are an expensive item for the households that make up such communities.

The second one suggests free access to the internet to enable digital inclusion. It is believed that this solution is also important to facilitate civil protection communications, as well as to enable remote training activities.

3. POST-COVID19 SCENARIOS: POSSIBLE CITIES, VISIBLE FUTURES

Based on these initial premises, we started to identify fundamental values that motivated the design team to encourage reflections for the transformation of the post-COVID19 reality (figure 4).

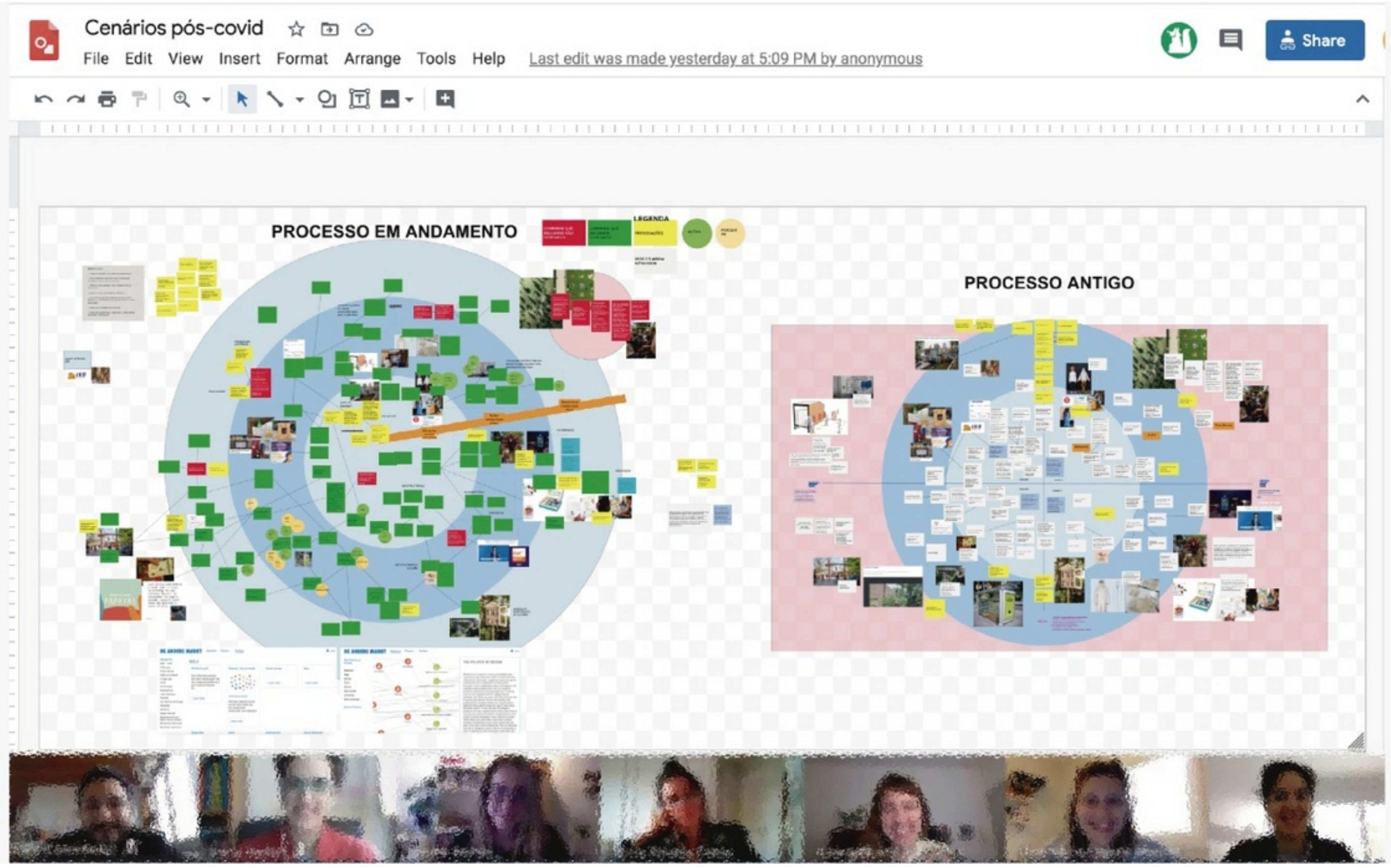

Figure 4: scenario development process

Still in the interview phase, the team of designers was struck by the fact that, in some cases, being “invisible” to the government is a choice by people, who want to escape the social control imposed by institutions. This made the team imagine urban futures based on multiple views for the city and multiple ways of city life, ways that did not abandon the values of dignity, civic consciousness and health. The team identified, as a first step towards this change, the recognition of the existence of other ways of living and other urban practices already in play in the city, which should not be necessarily and desirably placed within the centre-periphery polarity. From this perspective, it is important to value the initiatives already existing locally and, with them, to co-design a transition that allows focusing not on solving urgent problems, but rather on transforming the system. Figure 5 presents a partial result of the scenario development process, proposing the construction of reality through multiple perspectives and creative capacity as a way to resist the effects of COVID19 in the different spheres of social life.

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Figure 5: partial result of scenario elaboration.

4. WHAT WAS LEARNED: DESIGNING AMID EMERGENCY

The aim of the paper is to discuss how to design amid emergency. We found out that the main characteristics of this design process were: the openness and horizontality of the project management; and a diverse design team, supported by multiple digital resources that allowed for remote work, guided by visual deliverables of design results to speed up communication. The results that were achieved, in such a short time, were only possible due to the plurality of views of the assembled team, which was able to quickly capitalize on its intellectual and cultural knowledge in the proposed horizontal work process. Diversity of cultural experiences and technical expertise were fundamental. The openness to the multiple voices, where each of the participants was able to present proposals and criticize the proposals raised by colleagues in a very free manner, regardless of their title or level of experience was another key point. There weren't hierarchical positions. Everyone had the opportunity to express a voice.

The humanistic values of each participant, indispensable for them to engage in this intensive work on a voluntary basis, were decisive in interpreting the effects of the emergency context. Design understood as a sense-making activity (Manzini, 2015) allowed the design team to perceive the pandemic as a possible key to change, for the transformation of society against social inequalities and for sustainability. The pandemic presented itself as an opportunity to show to government authorities an alternative view of possible cities, desirable cities that one might have after pandemic, beyond the dominant understandings, including beyond the understandings of the designers themselves, who do not live in peripheral areas. In this sense, interviews with people in vulnerable situations and from their perspective to produce design inputs. Upon creating *personas* and storytelling, not only the design team, but also the City Government team had the opportunity to broaden their visions with regard to the

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context of the lives of people in need of assistance, their rights as citizens and their potential as agents for transformation. The practice of otherness is fundamental in this kind of project.

The design team demonstrated great adaptability in an environment, that of digital media, which was already intensely used, but not as exclusively as this time. Digital platforms were extensively explored, even if, at many times, the possibility of direct immersion in the field was needed. As a result, we understood the importance of designers' presence in situations where they are called upon to act. We realized that it is possible to deliver good design results amid emergency projects, working with people with whom we have not previously worked, in an intensive manner if: (1) we share the same values that are the drivers for change; (2) we agree on certain rules based on which to work and deadlines to meet; (3) we trust in the open design process and collaborate intensively with people with diverse capability to create meaningful results

At the end, the design result was a process to change the way the Government deals with its citizens: from delivering public services to co-creating it with social actors; a process based on systemic view, networks and a decentralized understanding of the city, i.e., a peripherical one. Although evident, the structuring of a support network for the population that considers the government, universities, private institutions and civil society as pillars is not so simple. Before setting up a robust and aligned network, it is important to work on the breakdown of barriers and models of action that prevent this collaboration. As a path, we point out the importance of identifying areas of convergence of interests, the creation of win-win policies and the daily encouragement of a culture of collaboration at the differing levels.

We also emphasize that, even in a sudden crisis, it is an opportunity to endorse and promote a long-term vision, with greater transformative potential, so that cities can become more resilient and better prepared to deal with emergencies. It is believed that only with deeper changes in the social fabric it will be possible to guarantee the dignity and quality of life of the population. In this regard, it is believed that it is necessary to involve the general population in the development of transition projects. This is the reason why we proposed the project as an open question to be explored critically by those who live the city. This demands a new understanding of the designer role in this cocreation process.

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The impact of sharing platforms on collaborative design development during emergencies: the case of COVID-19

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ABSTRACT

The COVID-19 outbreak resulted in an emergency of projects developed, shared and produced by makers, fablabs and open source enthusiasts. These projects are often released in design sharing platforms, e.g. Thingiverse, Github and Instructables under open source licenses. It is often argued that the release of such projects holds potential for enhancing collaboration, continuous development and design dissemination. These arguments have been subject of recent studies on the structure of maker/Open Design communities and sharing platforms. This study aims to contribute to the on-going debate on the potentialities of such communities. We adopt an explorative approach to (i) identify the influence of the COVID-19 outbreak on the activity volume of Thingiverse, the object of our study, (ii) analyze the designs metadata and its network patterns, and (iii) identify interaction patterns based on real-world localities. Based on our findings we comment on the importance of the maker/ Open Design communities to tackle critical situations and highlight the current limitations for a wider dissemination of open source designs. Our findings may contribute to build better tools for designers and enthusiasts of the maker/open culture as well as to studies on collaborative development.

Keywords: Design Remixes, Maker Movement, Open Design, Thingiverse

1. INTRODUCTION

The shortage of personal protective equipment (PPE), resulting from the health emergency caused by the COVID-19 outbreak, presents a high risk for healthcare workers. The high demand caused prices to double or even treble and let healthcare workers ill-equipped (WHO 2020). At the same time, workers from essential activities, such as groceries stores and pharmacies, also need PPE to prevent themselves from contamination. As a response to this situation, users started developing and releasing PPE designs with the aim to promote self-manufacturing of such equipment. These initiatives are linked to two recent trends in the design field, the maker movement and Open Design (OD).

The maker movement consists on a recent trend, driven by advances on personal/distributed fabrication technologies, and on information and communication technologies (ICTs). It encompasses do-it-yourselfers and high-tech enthusiasts (Gershenfeld 2012, 48) who usually share design models and experiences on online communities and/or forums. As for OD, it refers to a collaborative development process which outcomes are publicly shared for anyone to produce/use, study, modify and distribute them (Aitamurto, Holland, and Hussain 2015; Boisseau, Omhover, and Bouchard 2018). Openness in OD is based on how collaborative/accessible is the development process, how robust and available are the outcomes (source documentation) and how replicable it is (Balka, Raasch, and Herstatt 2014; Bonvoisin and Mies 2018). In general, OD projects are developed/shared in two main types of online platforms. The first one is linked to intentional collaboration – which hosts projects maintained by active users responsible for revision, modification and contributions to the design development. A well-known example of this type of repository is *Github. Github* enables not only users to perform commits (revision/contribution) to project files but also provides a version control system. The second type refers to online repositories of designs which are not necessarily developed in collaboration processes. Examples of this case are the *Thingiverse, Tinkercad* and *Pinshape.* In this study, the term "*maker/OD communities"* is adopted to refer to the movements and communities involved in this process.

Recently, studies in Open Source Hardware and OD explored the structure of online communities by using both quantitative and qualitative approaches, such as interviews (Malinen et al. 2010; Ferdinand 2017) participant observations (Macul and Rozenfeld 2015) and data mining of online platforms, such as *Github* (Menichinelli 2017; Bonvoisin et al. 2018; Freire and Monteiro, 2020) and *Thingiverse* (Flath et al. 2017; Moilanen et al. 2015). The results help researchers to understand interactions between users, the influence and importance of actors, the activity volume (Menichinelli 2017), the quality of shared information and documentation and license choices (Moilanen et al. 2015).

This article contributes to the discussion by analyzing the COVID-19 content produced by users of a sharing platform and the possible impacts it has on enhancing collaboration, continuous development and design dissemination. We opted for the *Thingiverse* platform as our object of analysis. As mentioned, *Thingiverse* is a user-generated content repository for sharing designs. It is not oriented for active collaboration but it enables users to comment (making suggestions and reporting issues) and make derivative works when allowed by original creator. The adoption of *Thingiverse* as a repository for healthcare designs has been previously studied by Buehler et al., 2015, identifying the existence of 363 designs (out of 100.000). For the purposes of this article, we outline three questions to guide our study.

RQ1: How does a sharing platform hosted contributions and favoured creative interactions during the earlier COVID-19 crisis?

RQ2: Do online platforms contribute to design dissemination in different locations?

RQ3: Do creators take advantage of previous design releases to make improvements, changes and adaptations?

This article is structured as it follows: In the following section we present the tools we adopted to extract the design projects' data, analyze the design's network and map the geographical connections of users. The analysis and findings are introduced next. Thereafter, we discuss the results and its implications on practice and research. The limitations of this study are also presented in the discussion and conclusion section.

2. METHODS

Thingiverse was adopted in our study as our object of study. It is an online repository for sharing user-generated content. Users of the platform are encouraged to assign an opensource license in order to allow others to copy, modify or reproduce any design (depending on the license type assigned). Once a design is shared on the platform, users are able to report makes, i.e. when they produce a specific design, develop derivatives (remixes) based on other designs, save designs (collect) or simply download the design files.

2.1. Data extraction

For the purposes of this study we developed six different scripts based on scrapy, a python module for extracting information from the site by parsing its web pages. Scripts were released under an OS license on an online repository (Freire 2020a). The first script was used to search for designs, hosted by *Thingiverse*, related to COVID-19 by using the keywords 'coronavirus' and 'COVID-19'. The search returned 4036 occurrences. Duplicated projects (n= 656) were removed, resulting in 3379 design projects related to COVID-19. The individual ID of each project was applied to other scripts (Figure 1) to collect the (i) Project Data, (ii) Ancestors Data, (iii) Makes Data, (iv) Derivatives/Remixes Data and (v) Creator Data.

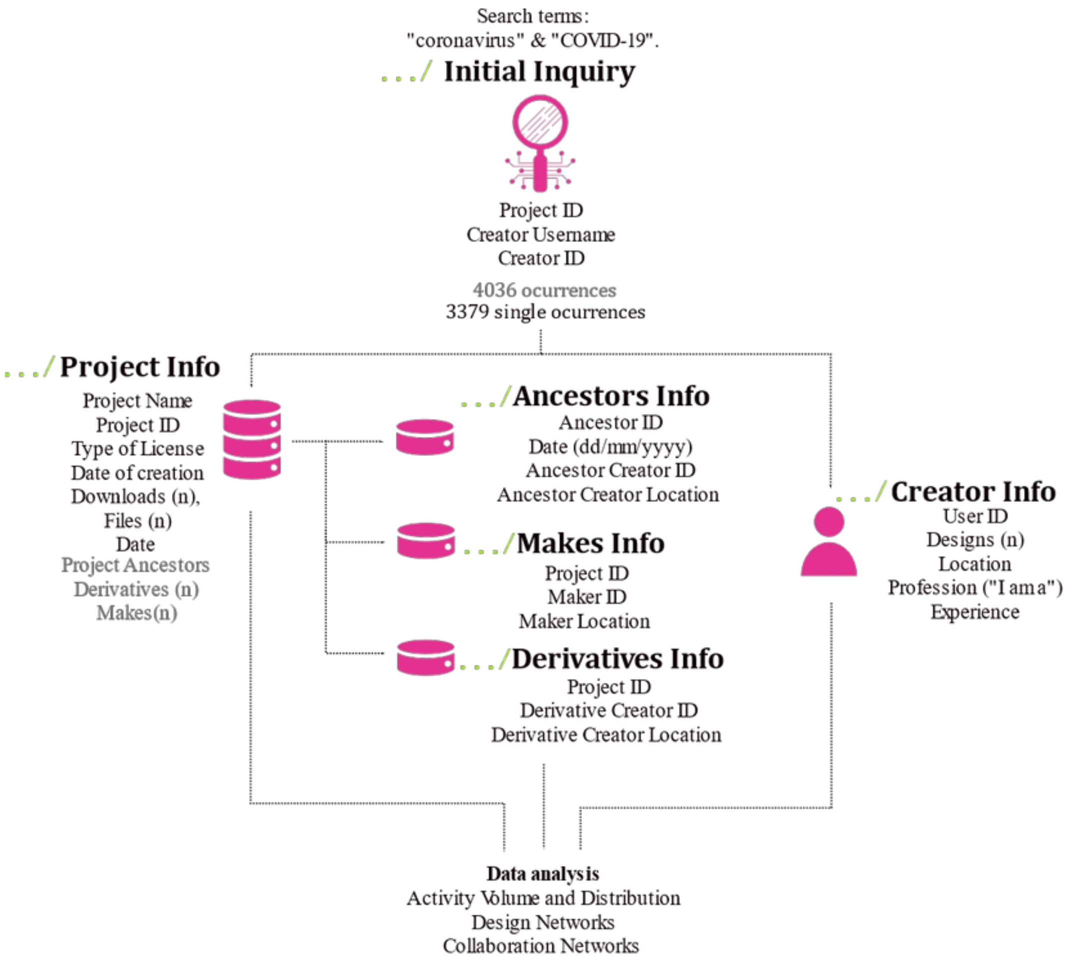

Figure 1 – Data mining process and information collected on *Thingiverse* from January, 1st to July, 1st

The data was used to analyze the activity volume for the periods ranging from January, 2020 to July, 2020 considering the original designs release, derivatives and makes. For each design, we identified the license types, the file types, the existence of derivatives, makes, number of downloads and related users. Finally, for each user we identified their location (country), profession and previous contributions to the sharing platform. It is important to note that while the data mining process enabled us to automatically organize the data, manual steps were conducted to check data consistency and refine the data. For example,

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users' location data doesn't follow a pattern, i.e. it could provide either their full location (e.g. city, state and country) or a single information. In this case, manual work was performed to include only the country of residence.

The activity volume was calculated considering the designs (n=3.379) shared and the number of downloads they have (n=167.779) for the period ranging from January, 2020 - July, 2020. A running total calculation was performed to identify the activity volume distribution of the designs. We also measured for each design (i) the number of reported makes – when a user reproduces and reports it in the community, (ii) the number of derivatives *(remixes)* – when the design is combined or modified into a new version – (iii) the number of downloads, (iv) the number of likes and (v) comments. Finally, the designs were classified in terms of license types. For replicability purposes, the complete raw data is available at (Freire 2020b) including the scripts adopted in this study.

2.2. Network analysis

We adopted the Open Graph Viz Platform (Gephi[2]) for network visualization and network analysis (NA). First, we traced back the project ancestors, i.e. projects that were improved, combined or partially used to the development of the projects of our interest ("COVID-19" and "Coronavirus"). Up to four generations of antecessors were identified, and duplicate results were removed (1°=458, 2°=114, 3°= 28 and 4°= 22). These projects were added to the initial inquiry, resulting in 4001 projects. Following that, we structured the data based on the platform requirements, identifying antecessors projects as *source* and derivatives as *target,* their Ids and dates of creation. Force-Atlas2 layout algorithm was used to represent the network of the designs. The algorithm is force-directed, i.e. it uses attraction and repulsion forces acting between the bodies of a system, enabling some (but limited) inferences about the visual results. Projects unrelated to a *source* or a *target* were excluded from our analysis at this moment. We also calculated two topological indicators. First, the Degree Centrality (DC) was adopted to measure the influence of a node in a network based on the number of edges linked to it. Second, we adopted the *Modularity* measure (Blondel et al. 2008) to extract the different clusters of the given weighted network. It is based on the repetition of two iterative phases. The indicator assigns a different community to each node and evaluates the gain of modularity by changing the community each node belongs to. The analysis stops once the maximum modularity is achieved for each one of the nodes.

2.3. Geographical mapping

Mapping generation was performed in R. Based on the users' location data, we developed an origin-destination map to assess the relations between creators-remixers and creators-makers. As mentioned, locations were collected from the users' profile and adjusted to only include the user's country. Edges were color-weighted based on the number of connections and nodes (countries) weighted by the number of "Coronavirus/COVID-19" designs released.

3. RESULTS

3.1. Activity volume and characteristics

For the period considered for this study (Jan-Jul, 2020) we identified 3.379 designs shared in the *Thingiverse* platform. These designs were downloaded 167.779 times and have 3.299

remixes and 1929 makes reported. It is important to highlight that the number of remixes is influenced by *Customizer* designs, i.e. designs that can be easily customized directly on the website. For example, two designs - *"Parametric Surgical Mask Retainer"* (ID: 4192643) and *"Surgical Mask Strap Generator"* (ID: 4272985) – are responsible for 1.068 remixes (32,40% 3.299).

It is important to highlight that some designs are not exclusively related to PPE. It is possible to find, amongst them, knickknacks and *"fun"* objects. However, we did not exclude these of our analysis. The designs related to COVID-19 started being shared in January, 28th, but the first design dedicated to PPE was shared in February, 3rd named *"Coronavirus / Flu Reusable Emergency Respiratory Mask"* (ID: 4141338). A surge in designs, however, can be observed by the third week of March, varying from 14 uploads in March, 14th to 54 uploads in March, 21st (Figure 2). The designs released during this week are those who had more downloads for the whole period, over 45.000 downloads. Interestingly, both trends match the behavior identified in *GoogleTrends* for the term *"coronavirus"* (Figure 2.c). A peak is observed (n=104 designs) in April 9th and, from then, design uploads dropped continuously, possibly indicating a decrease in interest or a saturation of design options.

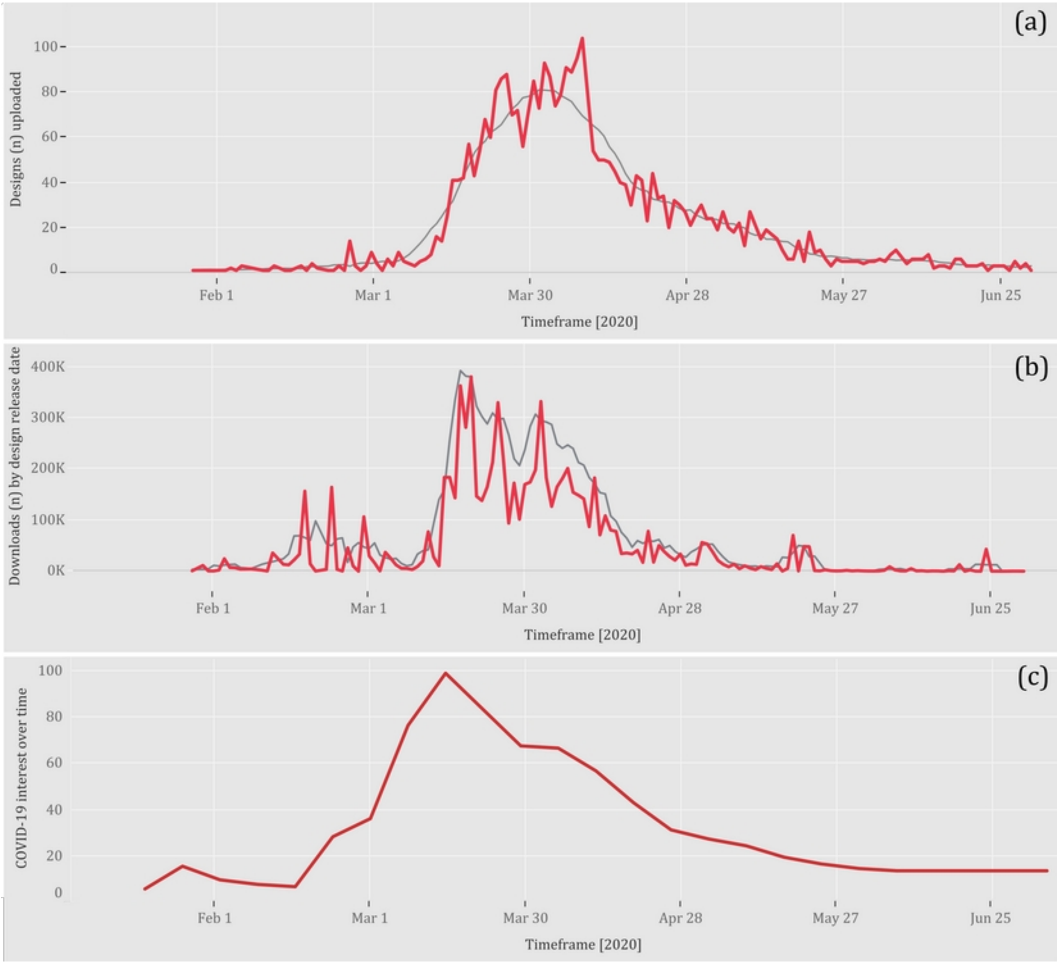

Figure 2 Activity volume (a), downloads by design uploaded (b) and *"Coronavirus"* user's interest over time based on *Google Trends* (c)

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Despite the high number of designs, only a few are significant in terms of downloads, makes and derivatives. For instance, out of the 1.628.432 downloads, 100 designs are responsible for 782.100 downloads (48,02%) and 50 account for 613.836 downloads (37,7%). Regarding the 1929 makes reported, 1000 (51,80%) are linked to 52 designs. Finally, out of the 3287 remixes, 10 designs are responsible for 2500 (76,05%) remixes. We highlight however that a high number of remixes are customizer remixes, a simple form of customizing that can be directly done on the website (Flath et al. 2017), e.g. changing the text included in a design. In Table 1, the descriptive statistics show the large difference of designs' importance. Considering the number of downloads, for example, it ranges from 0 to 12.160 with a SD of 2.036,67.

Table 1. Metrics for designs uploaded to *Thingiverse* (n=3376)

Metrics	Makes	Remixes	Collects	Likes	Comments	Downloads
Min	0	0	0	0	0	0
Max	190	891	12.160	9.587	742	47.742
Mean	0,57	0,974	49,71	38,37	2,87	483,35
Median	0	0	0	0	0	0
SD	4,36	20,67	288,60	226,51	16,55	2.036,67
SDERR	0,07	0,35	4,97	3,90	0,28	35,08

The data associated to the users indicates that 2647 users account for 35188 designs shared on the platform, including the 3379 designs related to COVID-19. The numbers of COVID-19 designs indicate that some users uploaded either more than one design object or more than one version of the same object, a remix. We also identified that 605 users (22,90%) had a single design shared on the platform, the one related to COVID-19, and other 340 users had two designs. A complete profile of users is presented in Table 2. The mean and median values possibly indicate certain degree of activity by the users prior to the COVID-19, although it also shows that few users concentrate the largest number of designs. For example, 50 users have 10196 designs shared (29,00% out of 35188).

Table 2. Metrics for users with COVID-19 designs uploaded to Thingiverse

Metrics	Users
N of designs	35188
N of designs related to COVID-19	3379
MEAN	13,30
MEDIAN	4
SD	38,95
SDERR	0,75

3.2. Network structure

The network structure of the designs highlights the relationships of original designs and derivatives (designs based on other designs). It includes only those designs that have a *"parent-child"* relationship, totalizing 1165 designs (nodes) and 1017 connections (edges) (Figure 3). The results indicate the existence of a large number of simple linear designs' evolution, when limited to two or three nodes (1→2→3 or 1→2). More diverse and complex relationships between remixes and original designs can be observed in larger clusters, defined based on the network's *Modularity.* For each cluster, we highlighted the design examples that correspond to it. The types of connections between nodes show that in a short period of time (February – July, 2020), users were able to develop a more complex structure of derivatives. Cluster "5", for example, is defined by 13 designs identified with their corresponding ids in Figure 4. If we consider the designs' connections independently, linear evolution can be observed in different situations, e.g.

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(i)4235098→4238300→4284721 and (ii) 4235098→4261923. However, we can also note that the designs (iii) fork into 2 or more alternatives. Id 4264881, on the other hand, refers to a design resulting from a merging process (iv) of 4 other designs - 4243531, 4228123 and 4273350, which is also a merging result of other designs). Forks and merges represent the two classes of remixes identified in Flath (2017): *divergent* and *convergent*. *Divergent* remixes consist on a particular case when a design is the source for other designs and *convergent* refers to a design that is based on different sources. In Figure 5, for instance, the Id **4264881** is a convergent remix once it is based on Ids 4243531, 4273350 and 4228123. As for Id 4243531 it generates the diverging remixes with Ids 4305770, 4305798, **4264881** and 4273350. As we can note, a remix can be a result of both converging and diverging processes, e.g. Id **4264881.**

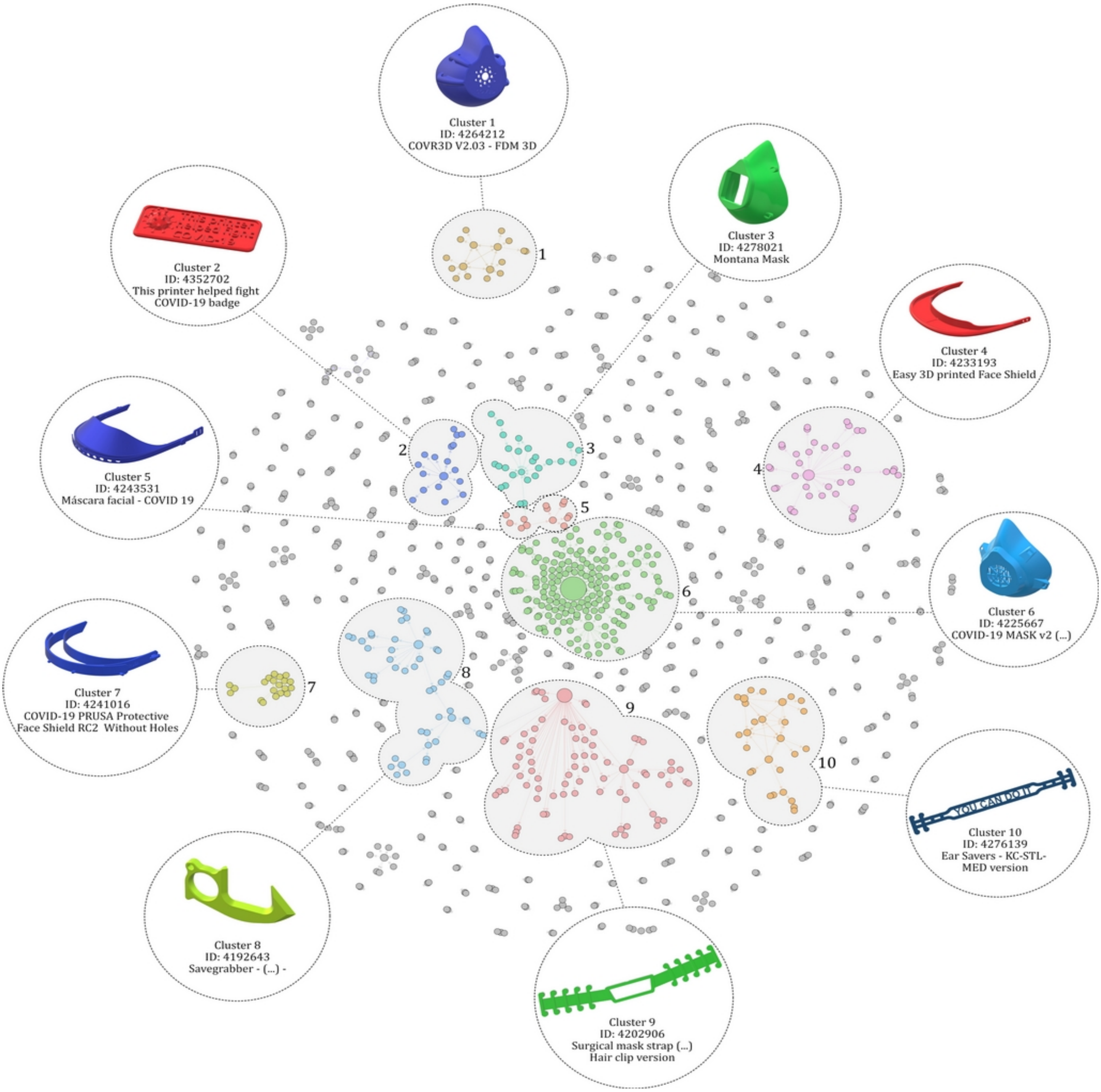

Figure 3 - Network structure of original designs and derivatives (remixes) developed and reported on *Thingiverse*

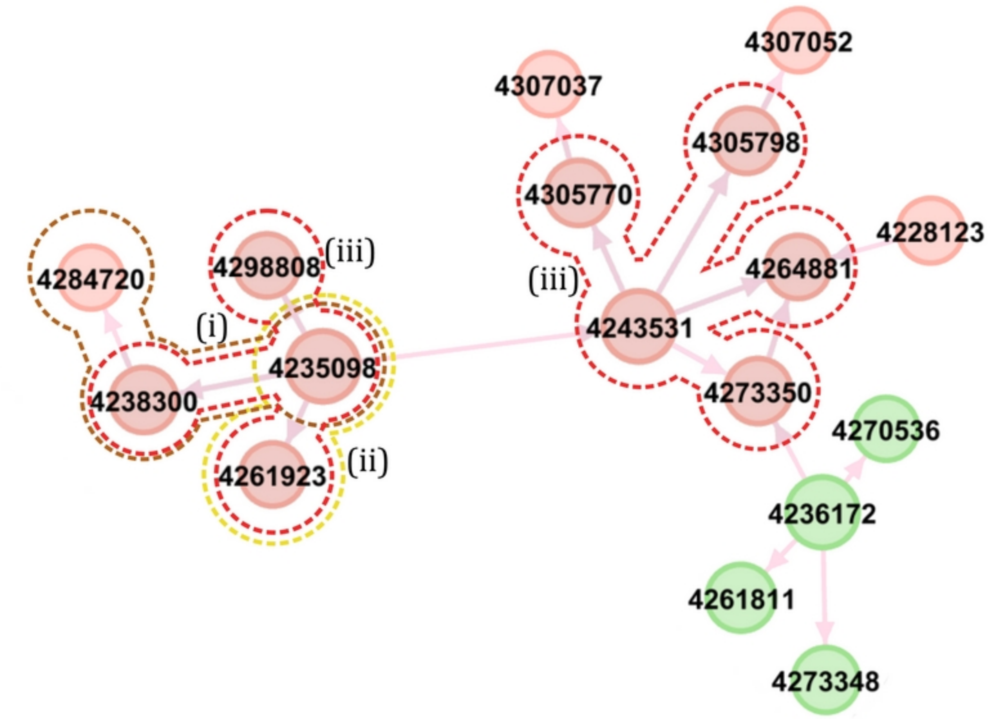

Figure 4 - Parent-child relationships between designs of Cluster 5 and part of Cluster 6

The clusters indicate the existence of 5 types of designs. The first one refers to respirator masks (clusters 1, 3 and 6). The designs include a large set of components including caps for filters and connectors. Non-PPE objects are limited to Cluster 2, which includes decorative designs, e.g. tridimensional representations of the coronavirus. The third type consists on face shields (clusters 4, 5 and 7) having a wide range of alternative designs. The fourth type (cluster 8) consists on- door openers/button pushers. Finally, the last type consists on surgical mask straps (clusters 9 and 10), of which some are highly customizable. It is important to mention that by choosing the 10 largest cluster, some types of designs may have been ignored, e.g. the “Emergency Ventilator (EV-02)” (Id: 4302479). However, a random check on designs indicates that the majority of design types is addressed by the clusters.

3.3. Geographical distribution of design creators, makers and remixers

Finally, the last aspect associated to the emergence of COVID-19 related designs refers to the real implications of the Maker Movement and OD on connecting users from different localities. For this purpose, we connected the original designs to its corresponding remixes and makes, based on users’ locations (when available). Figure 6 illustrates these connections in two different maps: (a) Original→Remix (O→R) and (b) Original→Make (O→M).

We managed to identify 81 countries from which user’s shared their designs. The results indicate, however, a high concentration of users in North America (Canada and USA) and in Europe (e.g. Germany, Spain and France). Out of the 1882 designs we managed to identify the user’s location, these six countries account for 1224 of them (65%). This concentration is also reflected on the O→R and O→M connections identified (Table 3). It is worth mentioning the existence of a modest but diverse interaction system between users located in different countries, as observed by the number of distinct connections in O→ R (n= 192) and O→M

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(n=257). The number of reported makes (with location details) is slightly higher than the number of derivatives but both have similar behaviors when comparing the statistics of both (MEAN, SD and SDERR). A valuable metric however is the number of connections generated by O→M, indicating a high potential for design dissemination.

Table 3: Metrics of geographical connections between original designers, remixers and makers

Metrics	Original→Derivatives	Original→Makes	Top 15 countries by number of designs (weighted by population) [a]	Top 15 countries by number of designs (absolute numbers)
N of connections	739	868	Hong Kong Spain Czech Republic Belgium France Austria Italy Lithuania Canada Luxembourg Australia Portugal Slovakia United States Slovenia	United States Spain France Italy Germany United Kingdom Canada Argentina Brazil Australia Czech Republic Hong Kong Belgium Russia Mexico
N of distinct connections	192	257		
MEAN	3,86	3,39		
MEDIAN	1	1		
SD	9,37	8,25		
SDERR	0,70	0,51		
Frequency of connections (highest 10)	USA → USA (n=80) Spain → USA (n=71) Canada → USA (n=58) Spain → Spain (n=43) Germany → Germany (n=36) Canada → Spain (n=25) Spain → Portugal (n=22) Spain → Germany (n=16) France → France (n=15)	USA → USA (n=97) Spain → USA (n=70) Spain → Germany (n=39) USA → Germany (n=26) Spain → Spain (n=21) Germany → Germany (n=19) Canada → USA (n=13) USA → UK (n=13) Austria → Germany (n=12)		

[a] Guernsey, Monaco and French Polynesia were excluded from the top 15 list given the small population size.

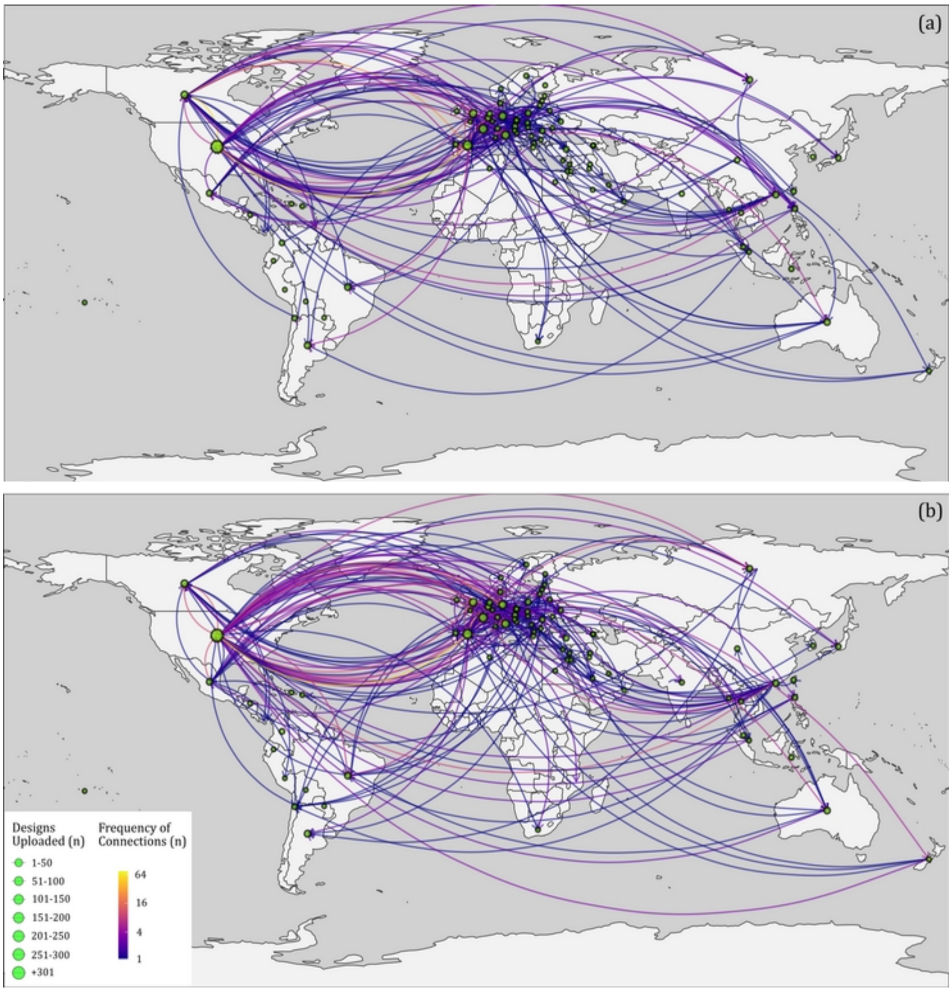

Figure 5 - Connections between users' locations considering (a) original design → make and (b) original design → remix

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4. DISCUSSION

Understanding the functioning of maker/OD communities is of much importance to assess its potentialities to address real-world issues, its responsiveness and current hurdles. Researches on the structure of maker/OD repositories and their impacts are at an initial stage with some distinguished works (Bonvoisin et al. 2018; Flath et al. 2017; Freire and Monteiro 2020; Menichinelli 2017; Oehlberg, Willett, and Mackay 2015). We adopted an explorative approach and data mining techniques to shed light on the characteristics and potential impacts of the designs developed and shared during the COVID-19 outbreak. For that purpose, we retrieved the metadata from designs available on *Thingiverse* and analysed it based on the activity volume, the network structure of the designs and the geographical distribution of users. The discussion we present next is therefore limited to the object of our analysis, the available data and based on the few existing studies on the structure of maker/OD communities.

We explored the possible real impacts of maker/OD platforms on promoting design dissemination of COVID-19 related designs (RQ1). OD and distributed manufacturing are often put forward as a means for design democratization and dissemination (Haldrup et al. 2018). One of the motives is the possibility to have an object designed anywhere in the world and shared through online platforms (Fox 2014; Kostakis et al. 2015). However, it is also argued that limited access to resources, the lack of computer skills and functional literacy in languages usually adopted in such platforms, e.g. English, might configure a bottleneck for such dissemination (Fox 2014; Freire, Monteiro, and Ferreira 2018). As our results show, major contributions and interactions are performed by users located in North America and parts of Europe. One could argue that the geographical distribution of design creators, makers and remixers, and the volume of executed/remixed designs in developed countries were influenced by the fact that these locations were hit earlier by the COVID-19 pandemic. It is a plausible argument if we consider, for instance, the volume of activity in countries such as Spain, France, Germany and the USA which faced a high volume of COVID-19 cases earlier than other locations in the global south. Still, it is not possible to confirm this as the single cause for higher activity volume. The modest participation of countries located in Latin America and Africa, confirmed by the weighted number of contributions may also indicate a possible gap to the maker/OD culture and technological accessibility confirming previous studies (Fox, 2014). Nonetheless it shows that design collaboration/dissemination is in fact promoted by sharing platforms, as shown in Figure 6. It increases the chances of designs, oriented to tackle real-world issues (e.g. COVID-19), to be adopted in different locations (RQ2). In time, we emphasize that our dataset represents just a small portion of the data available on the platform, limiting a complete overview of users' locations. It is also dependent on self-reports of makes and remixes, which has two implications: The number of makes are greater than observed and not all remixes are correctly reported.

As for the results related to the activity volume, they indicate that the maker/OD communities are potentially motivated by the will to make a contribution to the society. It is clear that users provided a fast response to the outbreak, considering the design's volume increase in the third week of March — right after a surge on the number of COVID-19 cases, especially in Europe. The number of 605 users with single designs shared on the platform is also important. It comprehends 22,90% of the total number of users with designs related to COVID-19 and indicates a possible potential of critical events to motivate users to join and participate in maker/OD communities more actively. However, some other observations are necessary. After the increase of designs, we can observe a continuous drop on the activity after its peak in late April. Here, we discuss three possibilities. Firstly, users' activity reflected the society's interest on the outbreak, following a similar pattern to the one given by Google Trends. Secondly, the designs reached a saturation stage where innovative remixes/adjustments are unlikely to happen. And thirdly, the platform community and structure limit the possibilities for different types of designs, especially those dependent on processes other than 3D-printing and laser cutting. It was expected that 3D-printing-oriented designs would count for the majority of the designs, since *Thingiverse* is owned by a 3D-printer company. However, as successful mechanical/electronic projects are also shared in the community, e.g. *"FoldaRap, the Folding Reprap"* (ID: 15877) and *"Omnidirectional Selfdriving Robot With Mecanum Wheels"* (ID: 3815005), an expected outcome that did not confirm was that the community had a potential to trigger such types of designs. But even when they exist, as we noted on the *"Emergency Ventilator (EV-02)"* (ID: 4302479), they did not promote continuous development nor reported makes.

Regarding the design aspects and network structure, which relate to RQ3, we explored the largest 10 clusters based on the *Modularity* calculation we performed. These clusters are linked to very clear categories of designs, indicating that *Modularity* is a viable measure to identify design patterns in maker/OD communities. The majority of the designs is strictly contained within its cluster, i.e. does not interact with other types of designs. This is not an unexpected result for two reasons. First, the object types are very different in terms of functionality, e.g. face shield and door opener. Second, this specific behavior was already identified in Flath et. al (2017) when investigating the remixing phenomenon in online communities. The authors identified that few designs establish connections outside its original categories. In our study, this was also confirmed. Almost none design was developed (remixed) based on designs released prior to the COVID-19 outbreak. On the other hand, the rapid proliferation of remixes during the 5 months we analysed do indicate that open repositories enable fast development of solutions because of the possibility to adapt and modify existing solutions. However, it also indicates some limitations to the degree of inventiveness, as adaptations rarely adopt solutions outside its own category (COVID-19). An example of design that incorporate references from previous designs is the *"DIY coronavirus (COVID-19) mask holder"* (ID:4234861) remixed after a bag clip (ID:330151). Finally, the forms of remixes described by other studies in remixes patterns of online platforms (Flath et al. 2017; Oehlberg, Willett, and Mackay 2015), e.g. *self-loop, convergent* and *divergent*, were also present. These patterns reflect an important aspect of creative problem-solving processes inducing, for instance, a greater number of ideas (Müller-Wienbergen et al. 2011). Our understanding is that, despite the short period of time, the system's network of COVID-19 related designs was able to reproduce the similar and more complex patterns observed in larger datasets.

The results may also indicate that, while there is an attempt in *Thingiverse* to promote design collaboration between its users, the degree and complexity of interactions is still poor when compared to platforms like *Github* and *Gitlab*, which have a more complete set of tools for collaboration. It should be put that this is not necessarily a downside, as the platform *(Thingiverse)* presents a friendlier interface to new users, including 3D visualization and easier access to images and files. The current characteristics of *Thingiverse* make it closer to a repository platform than a creator hub/collaborative platform. However, recent

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improvements, such as including an online parametric modelling tool, are important steps to turn it a more complete environment for OD practices, for instance.

Finally, despite the limitations of our study, we highlight the valuable contribution of maker/OD communities to tackle the COVID-19 outbreak. The decentralized collaboration process plus the distributed manufacturing technologies potentially helped citizens (including workers from the healthcare sector) to obtain locally produced PPEs when faced the shortage of industrialized products. In practical terms, we expect this exploratory study to contribute to the debate on design democratization by highlighting its current limitations. In practical terms, the discussions will hopefully contribute to the development of more inclusive platforms for inexperienced users and non-English speakers.

5. CONCLUSION

In this study, we explored the characteristics and potential impacts of the designs developed and shared during the COVID-19 outbreak. For the purposes of this study we adopted the *Thingiverse* platform as our object of analysis. Based on the data, we illustrate the potential of maker/OD communities to provide fast-response to critical situations, develop improved versions of designs and build a network of collaboration. It also confirms its potential to design dissemination although it is still concentrated in North America-Europe. The limitations of this study are mainly related to the limited information available. For instance, we were not able to identify in which country users downloaded the designs. Aware that this is an important aspect of privacy, we relied on the information made publicly available by the users themselves.

The current limitations to promote continuous collaboration, observed in *Thingiverse*, are an important aspect that needs to be further explored. A deeper analysis/comparison with existing platforms, other than *Thingiverse,* and their corresponding tools, could provide significant insights about their effectiveness in fostering collaborative practices. In addition to that, it is crucial to understand the existing differences between maker/OD communities between the global north and global south, in terms of activity volume, and why these differences exist. Although studies indicate that language and access to technology are current hurdles to the democratization of maker/OD communities, these statements need to be confirmed with more robust data. We consider that the adoption of different research methods, including action research and participatory action research, may provide additional insights to confirm or reject these statements. Finally, future works may address the development of potential new platforms/tools prototypes aimed at maker/OD communities.

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Design for Emergency: An Open Platform to Design and Implement User-Centered Solutions in the COVID-19 Pandemic.

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ABSTRACT

As a consequence of the lockdown enforced to fight the COVID-19 pandemic, people found themselves in a state of social isolation, uncertainty, and vulnerability. *Design for Emergency* is a data and design open platform launched to ideate and develop user-centered solutions addressing people's needs and emotions during and after the lockdown. The project is composed of four steps: data collection, data analysis & visualization, design, and implementation. The initiative was launched in Italy, but it soon became global, covering 11 countries in three continents. As a result, data about people's experiences during the pandemic have been collected and visualized at a global level. The ideas repository, still growing, includes 36 seed ideas of solutions helping individuals and communities to cope with the pandemic. Ideas are openly available for development, and some of them are currently being implemented. This initiative can be used as a reference and a pilot project to create a framework for designing under uncertain conditions and in situations of emergency, or crisis, where design can quickly discover and address emerging feelings and needs.

Keywords: COVID-19, Data Platform, Design for Emergency, Open Design Platform, Seed Ideas, User Experience.

INTRODUCTION

On March 11th 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a pandemic. Italy was at that time the first western country to experience a significant growth in cases, with a number of infections close to 20,000 and a second "red zone" activated in Bergamo.

In recognizing the status of pandemic, the Director-General Dr. Ghebreyesus stated that the WHO was "deeply concerned both by the alarming levels of spread and severity and by the alarming levels of inaction" (WHO, 2020). Information uncertainty, the novelty of the problem, and its complexity were likely contributing to such institutional inaction, and they were about to become something not only governments and institutions, but also people worldwide, would deal with for longer than expected. In the days that followed the WHO remark, inaction quickly turned into rigid measures to contain the pandemic. In addition to the uncertainty and complexity of the situation, entire countries found themselves to cope with social isolation imposed by lockdowns.

In that context, social isolation and the consequent departure from everyday routines and social habits could have serious effects on people's emotional and mental wellbeing, also in those who were not previously suffering from mental health issues (Usher et al., 2020). Moreover, with isolation and social distancing, almost every activity – from mobility and education to healthcare and grocery - needed to be reconfigured. In this climate, individuals often struggled to re-imagine such activities by themselves, and very few solutions were made available to them. While a flood of measures and interventions, including design ones, were being developed to limit the negative impacts of the pandemic on the healthcare system, very little attention was being paid to the widespread psychological and social vulnerability associated with this crisis.

These are the motivations that prompted us to start the *Design for Emergency (DfE)* project: a design-driven reaction to the wickedness of the issues we were witnessing and to the lack of available solutions to cope with the social consequences of an unexpected and abrupt condition of isolation.

The project, launched on March 12th, aimed at creating an open platform to share ideas and implement solutions addressing the needs, problems, and emotions of people forced to isolation and social distancing. The initiative has been progressively built on two main pillars: learn and act (Figure 1). The learning phase aimed at understanding the unprecedented condition of isolation experienced by people, and it was formulated in two stages: a survey collecting data, and the analysis and visualization of all the data collected. The insights stemming from the analysis became the input to orient the action phase: a series of design challenges in the form of both open calls and 'closed' workshops with partner institutions. Making an impact was the ultimate goal of the initiative, so a fourth step - implementation - was added as part of the action phase, with the aim of developing the ideas collected through the design challenges into real solutions addressing the emerging needs. This four-stage framework is not necessarily linear, but it can be iterative, in that the generated solutions can also require the collection of more detailed data on specific issues.

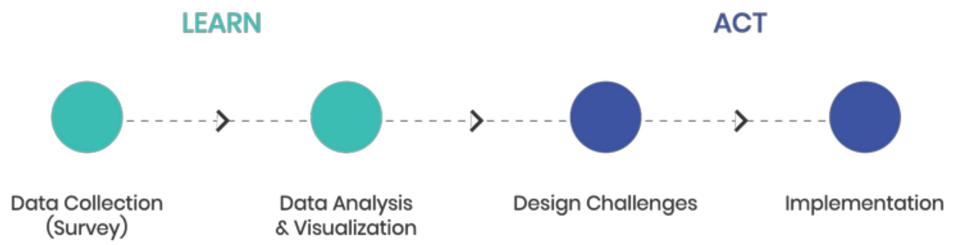

Figure 1. The four phases of the Design for Emergency project, structured around the two main pillars of the initiative: learn and act.

Italy was the initial target area of the project, mainly because it was the first western country hit by the pandemic, and for the severe conditions experienced by residents there. As soon as the initial results of the survey were publicly available and circulated on the media, other research groups and institutions contacted us asking to replicate the survey in their countries. The initiative therefore started to expand globally, following the spread of the pandemic.

This paper presents the Design for Emergency project and provides an account of the activities and results of each phase of the process.

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In section two, the learning phase is described by introducing the survey, explaining the tools and the methods applied in the analysis of structured and unstructured data, and summarizing the main results and the insights that have been transferred to the design phase.

Section three presents the formats adopted for the design activities and their outcomes. A repository of seed ideas was implemented after the conclusion of a series of design challenges, both open and custom.

Section four illustrates how some seed ideas found their way through the development stage and are at the time of writing candidates to become concrete solutions for the issues emerged during the learning phase.

In section five, the open and global nature of the project, the challenges encountered, and future developments are discussed. The decision to not mention COVID-19 in the project name was an anticipation of a broader understanding of the idea of "emergency", which would explicitly emerge in subsequent reflections about the evolution of this initiative.

Although the project has a global nature, the account included in this paper is particularly focused on the activities that stemmed from the survey launched in Italy. Indeed, results from other countries are currently being analyzed and published, and they will lead to similar activities in the near future. For instance, a national design challenge has just been completed in Brazil, but it will not be discussed in this paper.

1. UNDERSTANDING PEOPLE'S EXPERIENCES

1.1. Survey

The DfE project started with an investigation of the experiences of people during the lockdown in Italy. Italy was the first European country to be hit by COVID-19 and to implement drastic social isolation measures for its containment. On March 15th, just days after the lockdown had been extended to the whole country, the Design for Emergency survey was launched.

The survey, in Italian, was aimed at collecting data on people's experiences, feelings, needs, and issues. It covered four thematic areas, and it included both multiple-choice and open-ended questions.

The questionnaire started with an introduction on the project and the informed consent. The first part of the survey asked for general demographic information. The core section investigated what people were experiencing during the lockdown, in terms of recurring emotions, negative sensations, and concrete issues they were facing, mainly through multiple-choice questions. The last section, based on open-ended questions, explored more in depth people's hopes, fears, reasons for positive and negative feelings, desires, and longings. Google Forms was used to generate the online survey and to collect responses.

The website designforemergency.org was designed to describe the project and to disseminate the survey, which was also spread through social media, personal contacts, and online social platforms related to COVID-19. In a span of four days, more than 1600 responses were collected. After two weeks, the number of responses was 1,748.

1.2. Data Analysis

The analysis of data collected through the survey followed two different methods. Quantitative results (from multiple-choice questions) required an approach based on counting and clustering, while answers to open-ended questions represented a challenge, given the high number of responses received. Qualitative analysis was needed to identify the most relevant keywords, concepts, or topics, mentioned by respondents. Because traditional qualitative research methods for the analysis of text-based responses entail considerable manual effort (Crowston, 2010), alternative approaches were investigated. Indeed, the situation required an immediate response, and making data available to designers as soon as possible was crucial For these reasons, we decided to adopt Natural Language Processing (NLP) tools, which are often used in the field of digital humanities to extrapolate keywords, concepts, and themes from large documents or collections of works (Brooke et al, 2015).

With the help of experts in the field, different NLP tool were tested, spanning from the analysis of words frequency to topic modeling based on machine learning. As a result, an existing NLP tool, the Keyphrase Digger (KD) was selected for our analysis. The KD tool is "a rule-based system that combines statistical and linguistic knowledge given by PoS (Part of Speech) patterns" (Moretti et al., 2015). The tool is available in Italian, English and French, and it is open-source, so it could be developed to include additional languages. This feature turned out to be extremely useful as the project expanded to different regions.

With the help of the KD tool creators, the most relevant 100 key-concepts (n-grams of different length) associated to each question were selected. Relevance was calculated based on frequency, as well as other linguistic and statistical parameters. The 100 resulting key-concepts were manually clustered into broader topics in order to effectively visualize and communicate the results. This step allowed us to generate an overview of the main themes emerged around each question.

1.3. Data Visualizations and Results

The results generated from the data analysis were communicated to our audience through a number of visualizations, both static and interactive (Fig. 2-4). Visualization is a crucial component of the project as the intention is to fully support the continuum between data and knowledge (Masud et al., 2010) as a pre-condition for a well-informed design process. Given the scope of the initiative, designers were the primary target of our visualizations, but results were meant to be accessible to a broader public as well. Results were clustered into five main sections, in order to guide designers in the interpretation of users' experiences around five major topics: problems & needs, emotions, desires, motivations, and time. All visualizations were published on the project website designforemergency.org.

Visualizations were first published in Italian, and soon translated into English as well, to make them accessible to non-Italian speakers.

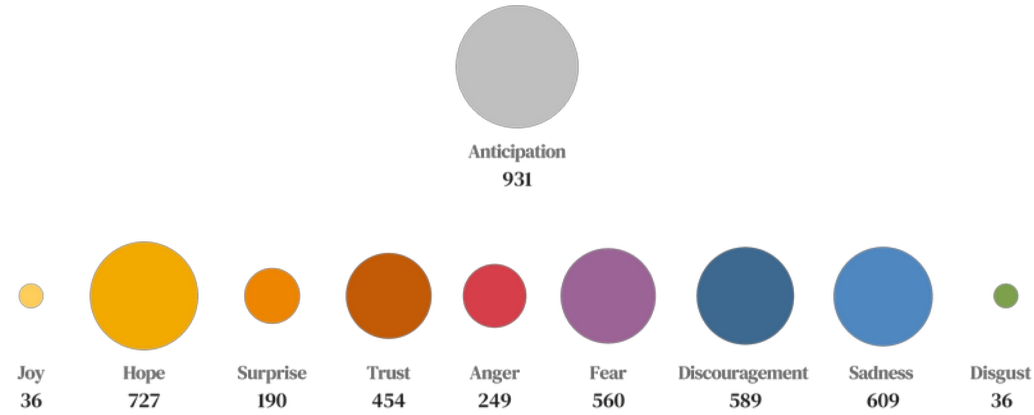

Fig. 2. Participants' responses to the question: "What was the most recurring emotion in the past 3 days?" (English translation).

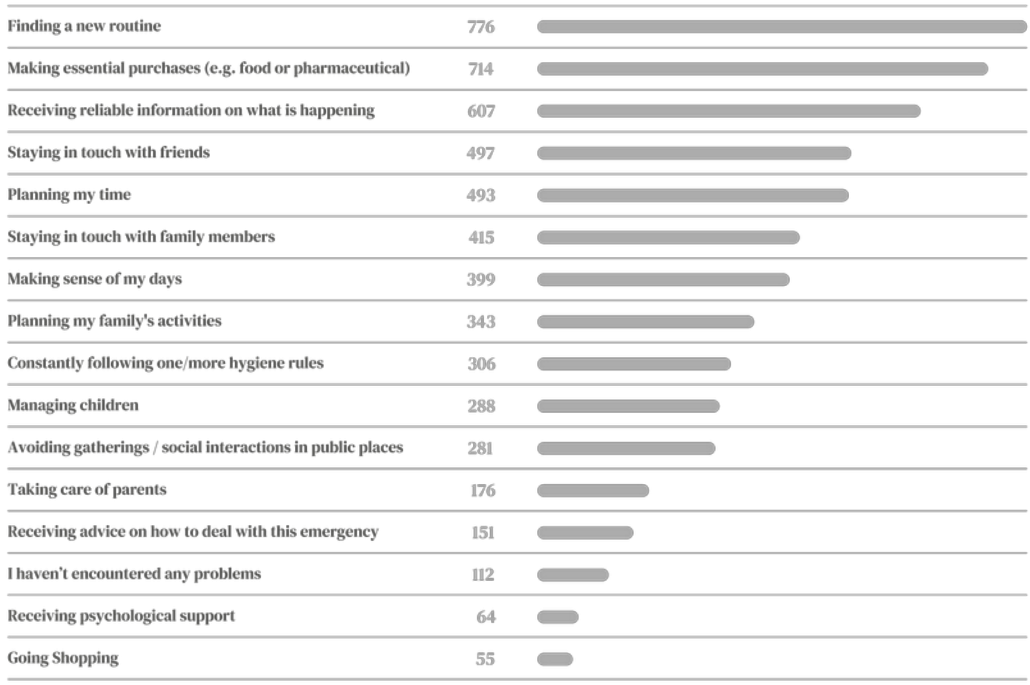

Fig. 3. Participants' responses to the question: "What concrete problems have you encountered since freedom of movement was reduced?" (English translation).

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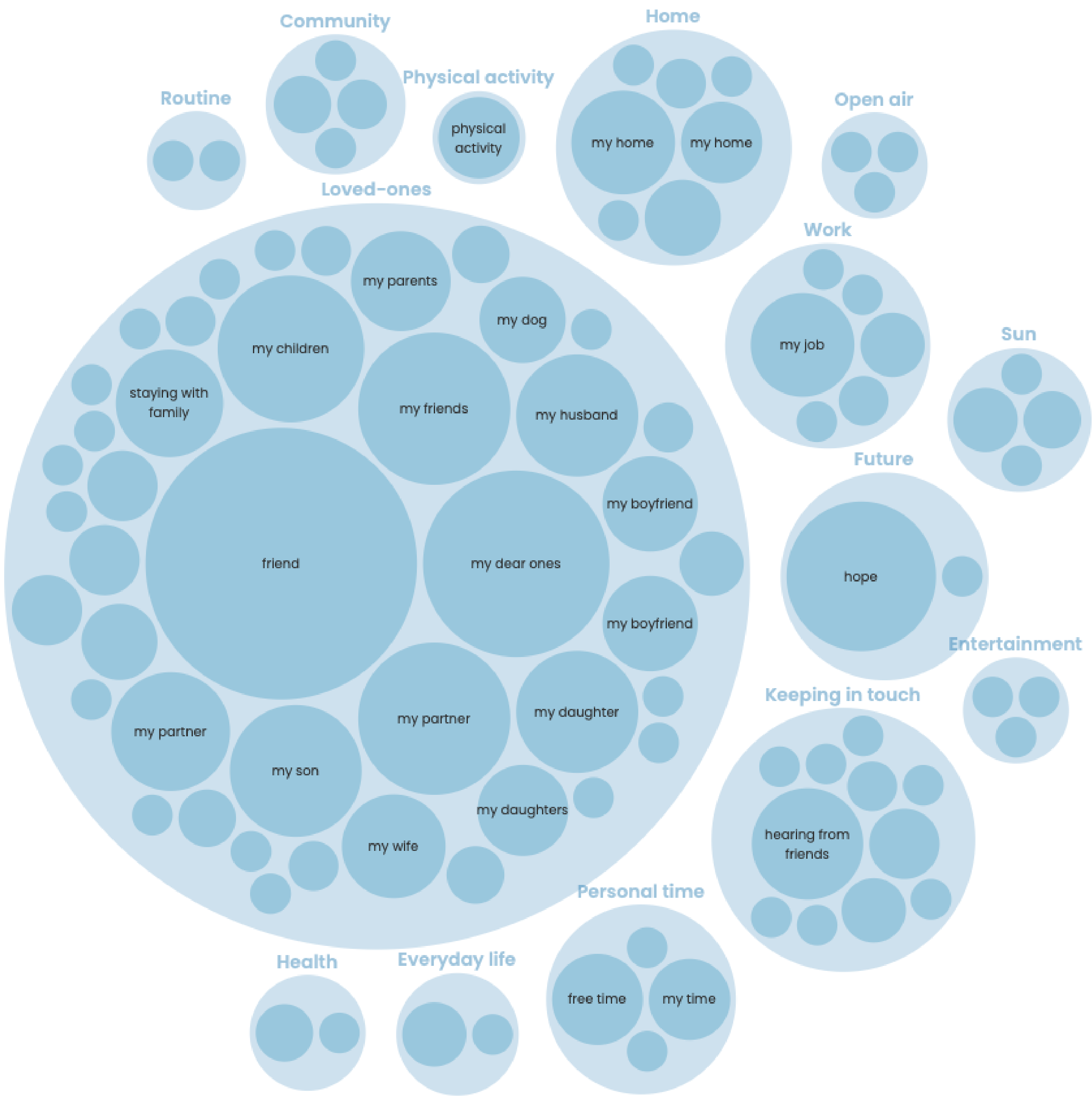

Fig. 4. Topics and key-concepts emerged in response to the question: "What makes you feel good in this moment?" (English translation).

1.4. Global Expansion

After the Italian release of the survey, more than 20 international organizations (mainly universities and research centers) contacted us in order to bring the survey, and the initiative, to their own countries. By the end of June 2020, Design for Emergency was extended to 11 countries, in three continents. Both the survey and the website pages were translated into local languages, with the help of our local partners, who were also responsible for disseminating the survey locally. Little changes were implemented to the survey to adapt it to the local context (e.g. specific containment measures, or demographic elements local researchers were interested in gathering, e.g. the number of people in the respondent's household, in Brazil). The list of countries as of July 15th includes (in chronological order): Italy, Spain, Brazil, France, South Korea, UK, USA, Mexico, Peru, Ecuador, and Russia. In such a challenging and dynamic situation, there was not a specific

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plan guiding the geography of the expansion. Given the nature of the initiative - both global and local at the same time, partners' commitment was a fundamental key for the success of the project at the local level. Therefore, partnerships were created based on the proactivity of the actors involved.

2. DESIGNING FOR PEOPLE IN LOCKDOWN

As soon as insights from the Italian survey analysis were extrapolated, design competences were activated following two directions:

- open calls for ideas (i.e. design challenges);
- custom design activities performed in collaboration with organizations that were in the process of activating workshops and sprints with similar intentions.

The open calls were meant to maximize time and to prompt a quick design reaction, whereas the joint workshops secured an outcome and guaranteed more control over the quality of the proposed ideas.

Both the open calls and the custom workshops were structured around a design framework that ensured consistency among the results. The framework consisted in providing designers with the survey results, defining focus questions and application domains for the ideas, and providing a template to describe them.

Survey results and visualizations were published on the website and were made accessible to designers. Designers were encouraged to address one or more of the following questions, using the data emerged through the survey:

- *Problems and needs*: How can relevant problems highlighted by the survey be solved? (E.g. helping people to create a new routine, to make sense of their days, etc.).
- *Desires*: How can people be supported in fulfilling their desire to go back to the habits, activities, and relationships that were part of their lives before the pandemic?
- *Emotional wellbeing*: How can people still feel good, and be hopeful? How to reduce fear and suffering?

Starting from these questions, which served as inspirations, designers could submit ideas related (but not limited) to the following application domains: *Connecting*, *Supporting*, *Entertaining*, *Informing*, *Organizing*, *Preventing*. To facilitate the work of participants, and to limit the required effort, designers were encouraged to submit and share *seed ideas*, i.e. high-level concepts of solutions. They were also asked to follow a standard format for submission – a two-page template with a pre-defined structure to describe ideas. Designers were free to share solutions belonging to any field and domain, spanning from services to products, apps, social initiatives, games, etc.

The design activities are described in detail in the following sections.

2.1. Open Design Challenges

Once the results of the Italian survey were available, a call was opened to any designer or individual with ideas that could help addressing the uncovered needs. The call was described on the project website, and detailed instructions for submission were included. Three deadlines were defined between April 7th and 21st for the ideas submission. Working with tight deadlines helped to accelerate the ideation process: a quick response was essential, especially in the first phases of the emergency. After the first three deadlines, the call remained open, with no further specific deadlines. Every week, newly-submitted ideas were published in the repository.

The communication and promotion of the open design challenges were performed through the social media accounts and mailing lists of the Center for Design and the College of Art, Media and Design (Northeastern University), as well as the personal accounts of the initiative authors, collaborators and partners.

2.2. Custom Design Workshops

As a result of the communication campaign, a number of organizations embraced the initiative and partnered with us to contribute to the design phase. Four collaborations are described here, which showcase a range of diverse organizations, from academic institutions to companies. For every partnership, a custom format was developed, in order to accommodate the specific needs and goals of the activity. However, the framework developed and used for the open challenges (focus questions, application domains, ideas template) was applied without modifications, to ensure a smooth integration of the ideas into the repository that collects results from all the design initiatives.

1. Domus Academy – a design school based in Milan, Italy - contacted us while they were re-orienting students' design activities to face the local COVID-19 crisis. A design sprint was launched involving 40 students of three different Master programs: Visual Brand Design, Interaction & Service Design, Business & Luxury Brand Management.
2. The founders of Berkeley Innovation Group (BIG) and lecturers at Haas School of Business (University of California, Berkeley) invited DfE to join a global workshop they had started a few weeks before. Their workshop was aimed at designing solutions for elderly, front-line workers, and people quarantined at home, during the pandemic. The two initiatives partnered and continued working together in the subsequent steps of ideas generation and development.
3. In addition to launching a dedicated communication campaign, the launch of initiatives with goals and aims similar to DfE was also monitored, to proactively connect with potential partners. The COVIDDesignJam, organized by Digital Entity and NOIS3 - two design agencies based in Milan, Italy, aimed at designing solutions to adapt to the living conditions forced by COVID19 in a three-day design jam session. The initiative was meant to address five areas heavily impacted by the pandemic: daily life and social relations, work and entrepreneurship, travels and mobility, entertainment and culture, education. The two design agencies had already developed a knowledge base about people's condition and feelings through qualitative interviews; the available information was complemented with the 1,800+ answers collected in Italy through the DfE initiative. Participants used such data as a basis to develop their concepts.

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4. The spread of COVID19 in Brazil was just at the beginning, but it was growing quickly, when the Universidade de São Paulo (USP) reached out to join the project in late March. The growing intensity of the emergency translated into a strong commitment by the faculty members at USP to promote the local iteration of the DfE initiative. After launching the survey, collecting over 2,000 responses and extrapolating the insights, USP partnered with Museu Da Casa Brasileira – one of the most important institutions for Design and Architecture in Brazil – to launch a design challenge based on the DfE framework.

As visualized in Table 1, some of the partners involved in the design phase also contributed to other steps of the initiative, while others only focus on the ideas generation.

Table 1: Partners involved in the design phase, and their role in other stages of the initiative.

	Survey	Analysis	Design	Implementation
Domus Academy			x	
COVIDDesignJam			x	
BIG			x	x
USP	x	x	x	

2.3. Seed ideas

Through the open design challenges and the custom workshops with partners, the Design for Emergency initiative collected 36 seed ideas for solutions that could address the issues and needs emerged through the survey (ideas from the Design Challenge in Brazil are not included in this count, as the challenge is still ongoing at the time of writing). All ideas were published online on the project website.

Four clusters were defined, to both categorize the incoming ideas and orient the generation of new ones: *Physical safety* (9 ideas collected), *Wellbeing & Mental Health* (12 ideas), *Shared experiences* (10 ideas), and *Community Support* (5 ideas).

The template provided to describe the concept is deliberately simple, and privileges synthesis over details in order to favor a rapid submission of ideas. Authors have the possibility to add links to additional material, and to leave contact information to provide any further details to interested stakeholders. In addition to a brief description of the idea, the template includes four questions, formulated as a bridge to the implementation stage:

- Whom is the idea for?
- Why is it relevant?
- What is needed to implement it?
- Who can contribute?

Most of the collected ideas (about 75%) propose *digital services* and the creation of related web platforms and/or mobile applications. They typically aim at ‘digitalizing’ or facilitating the access to existing services that are no more available as in-person experiences: music lessons, job interviews, shopping at local/small businesses, socialization. Some of them propose completely new services based on the situation-specific needs uncovered by the survey, e.g. avoiding procrastination while working from home, or finding new routines. The

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remaining ideas cover different categories, including *physical devices* (2), *visual icons* (1), novel *interfaces* improving existing services or devices (4), new *social codes* (1), and *educational formats* (1). All the proposals are in the form of high-level concepts, thus requiring further designing and detailing, except for a set of graphical icons specifically designed to address the communication needs in the pandemic.

Only three ideas make use of advanced technologies, particularly machine learning. They leverage such technology to i) detect fake news, ii) develop Deep Fakes to effectively teach hygiene rules, iii) learn about users' routines that can no longer be performed, and suggest valid alternatives.

3. IMPLEMENTING IDEAS

The fourth step of our project was aimed at encouraging the rapid implementation of the ideas published on the platform. All ideas were published under Creative Common International 4.0 license, which allows anyone to develop, modify, and build on the published seed ideas, as long as the original authors are credited. The license facilitates the implementation of ideas by any actor who has the means to make them real. This choice meant to favor a rapid development of solutions, while still protecting the authors' intellectual property, and positioned the initiative in the domain of 'open design' (Van Abel at al., 2011, Fjeldsted et al., 2012),

In designing the initiative, we envisioned open ideas being implemented by at least three types of actors:

- The same designer/team who created the idea, who would find the resources to make it real, as a designer-entrepreneur;
- Companies or institutions invited to join the initiative and to develop one or more ideas;
- Independent professionals or companies that would browse the platform and decide to bring an idea to life with their own resources.

The first two cases turned out to be effective. Berkeley Innovation Group decided to develop three of the ideas published on the platform. Two other ideas were selected by a design firm in Italy, which decided to look for both private and public funding to develop them.

In the first case, the solutions were developed consistently with the ideas published on the platform. In the second case, the selected ideas turned out to be useful as inspiration to generate solutions addressing the same problem, but with different approaches and technologies than the original ones, ultimately resulting in new concepts.

This phase of the project turned out to be the most challenging one. The main obstacles consist in the effort required to develop an idea, and the lack of resources or incentives. Additional, more structured initiatives aimed at developing solutions would favor their implementation. However, the project started with no funding, and it was not possible to provide these kinds of incentives. Activities are currently being planned in that direction, including development challenges, hackathons, or prizes that might serve as seed funding to implement some of the ideas.

Although the original goal of the project was to quickly develop user-centered solutions and to make them available to the public, the unexpected scale this initiative assumed did not allow for the development of this fourth step as originally planned. Indeed, as the pandemic spread worldwide, the attempt to include as many countries as possible resulted in less resources available for the implementation process.

4. DISCUSSION

4.1. Results

The results achieved in the first four months of the initiative can be summarized as follows:

- A data platform collecting people's experiences during the pandemic in 11 countries;
- Visualizations that make data understandable and available to different types of audiences, for different purposes;
- Seed ideas of user-centered products and services addressing the needs, problems, and emotions of people dealing with different forms of confinement measures;
- A subset of solutions in development, which address people's needs emerged the current situation, but which will likely survive beyond the pandemic;
- A global network of partners, including institutions, research centers, companies, and professionals, which have tested a consistent approach to tackle similar emergencies by design;
- An operative model and a design framework useful to uncover and target emerging needs and issues through design solutions, in a rapid and collaborative manner.

4.2. An iterative process

The four-step design framework we developed is not necessarily linear, or unidirectional. The action phase can also generate insights that feed the learning phase, aimed at knowledge generation. Ideas could be analyzed to achieve a deeper understanding of the problems uncovered in the data collection phase, or to identify new sets of problems that had not emerged in that phase. For instance, the fact that many of the collected ideas fall into the category of 'wellbeing and mental health' might indicate that these issues were collectively perceived as more prominent than others.

In some cases, seed ideas address problems or needs that were not highlighted by the research activity. A few solutions refer to specific categories of users, e.g. children or elderly people, which had not been reached by the survey. However, the ideas themselves are able to shed light on emotions and issues of certain groups of people that had remained hidden.

Seed ideas have also been collected during the transition phase that followed the initial lockdown. Some of them address new sets of problems (such as how to safely visit elderly people in nursing homes) that had not been identified in the research phase, but emerged as a consequence of the changing context and measures.

In all these cases, designers contributed to highlighting some latent or hidden needs, or subsets of needs, through the ideas they submitted.

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4.3. Challenges and Limits

Due to the unique situation it addresses, the Design for Emergency project followed a highly experimental process, which posed a number of challenges.

The main challenge is associated with designing in and for an extremely uncertain and dynamic context. The COVID-19 emergency, in addition to being completely unexpected, carried an exceptionally high degree of uncertainty, which was disrupting the healthcare, social, political, and economic systems on many levels. The need to quickly respond to this emergency with limited resources and a lack of knowledge of how the situation would evolve made it difficult, at some pivotal points, to make informed decisions. A certain level of risk had to be taken while investing time and resources into project phases that had no guaranteed outcomes, because they were depending on factors beyond our control – e.g. changing users' needs, context, containment measures, etc.

A second challenge concerns the geographical expansion of the project. The need to extend the initiative to different countries in local languages, while very rewarding from a research and design viewpoint, posed challenges in terms of time allocation, resource management, and the need to adapt our project to different contexts and measures put in place during the pandemic. The proactive effort of local partners and their insights on the situation of each country turned out to be essential.

The lack of resources to allocate to this initiative was balanced by the effort of a team of volunteers, who reached out to join the initiative, and offered their time and skills to this project. Their contribution was essential for the project survival, particularly on the data analysis and visualization levels. However, very soon it became clear that the mobilization that follows a state of emergency, and that makes people willing to contribute, does not last long. As the pressure is relieved, and the situation starts to move back to normality, or towards a state that is no longer seen as an emergency, the interest of media, professionals, institutions, companies, and new potential volunteers, quickly decreases. In similar situations, the moment when people are willing to contribute should be leveraged to make an impact. Building the project structure, planning – and re-planning - the steps to constantly adapt them to the changing situation required a significant amount of time. This prevented the project team from allocating more time to support a rapid implementation of the collected solutions.

However, the DfE project succeeded in developing and testing a four-step process to design for emergency, creating a framework for each activity, and building a network of partners that might be leveraged again in the future. Its natural evolution consists in transforming these experimental results into a more structured design methodology, which can be used to tackle future unexpected situations, emergencies, or crisis.

Although the framework provides a useful starting point, it currently shows some limitations, including the lack of explicit iterations between the learn and act phases, and the absence of a validation phase. Further developments could see the use of collected data to validate seed ideas, or the involvement of diverse audiences in the ideas assessment. Such additional steps would help to ensure that implementation efforts are allocated to solutions that have a greater potential to positively impact people's lives.

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4.4. Future Developments

As the project took shape and progressed through the four stages – from learning to action, from data collection to design and implementation – and new services and applications were reshaping people's daily activities (work, education, social relationships) it became evident that the project scope and scale could be broader than the contingent emergency around COVID19. This was due to three main reasons:

- A second wave of the pandemic is still possible, if not probable, calling for an extension of the project's timeframe and lifecycle;
- Some of the proposed solutions – within and beyond DfE - impact people's behaviors and attitudes in such positive ways that they candidate to survive the epidemics and transform indefinitely daily routines and practices;
- Needs that emerged as new for certain categories of users were in fact not new for others. As one DfE's contributor states in the description of her idea: "For elders, people with disabilities, and persons living alone of all ages, confinement and 'social distancing' is rather the norm than the exception." - Brigitte Borja de Mozota, "Wilson2" seed idea.

It is therefore plausible that the data about users' experiences, the 36 ideas collected so far plus the ones that will be further collected, and the whole DfE platform will prove useful beyond the current pandemic phase, while transitioning into the next stages and in what will be the new normal .

In this light, the project is adopting a broader frame assuming the condition of 'emergency' less as punctual and limited in time and more as a permanent status, where new issues will continuously 'emerge' as unexpected. With this assumption, design is a strong candidate to be a leading discipline in tackling emerging challenges, with its capacity to face wicked, ill-defined problems, in a context where limited information is available and a quick reaction to the unknown is needed. The connections between this idea of emergency, the concept of resiliency and the role of design in both is currently being explored.

Finally, the initiative can be seen as a pilot project, which is serving the purpose to create an international network of partners who share approaches and methods to face crises or emergencies through design. The project is therefore working as a collector – a filter that brings in very motivated actors and organizations that build a solid network also for grants opportunities and future projects.

The fact that the pandemic is unfortunately still expanding at the time of writing increases the significance of the initiative, especially as a virtuous cycle between the two pillars learn-act will be established. Learning from action can help to generate new, improved surveys and data, which can in turn make future design challenges and workshops more relevant and effective.

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