Chapter 4

Prototyping intervention 1/ Placing a Co-Drive stop

In Chapter 3, I have collocated Co-Drive concept in the Extended Reality (XR) domain and I have outlined an early prototyping methodology which would be implemented later on in the rest of the project. In Chapter 4, I will describe the Prototyping intervention 1/ Placing a Co-Drive stop. I will recruit driver participants and they will place Co-Drive stops around the world. Beyond private drivers, I will also conduct the experiment with traditional bus drivers in Ghana to address passenger participants feedback, such as to reach far away locations and keep on their routine to travel collectively by bus, as collected in the early exploration. Chapter 4 opens up the experimental study conducted during my PhD research.

The collection of Co-Drive stops was released through an online public call [58]. Participants were asked to enact a situated intervention as well as to answer an online survey. They were required to physically inspect the space; provide reasons for their selection; give or take their availability to be a driver; envision future interactions among the driver and the remote passenger; indicate geolocation coordinates; and take a picture of themselves at the place while holding the "Co-Drive stop" sign, which was made available for them to print on the website. The situated intervention aimed to explore the social construction of the Co-Drive

stop as a place by the driver [59] as well as to collect stops to be featured in the Atlas and recruit perspective drivers for the future prototyping phase of the virtual shared trips.

Figure 4.1: Some Co-Drive stops collected by participants: Rovereto in Italy (top left); Melbourne in Australia (top right); Kumasi in Ghana (bottom left); Milan in Italy (bottom righht).

Participant L., for instance, submitted the Co-Drive stop in Rovereto, Italy, as shown in Fig. 4.1, and argumented her choice as follows: *" At the stop, [I would like to have] a sign painted on the floor or a street lamp. The contact information should include a telephone number, because not all the interested passengers might be tech-savvy with the use of smartphone, qr-codes, websites, etc. There are stairs at the fountain in the center and benches where remote passengers could " wait" for the ride. This to give them a more immersive experience."*

Participant Lr., instead, didn't submit a stop at a specific space in a city, but geographical coordinates of a crossroad where a mountain road departs. This is how he describes his choice: *"This is the start of a beautiful mountain road that goes from the Sarmento Valley in Basilicata to the Ionian sea coast in Calabria, Italy. It is one of my favourite roads to drive, and the landscapes are beautiful. The whole area is not very well known, and worth a visit. I don't think there's a need for a stop, it could just be a notification. Stopping is already dangerous enough when taxis and other cars do it (cyclist's perspective). And I think the point of the project is the drive, more than the stop. [...] I picked the place because of its beauty and because it's very much a place where people pass by to go somewhere else, a 'middle of nowhere' type of place.*

4.1 Why the drivers of Trotro buses?

During the time I spent with prospective remote passengers and with their social workers, I got to know that they were used to traveling together by bus, during trips organized by the elderly center. This made me think of the recruited group of seniors as a particular community of practice [60] and I thought to extend my call for Co-Drive stops also among bus drivers. Moreover, after the first experience prototyping of the Co-Drive trip [22], the group of remote passengers asked for further and culturally diverse destinations. For the above reasons I also started to look for peculiar bus services around the world which could offer the right setting for the next Co-Drive trip as a "bus trip". Eventually I came across the Trotro buses in Ghana and they resulted in being the potential collective vehicles for a Co-Drive trip (Fig. 4.2).

Trotros consist of the Ghanian informal public transport service, which emerged in the colonial era for the autonomy of farmers and traders and is still nowadays embedded in the

Figure 4.2: Some Trotro buses queueing in the street of a busy Kumas.

culture of mobility of contemporary Ghana, serving around 85% of its population [61]. They are usually rung by a pair of 2 operators working together: the driver and the mate. The mate is in charge of getting people onboard and off; closing/opening the door; selling the tickets. Due to the Coronavirus pandemic in 2020, I couldn't travel to Ghana, so I teamed up with a local researcher from Kumasi who helped me with recruiting and interviewing Trotros drivers remotely.

4.1.1 Fielwork and co-creation with Trotro operators

The research with Trotro drivers was undertaken in Kumasi, Ghana, in 2020, using a mixed modality (remote and in-person) by myself, based in Italy, and the local researcher, based in Ghana [62]. Three pairs of Trotro operators were interviewed, each one constituted by a driver and a mate. They were interviewed for about 2 hours by the remote researcher connected via Google Meet from Rome, while the local researcher in Kumasi was present with them and translating from Twi to English, and viceversa, when needed. The interviews

firstly covered the Trotro service and the personal experience of the operators, secondly the Co-Drive concept was explained to the interviewees and finally they were prompted to envision how Co-Drive trips could run in Kumasi through their Trotro service. The operators imagined where to mount the Co-Drive in-car prototype; where to place the Co-Drive stop; the routes to travel through during Co-Drive trips and which seat to reserve to the remote passengers (Fig. 4.3). They also reflected on the cultural and social aspects, such as on how to properly greet and speak to an elderly person who is remotely hosted in the Trotro, as well as on possible trips fares for remote passengers.

I summarise below some highlights from the study. The seat for the remote passenger that the drivers would allocate would be the one next to the driver, so that the remote passenger could enjoy the view better. The in-car equipment should be removable, so that drivers could put and remove it when they park the bus and leave it unattended (the equipment may be stolen). Some drivers may need to remove the screen (made from wood or glass) behind the driver seats to place the prototype, but it would be not a big deal since there is plenty of "Trotro fixers" able to do such a work.

Some drivers suggested that the fare for the remote passenger would be higher than the regular passenger, about 20 cedis (about less than 3 euros). The reason was that remote passengers could stay for the time they want, even take a return trip.

Drivers were also asked how they thought that regular passengers would react to the introduction of the Co-Drive service in Trotros. This is how driver S. answered: *"The regular passengers will be surprised, curious... We, as the operators, would need to explain before starting the trip what's going on, to make them aware that we carry also a remote person. We need to be in a sort of agreement with the regular passengers."*

Figure 4.3: Some Trotro drivers from Kumasi show the seat they would reserve to remote passengers as well as the headrest where they would mount the Co-Drive prototype onto.

4.2 The generation of the Atlas of the Co-Drive stops

Five Co-Drive Stops were collected through the public call, across Europe, Australia, Africa and Oceania. They were visualized in the Co-Drive Atlas, which was built on Mozilla Hubs [63]. Mozilla Hubs was chosen because it is a very easy-to-use platform for 3D social virtual environment which does not require any coding skills. Prospective remote passengers would select and embody their own avatar as soon as entering in the atlas environment.

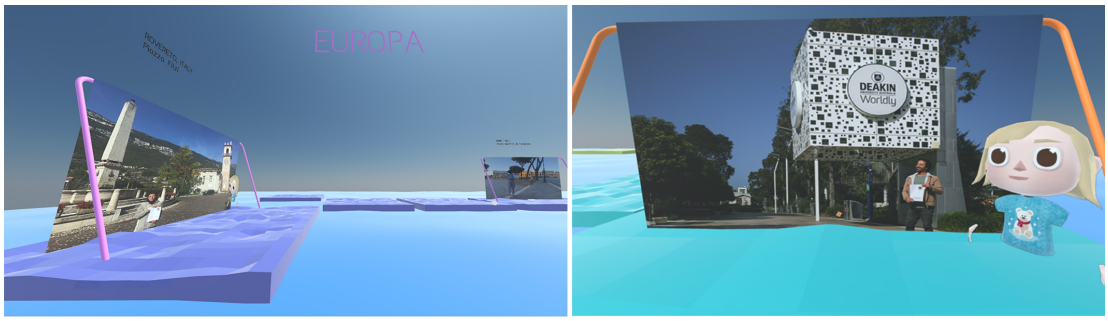

Figure 4.4: The Atlas of Co-Drive stops in Mozilla Hubs. A close up of a particular stop in Oceania where an avatar has been anchored (on the right).

By placing a copy of their avatar in front of the Co-Drive stop in the VR environment, remote passengers would book a Co-Drive trip departing from that specific location. The 3d space of the Atlas was conceived as a topography neutral space, composed by floating platforms where the pictures of the Co-Drive stops taken from the real would be attached to pipes of a virtual stop (Fig. 4.4). The aim was to remove any concern related to the real world physical distance among the locations and inspire a sense of freedom of travelling and meeting people from different cultures in an easy way. I will deepen into the Atlas of the Co-Drive stops in section 5, where the prototyping session with remote passengers booking their trip will be described.

Chapter 5

Prototyping intervention 2/ Booking a Co-Drive trip

In Chapter 4, I described the Prototyping intervention 1/ Placing a Co-Drive stop. I recruited driver participants and they placed Co-Drive stops around the world. Beyond private drivers, I also conducted the experiment with traditional bus drivers in Ghana to address passenger participants feedback, such as to reach far away locations and keep on their routine to travel collectively by bus, as collected in the early exploration. In Chapter 5, I will describe the Prototyping intervention 2/ Booking a Co-Drive trip. I will recruit passenger participants, they will create their avatar through a paper-based co-creation tool kit and they will book a Co-Drive trip by using the virtual Atlas of Co-Drive Stops.

This prototyping intervention was meant for prospective remote passengers to prepare for their first encounter with the driver at a Co-Drive stop. How would they represent themselves as avatars? Which Co-Drive stops would they prefer to book? In order to come up with a set of design techniques to run such intervention, I firstly addressed two main issues.

The first issue was whether the participants should be required to create their avatars from scratch rather than selecting their avatar from a collection of possible designs, which still could be customized. The second issue was whether limiting the choice to realistic looking

avatars or opening up to fantasy and non anthropomorphic ones.

Previous research by Carrasco et el. [64] showed how older adults created their own humanoid avatar by being guided using the software *Makehuman* [65] [66]. The elderly people involved in that study had reasonable experience using smartphones, tablets and desktop computers. Carrasco's study aimed to demonstrate how older adults were negotiating ageing sterotypes when creating a virtual human body, hence the choice to limiting the avatar representation to a human like appearance was considered appropriate for the case. On the other hand, Turkle's milestone work [67] opens up to unlimited fantasy self-representation through avatars, beyond human like appearance. Turkle elaborates that the engagement with computational technology facilitates a "second chance" in older adults, who can safely confront themselves with questions about their own identity and either build their ideal selves (as in the *Ego Ideals* users) or experiment several versions of themselves, (as in the *Role Players* users). Recently, a research by Cheong et al. [68] investigated which type of avatars elderly users prefer among anthropomorphic and non anthropomorphic avatars (animals and objects). Participants were asked to rate 20 pictures of ready made avatars and results showed a strong preference towards child, animal and object avatars. Furthermore, it should not be overlooked that both studies conducted by Carrasco and Cheong agree that the association between avatar representations and the social contexts that avatars would be embedded in should be explored more, as participants might tune their representational appearance in relation to the *other people* they would encounter in VR [69] or to the emotional attachment they might feel towards the plot of the virtual environment [68]. Considering that in this study 1) the group of elderly participants was completely unfamiliar with computational technologies and avatar representations and 2) the envisioned experience was already situated in the scenario of a Co-Drive ride and participants were aware of it, the co-creation session was designed so that participants would not be required to use

any software to build their avatars representations, but that they would select them from a given set of possibilities including from humanoid to fantasy and non anthropomorphic characters. The full intervention was conducted in two phases over a three months period: a co-creation session, oriented to the avatar selection, and a following prototyping session, allowing participants to digitally embody their avatar in a VR environment. Both phases consisted in individual remote meetings run at the participant's home through the support of a social worker who physically visited the elderly and supported the remote researcher. The following research tools were created to support this intervention, ranging from paper-based to AR/VR prototypes:

- the AR diorama
- the paper prototypes of the Co-Drive stops
- the avatars board
- the Atlas of the Co-Drive stops

5.1 The AR diorama and the paper prototypes of the Co-Drive stops

An interactive AR diorama was built to show remote passengers that they could place their avatar at a chosen Co-Drive stop, as a way to book a Co-Drive trip departing from that place (Fig. 5.1). The interactive diorama features i) a background scene of the Co-Drive stop at the Colosseum in Rome, consisting of a panoramic picture taken with an Iphone XR, and ii) a miniature-car (1/10 scale) equipped with an IPhone XR as the interactive windshield. The Adobe Aero software, which is an AR prototyping tool, runs on the device.

An anchor image is positioned on the background picture to allow an AR content to be displayed. By enacting the interaction inside the diorama, the remote passenger avatar gets revealed at the Co-Drive stop through the Iphone screen, as soon as the smartphone camera identifies the anchor image on the background picture. The AR diorama allows to represent a medium-high fidelity experience of a driver from a scaled perspective, yet demonstrating the technology, and to narrate to prospective remote passengers how their presence would be embodied in their avatar at the selected Co-Drive stop. The reasons why we went for an interactive scaled diorama enabling a 3rd person view were multiple: i) we didn't have at our disposal an interactive, full scale, car windscreen; ii) since our users were completed inexperienced of XR technologies, we had to provide a medium-high fidelity prototype so to avoid any need to "imagining technology"; iii) we wanted to focus the attention of the experience in the environment, rather than on the "device". Due to Covid-19 pandemics, the diorama could not be enacted in presence, so a video of it was remotely shown during each individual prototyping session at the user's home. The social worker, who was allowed to visit the seniors, acted as the physical twin of the researcher, who was connected with the participant via Google Meet.

The challenges and the reasons of the AR representation

The representation of the remote passenger at a roadside stop could have been conceived in many other different ways, including a less complex and ready-to-use mobile phone interface having a remote passenger icon on a map. Anyway, the design choice to go for an AR windscreen derived from a reflection on the driver and remote passenger user experience, as well as on the current conception of (semi) autonomous car interfaces. Considering the perspective of remote passengers, the idea that the driver could spot their avatar through the windscreen would make much more tangible to them their virtual presence at the Co-Drive

Figure 5.1: The AR diorama is composed by a model car and an Iphone whose display works as AR enabled windshield.

stop, thus reducing, especially in the actual older participants engaged in this research, the level of abstraction with maps and icons they are not likely been used to. This is also true if we consider the perspective of the driver, who can see the dynamically-scaling avatar as s/he drives towards her/him. I chose the virtual representation of the avatar as AR overlay in the actual space because it seemed to increase the tangibility of the remote presence of passengers for both users. It was also functional to the merging of the real and the virtual domain as it served as an act of visual marking within the *place-making* process of Co-Drive as an XR experience [59].

Besides the driver and remote passenger user experience, the AR representation will allow me to explore the social role of (semi) autonomous cars interfaces beyond safety and driving

capabilities, which is one of the main research focus of my work.

5.2 The avatars board

Following the screening of the diorama video, each participant was invited to select her/his own avatar from the ones available in the avatars board. The avatars board was comprised of a total of 11 avatar print-outs and was organized into 4 sections, according to the kind of representation: realistic, cartoonish, robotic, animal shaped (Fig. 5.2). There was a female version of the board and a male one. The realistic and cartoonish section presented human-like avatars either in a realistic or puppetry style. Realistic avatars has also been automatically generated from photos of each participant through the online service Ready-PlayerMe. In both the 2 sections, the avatars differ for their age: elderly, adult, young. In the realistic one, a half bust avatar was also included. The realistic avatars were not designed to realistically represent the physical appearance of each specific participant, but just to show some ageing traits, for instance the elderly avatars had wrinkles or white hair. Anyway, it was specified to the participants that an avatar could be customized to resemble their own physical appearance. The robotic avatar section presented box-bot avatars from the ones available in Mozilla Hubs [70], while the animal shaped section provided a couple of animals shaped avatars: a domestic animal and an exotic one, given that participants belonged to the Italian culture. Participants were guided by the researcher to go through each section and look closely to the avatar print-outs in each one. They were invited to overlay the avatars' transparent cards on top of the printed pictures of the Co-Drive stops to get an idea of how an avatar would fit into the context (Fig. 5.3).

For each board section, participants were asked to select the avatars they were more likely to place at the Co-Drive stops, explaining why they discarded some and why they were opting

Figure 5.2: Participants reviewing the printed pictures of Co-Drive stops and interacting with the remote researcher through Google Meet.

for others.

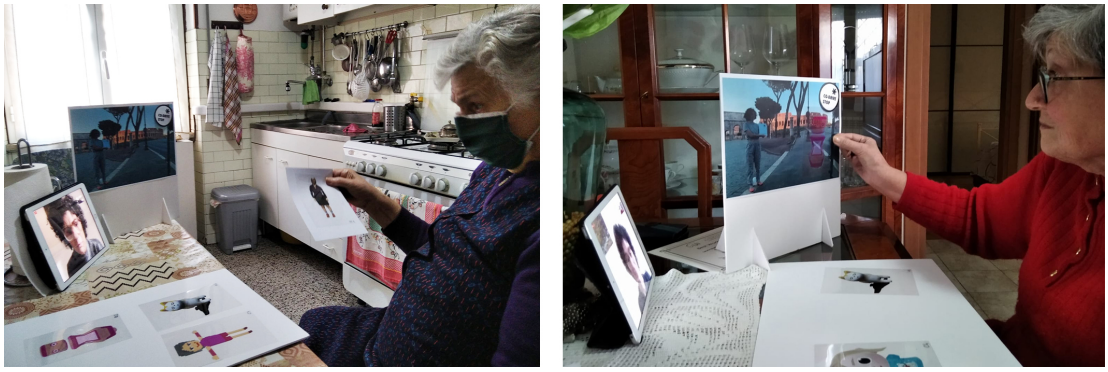

Figure 5.3: Two participants working on the selection of their own avatars and overlapping the transparent avatar card onto a Co-Drive stop picture. This prototyping session happened remotely while the researcher was connected through Google Meet with the participant.

At the end of the session, participants were asked to select their very favourite ones (Table 5.1). There was no limit on the number of preferences. The reasons why the avatars board was not including a realistic representation of each single participant were that: i) this first part of the session was focusing on giving participants a full overview of avatar possibilities, beyond anthropomorphic and realistic ones; ii) the option to get a self-representing realistic avatar was postponed to a second part of the session.

5.3 The Atlas of the Co-Drive stops

Two months later, each participant was invited to a follow-up of this prototyping session. The buffer period was due to the production of digital versions of the selected avatars, as well as a first VR prototype of the Co-Drive Atlas in Mozilla Hubs [63]. This part of the study was meant for participants to confront with their virtual self and enact her/him in the Co-Drive Atlas virtual environment. The prototyping session was facilitated by the remote researcher, connected through video call with the participant, and by the social worker who was physically at the participant's home. The social worker had the duty to use the computer and show around the Atlas on Mozilla Hubs, as participants were not completely familiar with it. Two of the participants who took part in the first part couldn't follow up due to Covid-19 related reasons. The whole session took place inside the virtual environment. At the beginning, each participant was introduced to the Co-Drive Atlas inside Mozilla Hubs and the social worker showed it on the laptop.

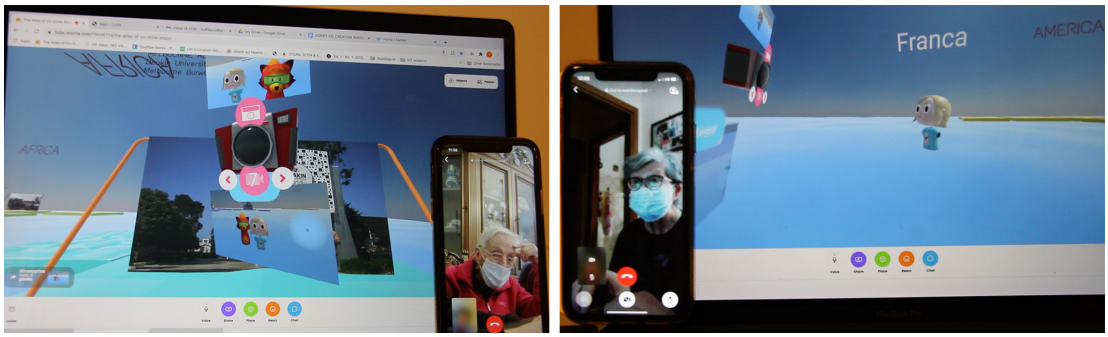

Figure 5.4: The researcher and the participants taking a selfie together in the Atlas environment. The pictures were taken by the researcher, who was also remotely connected to the participants through video call.

The researcher, represented as an avatar, was waiting in the Atlas virtual room for the participant to enter, and remotely greeted the participant as soon as she/he stepped in.

The participant as well was represented through the digital avatar which was selected by her/him during the previous co-creation session. In order to reveal the participant her/his digital avatar appearance, the researcher and the participant took a selfie inside the Hubs environment soon after greeting each other (Fig. 5.4). Then, they toured the environment together walking through the several Co-Drive stops. Each participant was asked which Co-Drive stops she/he would have liked to book for a remote trip and to place their own avatar at that location. At this point the researcher reminded the participant the reason why placing the avatar was an essential step in the experience: the real driver who would be passing by that geographical location could spot the avatar as a digital image on the windscreen, thus realizing that a remote passenger would like to board her/his car for a virtual car trip together. The participants who had multiple favourite avatars, at the moment of booking a Co-Drive stop, were also asked to select the most suitable one to put at that specific location and explain why. As a conclusive act, the researcher prompted participants with a last provocation and confronted each one with the possibility to have a hyper-realistic avatar (Fig. 5.5).

This was technically possible by using a full body picture of each participant as a digital representation. The hyper realistic avatar was placed inside the Atlas environment next to the previously pinned avatar, sparking a conversation with the participant on subjective reactions and preference.

5.4 Discussion

Watching the AR diorama video was key for the participants to get familiar with the role of the avatar, since they were new to that concept. The following selection process of the preferred avatar/s from the avatars board resulted in a quite emotional and quick response by

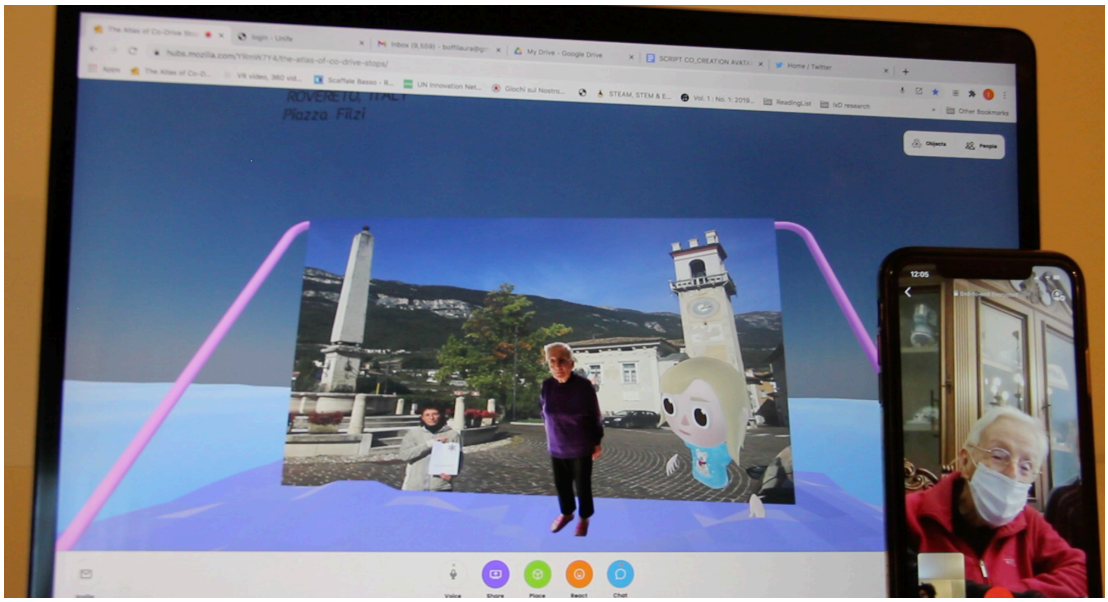

Figure 5.5: A participant, pictured in the smartphone screen of the researcher, sees her hyper-realistic avatar. Again, the prototyping session happened remotely due to Covid-19 restrictions and this picture was taken by the researcher who was connected with her through Google Meet while both were visiting the Atlas on Mozilla Hubs.

all the participants, lasting for a maximum of 30 minutes. No one showed any disappointment that the characters presented in the avatars board were not specifically customized to be physically similar to her/himself, and this may be due to the fact that none of them was aware of the hyper-realistic appearances that could be achieved through computer graphics. Moreover it seemed that each participant was pairing their own self with the avatar that was resonating more with personal memories, beliefs or personality, without questioning the choices the researcher made in building the Avatar board. When interrogated on the reasons for their selection, often participants answered by saying *" That character made an impression on me..."* followed by a personal, subjective explanation, such as: *" I am selecting this avatar [referring to a cartoonish, child-like character] because of her big eyes...she is opening them wide because she would like to see... who knows what! "*, participant G said. *"I*

am crazy for children...I would rather choose this one [referring to a voxels style character] and leave the adult one out [referring to the realistic, senior like avatar]. It reminds me of my grandchildren...”, participant F1 said. A couple of participants also referred to the fact that some avatars were inspiring them trust and self confidence for the way they were standing straight and how focused their gaze was.

3 participants out of 6 discarded the realistic avatars. Participant F2 explained: *”I do not like the human shape...the avatar should inspire fun or tenderness...Look [pointing to a cartoonish avatar], this reminds me of my childhood dolls.”*. Two participants, G and P, who selected a middle aged realistic avatar, had a clear idea about why they were rejecting the elderly looking representations. Participant G told *”It is fine that the [realistic, human like] avatar does not resemble me: I am old, I have wrinkles...I do not see myself well...I am not as I used to be.”* and referring to the younger adult avatar, she followed by saying *I prefer the younger avatar who looks like me of some years ago...”*. Participant P instead said *”This adult avatar looks confident about herself... more awake than the elderly one. It inspires me the confidence... of a person who is [consciously] waiting.”*

An animal shaped avatar was selected by 3 participants out of 6, not as unique preference but in combination with other characters. Again, the reasons of such selections where heterogeneous. Participant M refers she went for the cat avatar *”...because I have had one...”*, while participant F2 found the cat fitting pretty well with the context of the Co-Drive stop at the Colosseum, in Rome (Italy). Participant F2 ended up selecting different avatars in relation to the city where the Co-Drive stops were placed: a robot avatar for New York, to suit the modernity of the city; a cat avatar for Rome, at the Colosseum; a cartoonish avatar for Rovereto, a small village in Northern Italy. Instead, participant G. refused to be represented by an animal- shaped avatar because she felt it inappropriate for the first encounter with the human driver in a public space. Nobody selected the realistic, full height,

elderly avatar. While discarding them, participants commented that: *"It looks like a man, not a woman...", "It looks ill...sad", "It is not similar to me."*

Concerning the follow-up part of the intervention, when participants could navigate the virtual environment of the Atlas of the Co-Drive stops, they could easily recogniz in the 3d environment the stops they had been previously introduced to as print-outs cards. However, each participant took some time to appreciate that the point of view s/he was experiencing from the laptop was actually the one of their virtual self inside the 3D world. Taking a selfie with the researcher inside the virtual environment was a key strategy to revealing them their digital avatar appearance inside the Atlas. No particular reaction was sparked in the participants from pinning the avatar to the Co-Drive stops they selected, so the remote researcher repeatedly prompted them that, by doing so, their avatars would get anchored to the real world and be visible from the windshield of the driver passing by. Instead, all participants were pretty surprised to see their own hyper realistic avatar in the 3d environment, but reacted very differently whether or not going for it or still preferring the one/s selected on paper. One participant asked to change the picture of the hyper realistic avatar with one picturing herself during a family event, even if it might not be a recent one. The reasons she brought up were that she was elegantly dressed and that she was emotionally attached to that picture. Another participant, who had previously favoured several avatars so to match with different locations, decided to use the hyper realistic avatar for the location where she actually lives, Rome. A third participant complained about how poorly her hyper realistic avatar was dressed and wondered whether she would choose that if instead she had properly prepared for the photo shooting.

As a general lesson learned, this intervention showed the importance to give participants plenty of possible choices to select their avatar from, especially if they can't design their own

themselves and if they have no previous reference about what an avatar is. Concerning the need of having the social worker using the computer to show participants around Mozilla hubs, in the future I might consider to design an user interface as the atlas that each participant could access to independently and use without the need of a skilled helper. This could be a physical diorama with figurines to be placed at the nursing home, working as a tangible user interface for the elderly people.

As a conclusive reflection, it seemed to me that participants were less engaged in the follow-up session compared to the previous one, and this made me doubt that the whole concept of booking a Co-Drive stop passed through. I decided to address the issue through an interview with the social worker, who knew very well the participants and their attitude. The social worker agreed that the participants were less talkative and apparently less enthusiast in the follow-up: *"I think that during the first session participants looked more active and engaged...It might be due to what I call "the abstraction effect", which highlighted the novelty of the project and the fun aspect of it. Even if we did give an appearance to the avatars through the print-out cards, I think the experience remained abstract to them because they didn't realize where the avatars might be actually exist and move... Instead, during the second session they were immersed in the experience and this might be the reason of their apparent disengagement. For the first time in their life they have been projected in a virtual domain as a digital self... Their detached behaviour could either be interpreted as a tentative retreat from the whole experience or as an initial shock, in a positive sense, to see themselves as digital characters existing and moving in another dimension. We might expect very different reactions as we going forward to the next step of the prototyping process..."*

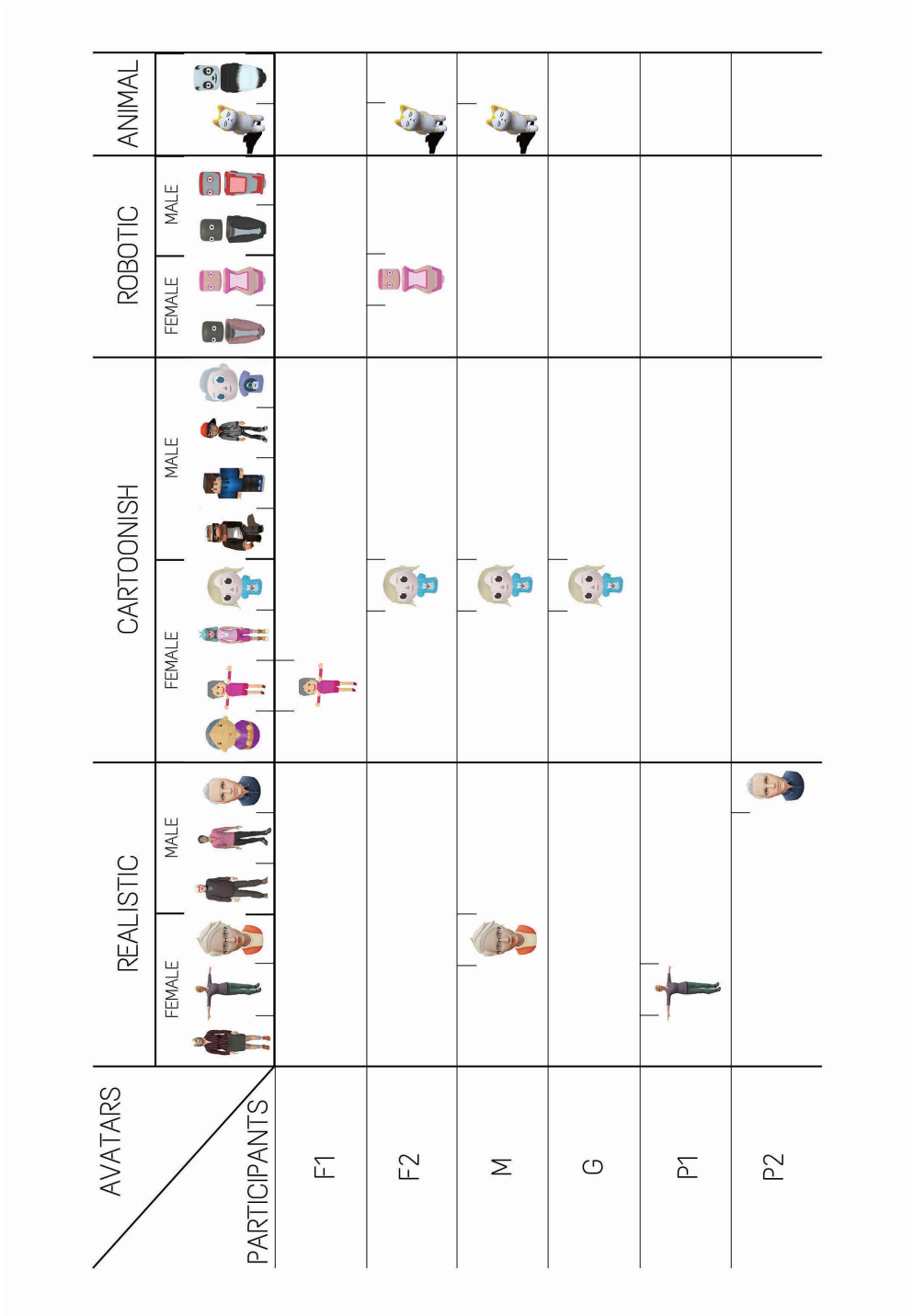

Table 5.1: The avatars selection made by the 6 participants.

Chapter 6

Prototyping intervention 3/ The shared car trip

In Chapter 5, I have described the Prototyping intervention 2/ Booking a Co-Drive trip. I have recruited passenger participants, they have created their avatar through a paper-based co-creation tool kit and they booked a Co-Drive trip by using the virtual Atlas of Co-Drive Stops. In Chapter 6, I will describe the Prototyping intervention 3/ The shared car trip. I will pair driver and passenger participants to run shared car trips in 3 cities in Italy. The car-pod prototype will be deployed. Passengers will test 3 modalities to join the trip: screen, projection and VR headset. Chapter 6 wraps up the experimental study conducted during my PhD research.

This final prototyping intervention was about the shared car trips that were eventually run at the end of the process. Each remote passenger was invited to three shared car trips in three different cities in Italy, where the relative drivers placed their Co-Drive stops and made themselves available to drive for the experiment: Rovereto, Pescara and Milan. Each city trip happened with some weeks of interval between each other, thus to allow the in-car prototype to be shipped to the different driver and the driver to be instructed on how to mount and use it. The three drivers were all around 40 y.o, two males and one female.

The group of participants acting as the remote passengers was the same participating in the previous prototyping intervention, but, due to Covid-19 reasons, one withdrew before the intervention/3 had started, so only 5 persons participated. There was not a fixed duration for the trips: it was left to the participants to end them, even if it was influenced by the power consumption of the equipment and its overheating. Anyway, each trip lasted around 20/40 minutes. Before leaving, the researcher left each participant with a postcard picturing the driver at the Co-Drive stop and invited the remote passenger to write a reflection on it to share back at the following session.
Passengers could try three different interfaces to join the trip by, starting from the desktop and gradually moving to the VR headset and wall projection. The gradual offer of interfaces was arranged as the following:

- during trip 1 and 2, each participant started with the desktop interface and then s/he was prompted to switch to the VR headset after 20 minutes. The session was always individual;
- during trip 3, the participant started with the wall projection and then s/he was prompted to switch to the VR headset after 20 minutes, if the session was individual. If instead the session was joined by a group of 2 participants together, they just experimented the wall projection session.

This plan allowed each participant to experiment with each interface at least for one time.

6.1 The technical set-up

The technical set-up refers to the car pod and the Co-Drive web application. The car pod is the in-car prototype which consists of a 360° camera mounted on the headrest of the passenger

seat in the driver's car, a PC and a software that allows video and audio interaction between driver and the remote passenger by a 4G/5G mobile network connection (Fig. 6.1).

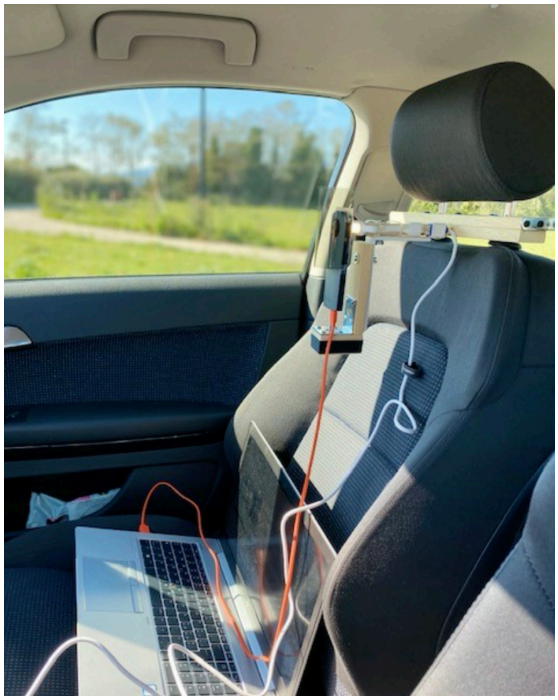

Figure 6.1: The car pod mounted in a car.

The camera is a Rhico Theta V model. It is screwed on a wooden support which can be clamped on the headrest, so to provide a first person perspective (1PP) to the remote passenger. To ensure a right light exposure of the camera's view towards the outside of the windshield, a flash light has been positioned on the back lens of the 360° camera to trick its sensor, as a low-cost and rapid prototyping workaround. Ericsson R&D Italy Innovation Garage offered its collaboration in defining and integrating the open source architecture used by the system to communicate. The software design is mainly based on WebRTC standard that allows a low latency video, data and audio streaming. The drivers were shipped the car pod in advance so that they could mount it on their cars and test it (Fig. 6.2).

Figure 6.2: Driver G. mounting the car pod prototype. The two sunglasses were a quick fix to the overexposure to summer sunlight.

The Co-Drive web application runs over browser, displaying video in VR mode. The application is the access point for both the driver and the remote passenger, who will be able to start their distinct journey by selecting their role in the trip as soon as connecting to the website. On the day of the trip, myself, as the researcher, and the social worker reached the senior at home or at the elderly centre and managed the technical aspects of the trip. The plan was that the seniors would gradually try 3 possible interfaces to join the trip from: the laptop, the VR headset and the wall projection (Fig. 6.3).

The car pod and the Co-Drive web application were developed by the Ericsson Innovation Lab in Genova, Italy, which joined the project as technical collaborator.

The system prototype provided a high fidelity experience to both driver and remote passen-

ger. As the camera in the car streamed 360°, the remote passenger would be able to enjoy the trip as if s/he was sitting at the passenger seat and to look around either through the laptop mouse or by turning the head while wearing the VR headset. Through the system, the remote passenger and the driver could talk to each other in real time during the whole trip.

6.2 Observations and learnings from the trips

The observations and learning from the trips were various from drivers and remote passengers and I clustered them into the following main topics.

Locations of the trip

Some remote passengers were happy to have the chance to visit again a place that already had a personal meaning in their life, like participant P. who had her honey moon in the place of the trip. When instead they have never been to the place, the passengers tried to get as much as possible from the view, trying to draw insights on the local people and discuss that with the driver. Some participants suggested to organizing trips to exotic and far away places, while others said that every place could be fine since they had never had the chance to travel in their life.

All the drivers planned the route to drive through in advance in order to give a particular focus on their conversation, as well as not to adventure through locations with reduced mobile data connection which would have made the system fail. Driver M. tried to show the neighbourhood where he lived, revealing some insights on the history of Milan. Driver G. tried to show the waterfront and the people populating the seaside in Pescara. It was also interesting to pay attention to how the passengers were influencing the drivers on the

way to drive through: sometimes to allow a better view, for example with improved light conditions, the driver made the route twice or decided to stop and park for a while.

Conversations in the car

Lot of talks were about knowing each other: the driver and the passenger were jumping from personal topics to more casual chats about the place. Driver M. pointed out that the first five minutes were the most problematic because each had to introduce each other, but then the conversation flew as when meeting for the first time a new person in the real world. Participant M. also reflected on the fact that he would need some neutral topics to talk about, so that the conversation would not be unbalanced.

Some passengers were interested in their final destination and during the trip they asked the drivers to update about that. They also invited the drivers to stop and take a coffee together, but this kind of action was never really taken into consideration and just sparked a laugh in both participants. Before starting the first trip, participant M. warned that she would likely not talk much because of her personality. Instead, as soon as she met the driver, she started conversing without any problem, using enthusiastic ways of engaging with the driver, such as *"Let's go!"* or *"Where are we travelling to today?"*.

Intergenerational encounters

Some drivers reflected on the age gap with the remote passengers. Driver M. reported: *"[...] I have many acquaintances of 60 y.o.+, but none of them is a "friend". I think it is a complex thing to make friends with a person older than you, because there is an unconscious barrier for both. Then, under some conditions, this barrier may fall apart and we may find out we have the same interests and curiosity towards life."*

Driver L. instead reported that the trips made her reflect on how "being old to someone" is

a relative concept: *" [...] After I surpassed 30 y.o., I realize that younger people started to call me or treating me as an "old person". This is an ageism approach that is much bigger in smallest cities..."*

Remote passengers valued that meeting people of different ages can contribute in making the conversation more various and being exposed to different ways of thinking. Participant G. describes herself as being a very curious person and explicitly said that she prefers that the driver is a young adult. The advantage for her is that, by talking to a person much younger than her, s/he can update herself.

Passenger M. thought that the drivers were not much younger than her instead, but around 50-60 y.o. She explained that they seemed mature persons from their way of talking.

Safety and trust

During the trip, a couple of passengers commented on the drivers way of driving, which inspired safety and trust toward the driver. Participant P. stated that by the way s/he was driving, she could *perceive how the driver was*. She said: *" [..] I want to do it again, with driver L. if possible. She is a fair person, she drives perfectly...she is cautious and always focused on driving even if she was talking to me. I had a serene and safe trip!"*

Participant G. reported that, knowing that the driver was a younger person, she felt safe during the trip because she believed s/he might have quicker reflexes.

Participant M. also appreciated the way the driver G. was talking to her, his kindness and generosity in explaining the surroundings.

Participant F2 reported that the fact that she could turn her head while wearing the VR headset and look at the driver made her feel safe in the car. Referring to the female driver in Rovereto, she also said that she hasn't felt any diffidence towards her maybe because they were both women, and affinity may have derived from that.

Sense of presence

The drivers complained that the system was failing from time to time and the audio connection interrupted. This aspect tremendously influenced the way they felt the remote passenger present during the trip. Otherwise, when the audio was smooth with no latency, driver M. and driver G. reported that it was like having the remote passenger sitting next to them. From the remote passengers, the reactions were pretty similar, expect that the video stream too was influencing their sense of being present in the car. When the video was smooth, with a good resolution, all the participants agree that it was like being in the car.
Participant F2 reported that wearing the VR headset made her feel *"in first person there, living the moment"*.

Remote passengers' interfaces

Passengers could try three different interfaces to join the trip by: they started from the desktop and gradually moved to the VR headset and wall projection (Fig. 6.3).

About the use of the VR headset, I surprisingly didn't come across any rejection towards trying it. I believe that it may be because participants were gradually introduced to it, at the very end of the prototyping process, and as an option among the desktop and the wall projection. Two remote passengers really enjoyed the VR headset. For example, participant F2 reported: *" Joining the trip with the headset is much more real: it seems you are in the middle of it...you see things and people moving around. Instead from the computer it is like watching TV."*. A passenger instead openly said to prefer the desktop because the headset is not so comfortable, especially wearing a Covid-19 mask. A couple of participants asked to join a trip with a fellow passenger from the elderly center, so that they could converse among themselves too and have richer conservations with the driver. To meet that request,

Figure 6.3: The three different interfaces passengers could join the trip by: laptop (top left); VR headset (top right); wall projection (bottom left and right).

both participants were invited to the elderly center and the trip was displayed through a wall projection.

Travelling vs being together

Driver L. and M. described Co-Drive as an experience of "being together" and sharing, more than travelling. The "travel" was just an excuse to be together. For passengers instead the travel aspect was much important and they valued both being together and travelling to new places, though virtually. Most passengers reported that they cannot do real travels anymore and Co-Drive represents an alternative. In this regard, passenger F2 complains that to go on a trip nowadays she always needs someone to go with her, a sort of caregiver, and for this

reason her chances are almost zero unless the daycare organizes it.

Passenger P. has travelled extensively until her husband passed away. She said that: *"Co-Drive is also a way for me to travel with my mind. [...] When I travel with Co-Drive I do not get tired. Travelling has always been important in my life. I would like to do more trips with Co-drive."* Passenger F1 pointed out that Co-Drive represents another way of travelling for her, because one cannot really go there, but it is still a beautiful experience, for different reasons. Passengers M. and G. really value the travelling aspect because Co-Drive makes them discover *"new things"* that they do not know and will never have the chance to get to know otherwise. Passenger G. even suggested to have video recordings of the trips so that she could go back and watch the places again.

The after-trip

All the drivers expressed the interest in driving again with the same people, to meet them again and continue knowing each other, as well as driving with new ones. Passengers as well asked to meet again the same drivers and revisit a place, as well as to change location and meet new drivers from other cities. After the trip in Milan, Driver M. said: *" I am curious of the impression I made to the passengers...".*

Driver L. instead reported: *"I would like to be able to send a picture of the city after our trip has ended... Something tangible that could stay with them as a memory. Or it could be nice if the passengers could take pictures of the trip and then send them back to me."* Many passengers explicitly said that they have memories connected to the Co-Drive trips, both regarding the places and the people they met. Passenger P. also explained that the positive vibe of Co-Drive perpetuates for her through the memories she made of the trips: *"When I am at home sometimes, I think of the Co- Drive trips and recall the nice memories I have. It is a way to fight the solitude I may feel that moment."*

Value of the trips

Driver M. reflected on the fact that Co-Drive was an opportunity for him to " actively care" for people: *" Usually we do not have time for activism in our society, meaning doing something for other people, but this should be the fundamentals of our community way of living. [...] I think Co-Drive could be a way to fight isolation in older people."*

Driver L. reported that: *" I suddently realized that even if the lockdown [due to Covid-19 regulations in Italy] ended up for me, for older people is not the case...and Co-Drive was a way for them to meet people and going around."*

For passenger P., the trip in Rovereto had a particular emotional value, as she described it in the notes on the postcard. The trip made her visit again a place she had been during her honeymoon, and she had beautiful memories (Fig. 6.4).

As already described in the previous sections, for many passengers Co-Drive represented the only feasible way to travel and get to discover things that they would never see otherwise. Moreover, it allows sharing the experience with another person, the driver, who is not a caregiver, but a trip mate.

When I visited again passenger F1, I found out that she displayed the postcard of the previous trip together with her family pictures on the cupboard, and she has been keeping the picture there until now, that 6 months has passed. She motivated that by the fact that she felt connected to driver L., who was pictured in the photo, and somehow it made it a nice memory to be displayed (Fig. 6.5).

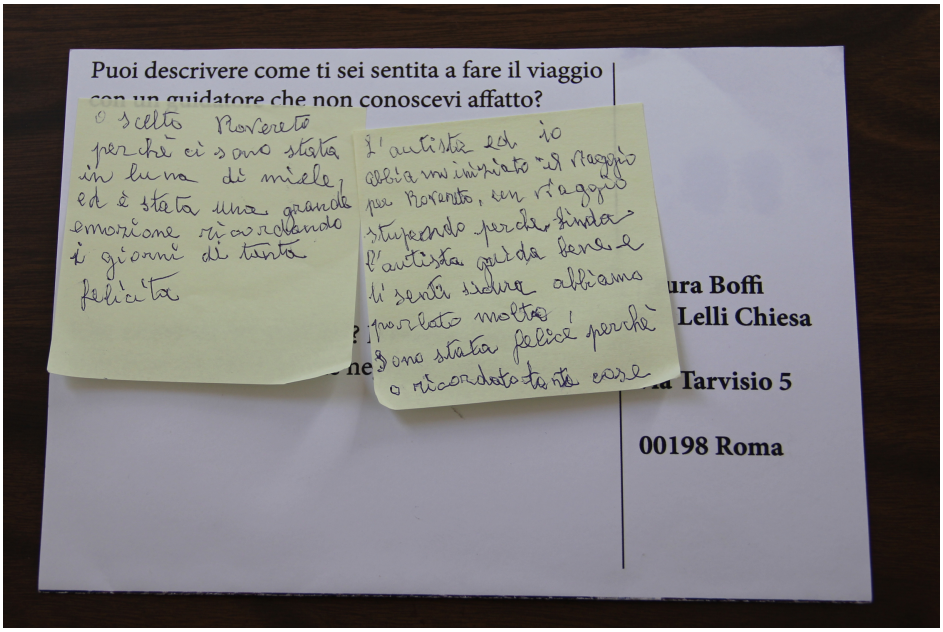

Figure 6.4: Participant P. wrote notes on the Rovereto postcard describing the emotional value of that trip to her.

Figure 6.5: Participant F1 displayed the trip postcard together with her family pictures.

Chapter 7

Conclusions and one more question

Chapter 6 wrapped up the experimental study conducted during my PhD research, describing the last Prototyping intervention/3 The shared car trips which I conducted with drivers and remote passengers in 3 Italian cities, testing 3 modalities to join the car trip: screen, projection and VR headset. In Chapter 7, I will draw initial conclusions on how Co-Drive can enable intergenerational relationships and a new social assemblage to emerge, as well as to tackle the sense of loneliness in senior adults. I will highlight the early prototyping strategy for XR experiences as a contribution for the research domain, as it lowers the technical prototyping barriers and avoids preventive rejection in new users of AR/VR. I will reflect back on the meaning of "intent" in term of social intent of autonomous cars, especially applied to the Co-Drive concept. I will suggest that the capabilities of social "intent" in autonomous cars may emerge through i) teledriving, as a combined intent between the autonomous car and the human; and ii) the in-car interfaces.

At the end of this study, I can start drawing conclusions which fall into three main categories:
i) the initial answers to my research questions;
ii) the early-stage prototyping strategy which allowed participants to enact the Co-Drive experience;
iii) the future of the Co-Drive project.

Surprisingly, this journey took me towards many unpredicted challenges, first among all the Covid-19 pandemic. However, even if the pandemic made everything slower and chaotic, it gave senior participants additional motivations to continue the Co-Drive experiments since they couldn't meet at the elderly center. The fieldwork in Ghana as well was not possible and the experiments with local Trotro drivers had to be paused, although agreements with local institutions had been made and fundings allocated for me. The challenge related to the design of an early-stage prototyping methodology for Co-Drive unfolded in front of me during the progress of the work and it became a big part of my research. For this reason, one of the conclusions of my study is the early-stage prototyping strategy for XR experiences. Among the drawbacks of this study, I want to mention the fact that it mainly focused on the remote passengers experience, postponing the focus on the drivers to a later continuation of the project. This is the reason why the last part of my conclusions is about the future of the Co-Drive project. Unfortunately, I do not have final answers to my research questions, but just initial ones, though encouraging. This may be due to the fact that the research questions I posed to myself were simply too big to be answered in the time of a PhD and that I narrowed down the Co-Drive concept only after a beginning excursus on autonomous driving and its opportunities in terms of new social relationships. I will need to run more Co-Drive trips, engage participants for a longer period of time and make the whole technological system more stable to reach more consistent answers to my research. The good news is that all the initial results call for more research to be done, and I am making room for it in the upcoming months after my doctorate.

7.1 Initial answers to the research questions

At the beginning of the Co-Drive project, I defined the following main questions:
i) How can Co-Drive support intergenerational encounters and relationships?
ii) Which form of social group and togetherness would the Co-Drive trips let emerge?
iii) How can Co-Drive reduce the sense of loneliness in senior adults?
I will unfold the answers I reached through this study below.

How can Co-Drive support intergenerational encounters and relationships?
Senior participants who acted as remote passengers acknowledged that the age gap between the drivers and the remote passengers could stimulate new discussions and vary the kind of people one may potentially encounter. Seniors agreed that in real life they never have the chance to get to know new people of different ages, while Co-Drive could allow this to happen by chance. The accidental nature of the encounters seems to be a key element for the experience from the point of view of the senior participants and should be preserved against any unfortunate attempt of fixing the roles in terms of age. As a matter of a fact, when in a reflection moment at the end of the Prototyping intervention/3 I revealed to seniors that the Co-Drive experimentation they took part to was intentionally planned between young drivers and senior remote passengers, the senior participants firmly suggested that I should keep the age range open in the future, so to get every-age drivers. Participant P. formulated it very clearly: *"It is not the age of the driver that makes the encounter an interesting one, but the mutual interest in knowing each other."* The tension that participant P. and a couple of other participants showed when I unfolded the recruitment strategy of the specific study made me realize that I could easily harm the Co-Drive concept if I had ever defined the roles for the sake of the intergenerational relationships because I would unintentionally confine the project to an assistive domain. Moreover, this is confirmed by the fact that roles could be

switched and the remote passenger could want to take over and drive the car, as envisioned by many senior participants. Co-Drive already embeds the intergenerational aspect by the nature of the concept itself and, the good part of it, lies on the fact there is no need to claim it explicitly.

In terms of intentionality of the Co-Drive experience as an intergenerational program (see Chapter 1), the explicit intention which both the drivers and the remote passengers shared is the curiosity of getting to know new people who may be very different from themselves, and making a car trip together is a way to ease the encounter. The trip doesn't need to be to a new location, but that could be a motivation for specific participants to join the program. During the study, both drivers and remote passengers recognized additional personal motivations, which they couldn't rationalized before they hadn't tried out the experience, such as the caring for another person and the possibility to see again places linked to personal life. As an intergenerational program, Co-Drive supports flexibility in the fact that participants can also accommodate very personal intentions to join beyond the explicit intention of the program.

Which form of social group and togetherness would the Co-Drive trips let emerge?
Co-Drive trips let the collective assemblage of driver - multiple passengers - car ermerge, as participants asked to join the remote trip together from the same physical location. In that case, the video stream was projected on the wall, the audio connection was enabled in the room and the remote passengers were sitting one next to the other facing the wall projection. Some participants referred to prefer such a set-up because it allowed different level of conversation happening at the same time, both between the remote passengers in the room and with the driver. The remote passengers ended up knowing each other better and

continuing their conversation even after the trip when they had the possibility to meet again at the daycare. This opens up new opportunity for the future of Co-Drive, as an activity that could be integrated at the elderly centre and that could involve a group of seniors at a time.

How can Co-Drive reduce the sense of loneliness in senior adults?
Seniors acknowledged that they could see themselves initiating Co-Drive trips when they are at home and liked to be in company, but they regarded the system as too complex at the state it is now for them to manage it. An interesting finding was that some people found themselves tracing back the memories they had of the Co-Drive trips and the drivers in moment of loneliness and boredom at home.

7.2 The early-stage prototyping strategy for XR experiences

The isolation of the Co-Drive interactions into separated prototyping interventions aimed to exploit the existing heterogeneity and seams of the Co-Drive experience in order to explore how people would accommodate and appropriate the system into their everyday activities. To probe the value of the seamful prototyping strategy, I decided to couple my observations and participants feedback with the reflections of the social worker, who actively assisted me and shadowed the whole process. I limited my focus on the remote passengers, since the interventions allowed them to experiment the whole experience, while drivers missed the prototyping of the passenger embodiment in the car, which has been postponed for the near

future. The social worker knew all the participants well, their social relationships and life context before the study and I believed he could provide deeper insights on the impact of the separated prototyping interventions on the way remote passengers accommodated and appropriated the new experience in their life. In his interview, he reported: *"[..] The value of having participants going through the different phases of the experience, without bypassing any and going straight forward to the trip and the VR headset... that would have been a reduced experience. Participants managed to make a parallel with real life between planning a trip in the real world (they need to prepare the luggage, get information, and so on) and visiting the Co-Drive Atlas, positioning their avatar. Between deciding and really going on a trip, there is a gap where you put substance and content. If I look at the question from the point of view of myself as a therapist, working with older people, than I can say that dividing the experience into capsules can lower the barrier to all those people who have no familiarity with technologies and reject them on a preventive level because they have never used them and do not find any need to commit to learn them now . For the people who instead have already a curiosity towards technologies (and there are many among elderly people, they are not conscious of their own potentialities sometimes...), going through the different phases can make them aware of their own potentialities, increase their self-confidence towards the use of technologies and strengthen their knowledge of such technologies. [...] Moreover, the fact that they build their own avatar from paper and then digitally, it was like rehearsing the process ...and the fact that they could navigate a virtual environment...that made them participating in the construction of the experience at their own pace, increasing their knowledge of the medium and the technologies."*

The reflections above plus my observations and participants' feedback suggest that the seamful prototyping strategy supported participants in making sense of the overall experience, beyond the single interactions, even if pieces of technologies were missing or just-enough prototyped. By means of drawing parallelism and point of contacts between the Co-Drive

experience and their own life, participants managed to accommodate and appropriate the Co-Drive experience in their existing network of relationships and context of life. They created cross-reality seams whose evidences can also be retraced in their oral comments and in physical probes. One example is by participant G. and her concern in getting a proper avatar whose appearance could suit the first encounter with an unknown driver in a public space, rejecting the idea of an animal avatar. A physical example could be by participant F. and the postcard of the driver at the Co-Drive stop which she displayed among the family pictures on the cupboard (Fig. 9). According to Weiser [71], in good mixed reality design, a heterogeneous system is so tightly coupled with people's activity and context, that the gaps between the interactions become less significant than the quality of interaction within the whole experience. To summarise, within the same XR system, the technology could be seamful, yet the experience could be seamless if the single interactions interweave with the users' context and activity in a consistent and meaningful way. The learnings drawn from this study make me believe that the seamful prototyping approach could help designers understand if an XR concept may afford people accommodation and appropriation before any major technological endeavour.

Besides that, I also highlight that the prototyping strategy had a particular impact on the participants enacting as remote passengers, who had absolutely no experience with XR technologies and, only a few of them, just an initial acquaintance with common digital devices, such as computer and smartphone. The prototyping strategy contributed to avoid preventive rejection in newcomers because it lowered the entry barrier for those who have never made use of technology in their life and do not find a reason to start at a later age. I think that this may be due to the fact that in the single prototyping sessions the commitment to learn, as well as the interactivity was set to very low and gradual, so that people could focus on the meaning of the Co-Drive experience and not on making it work.

Lowering the entry barrier also increased the possibility for unmotivated people to discover new, exciting, experiences and to be tickled by the curiosity of introducing new technologies in their life. For the few participants who had an initial knowledge of digital technologies, the strategy contributed in increasing their self-confidence in the use of technology. The seamful prototyping strategy revealed the structure of the Co-Drive experience, how it was being built and the technology failures in the system. This provided a safe, technologically incomplete environment for participants to rehearse the experience within, without the risk of "failing" themselves, plus it made people more aware and in control of the technology.

7.3 The future of the Co-Drive project

The Co-Drive project is going to continue after the PhD period following three parallel paths: i) the prototyping of the embodiment of the remote passenger in the car; ii) the co-creation with the staff of the elderly center of a curriculum activity based on the Co-Drive service; iii) the deployment of a long term program of shared trips; iv) how to make the system simpler for people not familiar with AR/VR technologies; v) the prototyping of the experience beyond elderly users. The embodiment of the remote passenger will be prototyped as a robotic headrest in the drivers car. A concrete possibility is to collaborate with the High Performance Humanoid Technologies (H²T) at the Institute for Anthropomatics and Robotics at Karlsruhe Institute of Technology (KIT). They offered me a design residency through the Eu project Terrinet [72], but, due to the lack of additional funding, it didn't happen yet. The objective of my collaboration with H²T will be to enable the Co-Drive headrest to move in a synchronous way with the head of the remote passenger connected via VR at home, so to allow the partial embodiment of that person in the passenger seat. I will make use of the H²T Humanoid Head robot, already developed by the H²T group, as a

material to prototype with. My broader research aim is to conduct an ecologic observation of the social interactions emerging between the drivers and the remote passengers during a series of Co-Drive trips which I will organize in real contexts, and in particular how the technological solution in the car affects this interaction. This future study will help me answer secondary research questions about how Co-Drive could act as a counter-narrative to help with fighting a biased, stereotyped and problematic understandings of older adults.
The co-creation with the staff of the elderly center has been inspired by the feedback of the remote passengers and the social worker who assisted me during the study. The elderly center participants, infact, suggested to integrate the Co-Drive trips as a regular activity of the day care. The social worker jumped on this idea and envisioned how the whole process of building one's own avatar, booking a trip, and so on, could become part of the weekly schedule at the center and have a real impact on people. I will organize a co-creation workshop with the elderly center staff to design how the interactions of the Co-Drive service could be performed at the elderly care and which interfaces would support the different interactions between the drivers and the remote passengers at the center. Moreover, I will focus on the role of the social worker as the facilitator in the whole experience and how s/he could be supported within the project.
I will organize a long term program of Co-Drive trips, broadening the call for drivers. I aim to collect more numerous and reliable insights from participants, both drivers and remote passengers. This will be key to understand the social impact of Co-Drive in the long term and the value that participants will give to such an experience.
In the future, I aim to make the system simpler for people not familiar with AR/VR technologies to manage. As a concrete example, I will focus on the Atlas of Co-Drive stops and how to make senior participants independent from the technological help of the social worker who was managing Mozilla hubs. As described in Chapter 5, a direction could be to iterate the design of the atlas and make it into a physical diorama with figurines to be placed at

the nursing home, working as a tangible user interface for the elderly people.

To conclude, I would like to test the experience with remote passengers of different ages, without limiting the recruitment to elderly people, as I did in my PhD research. To be true, as a demo presentation Co-Drive has already been presented and tested at CHI 2021 and ISMAR 2021 conference, thus allowing conference attendees of any age to board a car in Rome (Italy) as remote passengers [73] [74]. Even if those tests were just conducted as technological demonstrations, I noticed that they started to elicit a different range of initial reactions from remote participants, whose analysis goes beyond the scope of this thesis, but which will be worth exploring in the future continuation of the project.

7.4 One more question: does it need to be an autonomous car? What and whose intent then?

In a nutshell, the answer is the following, and in the following subsection I will elaborate on that.

No, it doesn't, at least at this stage of the prototyping process in which the experience of the remote trip has been validated without switching the driving roles, yet nevertheless remote passengers could envision themselves teledriving the car and could anticipate the value that such an activity would have for them.

Yes, it will need to be an autonomous car if we want Co-Drive to embed social intentions other-than human's.

7.4.1 Teledriving as an enabler of embedded social intent in autonomous car

So far, I haven't deployed a prototyping intervention to introduce to the remote passengers the possibility to take over and drive the car remotely, which indeed would be possible only if the vehicle was an autonomous car and it could correct itself the trajectory and the speed in real time. In line with my gradual prototyping strategy, I decided not to introduce autonomous driving to the participants at the same time they were introduced to AR and VR technologies, and rather postpone it to another phase of the project. It seemed to me that delivering prototyping interventions as *episodes* allowed the design process to follow the pace of the participants while they were making their own sense of the new experience and appropriating the new technologies.

Nevertheless, during a final workshop with remote passengers that wrapped-up our collaboration, I launched the idea that in the next phase they may have the possibility to drive the car remotely, without worrying of the safety issues because the in-car technology would be able to correct the trajectory and the speed of the vehicle and to be aware of other road users. Two participants (out of five) rejected the idea explaining that driving has never been their passion and that they have always been so scared of driving to the point of never getting the driving licence. Other two, instead, who used to drive, jumped on the idea. Participant G. envisioned she would like to drive in a city she has never been to, like New York, and that it would be herself to host some local person in the car, in a sort of *reverse Co-Drive*.

For some other participants the autonomous driving capability of teledriving would make the Co-Drive concept more exciting, but they would need to experiment such scenarios for real because it was too hard to imagine the implications.

7.4.2 Emerging intents: combined intent and in-car interfaces intent

I posed this question at the beginning of Chapter 1 - *"What and whose intent?"* - and left it open until the final conclusions of the work.
In order to probe if autonomous cars could also include social intentions, I have explored two design concepts, I decided to focus on the Co- Drive service and studied the emerging social relationships between humans through autonomous cars. At the end of my exploration, I can draw 2 main findings around the capabilities of social intent in autonomous cars:

- Combined intent between the autonomous car and the human
- In-car interfaces intent

Combined intent between the autonomous car and the human
If a remote passenger will actually take over and teledrive, as in Co-Drive, the automated system will need to take account of her/his driving intentions, watch over and improve trajectory and speed if needed. The resulting driving activity will be a combination of the human intent plus the autonomous car intent. This finding draws from the traditional definition of intent in autonomous car, according to which it is meant as the short term plan that the car will perform in an autonomous way, such as slowing down, breaking to let a pedestrian cross, following a particular trajectory, and so on.

In-car interfaces intent
By expanding the design area of autonomous cars beyond the driving and safety capabilities, I designed and prototyped the Co-Drive service as an extended reality experience (XR) supported by several interfaces. Co-Drive interfaces spread inside and outside the car, ranging

from the AR windscreen and the robotic passenger seat to the digital avatar and the Atlas of Co-Drive stops. Focusing on in-car interfaces, the social attitude of a car could be expressed through such interfaces, by their capability i) to spot and board remote passengers, as in case of the AR windscreen, and ii) to host and embody remote passengers during the car trip.

What if through its windscreen the car would express an intention to reach avatars at a Co-Drive stop to the driver and other occupants? What if through its robotic passenger seat the car would express its intention to board and embody remote passengers to the driver and other occupants?

This could be part of the future development of the project: to prototype the social intent of the in-car interfaces and to broaden the definition of autonomous cars beyond the driving and safety capabilities, the already mentioned short term plan of the autonomous car, and towards a social attitude, as what it could be its long term plan.

In an interview, designer and educator Antony Dunne said: *"We need alternative narratives – not just the motive of optimisation – driving technological development."* [75]. I will conclude that I did not collect motives of optimisation for autonomous driving technology in my Co-Drive research, yet I developed and (partly) prototyped an alternative narrative departing from autonomous cars premises that suggests different technological development for mobility experiences inside and outside the car.

Bibliography

[1] C. Breazeal, *Designing sociable robots*. MIT press, 2004.

[2] Greenfield-Labs and Gehl, "Living streets," 2018. Retrieved January 2, 2021 from https://www.ourlivingstreets.com.

[3] A. Shariff, J.-F. Bonnefon, and I. Rahwan, "Psychological roadblocks to the adoption of self-driving vehicles," *Nature Human Behaviour*, vol. 1, no. 10, pp. 694–696, 2017.

[4] F. Ekman, M. Johansson, and J. Sochor, "Creating appropriate trust in automated vehicle systems: A framework for hmi design," *IEEE Transactions on Human-Machine Systems*, vol. 48, no. 1, pp. 95–101, 2017.

[5] A.-K. Frison, P. Wintersberger, A. Riener, C. Schartmüller, L. N. Boyle, E. Miller, and K. Weigl, "In ux we trust: Investigation of aesthetics and usability of driver-vehicle interfaces and their impact on the perception of automated driving," in *Proceedings of the 2019 CHI conference on human factors in computing systems*, pp. 1–13, 2019.

[6] A. L. Baker and J. R. Keebler, "Factors affecting performance of human-automation teams," in *Advances in Human Factors in Robots and Unmanned Systems*, pp. 331–340, Springer, 2017.

[7] A. Löcken, W. Heuten, and S. Boll, "Autoambicar: Using ambient light to inform drivers about intentions of their automated cars," in *Adjunct Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '16 Adjunct, (New York, NY, USA), p. 57–62, Association for Computing Machinery, 2016.

[8] A. Löcken, A.-K. Frison, V. Fahn, D. Kreppold, M. Götz, and A. Riener, *Increasing User Experience and Trust in Automated Vehicles via an Ambient Light Display.* New York, NY, USA: Association for Computing Machinery, 2020.

[9] P. Wintersberger, A.-K. Frison, A. Riener, and T. v. Sawitzky, "Fostering user acceptance and trust in fully automated vehicles: Evaluating the potential of augmented reality," *PRESENCE: Virtual and Augmented Reality*, vol. 27, no. 1, pp. 46–62, 2019.

[10] J. Zihsler, P. Hock, M. Walch, K. Dzuba, D. Schwager, P. Szauer, and E. Rukzio, "Carvatar: Increasing trust in highly-automated driving through social cues," in *Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications Adjunct*, pp. 9–14, ACM, 2016.

[11] E. Vinkhuyzen and M. Cefkin, "Developing socially acceptable autonomous vehicles," in *Ethnographic Praxis in Industry Conference Proceedings*, vol. 2016, pp. 522–534, Wiley Online Library, 2016.

[12] D. Dey, A. Habibovic, A. Löcken, P. Wintersberger, B. Pfleging, A. Riener, M. Martens, and J. Terken, "Taming the ehmi jungle: A classification taxonomy to guide, compare, and assess the design principles of automated vehicles' external human-machine interfaces," *Transportation Research Interdisciplinary Perspectives*, vol. 7, p. 100174, 2020.

[13] D. Dey, C. de Zeeuw, M. Bruns, and B. Pfleging, *Shape-Changing Interfaces as EHMIs: Exploring the Design Space of Zoomorphic Communication between Automated Vehicles and Pedestrians*, p. 137–141. New York, NY, USA: Association for Computing Machinery, 2021.

[14] H. Strömberg, I. Pettersson, J. Andersson, A. Rydström, D. Dey, M. Klingegård, and J. Forlizzi, "Designing for social experiences with and within autonomous vehicles–exploring methodological directions," *Design Science*, vol. 4, 2018.

[15] B. C. Stahl, N. McBride, K. Wakunuma, and C. Flick, "The empathic care robot: A prototype of responsible research and innovation," *Technological Forecasting and Social Change*, vol. 84, pp. 74–85, 2014.

[16] L. Boffi, "Co-drive." Video, Mar 2018. Retrieved June 17, 2021 from https://vimeo.com/259302417.

[17] M. Buchenau and J. F. Suri, "Experience prototyping," in *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '00, (New York, NY, USA), pp. 424–433, ACM, 2000.

[18] J. Halse, E. Brandt, B. Clark, and T. Binder, *Rehearsing the future*. The Danish Design School Press, 2010.

[19] M. Slater, "A note on presence terminology," *Presence connect*, vol. 3, no. 3, pp. 1–5, 2003.

[20] Kayvon Beykpour, Joe Bernstein, Aaron Wasserman, Tyler Hansen, Geraint Davies, "Periscope," 2017.

[21] E. Brandt, T. Binder, L. Malmborg, and T. Sokoler, "Communities of everyday practice and situated elderliness as an approach to co-design for senior interaction," in *Proceedings of the 22Nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction*, OZCHI '10, (New York, NY, USA), pp. 400–403, ACM, 2010.

[22] L. Boffi, "First co-drive experience prototyping." Video, June 2019. Retrieved June 18, 2019 from https://vimeo.com/342940436.

[23] S. Serholt, S. Ljungblad, and N. N. Bhroin, "Introduction: special issue—critical robotics research," 2021.

[24] M. Kaplan, L. L. Thang, M. Sánchez, and J. Hoffman, *Intergenerational Contact Zones: Place-based Strategies for Promoting Social Inclusion and Belonging*. Routledge, 2020.

[25] R. Beamish and S. Wolfe, "Hidden in plain sight: How intergenerational relationships can transform our future." Stanford Center on Longevity, June 2016. Retrieved Jan 11, 2022 from https://longevity.stanford.edu/hidden-in-plain-sight-how-intergenerational-relationships-can-transform\-our-future.

[26] J. Danely, "Playful perspectives and everyday spaces: Imagining a bus stop as an intergenerational contact zone," in *Intergenerational Contact Zones*, pp. 69–74, Routledge, 2020.

[27] E. Laurier and T. Dant, *What else we do while driving: towards the driverless car*, pp. 223–244. Transport and Society, Ashgate Publishing, 2012.

[28] T. Dant *et al.*, "By car: carrying modern society," in *Ordinary consumption*, pp. 151–166, Routledge, 2013.

[29] T. Dant, "The driver-car," *Theory, culture & society*, vol. 21, no. 4-5, pp. 61–79, 2004.

[30] D. Burema, "A critical analysis of the representations of older adults in the field of human–robot interaction," *AI & SOCIETY*, pp. 1–11, 2021.

[31] E. Laurier, H. Lorimer, B. Brown, O. Jones, O. Juhlin, A. Noble, M. Perry, D. Pica, P. Sormani, I. Strebel, *et al.*, "Driving and 'passengering': Notes on the ordinary organization of car travel," *Mobilities*, vol. 3, no. 1, pp. 1–23, 2008.

[32] E. Laurier and T. Dant, "What else we do while driving," *Mobilities, Ashgate, Aldershot, repr*, pp. 223–44, 2016.

[33] P. Milgram and F. Kishino, "A taxonomy of mixed reality visual displays," *IEICE TRANSACTIONS on Information and Systems*, vol. 77, no. 12, pp. 1321–1329, 1994.

[34] M. Hirose, Y. Ohta, and S. Feiner, "Guest Editors' Introduction," *Presence: Teleoperators and Virtual Environments*, vol. 11, pp. iii–iv, 04 2002.

[35] R. Grasset, J. Looser, and M. Billinghurst, "Transitional interface: Concept, issues and framework," in *Proceedings of the 5th IEEE and ACM International Symposium on Mixed and Augmented Reality*, ISMAR '06, (USA), p. 231–232, IEEE Computer Society, 2006.

[36] M. Billinghurst, H. Kato, and I. Poupyrev, "The magicbook: a transitional ar interface," *Computers & Graphics*, vol. 25, no. 5, pp. 745–753, 2001.

[37] R. Skarbez, M. Smith, and M. C. Whitton, "Revisiting milgram and kishino's reality-virtuality continuum," *Frontiers in Virtual Reality*, vol. 2, 2021.

[38] N. Ashtari, A. Bunt, J. McGrenere, M. Nebeling, and P. K. Chilana, *Creating Augmented and Virtual Reality Applications: Current Practices, Challenges, and Opportunities*, p. 1–13. New York, NY, USA: Association for Computing Machinery, 2020.

[39] M. Billinghurst and M. Nebeling, *Rapid Prototyping of XR Experiences*. New York, NY, USA: Association for Computing Machinery, 2021.

[40] N. Ashtari, A. Bunt, J. McGrenere, M. Nebeling, and P. K. Chilana, *Creating Augmented and Virtual Reality Applications: Current Practices, Challenges, and Opportunities*, p. 1–13. New York, NY, USA: Association for Computing Machinery, 2020.

[41] M. Speicher, K. Lewis, and M. Nebeling, "Designers, the stage is yours! medium-fidelity prototyping of augmented amp; virtual reality interfaces with 360theater," *Proc. ACM Hum.-Comput. Interact.*, vol. 5, may 2021.

[42] K. Son, H. Chun, S. Park, and K. H. Hyun, *C-Space: An Interactive Prototyping Platform for Collaborative Spatial Design Exploration*, p. 1–13. New York, NY, USA: Association for Computing Machinery, 2020.

[43] H.-J. Kim, J.-W. Kim, and T.-J. Nam, "Ministudio: Designers' tool for prototyping ubicomp space with interactive miniature," in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, (New York, NY, USA), p. 213–224, Association for Computing Machinery, 2016.

[44] A. Kelly, R. B. Shapiro, J. de Halleux, and T. Ball, *ARcadia: A Rapid Prototyping Platform for Real-Time Tangible Interfaces*, p. 1–8. New York, NY, USA: Association for Computing Machinery, 2018.

[45] T. Glenn, A. Ipsita, C. Carithers, K. Peppler, and K. Ramani, *StoryMakAR: Bringing Stories to Life With An Augmented Reality amp; Physical Prototyping Toolkit for Youth*, p. 1–14. New York, NY, USA: Association for Computing Machinery, 2020.

[46] G. Leiva, C. Nguyen, R. H. Kazi, and P. Asente, *Pronto: Rapid Augmented Reality Video Prototyping Using Sketches and Enaction*, p. 1–13. New York, NY, USA: Association for Computing Machinery, 2020.

[47] R. Suzuki, R. H. Kazi, L.-y. Wei, S. DiVerdi, W. Li, and D. Leithinger, *RealitySketch: Embedding Responsive Graphics and Visualizations in AR through Dynamic Sketching*, p. 166–181. New York, NY, USA: Association for Computing Machinery, 2020.

[48] M. Nebeling, K. Lewis, Y.-C. Chang, L. Zhu, M. Chung, P. Wang, and J. Nebeling, *XRDirector: A Role-Based Collaborative Immersive Authoring System*, p. 1–12. New York, NY, USA: Association for Computing Machinery, 2020.

[49] M. Nebeling, J. Nebeling, A. Yu, and R. Rumble, *ProtoAR: Rapid Physical-Digital*

Prototyping of Mobile Augmented Reality Applications, p. 1–12. New York, NY, USA: Association for Computing Machinery, 2018.

[50] M. Nebeling and K. Madier, *360proto: Making Interactive Virtual Reality amp; Augmented Reality Prototypes from Paper*, p. 1–13. New York, NY, USA: Association for Computing Machinery, 2019.

[51] S. Dow, J. Lee, C. Oezbek, B. MacIntyre, J. D. Bolter, and M. Gandy, "Wizard of oz interfaces for mixed reality applications," in *CHI '05 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '05, (New York, NY, USA), p. 1339–1342, Association for Computing Machinery, 2005.

[52] R. Skarbez, M. Smith, and M. C. Whitton, "Revisiting milgram and kishino's reality-virtuality continuum," *Frontiers in Virtual Reality*, vol. 2, 2021.

[53] L. Boffi, "Co-drive scenario," 2018. Retrieved January 2, 2021 from https://www.vimeo.com/259302417.

[54] S. Benford, G. Giannachi, B. Koleva, and T. Rodden, *From Interaction to Trajectories: Designing Coherent Journeys through User Experiences*, p. 709–718. New York, NY, USA: Association for Computing Machinery, 2009.

[55] T. Ingold, *Lines: a brief history*. Routledge, 2016.

[56] M. Chalmers and A. Galani, "Seamful interweaving: Heterogeneity in the theory and design of interactive systems," in *Proceedings of the 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques*, DIS '04, (New York, NY, USA), p. 243–252, Association for Computing Machinery, 2004.

[57] Data.worldbank.org, "Population ages 65 and above, male - italy," 2021. Retrieved

January 2, 2021 from https://data.worldbank.org/indicator/SP.POP.65UP.MA.IN?locations=IT.

[58] L. Boffi, "Where would you place a co-drive stop?," 2020. Retrieved January 2, 2021 from https://carswithanintent.com/atlas-of-codrive-stops.

[59] L. Boffi, "Designing for place-making in xr: the process of the co-drive stops and its atlas," in *Media Architecture Biennale 20*, pp. 210–214, 2021.

[60] E. Brandt, T. Binder, L. Malmborg, and T. Sokoler, "Communities of everyday practice and situated elderliness as an approach to co-design for senior interaction," in *Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction*, OZCHI '10, (New York, NY, USA), p. 400–403, Association for Computing Machinery, 2010.

[61] J. Hart, "Informality, urban transport infrastructure, and the lessons of history in accra, ghana," *Routledge Handbook of Urban Planning in Africa*, pp. 320–338, 2019.

[62] A. P. Kambunga, R. C. Smith, H. Winschiers-Theophilus, N. Pinto, X. B. Abril, L. Boffi, E. Dzisi, T. Zaman, D. H. Ibinarriaga, A. Chahine, *et al.*, "Pluriversal design: A virtual decolonising exhibition," in *Supplementary Proceedings of the 10th International Conference on Communities & Technologies*, EUSSET, 2021.

[63] L. Boffi, "Atlas of co-drive stops," 2020. Retrieved January 2, 2021 fromhttps://hubs.mozilla.com/YRmW7Y4/.

[64] R. Carrasco, S. Baker, J. Waycott, and F. Vetere, "Negotiating stereotypes of older adults through avatars," in *Proceedings of the 29th Australian Conference on Computer-Human Interaction*, OZCHI '17, (New York, NY, USA), p. 218–227, Association for Computing Machinery, 2017.

[65] M. Bastioni, S. Re, and S. Misra, "Ideas and methods for modeling 3d human figures: The principal algorithms used by makehuman and their implementation in a new approach to parametric modeling," in *Proceedings of the 1st Bangalore Annual Compute Conference*, COMPUTE '08, (New York, NY, USA), Association for Computing Machinery, 2008.

[66] makehumancommunity.org, "Make human open source software," 2013. Retrieved January 2, 2021 from http://www.makehumancommunity.org/.

[67] S. Turkle, "Constructions and reconstructions of self in virtual reality: Playing in the muds," *Mind, Culture, and Activity*, vol. 1, no. 3, pp. 158–167, 1994.

[68] W. L. Cheong, Y. Jung, and Y.-L. Theng, "Avatar: A virtual face for the elderly," in *Proceedings of the 10th International Conference on Virtual Reality Continuum and Its Applications in Industry*, VRCAI '11, (New York, NY, USA), p. 491–498, Association for Computing Machinery, 2011.

[69] K. Fong and R. A. Mar, "What does my avatar say about me? inferring personality from avatars," *Personality and Social Psychology Bulletin*, vol. 41, no. 2, pp. 237–249, 2015.

[70] Mozilla, "Mozilla hubs," 2020. Retrieved January 2, 2021 from http://hubs.mozilla.com.

[71] M. Weiser, "Creating the invisible interface: (invited talk)," in *Proceedings of the 7th Annual ACM Symposium on User Interface Software and Technology*, UIST '94, (New York, NY, USA), p. 1, Association for Computing Machinery, 1994.

[72] E. Commission, "The european robotics research infrastructure network." Retrieved January 2, 2021 from https://cordis.europa.eu/project/id/730994.

[73] L. Boffi, G. Mincolelli, S. Bertucci, F. Pes, M. Garofoli, and L. Gammarota, "Co-drive: Experiencing social virtual travel on a car trip," in *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI EA '21, (New York, NY, USA), Association for Computing Machinery, 2021.

[74] L. Boffi, G. Mincolelli, S. Bertucci, L. Gammarota, F. Pes, and M. Garofoli, "Co-drive: the experience of a shared car trip between a driver and a remote passenger," in *2021 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, pp. 497–499, IEEE, 2021.

[75] T. Geisler, "Interview with dunne raby." Retrieved January 2, 2021 from www.designmuseum.de/en/ueber-design/interviews/detailseiten/interview-dunne-raby.html.