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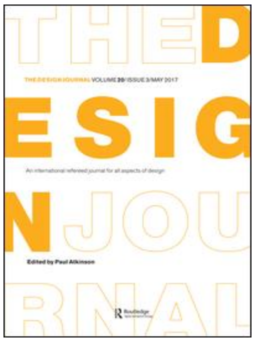

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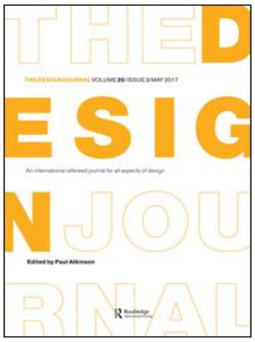

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New Domestic Healthcare. Co-designing Assistive Technologies for Autonomous Ageing at Home

Giuseppe Mincolelli[a*], Silvia Imbesi[a], Michele Marchi[a], Gian Andrea Giacobone[a]

[a] Department of Architecture, University of Ferrara, Via Quartieri 8, 44121 Ferrara, Italy
*Corresponding author e-mail: mscgsp@unife.it

Abstract: Ageing is connected with increased chronic psychological and physical disabilities, which are today delayed to older ages than in the past. The constant growth in number of older people in our society creates a larger demand of goods and services related to home care, due to the willingness of the elderly to live at home remaining autonomous as long as possible. Using a Human Centred Design method, this research aims to support ageing in place and to extend independence of older people through appropriate technological strategies for families, reducing both costs and risk factors of caregiving. Quality Function Deployment tool and Co-Design technique are the main approaches that have led the design process, including older people in every decision-making step. The final result is an assistive IoT ecosystem, which provides at the same time a customizable healthcare service to the elderly and a home care management system to their caregivers.

Keywords: Inclusive Design, Elderly, Ageing in place, Assistive environments, Internet of Things.

1. Introduction & context

Older people are a rapidly growing proportion of the world's population because the life expectancy of our society is getting longer than in the past. The constant growth of this trend creates a larger demand of goods and services related to healthcare and safety issues (WHO, 2015). In fact, ageing is connected with increased chronic morbidity, diseases and functional disabilities, and it is possible to evidence that psychological and physical disabilities are delayed to older ages than in the past (Freedman et al., 2002). Consequently, this phenomenon puts great pressure on social welfare systems that will face the challenge to provide the standard of care both for longer time and to more people from all over the world in the next years.

Concurrently, home has become the primary setting for short-term and long-term caregiving provided mainly by families and secondarily by friends or neighbours. The boundaries between hospital and home have become blended, where the volume of home care supported by informal caregivers have already provided over 80% of home care to dependent older people (Binstock & Cluff, 2000) and the role of the family as primary caregiver is projected to continue and expand in an

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ageing society. This trend will become more evident because the majority of older people wants to age in their contexts, to remain autonomous, active and independent as long as possible and live at home surrounded by their family and friends (Rantz et al., 2005). In this case, for the elderly and their families, autonomy consists of decisional control and choice in shaping their own personal life, where institutional care is perceived to be a last resort. The move to senior residential housing and later to a long-term care facility is often the result of inadequacies of the home to meet the changing needs of older people due to decline in health and self-care abilities, loneliness, accessibility barriers within the home and the surroundings, the unavailability of necessary services and a poor quality of care (Lecovich, 2014). In particular, this tendency is increased by the families that are not able to provide essential support to their parents because of long distances and work commitments (Campanini, 2004), subsequently producing uneasiness in both parts.

Understanding the role of home in providing daily care is very important to develop appropriate and effective strategies to support families and to reduce both costs and risk factors associated with caregiving. Thus, it is necessary to find new solutions that can facilitate ageing in place, promoting a longer independence for older people. Ageing in place develops in four interrelated dimensions: a physical dimension that can be seen and touched like home or neighbourhood; a social dimension involving relationships with people and the ways in which individuals remain connected to others; an emotional and psychological dimension, which manifests with a sense of belonging and attachment; a cultural dimension, which relates with older people’s values, beliefs, ethnicity, and symbolic meanings. Hence it means that ageing issues are not referable to the physical sphere only, but it is also necessary taking in account the psychological sphere, because it includes factors that contribute to preserve the social identity, the sense of personhood and a level of independence, according to both the living environment and social interactions (Gitlin, 2003).

2. Objectives

The current scenario in which older people require constant assistance and the availability of caregivers is insufficient, an important challenge for designers is to rethink and redesign the domestic environment toward new ways of providing home care service and preserving ageing in place. Digital technology can be a useful tool to tackle health issues by supporting elder care with ubiquitous services, especially aimed to the most fragile categories of the elderly (Mincolelli et al., 2017: B). If we look at the Internet of Things, for example, scientific community is still investigating about what effects and positive impacts may assistive agents have on people who need daily home assistance (John Clarkson & Coleman, 2015). In fact, some researches are focusing nowadays on assistive environments, because they can easily monitor and support people in their environments through an intelligent sensor network, which collects, records, analyses and shares health data (Goodman et al., 2007).

This paper shares the same objective and it presents a research project specifically developed to enable ageing in place, helping people to stay healthy and autonomous for longer time at home. ‘Habitat’, the project examined in this contribution, is a multidisciplinary design research focused on Inclusive Design for older people. It aims to develop an assistive environment through an IoT-based platform that provide a customizable healthcare service to its residents. The objective is to create a smart domestic environment that can be used not only with a medical purpose, but also for social entertainment. This dual purpose drives the research towards creating a smart system that can be less intrusive than assistive-robot agents and less annoying than a non-predictive reminder tools, in such a way that technology can be hidden into the home and act only when its intervention is necessary. The overall IoT platform expects an integrated system – with several sensors integrated into traditional objects, such as radios, armchairs, lamps and so on – able to monitor older people and consequently to offer the right support for improving their life quality, according to a predictive analysis of their monitored parameters. In order to put the attention on user needs, this research has used participatory techniques and human-centred approaches throughout all steps of the design process.

'Habitat' is funded by POR FESR 2014-2020 program of Emilia-Romagna Region in Italy and it is developed by an interdepartmental research group composed of several partners coming from both university and industry. The entire team is composed by:

- (a) CIRI-ITC (Centre for Industrial Research of the University of Bologna), which is the head partner of this research, specialized in radio frequency systems. Its task is to design and realize an indoor localization system that can interact both with users and smart objects, integrating itself in the domestic space. The aim is to monitor elderly at home, in order to preventing possible dangerous situations.
- (b) CIRI-SDV (Life Sciences and Health Technologies of the University of Bologna), which is expert on technical validation of inertial sensors. Its task is to realize both the digital system of SEPA module (a communicating semantic protocol that interconnects the smart objects together) and the wearable inertial sensor for the analysis of indoor and outdoor movements of older people.
- (c) TekneHub (Tecnopolo of Ferrara, belonging both to the Thematic Platform Construction of the Emilia-Romagna's high technology network and to the University of Ferrara), which is the leading team of the entire design process, specialized in Human Centred Design methodologies. Its task is to develop design solutions for every smart object taking in consideration the voice of users but also every technical or engineering constraint arising from prototypes of other partners;
- (d) ASC Insieme, which is the public entity for management of Personal Services in the Province of Bologna. It has several adult day care centres scattered around Bologna. Its role is to make available several groups of users of its network and its facilities to TekneHub for organising several Co-Design workshops.
- (e) Ergotech, which is an industrial company expert in designing ergonomic furnishing. Its role is to provide its industrial know-how for realizing and testing the final prototypes.
- (f) mHealth, which is a spin-off of the University of Bologna, specialized in the fields of motion analysis and wearable sensors for monitoring, assessment and rehabilitation of the motor function. Its role is to provide its experience in data management for wearable devices.
- (e) Romagna Tech, which is competent in communication and dissemination of results. Its role is to spread and disseminate every result of 'Habitat' through their communication channels located in the territory.

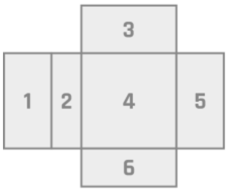
The final objective of this relationship between industry and academy is to design a concrete project that can move beyond the sole research in order to transform itself into a great opportunity for industrial economy for all of the Emilia Romagna territory. Indeed, the common objective is to ideate a technological transfer from academic research to healthcare industry in order to maximize the probability of a real impact on our society.

3. Methodology

The entire scientific research has been structured inside the context of a Human Centred Design approach, which has been used in the design process to satisfy the needs of people. In a multidisciplinary and complex project such as ‘Habitat’, it was fundamental utilizing this user centred method. Throughout this research a great challenge was taking into consideration every single expectation of users without compromising and affecting any design direction (by strategic, technological or morphological conveniences). This effort has enabled ‘Habitat’ partners to develop usable, accessible and inclusive products for all the users involved.

One of the intrinsic difficulties was to find an operative tool that could permit to all partners – with different skills and competences – to communicate throughout all phases of the research. For this purpose, the Quality Function Deployment (QFD) was used as decision-making tool, in order to set up the ‘Habitat’ project in a structured way. Due to its correlation matrix, QFD tool compares emotional and qualitative user needs (voice of customers) with measurable characteristics of the expected product (voice of engineers), identifying the most important technical parameters that must be used to develop the final project. The main goal was to develop innovative and qualitative products, which simultaneously meet both qualitative and quantitative requirements of the users involved (Franceschini, 2003).

QUALITY FUNCTION DEPLOYMENT



	RELEVANCE OF NEEDS	% RELEVANCE OF NEEDS	1. PROCUT SPECIFICATION	2. PROCUT SPECIFICATION	3. PROCUT SPECIFICATION	4. PROCUT SPECIFICATION	5. PROCUT SPECIFICATION	6. PROCUT SPECIFICATION	7. PROCUT SPECIFICATION	8. PROCUT SPECIFICATION	9. PROCUT SPECIFICATION	10. PROCUT SPECIFICATION	1. COMPETITOR	2. COMPETITOR	3. COMPETITOR	4. COMPETITOR	5. COMPETITOR
1. COSTUMER NEED	4	6%	0	9	0	0	0	3	1	0	0	3	2	1	3	3	3
2. COSTUMER NEED	1	1%	0	3	0	0	0	3	0	3	0	0	2	1	1	2	3
3. COSTUMER NEED	5	7%	0	3	3	0	1	3	1	3	3	1	5	3	4	2	4
4. COSTUMER NEED	3	4%	0	3	0	1	0	3	0	1	0	1	2	1	1	3	4
5. COSTUMER NEED	3	4%	0	3	0	9	0	3	0	1	1	3	2	3	3	3	4
6. COSTUMER NEED	2	3%	9	3	3	3	3	1	3	3	3	1	1	1	2	1	2
7. COSTUMER NEED	1	1%	0	3	3	1	1	3	1	3	3	1	1	2	2	3	1
8. COSTUMER NEED	2	3%	0	1	1	1	1	1	0	1	0	1	2	2	3	3	3
9. COSTUMER NEED	4	6%	3	3	3	3	3	1	3	3	3	1	3	3	2	4	5
10. COSTUMER NEED	5	7%	0	9	0	0	0	9	0	1	0	1	3	2	3	4	5
ABSOLUTE TECHNICAL IMPORTANCE			65	280	188	142	68	216	72	164	129	87					
% TECHNICAL IMPORTANCE			5%	20%	13%	10%	5%	15%	5%	12%	9%	6%					

Figure 1. An example of a QFD matrix. The 1st and the 2nd areas show user needs (voice of customers) and their weights. The 3rd area displays the product specifications (voice of engineers) that may satisfy user needs. The 4th area displays the assessment of the relationship matrix between needs and technical parameters. The 5th area represents the competitive benchmarking assessment. Based on the correlation matrix, the 6th area shows what are the most important characteristics that must be considered to develop the final product. Sequence of the steps follows the area numbers.

Although QFD is usually applied in marketing researches by industrial companies, this project has tried to use this model to lead the creative process of this research.

Within 'Habitat' project, the Co-Design practise has been used in support of QFD tool. Co-Design is a participatory and collaborative technique, used to enable stakeholders in making creative contributions in the solution of a specific problem. In this case, the practise has involved all categories of users (related to the project) in a collaborative process that has been useful to generate several ideas about the design of the final smart objects. Co-Design approach and its different ways for interacting with people have been decisive for the success of 'Habitat' project, for different reasons:

- The interactive and iterative involvement of users throughout design process has permitted to develop an assistive environment starting from the real needs of people involved. Due to this technique the research process has been capable of changing the perspective of the project, from designing 'for the users' to designing 'with the users'. People with different skills and operational levels (elderly, caregivers, physiotherapists, health operators, relatives) have worked together on the project, driving every criteria towards a common goal that was used for developing the final products;
- The involvement of users, from the early phases of the project, has contributed to establishing a qualitative relationship with the elderly through time-structured recreational activities. Co-Design practise has been useful to shake the elderly out of their daily routines (often repetitive), producing in them a feeling of curiosity and resourcefulness;
- The participatory activity has permitted an exchange of knowledge between experts and users. On the one hand, the moderators have made the elderly more aware about healthier lifestyle (derived by correct posture, right nutrition, daily movement and so on) and on the other hand, older people have made experts more conscious about elderly conditions, through the description of their everyday life experiences;
- The sincere and authentic dialogue established with users has made the elderly sensitive towards new technologies and new interactive tools, which could concretely support them in their daily routines.

4. Process

As glimpsed in the previous paragraphs, the development of 'Habitat' have constantly involved predetermined users into a collaborative, iterative and interactive process made up by a continuous cycle of ideas generation, testing and validation (Rizzo et al., 2001). Co-design techniques and the Quality Function Deployment tool have been utilized during the research to analyse and process user needs. Every step has been carried out by TekneHub's design team, which has managed and conducted all activities that have been useful to establish the guidelines of the final prototypes. This chapter describes every phase of development process that regards the ideation of 'Habitat' platform and its smart objects.

4.1 User and needs analyses

The first phase of research consisted in a careful analysis of the expected context, in which 'Habitat' will be inserted. This step was carried out by TekneHub together with the other partners, especially ASC Insieme. Then, several focus groups, direct interviews and questionnaires were organized including various stakeholders, in order to identify the main users who would have more interest in using the IoT platform. The main participants were: self-sufficient seniors, non-self-sufficient seniors, caregivers, relatives, health operators, physiotherapists and decision-makers. The activities involved roughly 100 people, which provided about 500 needs. Once data gathering was completed, a QFD matrix was created for each expected smart object of 'Habitat' platform. QFD analysis was performed through a meticulous sorting of the most important needs, selecting about 20-25 significant needs for each single smart object. In each QFD matrix, the selected needs were processed together with measurable product characteristics (identified by all partners) of the corresponding smart object (Mincolelli et al., 2017: B). The analytic correlation between needs and product specifications produced a technical assessment about the importance of every technical characteristic of each single smart objects. The final results were useful to define the design guidelines of the expected prototypes, which TekneHub would design during the following phases.

4.2 Co-Design activities

Figure 2. Two prototype solutions deriving from many participative activities with users, performed during the first Co-Design workshop. On left there is a chair elaborated through the opinions of users, whilst on right, a caregiver is testing the position of the inertial sensor. ASC Insieme's day centre, Casalecchio di Reno Bologna, Italy, 19th April 2017.

After the analysis of user needs, two Co-Design activities were performed together with some of the people already involved in the early stage of research. All Co-Design workshops were held at the ASC Insieme's adult day care centre in Casalecchio di Reno, Bologna, Italy. The Co-Design activities involved 12 families who were composed both by self-sufficient and non-self-sufficient seniors over 65 years old. Every family included a caregiver who was either a relative or a professional health operator. TekneHub's team and ASC Insieme's staff were the moderators of the two workshops. The two collaborative workshops contributed to define the final prototypes in collaboration with the main users. The active participation of older people gathered several insights, which were useful to better define proper solutions towards the main problems and needs encountered at old age (Slegers, 2015).

The first workshop permitted to delineate the early concepts and the first morphological shapes of the final products. Three main working tables were constituted with the specific intent to acquire as much information as possible about the smart object: the first one was on both the indoor localization system and the inertial sensor, the second one was on the smart chair for monitoring seniors' movements and posture; the third one was on the visual interface of the IoT platform. The participative activities were conceived for analysing daily habits and behaviours of the elderly in their homes through brainstorming and user journey maps, which defined how the assistive environment would satisfy their necessities. The final results have permitted to better understand shapes and functions of all smart objects. Through participative activities it has been possible to evaluate the level of acceptance of inertial and tracking sensors ‘wearability’ and the level of usability of the visual interface provided by the digital system. The first Co-Design workshop collected also emotional aspects of older people. Indeed, through an empathy map, it has been possible to gather several conditions of fear, frustration, satisfaction and pleasure – either related to their personal habits or to their relations with family or friends – which have been able to improve the expected quality of the overall project. After the first workshop, every consideration of users was considered in design phase. Several concepts were realized, which were analysed and evaluated with the same users, in order to evaluate the real correspondence between their previous expectations and their present opinions.

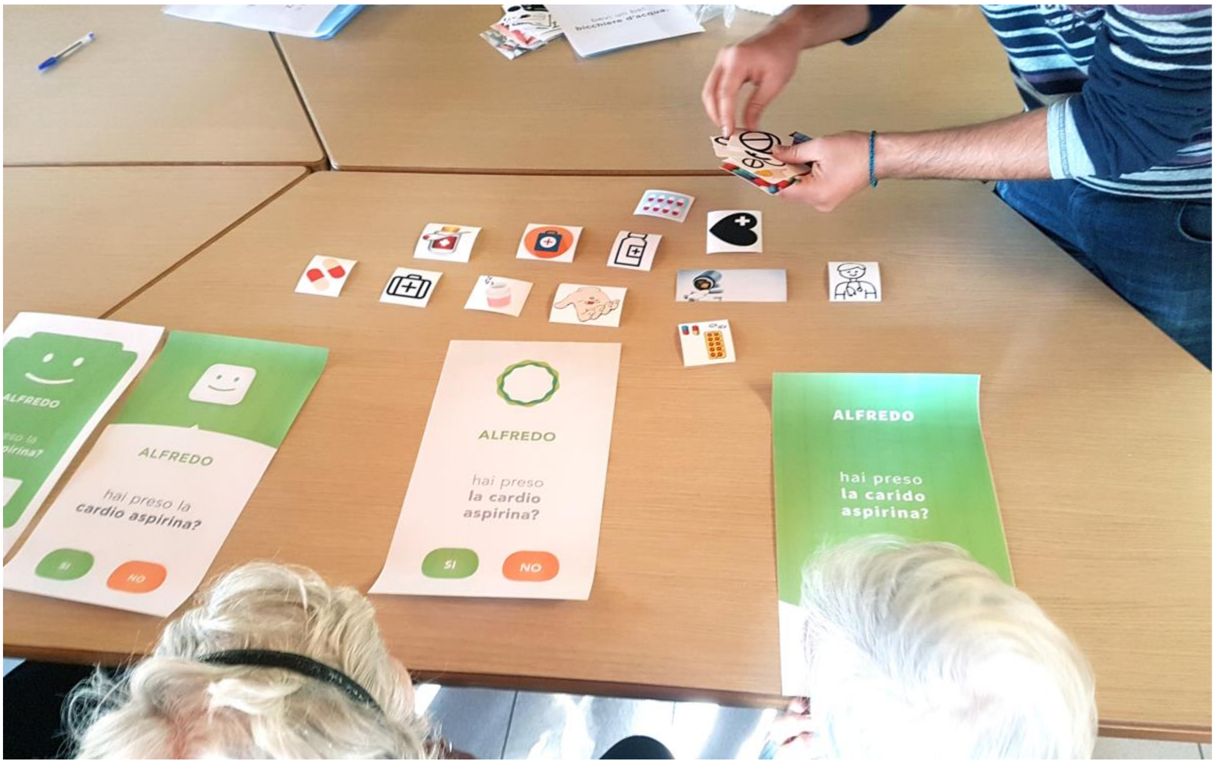


Figure 3. Older people are analysing ‘Habitat’ interface in terms of readability, aesthetics and usability during the second Co-Design workshop. ASC Insieme's day care centre, Casalecchio di Reno Bologna, Italy, 04th December 2017.

In the second Co-Design workshop, several practical assessments were performed to evaluate interactions between older people and physical objects. The main goal was to analyse strengths and weaknesses of the functional, technological and aesthetic characteristics of every smart object. This Co-Design activity was particularly useful to better improve both usability and accessibility of ‘Habitat’ interface. The workshop was performed by observing the elderly during the task-flow analysis of the digital service, as some of their impressions were easily identified from many cues elicited by their expressed behaviours (Brown, 2015). Any critical issue or problem encountered during the interaction with 'Habitat' platform was revised.

4.2 Testing phase

In the final phase of research, a usability test was executed both to evaluate 'Habitat' service and to verify the fifth level of Technology Readiness Level (TRL), adopted by European Commission to estimate technological maturity of European-funded projects (EU, 2014; Hedér, 2017). According to the European framework, the test has expected to validate the overall 'Habitat' project within a simulated or a real space environment. In order to achieve this goal, the test was held at the ASC Insieme's adult day care centre (real space environment) and it was deliberately performed by an external usability expert who had been never involved in the project, in such a way that the evaluation would not be affected by personal biases. Another objective was to evaluate the qualitative level of both usability and desirability of the overall system and its smart objects. The entire session involved 19 participants to whom 'Habitat' had been presented at the early stage. Within this specific phase, two complementary methodologies were used to inspect the project: heuristic evaluation analysis and individual interviews. In particular, two different interview scripts were designed, based on the two specific categories of users involved during the test (self-sufficient seniors and non-self-sufficient seniors with their respective caregivers). The interviews involved: 7 self-sufficient seniors; 4 couples composed of caregivers and non-self-sufficient seniors; 2 caregivers (interviewed individually); 2 non-self-sufficient seniors (interviewed individually). Time allocated to each interview was one hour and a half for each user and two hours for each couple. At the end, all users were able to finish their testing session and subsequently every consideration was reported into a final report provided by the usability expert. The document was important both to evaluate strengths and weaknesses of the overall system and to verify if the Technology Readiness Level of 'Habitat' had been reached.

5. Results

Starting from necessities and emotional aspects of users – but also involving them throughout Co-Design activities – it was possible to realize every functioning prototype, taking into account at the same time, functional and morphological product characteristics requested by the elderly. 'Habitat' system is a modular and scalable IoT-based platform for supporting ageing in place, designed to not compromise both the life quality of older people and the intimacy of personal home. The overall system is essentially composed by four smart objects. A smart chair, an indoor localization system and an inertial sensor constantly gathering data from the domestic environment while a digital interface processes that information and then takes operative decisions based on health status and indoor position of the elderly. Every smart object can be localized by unique identifiers that provide to the system their indoor position (Mincolelli et al., 2017: A). To make the assistive environment as acceptable as possible, the service has been designed not only for healthcare, but also to stimulate the emotional dimension of users, providing entertainment and enjoyment through its user experience (Dohr et al., 2010). 'Habitat' offers also a social support to families and health operators, helping them to remotely monitor their parents or patients through its IoT platform. Moreover, some industrial partners have tried to integrate the solutions of this research technology in the objects of their future product lines. Also, to use the system in different contexts, each smart object is expected to work together with its ecosystem, but also stand-alone.

5.1 Digital 'frame' interface

'Habitat' interface looks like a picture frame that can be hooked on the wall. The hardware of the interface is designed to be recognised as a part of the home furniture. Inside of it, there is a SEPA module (a communicating semantic protocol, utilized for connecting the smart objects together), which connects the software to the other smart objects. 'Habitat' software monitors health condition of users and manages their daily-life activities through the analysis of their personal data (provided by localization system, inertial sensor and smart chair). If the system finds critical issues on the elderly's life status, 'Habitat' interface can either communicate the problem to caregivers or suggest users to change their conditions through visual notifications. The 'Habitat' interface works on a 17" LCD touch-screen and shows simple messages designed to be very easy to read and understand by older people.

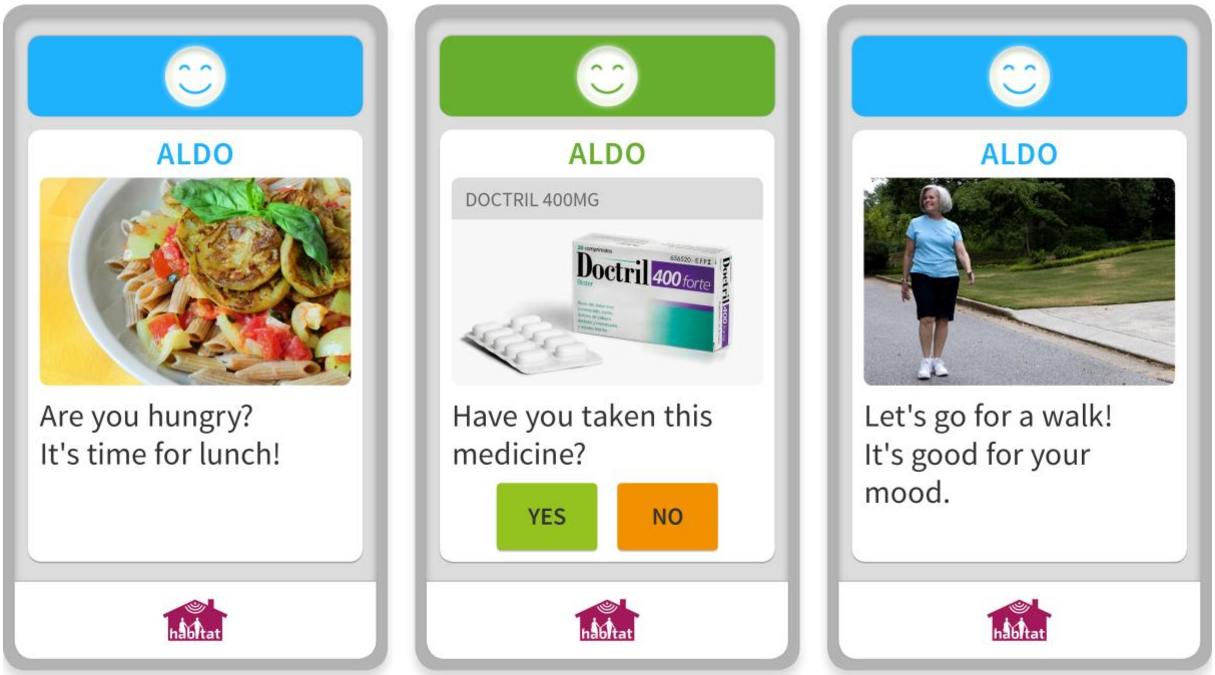


Figure 4. Some screens of 'Habitat' interface. The blue category indicates temporary advice to suggest the elderly to do specific practical actions and the green typology interacts with them in order to monitor their routines or health conditions.

Every message of the interface is composed by: a short phrase about a specific notification; a large image corresponding to the meaning expressed in the text; a coloured bar that identifies the type of message. The colour categories are two: light blue is used for temporary advice that try to push the elderly to do an action (for example drinking, eating, walking, changing posture or sleeping); green indicates the interactive messages, which are used by the system to ask the elderly to report some information about their daily routines (for example if they are fine or if they have already taken medicines at particular times). Also, at the end of the day, the interface requests to the elderly other data about their status, asking them to rate (on a level from one to five) the quality of their daytime, in base of five essential parameters: nutrition, mood, health, rest time and interpersonal relationships. All gathered data are used by the system to monitor and to improve health conditions of the elderly. The service provides also a mobile version designed for both the elderly and caregivers. It extends the service over the digital 'frame' and outside the domestic environment for older people and it mainly helps caregivers to monitor the elderly everywhere at any time. The mobile application shows health parameters of each senior monitored by 'Habitat' and it provides to caregivers correct warning messages in case of critical issues.

5.2 Smart chair

The smart chair has been realized in collaboration with Ergotech who has provided its know-how about ergonomic armchairs for the elderly. This smart object is a traditional domestic seat, in which several load cells were embedded in its feet, seat frame and backrest, in order to monitor different sitting parameters. Real-time data (about sitting posture and sedentary time) are sent to the digital 'frame' by an Arduino board, to create personal feedbacks for users. Information is processed by the software to improve either health with physical activities (like walking) or posture in a correct way.

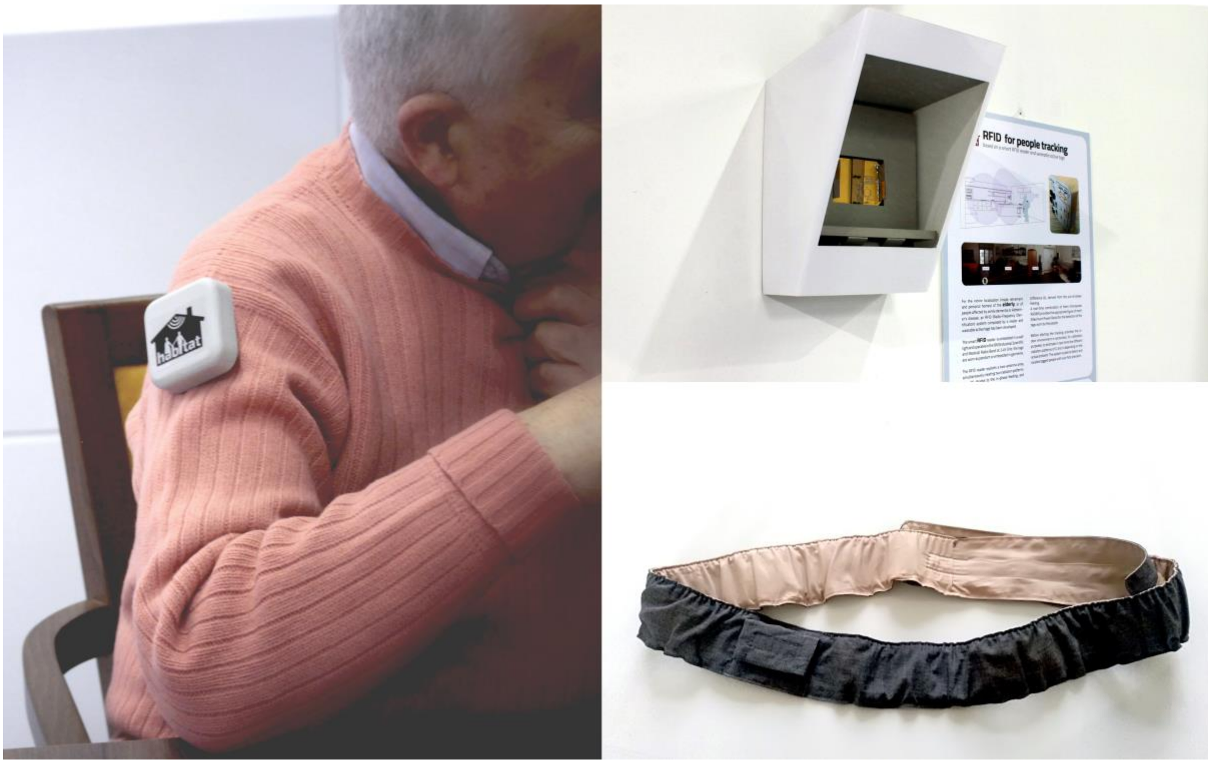


Figure 5. Functioning prototypes of 'Habitat' system: the wearable tag for localizing position (on left); the reader lamp of the indoor localization system (on top-right); the wearable inertial sensor for tracking elderly movements (on bottom-right).

5.3 Indoor localization system & inertial sensor

The indoor localization system is based on Radio-Frequency IDentification (RFID) and it is composed by two device categories: reader sensors for localization of people and smart object in the environment and recognition tags (Paolini et al., 2017). The recognition tags for artefacts are embedded into their electronic circuits, whilst the tags for people are wearable and should be worn on the upper part of the body to facilitate identification. The reader sensors are embedded into wall lamps or shelves in order to minimize the technological impact on the home spaces and they are utilized to monitor the position of older people. According to physical and mental abilities of older people, the indoor localization system can be divided into safe zone and unsafe zone. This configuration can prevent wrong access to the elderly into particular risky areas of the house (for example bathroom), warning caregivers in time through specific alert messages.

Inertial sensor is another wearable device, which monitors dynamic motion of older people inside and outside the house. In order to have correct motion tracking, the wearable sensor should be worn dorsally at waist level, in correspondence of the L5 vertebra. The sensor analyses activity time or sedentary time of the elderly and it is able to warn caregivers in case of critical events (such as fallings). The inertial sensor works in collaboration with the indoor localization system, to provide qualitative data about health of the elderly.

6. Conclusions

Figure 6. Simulated environment of 'Habitat' system performed within Expo Sanità exhibition. Bologna, Italy, 18th-21th April 2018. The image shows the functioning prototypes of 'Habitat' system: digital 'frame' interface (on top-left); smart chair (the light blue chair on left); indoor localization system inside the lamp (on top-right).

The research has allowed to realize a multidisciplinary project that has promoted the development of technical-fields-crossing solutions. As expected in the objectives, the final result has produced a beta version of 'Habitat' software and all functioning prototypes, which are utilized for evaluating both functionality and usability of the IoT platform during testing phase. In addition, the conception of desirability has been introduced within the performed tests, in order to evaluate adaptability level of 'Habitat' toward different needs manifested by older people, which can change over time in base of their personal ageing process. In this case, desirability refers to the willingness of the elderly to get older in a scenario in which 'Habitat technology is present and it is used to improve life quality.

During tests, the final report has taken note of all considerations of the elderly about the smart objects. Personal evaluations were positive, because almost all of the 19 people involved declared to be satisfied while interacting with the products. Specifically, the smart object with the highest appreciation (100%) is the inertial sensor, which has obtained excellent results both on aesthetic level (it has been perceived as intimate) and on colour and fabric customization. During tests, the inertial sensor was able to assess specific characteristics of balance, gait, postural transfers, and turns and sent data to 'Habitat' system in background and in real-time. Information was used to evaluate the number of steps, detect fallings and distinguish sedentary time from the active one. Also, algorithms that identify fallings showed possible improvements in order to recalibrate sensor parameters and avoid eventual false alarms or system misses.

The reader sensor of the indoor localization system has had a high level of appreciation (90%), because it could be easily integrated into any domestic context as a lamp or a shelf. However, it has been recommended to increase variety of colour and size during production, in order to increase flexibility of use. Tests showed that the reader sensor allowed angular detection in a scanning zone from -45° to 45° in the azimuth plane and it was able to localize the recognition tags in real-time with centimetre-level accuracy. For a correct installation and calibration of the reader sensor, a simple pre-scanning of the domestic environment was needed. Instead, the recognition tag has been the smart object that has showed the biggest room for improvement (60% of approval). Older people reported that they would prefer reduce weight and dimensions of the case, because it was not very comfortable to wear because of its large antenna (5x5 cm). In an advanced phase of the product development, it has been also advised to assess these changes in other evaluating tests.

The smart chair has been appreciated for its comfort and aesthetics (80% of satisfaction). The product derives from a chair model already engineered, in which sensors and a wireless system – that communicates with the digital 'frame' interface – are integrated. Data communication with the central system worked correctly, but in some cases, many tests highlighted some anomalies related to some messages (for example notify an incorrect posture), because sometime the algorithm – that analyses and processes data from load cells – resulted too sensible to recognize user behaviours.

The digital 'frame' interface has been considered pleasant in terms of use (80% of satisfaction) and customizable regarding superficial painting and displayed messages (based on needs and habits of users). Evaluating tests of the digital 'frame' and its visual notifications were performed through some expected scenarios (such as to notify incorrect posture, to remember drinking water, eating, walking, sleeping, or to fill in the daily report) whereby 'Habitat' had been designed for. During tests, when a particular situation of a specific scenario occurred (for example to advise older people to walk), the 'frame' displayed the corresponding notification message on time, which could be visible on its interface and, at the same time, on the mobile devices of both the elderly and caregivers. Interacting with 'Habitat' resulted enjoyable by the elderly and the system was perceived more as a companion, rather than an intrusive element creating anxiety or a sense of guilt. Some visual reminders such as "drinking water" or "walking" were indicated both as a useful support to remember tasks and an element of involvement in maintaining healthy lifestyle. However, it was recommended to match the different visual messages that came from the displayed graphic interface with audible feedbacks. The daily report was considered a useful tool to analyse both health status and life quality of the elderly in the long term, but some frictions arose during the interaction with the questions it asked, because the process required too much steps to confirm choices.

In addition, the evaluating tests were important because they showed the possibility to identify three possible service solutions of 'Habitat' platform to adopt at home, based on three different steps of ageing, which the service has to manage: self-sufficient senior; partially self-sufficient senior; non-self-sufficient senior. Due to the autonomy of self-sufficient seniors, it has been noted that 'Habitat' may be equipped only with the mobile application and the inertial sensor, which can be used only as reminder for healthy activities or scheduled tasks (for example taking medicines or going to the doctor appointment). While, the second category (partially self-sufficient senior) may include all the other smart objects (smart chair, indoor localization system and digital 'frame' interface), in order to extend the service also to home caregiving. In this solution, the system is more present in the everyday life of the elderly and it can warn caregivers in case of critical issues. Instead, for the last category of non-self-sufficient seniors, 'Habitat' may be used even as a warning system, where the platform is completely managed by caregivers, who can constantly monitor the elderly and help them to do their daily activities. In this case, the mobile application for older people is eliminated and all messages are displayed only on the digital 'frame'. These solutions may assist every category of senior during their ageing, without compromising habits or creating constraints to whom still live autonomously and do not need permanent caregiving compared to non-self-sufficient seniors.

In the end, the fifth level of TRL was achieved and many of the indications and suggestions – resulting from the evaluating test – have permitted to understand every critical aspect of ‘Habitat’ platform. All information has already been taken into consideration for subsequent development phases, leaving room for improvement related to system interaction, standardization and miniaturization of physical components.

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About the Authors:

Giuseppe Mincolelli is an Architect and Designer, specialized in HCD and Inclusive Design. He is Associate Professor of Design at the University of Ferrara, to which he is coordinator of Innovation Design (MSc). Numerous patents, publications and awards in Italy and abroad.

Silvia Imbesi is an Architect and Designer. She works in the inclusive design field as freelance designer. Now she is a Ph.D. candidate at the Department of Architecture of Ferrara, carrying out a research on Inclusive Design for the elderly.

Michele Marchi is an Architect and Ph.D. He graduated in 2010 at the Department of the Architecture of Ferrara. He is author of articles, speaker at national and international conferences and consultant for public and private associations on issues regarding physical accessibility, cognitive and sensory.

Gian Andrea Giacobone is a product-interaction Designer and a Ph.D. candidate of Design at the University of Ferrara. He conducts his research in the field of UX and in-car interaction and collaborates on other academic researches about digital interfaces and Internet of Things.