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Collecting People's Preferences in Immersive Virtual Reality: A Case Study on Public Spaces in Singapore, Germany, and France

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Abstract: In the design of urban public spaces, the inclusion of diverse voices enhances the development of products and services by synchronising designer expertise with people's preferences. Multiple participatory methods exist, each with their respective benefits and drawbacks in terms of the quality of results, time and cost needed for preparing and conducting studies, and knowledge required for participation. Providing more concrete representations of abstract or intangible design concepts would be beneficial for laypeople unfamiliar with design or the case study. We propose a Virtual Reality (VR) platform to discover subjective preferences on public waiting rooms through immersive design experiences. The VR platform was tested with 463 participants with variety in age and cultural background. Following a qualitative data analysis, we discuss the suitability of our VR platform for fostering inclusive participation and how it impacts the role of the designer, as well as propose design guidelines for future VR studies.

Keywords: virtual reality; participatory design method; user preferences; design guidelines

1. Introduction

Current participatory design approaches let people express their needs and wants by Current participatory design approaches let people express their needs and wants by generating, elaborating, evaluating, and challenging solution approaches (Kohler et al., 2017). However, some of these approaches involve a considerable amount of time and cost. Furthermore, using abstract methods for studies of hypothetical nature could lead to wrong design directions caused by a potential lack of comprehensibility and imagination of the study context for participants (based on Abley, 2000; Hirsch, 2014). Consequently, participants' stated preferences could show great discrepancies compared to their actual preferences due to a lack of imagination and experience of the study context (Bann, 2002; Murphy et al., 2003).

Immersive Virtual Reality (VR) could be a game changer for designers to solve this issue. Especially when scenarios or prototypes are too expensive or not feasible for manufacturing, the technology of VR enables immersive experiences that convey a desired message in a realistic and tangible way (Mihelj et al., 2013). However, this technology might be inaccessible for societal stakeholders such as seniors. Furthermore, aspects such as gender, place of living, and prior experience with VR could also have an influence on technology savviness.

Considering the aforementioned aspects, in the present study, we propose a VR platform for collecting people's preferences based on immersive experiences. As our research objectives, we want to explore i) if VR is a suitable tool for designers to collect preferences while considering people with various demographics, age groups, and prior knowledge with VR, and ii) how this method changes the role of the involved designers during the application development process and data collection.

2. Related Work

Current approaches in product development including the creation of meaning and value are shifting from company-centred to user-centred approaches (Prahalad and Ramaswamy, 2004). Thus, designers increasingly involve people into the design process for shared value creation activities since this involvement leads to the identification of people's needs and wants and increases the efficiency of product development while creating relationships with people (Prahalad and Ramaswamy, 2004). Variants of participatory practices are participatory design, co-design, and co-creation (Sanders and Stappers, 2008, 2012). A whole landscape of methods for participatory activities exist including methods such as paper prototyping, collages, diaries, card sorting, questionnaires, and interviews (Bartl et al., 2010; O'Haire et al., 2011; Sanders et al., 2010). While these methods show great benefits such the capability to facilitate collaboration and establish dialogues, they also show limitations such as a lack of comprehensibility for hypothetical studies, high involvement of time and cost, and low motivation for participation (Bann, 2002; Murphy et al., 2003; O'Haire et al., 2011). Nelson and Towriss (1995) investigated the accuracy of people's preferences in consideration of visual representation and concluded that individuals had problems making choices based on abstract attributes presented in textual form (based on Abley, 2000). Farooq et al. (2018) conducted a study to collect people's preferences in VR in the domain of pedestrian research. The researchers conclude that VR has the potential to improve the collection of people's preferences based on the establishment of experiences as a foundation for participants to express themselves. Farooq et al. (2018) further points out limitations such as requiring a considerable amount of expertise for the development as well as a great amount of effort for developing such a tool.

The usage of VR for data collection can also be challenging due to the uncertainty to which extent the technology is suitable for diverse people in consideration of aspects such as gender, age, societies with varying access to and perception of technology in general, or prior

knowledge regarding VR (Pick and Azari, 2009; Stadler et al., 2019; Venkatesh and Morris, 2000). O'Brien et al. (2012) discuss experiences of technologies considering age and prior knowledge. The researchers conclude that designers need to understand the targeted user group's prior knowledge with technology to facilitate the usage for participants with little training or instruction. Gregor and Newell (2001) state that seniors have different capabilities in terms of physical, sensory, and cognitive functionality compared to younger people. Thus, seniors for instance have different needs than children, especially in terms of accessibility to technology.

3. Method

In order to answer our aforementioned research objectives, we share our experiences, observations, and statements from our stakeholders throughout the process of VR platform development and data collection. We describe our experiences while testing our application with a diverse group of people and highlight the impact of developing and using our VR platform based on a predefined criteria set, including aspects such as validity and reliability of our results, time, costs, the complexity for the involved designers, as well as the complexity for participants.

3.1 General introduction to the case study

The case study dealt with the collection of spatial preferences of waiting rooms for public transport (e.g., metro or bus) for the development of future transport infrastructure. Local transport authorities were stakeholders in this project who were interested in considering a wide range of people's voices for creating future public transport waiting rooms. Therefore, the aim was to collect data from 400+ participants from Singapore, Germany, and France.

The VR platform was created to enable participants to configure an indoor waiting room based on the variables of room proportions, wall colour schemes, brightness of the room, and crowd level. A VR indoor environment was chosen to minimize the risk of distraction for participants, caused by independent influences from the outside environment (e.g., its visual representation or animations of traffic and/or crowd).

3.2 Development of the VR platform

During the development of the VR platform, we explored how our designers engaged with other fields for interdisciplinary collaborations and how the role of our designers changed during this phase.

Since one requirement from the transport authorities was the consultation of the public that includes diverse participant groups, events such as trade fairs, public exhibitions, scientific events, as well as community centre events were chosen for the data collection. Therefore, a low-cost stand-alone Head-Mounted Display (HMD), called Oculus Go, was used due to its flexibility and independence of high-performance computers and wiring. One benefit of using the Oculus Go device was the ensured privacy for participants throughout the

whole experience since their first-person-view was not visible to anyone else. We decided against offering a locomotion option for participants in VR via the touchpad since this would have needed an extended introduction and could have led to motion sickness. Therefore, we decided to offer teleportation points inside the configurator that allow participants to experience the room selections from a range of position points and perspectives.

To achieve a centralized collection and categorization of data, we decided to include a consent agreement form as well as the background questionnaire in the VR application. The background questionnaire asked participants for their age, gender, place of living, as well as prior experience with VR. Since we conducted the test in three different countries, we included three languages modes (i.e., English, German, and French) from which the participants could choose one language at the beginning of the VR experience.

The interactive configurator in VR constituted the core of our VR application. It consisted of an adaptable indoor environment that was visually similar to underground metro stations. The participants could change the variables of room proportion, colour scheme of the wall, brightness of the room, and crowd level with the help of a user interface that could be hidden when it was not in use (Figure 1). When the participants changed a variable, the surrounding automatically updated accordingly, thus allowing participants to directly experience a certain configuration in VR in an immersive way.
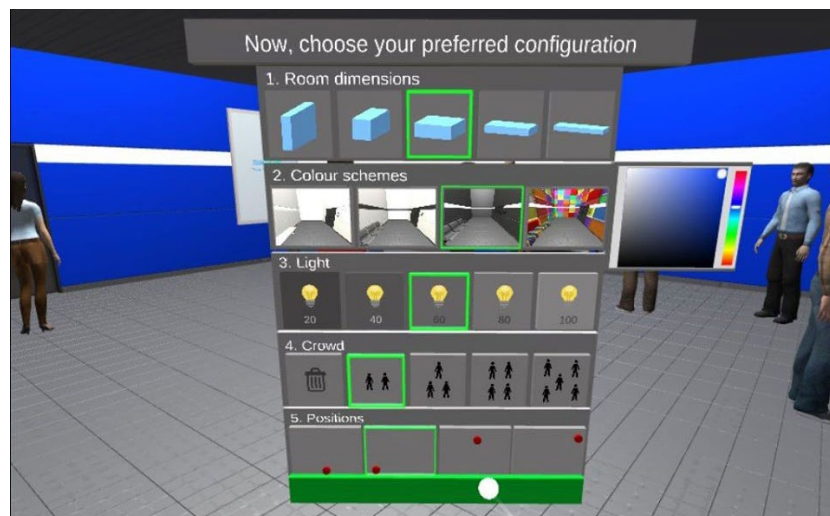

Figure 1   User interface of the interactive configurator

The participants interacted with the VR system by aiming at an option with the input raycast and select the respective option by pressing a button. This interaction technique was maintained throughout the whole VR experience.

The application was internally developed using the game engine Unity (version 2018.3.0). The timeframe from initiating the project to the completion of application development was four months, involving the continuous effort of two designers, two software developers, one 3D visualizer, and a team member with a degree in psychology.

3.3 Data collection and test of the VR platform

Besides gathering preferences about public spaces, the data collection concurrently enabled the testing of our VR platform. We explored the impact the immersive experiences had on the participants for expressing their preferences. Moreover, we investigated the role of our designers during the data collection with the VR application.

We tested our VR platform at public events in Singapore, Germany, and France at a trade fair, an open exhibition, a science event, a university information day, as well as two data collection events in community centres. Thus, we reached out to exhibition visitors, passer-by, students, families, children, and senior communities to include a diverse group of participants in terms of age, place of living, and prior experience in VR. Since the aim was to collect data from a large group (400+) of individuals from different backgrounds and test to which extent VR can be used by all, the only inclusion criterion to participate in the study was the ability to read in English, German, or French. During the data collection, we documented participants' feedbacks, comments, and stated excitement or disappointment.

At least one researcher per VR device was continuously present during every event to allow efficient data collection.

3.4 Evaluation of the VR platform

We qualitatively assessed our results considering a predefined set of criteria that was relevant for carrying out our project (based on Stecher et al., 1997). The considered criteria were as follows:

- Validity of collected results in terms of identifying preference patterns
- Reliability of results by comparing the similarity of data among one participant group (i.e., senior communities) that was collected during two independent events
- Time for developing the VR platform, for conducting the tests, and for data analysis
- Costs for the development of the VR platform and for the data collection
- Complexity for the designer during the development of the VR platform and for participants to conduct the test

The criteria set allowed us to qualitatively compare the development and usage of our VR application with other methods that designers usually would consider for this specific case study (e.g., conducting a pen-and-paper questionnaire or using physical prototypes).

4. Results

4.1 Development of the VR platform

During the development of the VR platform, we noticed that a wide range of expertise was required to ensure a rigorous and successful development of the application. Therefore, two

designers, two software developers, one 3D visualizer, and one team member with a degree in psychology were involved in the project. We noticed that, due to the interdisciplinarity of the team, the designers' role changed to being the project coordinators during the development of the application. This included aspects such as staying on schedule, establishing and maintaining a continuous dialogue among the team members, defining the methodology for rigorous data collection together with the team member with a degree in psychology (including the definition of the questionnaire and variables of the configurator), sharing CAD work with the 3D visualizer (i.e., model the required 3D models), and working together with the software developers to ensure a usable and comprehensible interaction with the VR application (i.e., define the inputs for making selections in VR, define the interfaces, and ensure usability). This interdisciplinary way of working and the collaboration led to the opportunity for all stakeholders, but especially the designers, to acquire expertise from other fields.

Figure 2 shows two examples of participants' room configurations.
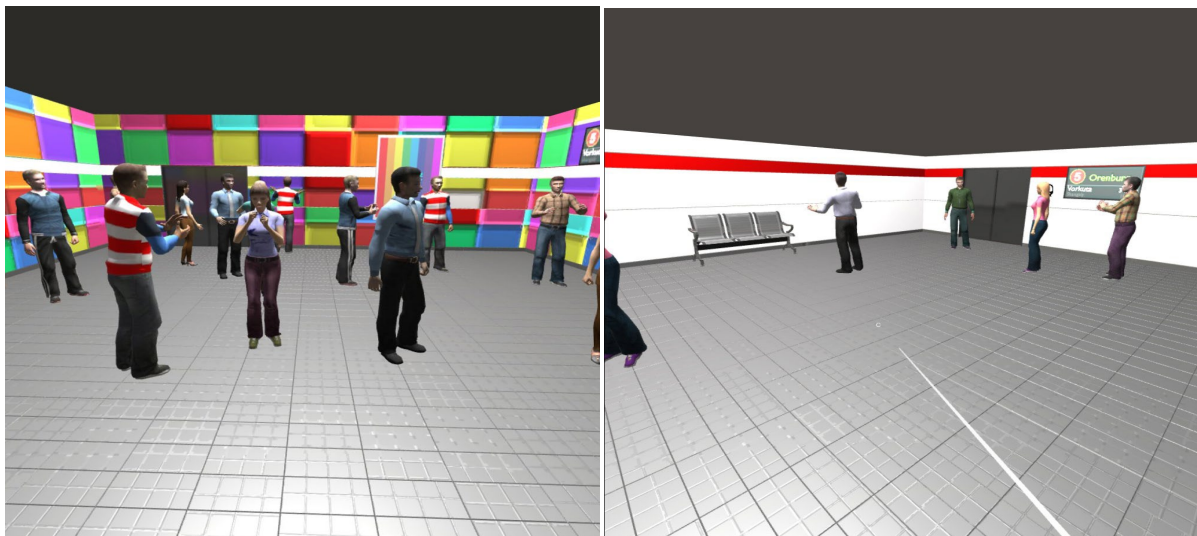

Figure 2   Two examples of possible room configurations

4.2 Data collection and test of the VR platform

We collected data from a total of 463 participants (50% female, 49% male, 1% prefer not to say) with an overall age range of 8 to 89 years (M=39.88, S.D.=19.96). Figure 3 shows the age distribution of all participants in consideration of place of living.
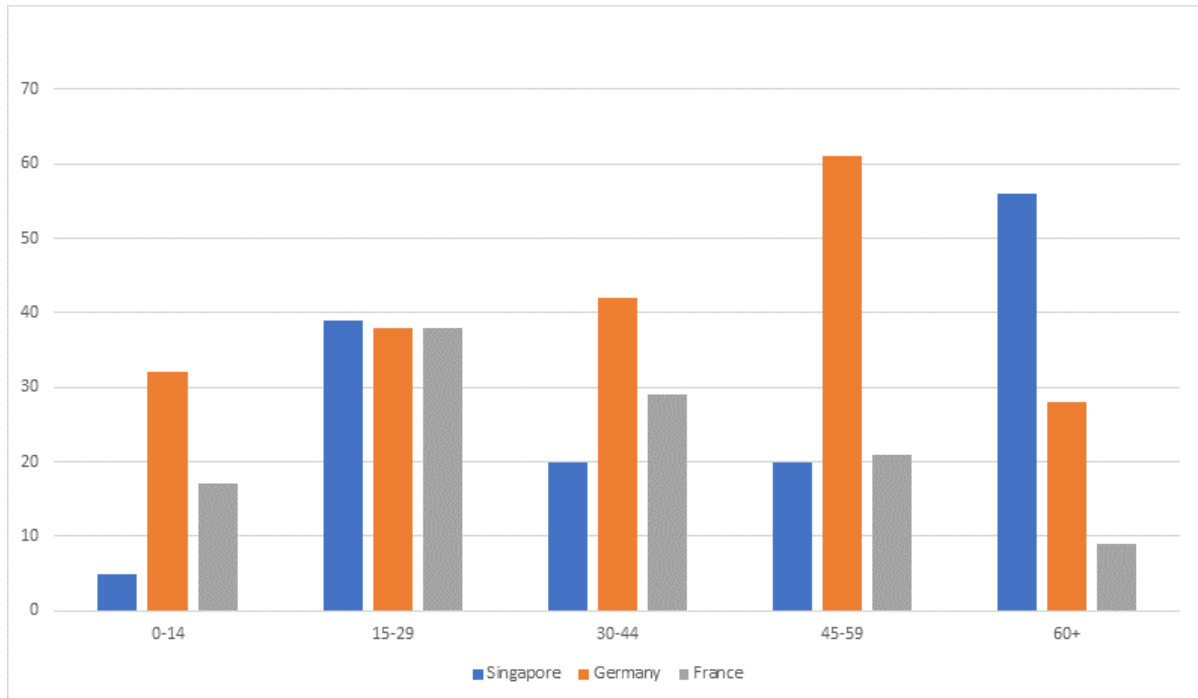
Figure 3   Age distribution of participants in consideration of place of living

We collected data from the following participant groups:

- 201 passer-by, families, and school classes during a public trade fair in Germany
- 122 visitors of an exhibition about new mobility forms in France
- 57 seniors from two community centres in Singapore
- 22 passers-by during a public science event in Singapore
- 61 students during an university information day in Singapore

As the aforementioned participant groups show, we could establish great diversity of participants. However, no homogenous age distribution across the 3 places of living was established (except for the participant group between 15 and 29 years of age). Figure 4 shows pictures from the data collection events.

Figure 4   Data collection events in Singapore, Germany, and France

Firstly, we want to highlight that the motivation for participation during the public events was unexpectedly high. Especially at public events such as the trade fair and the mobility exhibition, the VR devices attracted immense attention. In contrast, at the scientific event in Singapore, the VR devices apparently appeared intimidating for passer-by, which led to a more cumbersome data collection compared to the aforementioned public events. In general, we observed that during almost all data collection events, the majority of participants approached the researchers out of curiosity regarding the VR devices. This applied especially for young people such as school classes and families with young children who approached us with the motivation to try out the VR devices and with the expectation to experience a game or a virtual roller coaster ride. After introducing the visitors to the study and explaining the purpose of the VR experience (i.e., a research study and not a VR game experience), we expected less motivation from people and especially children to participate. Nevertheless, the majority of visitors were still motivated to participate in the study. For the data collection events at the senior community centres, we observed that the senior citizens saw it as their responsibility to register for the data collection session, with an intrinsic motivation to state their preferences and to help us develop a future public transport station that fulfils the needs and wants of people. In conclusion, the usage of VR highly motivated people to participate in the study. Furthermore, we were able to involve communities in our study consisting of seniors who have never tried VR before. Even though some seniors encountered problems while interacting with VR, the guidance of our designers led them to successful data submissions.

Secondly, regarding the changed role of our designers during the process of data collection, we noticed that throughout all events, our designers became facilitators and guides. Their

main task was to brief the participants and be available for questions and guidance. From the introduction onward, our designers motivated and guided the participants through the whole VR experience. Therefore, we observed that our designers bridged the gap between people and the technology of VR. Our designers encouraged the participants to experience all available variables of the configurator before submitting their preferences. Since some participants (and mostly seniors with no prior VR experience) faced problems with interaction with the system, our designers accompanied every participant to ensure a successful experience and data submission.

Thirdly, based on our observations and dialogues with the participants, we were able to explore the impact that the immersive experience had on participants to express their preferences. Due to the continuous guidance of our designers, the experience for all participants was tailored according to their needs. This fact distinguished our data collection method substantially from conventional surveys since all participants had a unique experience to find, verify, and express their preferences. Nevertheless, we anticipate that this individualized experience for every participant decreased the comparability of the collected data. A large number of participants emphasized after the data collection that the VR platform helped them to experience the room configurations and choose their favourite specification based on the immersive comparison. Our researchers also observed that almost all participants explored all available variables and took a considerable amount of time before submitting their preference. Furthermore, several participants even highlighted that they were not happy with a certain room configuration after seeing it in VR and then changed specific variables based on that experience. This indicated that the possibility to experience the room configurations and preferences in an immersive way allowed people to verify whether their stated preferences resembled their actual preferences.

Lastly, during and after the VR experience, many participants were talkative and described their experiences and impressions to our designers. Thus, a strong exchange from participants to designers and also among participants was established during the data collection events. Furthermore, the participants shared their opinions regarding the VR platform, its visual representation, and the interactivity with mixed statements. While some participants expressed their excitement regarding the virtual environment, representation, and interactivity, others expressed disappointment (e.g., the visual representation of the crowd was not convincing).

4.3 Evaluation of the VR platform

The data analysis and qualitative assessment in consideration of the predefined set of criteria shows a range of advantages and limitations for using the VR platform for collecting people's preferences in comparison to other design methods.

The main statements of the qualitative criteria assessment are summarized below.

Validity: Regarding the case study, which aimed at unveiling people's preferences regarding public spaces in dependency of demographics, we were able to collect significant data

showing an effect of age on room proportions and wall colour preferences, as well as an interaction effect of age and place of living on preferences in room brightness and crowd levels. This shows that VR was able to effectively capture the different preferences of individuals from different culture and age group, a further support in the validity of the tool. These results helped us to formulate recommendations for local authority stakeholders for the design of waiting rooms for public transport. Furthermore, statements from participants who claimed that the real-time immersive experience allowed them to reflect on their configurations support the validity of our method compared to conventional methods such as picture-based questionnaires.

Reliability: Comparison of data collected from both community centre events with 57 participants was conducted to see if there are any significant differences in preferences among participants from similar demographic background (all Singaporean elderly participants). Results revealed that the preferred room configurations from the 2 community centres were not significantly different, suggesting high reliability in the data collection tool.

Development time: We observed that the creation of the VR platform through the interdisciplinary team was more time consuming than preparing user interviews or questionnaires. Nevertheless, the development time for creating all room configurations in real-life conditions (e.g., a showroom) to allow participants to experience each configuration in an immersive way would be linked with tremendous efforts and appears rather infeasible to us. Therefore, we see VR as a trade-off to allow immersive experiences without the need to create environments in real-life conditions.

Data collection time: Based on our experience, the time consumption for participants to undergo the test with VR is comparable to other methods such as interviews or questionnaires. However, we noticed that the data collection for some participants and mostly seniors required additional time to clarify the interaction with VR.

Data analysis time: The centralized and digital data collection greatly facilitated the task of processing and analysing our collected data since all submissions were directly collected and categorized by the automatized back-end of our VR application and compressed into one data file. Thus, in contrast to a pen-and-paper questionnaire, no manual transcription was necessary. The data analysis time was comparable to digital data collection methods such as online surveys.

Costs: In terms of costs during the development and conduct of the study, we experienced disadvantages compared to questionnaires since the development of the application required a considerable amount of effort and expertise. Furthermore, even though we decided to use low-cost Head-Mounted Displays, the cost for conducting the study with VR devices is more expensive than conducting questionnaires (either pen-and-paper or digital). However, in contrast to real-size prototypes, our VR platform constituted an advantageous alternative in terms of costs.

Complexity for designer: Since the expertise of 3D visualizers, software developers, and a team member with a degree in psychology was required for the development of the

application, we experienced that the creation of the VR application led to increased complexity for the involved designers compared to the preparation of questionnaires or interviews.

Complexity for participants: The usage of VR for the data collection was challenging for some participants due to the lack of experience with VR. Thus, in comparison to face-to-face interviews or written questionnaires, we experienced an increased complexity for some participants to conduct the test.

4.4 Recommendations and design guidelines

The qualitative criteria assessment underlines that the process for the development of the VR platform as well as the data collection is linked to considerable efforts, which can only be addressed by a multi-disciplinary team. We recommend using a VR platform especially if an emphasis is placed on people's experiences. Further, if the goal is to create a link between the designers and people, the data collection process with VR can lead to strong connections.

A set of design guidelines has been compiled based on our experiences throughout the process. For developing a VR platform, we recommend the following guidelines:

- Ensure availability of the required expertise within the team.
- Establish a continuous dialogue within the development team (e.g., through frequent development meetings).
- Adapt the degree and complexity of interaction with the VR system in terms of usability and interactivity according to the identified participants' skill level of operating such a system (i.e., exciting enough for tech-savvy participants but not overwhelming for people unfamiliar with the technology).
- Prioritize interactivity over representation: An accurate and usable way of interacting with the system is more important than its visual representation.
- The implementation of aspects that might be influenced by technical limitations of VR (e.g., limited resolution) should be avoided since it could bias participants' preferences.

We recommend the following guidelines for using our VR platform for data collection:

- Make sure that at least one researcher with good knowledge about the hardware, software, and context of the study is present for each VR device. If needed, participants should be guided through the whole VR experience. This ensures trust from participants and allows a smooth process for the data collection.
- Take precautions to comfort participants in case of motion sickness.
- Ensure a protected area for the data collection (e.g., a quiet space) and privacy for participants (e.g., do not publicly stream the participants' first-person view).
- Establish context: Holistic experiences allow participants to fully understand the case study and the context to form an opinion on it.

5. Discussion

In the present study, we shared our experiences during the process of developing and carrying out an international large-scale study with the help of a VR platform for deriving people's preferences of public waiting rooms based on unique immersive experiences and the inclusion of individuals from diverse backgrounds - in terms of age, place of living, and familiarity with the VR technology.

Firstly, we found VR to be suitable for collecting people's preferences for our case study. We observed that the unique and immersive experience for each participant led to increased comprehensibility of the study context and allowed participants to verify whether their configuration resembled their preferences before its submission. Thus, we see an immense potential in using VR to collect people's preferences since it could bridge the gap between stated preferences and actual preferences. Researchers such as Farooq et al. (2018), List and Gallet (2001), and Murphy et al. (2003) conclude that preferences that are expressed based on experiences are more accurate while preferences that are based on hypothetical estimations can lead to discrepancies considering the participants' actual needs and wants. Our experiences support this conclusion.

Secondly, using public events as a data collection platform allowed the inclusion of participants with great diversity. We were able to collect data from 463 participants with an age range from 8 to 89 years including passer-by, families, students, and seniors. This showed us the potential accessibility of using VR even for participants without prior VR knowledge. Nevertheless, we experienced challenges for some participants and especially seniors to interact with the VR system. We observed that children and seniors have fundamental differences regarding their needs and accessibility to VR. This is consistent with findings of Gregor and Newell (2001) who conclude that designers have to detach from the mindset of designing for "typical users" and consider inclusive design. Billis et al. (2010) lists guidelines for improving the accessibility for seniors to use VR applications. These guidelines include aspects such as sufficient object and letter size, simple interfaces, and sufficient guidance. Our designers experienced similar phenomena especially regarding the simplicity of user interfaces and the required guidance for seniors.

Thirdly, we experienced how the role for our involved designers changed throughout the process. During the development, our designers were project coordinators who engaged with other stakeholders. During the data collection, our designers were facilitators and guides who accompanied every participant to ensure a unique experience and successful data submission. Thus, our designers bridged the gap between non-tech-savvy people and technology. Furthermore, our designers were the point of contact for the participants to share their experiences and opinions. Researchers such as Sanders and Stappers (2012), Hirsch (2014), and Ehn (1993) state that the role of the designer in participatory activities changes from creators and translators to facilitators and coordinators, allowing people to express themselves. Our study experiences imply the same transition. From a holistic point of view, we observed that during our project, synergies between our designers and

stakeholders were made: Firstly, during the development the available expertise of our interdisciplinary team led to a collaborative basis that allowed the creation of a usable VR platform for rigorous data collection. And secondly, synergies have been established between our designers and participants since the data collection with VR caused active participation and initiated vivid dialogues between participants and designers. This fact was particularly insightful for our designers since these dialogues provided insights to which extent the immersive experiences had an impact on participants and how our application could be improved.

Lastly, we were able to define design guidelines for developing and carrying out a study for collecting people's preferences with the help of a VR. We noticed similarities to the guidelines from Carlsson and Sonesson (2017) for developing VR user experience studies in vehicles, which also emphasize on the technology of VR and the interactivity of the application. In addition, we noticed parallels to the prerequisites of Sanders and Simons (2009) in the context of co-creation on establishing diversity of participants, a continuous dialogue, and holistic experiences.

By qualitatively comparing our method to other design methods such as digital or manual questionnaires and surveys, we conclude that our VR platform requires more time, involves more costs, and increases the complexity for designers and participants. However, the immersive experience that it enables leads to a valid and reliable data collection. On the other hand, in comparison to real size prototyping, our method was more efficient regarding time and cost while still ensuring immersive experiences. Thus, we consider our VR platform as an advantageous trade-off between these methods.

In regard to limitations of the VR platform, we noticed that its usability has space for improvements. Even though we tried to make the interaction in VR as simple as possible, we learned that people without previous experience with VR (often seniors) tended to have problems while interacting with the system. A further limitation was the guidance of our designers throughout the data collection. Since our designers accompanied every participant to ensure a successful experience in VR, we decreased the comparability of our collected data since the procedure from participant to participant was not fully standardized. We anticipate that this may have impacted the collected data. In future studies, we want to investigate how standardization could be established while having guided and unique experiences in VR for participants. Furthermore, we will apply our platform to other application domains to prove its transferability (e.g., collecting preferences of people who regularly use public transport such as Metro or Bus) since our guidelines are currently based on literature research and the experiences in the field of public waiting rooms.

6. Conclusion

Including people in the design process enhances designers' understanding of subjective preferences during the development of products or services. Such inclusion is essential in the context of urban public spaces, which are shared by diverse groups and so should be shaped

by diverse voices. While participatory methods offer benefits such as the shared creation of value and relationships, drawbacks include the considerable amount of time and cost involved for the development and data collection. Furthermore, a lack of subject knowledge or experience and contextual information hinders participants from concretely expressing their preferences. To address these issues, we explored the process of developing and using a VR platform for collecting preferences through simulated, immersive experiences and tested it with people from diverse cultural contexts, age groups, and prior knowledge with VR. The immersive design experience of designing a public waiting room created with VR saw positive impacts on participant motivation and interest in our studies, in addition to more precise data on user preferences. We encourage designers to consider using VR platforms for such hypothetical studies when physical prototypes are unfeasible or too expensive. We also propose design guidelines to facilitate the development and conduct of studies involving VR platforms for data collection. The findings contribute to the body of knowledge and tools available for participatory processes and form a basis for further research in enhancing participatory processes.

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