Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

Augmented and Virtual Reality Applied for Innovative, Inclusive and Efficient Participatory Planning

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Abstract

The research project VR-Planning aims to investigate improvements in participatory planning processes through the use of Augmented Reality (AR) and Virtual Reality (VR) to allow stakeholders to experience designs of buildings and public spaces before they are built. The biggest challenge for participatory planning is to include stakeholders from various backgrounds and with diverse knowledge. Thus VR-Planning examines how AR and VR can be used to optimally support participation in different application areas at different planning phases to facilitate a swift and effective decision-making process. This paper summarizes results from three user experience workshops with citizens and a workshop with an interdisciplinary group of professional planners and academics. Finally, an outlook with usage scenarios in future planning and design projects is provided.

Keywords: augmented reality; virtual reality; participatory planning; human factors; human machine interfaces; user experience; mobility; transport; smart street design; public space; urban design

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1. Introduction

Environmentally friendly forms of transport such as walking or cycling can be supported through targeted design of public space. The repurposing and redesigning of urban public spaces – mainly streets – from motorised forms of traffic to walking and cycling often leads to conflicts. In such a context, the planning and design processes for innovative street designs require to explore the interests of different user groups. Such a mediation is often complicated leading to long lasting planning-, design- and building-phases in public infrastructure projects.

Improving the participation of diverse user groups appears as viable strategy to raise acceptance and ownership in favour of a reallocation of public spaces towards environmentally friendly forms of transport. Nevertheless, participation processes – executed as information, consultation or cooperation – may face challenges in terms of the participants' ability to identify with future urban spaces and understand the proposed changes. The emergence of augmented reality (AR) and virtual reality (VR) technologies may offer opportunities to support participatory planning and design processes. Such technologies can allow stakeholders to experience the proposed redesign of public spaces, before they are built, in an interactive and highly immersive manner. A major challenge in participation processes is to include a diverse group of stakeholders representing all future users of a given project. Raising diversity implies to include persons with various backgrounds and diverse levels of knowledge. Thus, research is needed how the usage of AR and VR can support participants of various backgrounds and which further developments are required to integrate AR and VR technology into an effective and swift participation process.

The application of VR in planning processes has been investigated internationally in many projects and studies (Echevarria Sanchez et al., 2017; Nguyen et al., 2016; Portman et al., 2015), but only a few studies have dealt with the application of VR in real planning projects (Stauskis, 2014). VR was examined in the context of evaluation procedures for for architectural competitions (Suneson et al., 2008), for the mediation of planning scenarios in traffic projects (Chun, et al, 2008), for interdisciplinary sectoral planning in the field of urban mobility (Lopes and Lindström, 2012), for the investigation of scenarios in urban cycling or to research children's traffic behaviour (Bakar et al., 2011). These studies show the high potential of VR and AR to make planning more accessible to various stakeholders and to increase the social and ecological sustainability of urban planning (Stauskis, 2014).

VR-Planning investigates usage scenarios of AR and VR in participatory planning and design process by means of real world applications regarding smart street design to improve the conditions for walking and cycling. The project highlights differences of efficiency and effectiveness in terms of organization, technology, operation, resources and involvement of participants compared to established methods currently used in participation processes.

In this paper we start by introducing different AR and VR technologies in relation to a potential application in participation processes. Then we discuss participation methods, where AR and VR can be applied. Thereafter user experience workshops are described where AR and VR technologies have been tested to gain insights into applicability, technological and logistical aspects of using AR and VR in participation processes. The paper concludes with possible usage scenarios of AR and VR in participatory planning and design processes.

2. Augmented Reality and Virtual Reality

The terms augmented reality (AR) and virtual reality (VR) are not always used distinctively and therefore we refer to the reality-virtuality continuum from Milgram et al. (1994). The reality-virtuality continuum describes a continuous scale ranging from real environment to a completely virtual environment. The spectrum in between is defined as mixed reality in which real and virtual objects are presented together. A way to determine whether a technology is augmented, mixed or virtual reality is to think about what is being altered. If virtual objects are added to real world than it is AR, if a virtual environment has real objects inserted it is called augmented virtuality, and finally if the perception of a person is altered completely by a synthetic environment then it is VR.

Current popular consumer VR systems like Oculus Rift[2], HTC Vive[3] or PlayStation VR[4], are all wired head mounted displays (HMDs) and require a powerful PC to enable fully immersive experiences (Anthes et al. 2016).

[2] https://www.oculus.com/

[3] https://www.vive.com/

[4] https://www.playstation.com/de-at/explore/playstation-vr/

But these VR systems are quite expensive, which significantly limits scalability. In contrast to this, mobile HMDs for VR consists only of special smartphone cases with two lenses like Google Cardboard[5]. On the smartphone stereoscopic images are displayed and viewed through the lenses. The benefit of mobile HMDs is, that they are relatively cheap and can thus be used widely. But the computing power of smartphones must be sufficient.

The main devices for AR applications are smartphones and tablets and provides an AR experience using the video-see-through technique to blend digital objects and information seamless into the real environment. The advantages of smartphones are the portable and ubiquitous nature. The disadvantages are the physical constraints of users having to hold the device in front of them all the times as well the distortion through the wide-angled camera lens compared to the visual perception of the real environment through the eyes (Kesim and Ozarslan, 2012). Finally, the Microsoft HoloLens[6] is to be mentioned. It is a pair of mixed reality smart glasses that allows the user to display interactive 3D projections in the environment and works without a smartphone or additional computer.

3. Participatory Planning

Urban planning operates in a field of conflicting interests and while negotiating such conflicts – often in representation of a city's political or administrative entity – facilitators of participatory urban development processes have different methods available in which digital methods are increasingly common. Recently digital communication technology and web-based tools have enabled the public to participate to a larger extent in planning processes. Keywords such as *crowdsourcing* or *crowd intelligence* were enabled by technical innovations and currently represent a great opportunity to make planning and the subsequent design processes more inclusive by increasing public participation. Applying AR and VR in participatory processes is promising because of two inherent characteristics: *immersion* and *interactivity* (Chun et. al., 2008). *Immersion* is the perception of being physically present in a non-physical virtual environment. Ideally, the user's experiences are so realistic that she or he can no longer distinguish between real and virtual (or augmented) environments (Cummings and Bailenson, 2016). *Interactivity* stands for interaction techniques that allow users to interact and manipulate virtual objects in a "natural" and intuitive manner as well as for the support of easy collaboration and cooperation between different users. Due to an increased identification with planned scenarios, both – immersion and interactivity – can expand participatory methods and make participatory processes more inclusive, efficient and sustainable by making new street spaces and road designs tangible. The investigations in VR-Planning consider three forms of participation practices:

- *Information*: The use of AR and VR offers the opportunity to inform citizens about a project and offer new ways to access complex issues of urban development. It enables the presentation of planning variants over time, e. g. depiction of planting after the construction phase and after 5, 10 or 20 years, as well as at different times of the year and day. Furthermore, the linkage of VR with dynamic traffic simulation makes it possible to convey different designs from various situations and perspectives, e. g. of a cyclist, pedestrian, etc. with the aim of achieving an improved understanding of planning variants and a higher acceptance for a fair distribution of space.
- *Consultation*: Consultation extends the opportunity to inform citizens with the possibility to consult them about a project. Here the use of VR tools is very well applicable, in order to make aspects of the project easier to grasp and to incorporate ideas, suggestions and criticism.
- *Cooperation*: Cooperation requires sophisticated interaction capabilities that allow users to easily collaborate with each other. In a cooperation setting citizens are asked for their opinions and attitudes and at the same time encouraged introduce their interests and to participate in the development of solutions. Here VR tools can be very helpful to support questions visually, to present different variants in an easily understandable way and to develop own variants.

4. Workshops

The research project VR-Planning is testing VR and AR technology in participatory settings that are closely aligned with ongoing urban development projects; the rebuilding of the train station in Kapfenberg, Styria, and, the development of streets in the "Seestadt Aspern" project in Vienna. To pre-test participation methods enhanced with AR and VR technologies as well as the digital models themselves, a series of pre-tests was conducted in the

[5] https://vr.google.com/cardboard/

[6] https://www.microsoft.com/en-us/hololens

early phase of the VR-Planning research project between March and August 2017. This allowed the team to further evolve participation methods as well as technologies in an iterative manner.

4.1. Workshops with citizens

In March 2017 a workshop has been conducted to test AR and VR technologies in a participatory workshop setting. The goal was to test a first setting and to gain insights about the applicability of AR and VR technology from a group of participants familiar with participatory processes.

4.1.1. Study design

Workshop Setting. The workshop was set up similar to a typical workshop setting that can be applied in various participation processes. The workshop started with an activation where participants were asked to arrange themselves along a gradient of technological experience. Thereafter a brief introduction about the VR-Planning project was given. Then participants were given questionnaires that they filled out immediately after visiting the two stations where VR and AR technologies could be tested. Once all participants had experienced both VR and AR technologies a group discussion was started evolving around the questions "*Would VR and AR technologies be a reason for you to join a participation process?*" and "*Which opportunities and risks do I see for the involvement of VR and AR technology in participation processes?*"

Participants. The workshop was conducted in two phases, each inviting 6 participants resulting in 12 participants in total. The group had a mean age of 40 years with the youngest participant being 24 and the oldest being 68 years of age. Men and women were represented to equal parts in the study group. The study group was selected based on previous experience in participation processes so that they should be able to reflect how VR and AR technologies could impact such processes.

Technology and 3D Models. In this workshop participants engaged with AR and VR technology in two stations. At one station full immersive VR technology through a head mounted display (HMD) could be experienced. We used the HTC Vive[7] HMD and a fully immersive virtual environment (VE) that was developed in Unity[8] and was based on the free available Unity Asset Japanese Dosanko City[9]. Participants could explore the VE by walking in the tracking area provided by the HTC Vive or could teleport themselves with raycast beam using the HTC vive controllers. Apart from locomotion no interaction was provided, as our goal was to generate ideas how VR could be used in a participatory process. At the second station handheld VR and AR technology through smartphones and tablets was provided. Participants could explore an AR application that augmented a for paper plan with a virtual 3D model that was displayed on the smartphone (Nexus 6P). Second a VR application could be explored with the smartphone. The VR application consists of a 3D world (multiple 360 degree renderings), that could be experienced with a tablet (iPad Pro 13"). The renderings are part of a railway construction project in Vorarlberg[10],

4.1.2. Results

The workshops provided valuable insight how users experienced AR and VR technology and how that technology could be used in a participatory process.

Virtual Reality - Head Mounted Device (HMD): The results in the questionnaires (Fig. 1a) show that the technology was easy to use and that participants would use such a VR system. Also results for negative effects (nausea, dizziness and disorientation) are promising, with hardly any negative effects reported by the participants. Also participants noted that the experience in the virtual world allows to identify new questions and issues for a given setting. They appreciated the ability to move in a natural bodily movement in the virtual space. Ideas for improvements were: Integrating questionnaires into the virtual world, integrating more opportunities to interact with the virtual world and experience changes within it in real time. Participants also gave ideas for improvements such as using the virtual world to create an ideal setting, using a virtual world and a parallel mirror on a screen or experiencing the virtual environment while being seated to avoid nausea. Participants noted that a reference system

[7] https://www.vive.com/eu/

[8] http://unity3d.com/

[9] https://www.assetstore.unity3d.com/en/#!/content/36810

[10] http://www.bahnhof-hard-fussach.at/

within the VR would aid orientation or a real object such as chair which is placed in both real and virtual setting can act as point of reference.

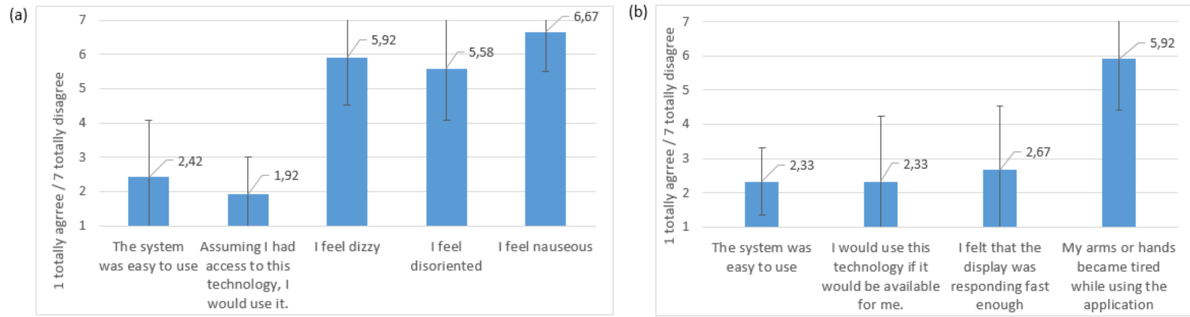

Fig. 1 Shows the mean participants answers in the questionnaires for (a) fully immersive VR through HMD; (b) Handheld AR / VR

In terms of negative feedback and concerns the workshop participants noted several aspects. Wearing a head mounted device was rated as constraint for communication amongst participants and a potentially negative effect on a discourse process was noted. Participants also voiced concern in regards to the quality of the 3D model. The lack of interaction between participants inside a virtual environment was noted. Participants also stated that the use of VR creates a new sense of privacy during the participation process as being exposed and vulnerable while wearing a HMD requires a new sense of trust and creates a feeling of being observed while being inside the virtual world. The debate also brought up the issue of group size that can be serviced with a VR experience and the personnel required for hosting the VR experience. Another aspect that was hardly discussed in literature but during the workshop was the aspect of hygiene when multiple people use the same HMD.

Handheld AR and VR: Similar to the immersive VR environment, handheld AR and VR was rated as easy to use and participants would use such a system (Fig. 1b). Participants noted that AR and VR on devices that are known to people (Smartphones, tablets) can provide a common experience that is easy to understand even if you are not used to reading plans. AR was rated as easier to orientate, in comparison to VR, as some aspect of known reality was still present. Handheld AR and VR were seen as improvement for communication between the participants. Problems were found when the technology was less intuitively to handle. For *handheld VR* positive aspects were found as many people can use the technology at the same time.

4.1.3. Implications and Design iteration

For *fully immersive VR technology* user feedback was positive, but users stated that manipulation of the environment was missing to fully use the potential. Participants explicitly mentioned that they would like to grab and move objects and also they wished for possibilities to get tools create objects and thus to actively design the environment. Also one participant mentioned the idea to provide feedback through questionnaires embedded inside the VE. As users wished for a more interactive virtual environment (VE) as improvement for the next workshop we implemented interaction modalities to provide opportunities for user feedback and manipulation of the environment. For concrete implementation we used the Virtual Reality Toolkit (VRTK)[11]. The following improvements were made:

- *Questionnaires in VR*: We implemented a Questionnaire on a 2D UI Canvas that could be manipulated by a raycast beam. This provides the opportunity to collect user feedback within the VE.
- *Creating and Manipulating Objects*: We implemented a selection menu (using the VIVE controllers), that allows creating objects (trees) and placing them in the environment. Planting trees was chosen as an example, but can be extended to other objects like buildings, cars, bikes, traffic lights, etc. Also we implemented the possibility to grab objects (Benches, Buildings, and Trees) and relocate them in the VE.
- *Taking Pictures*: We implemented the possibility to take pictures inside the VE by pressing a button on the controller. We aim to use this function to memorize situations or objects to later provide feedback, for example as a base for discussion.
- *Simulated pedestrians*: To add more realism to the street environment we incorporated pedestrian simulation. Within the VE animated virtual humans walked around controlled by the simulation.

[11] https://vrtoolkit.readme.io/

For *handheld AR technology* augmenting the real world was considered as more interesting that augmenting a paper plan. Thus as a design iteration for the next workshop we developed a 3D model that shows a design alternative (shared space) for a parking space in the real world. Also we decided to not only use handheld AR but additionally use a head-mounted AR device (Microsoft HoloLens).

4.2. Walk-in Workshop with citizens

In June 2017 a workshop was conducted to test a first AR model of a public space in central Vienna. The goal was to test the applicability of AR in a blended participation approach in an outdoor setting.

4.2.1. Study design

Workshop Setting: The walk-in workshop with citizens was conceptualized as blended participation workshop in a setting similar to a “Park(ing) Day” intervention[12]. AR was used to complement the idea-finding for a public space in Wiedner Hauptstraße in Vienna that was temporarily closed for parking on that day. A table was set up with a printed planview (1:100 scale) of the streetscape, next to it a flipchart with an invitation to re-imagine this public space and a blank sheet of paper to collect these ideas. Two large planters arranged on the sidewalk and a set of comfortable chairs were placed on the unused parking lots to complement the intervention. The AR provided the opportunity to look at an overlay of a simple redesign of this space over the parked cars and the street.

Participants: The workshop approached random passengers during the time of 10 AM until 2 PM. People were asked to stop and engage with the future of this public space and to test AR technology to see possible changes.

Technology and 3D Model: A simple 3D model of the space showed a simple vision of a shared space instead of the parking lots. Greenery was improved and expanded but no street furniture was included to leave room for wishes of the workshop participants. For displaying the 3D model we used a head-mounted AR device (Microsoft HoloLens) that displays the rendering of the Shared Space at the very spot as an overlay to the real environment.

4.2.2. Results

The user feedback gathered with the questionnaire (Fig. 2) shows that the technology was easy to use and motivated passers-by to participate. Also the answers show that AR technology is considered as helpful, inspiring and fostering understanding in participation processes. Participants also gave qualitative feedback in open questions at the end of the questionnaire.

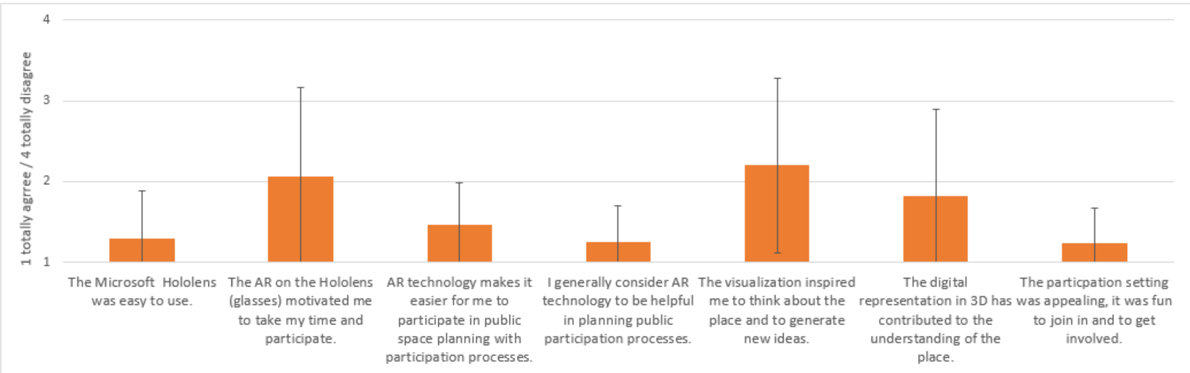

Fig. 2 Mean answers in the questionnaires for head-mounted AR technology in the blended participation workshop

The quality of the 3D model was rated as artificial and the lack of opportunity to experience alternative designs was noted. Participants also suggested to include interactive features for example for placing objects in the virtual space or to integrate more objects in the 3D model as visual anchors. Participants also stated challenges such as the labour-intensive support needed questioning how many people could be served with this technology at the same time. Participants noted that the technology itself made them curious to participate and that the additional augmented reality layer made them rethink the urban space. A difficulty for the workshop setting was the intense sunlight that made the AR application on the MS HoloLens challenging. Such technical problems can seriously

[12] http://parkingday.org/

jeopardize participation process that integrate AR applications on site.

4.3. Workshop with professionals

This workshop was conducted to assemble the learnings from the two previous workshops and discuss with professionals and potential implementers of AR and VR technology such applications in participatory processes.

4.3.1. Study design

Workshop Setting: The workshop followed the basic structure of an expert workshop that can be integrated in various participatory settings. The workshop was held in a meeting room with adjacent smaller rooms for testing VR technology and 360 Degree renderings. An AR application could be tested in the street in front of the building where the workshop took place. The workshop started by asking participants to arrange themselves according to gradients of pre-existing technological knowledge and experience with VR and AR. Thereafter the project VR-Planning was introduced and the goal of the workshop was stated, namely to test the technologies and gain feedback on their potential applicability in participation processes. Then participants were given a set of questionnaires that they filled out immediately after visiting each of the interaction stations, where the interaction with a handheld 3D model (360 degree renderings), VR and AR applications could be tested. Once all participants had experienced all three technologies a group discussion was started evolving around the questions *"Which opportunities and risks do you see for integrating VR and AR technologies in participation processes?"* and *"When and for which participatory formats would you apply VR and AR technologies?"*

Participants: A group of ten invited participants was attending the workshop. The group consisted of traffic planners, academics, spatial planners, architects, mobility researchers and representatives from urban administration (strategic planning and communications departments of the City of Vienna).

Technology and 3D Models: The participants experienced different AR and VR technologies in three stations. At one station, full immersive VR technology through a head mounted display (HMD) could be experienced. We used the HTC Vive HMD and a fully immersive VE developed in Unity[13]. Since the workshops with citizens the 3D model was changed from a Japanese City to a 3D model of the TU Graz campus Inffeldgasse. Participants could explore the VE by walking in the tracking area provided by the HTC Vive or could teleport themselves with raycast beam using the HTC vive controllers. In addition to the locomotion techniques provided also in the workshops with citizens we also included the interaction techniques described in section 4.1.3, which include: Questionnaires in VR, creating and manipulating objects, taking pictures and simulated pedestrians. At the second station participants experienced a handheld VR technology, a 3D world of multiple 360 degree renderings that could be experienced with the tablet (an iPad Pro 13"). The 3D world shows of a railway construction project in Vorarlberg available online[14]. The third station was placed outside in the street where similar to the walk-in workshop (section 4.2) an alternative design (shared space) of the real street was experienced by the participants. This 3D model has been improved since the walk-in workshop. A Shared Space instead of a parking lot was displayed as an overlay to the real environment on a tablet (Nexus 9) and a head-mounted AR device (Microsoft HoloLens).

4.3.2. Results

The workshop provided opportunity to gain experiential feedback from the participants right after experiencing the AR or VR technologies. Some of the key points are listed here according to technology

Virtual Reality – Head Mounted Device (HMD): The questionnaire results (Fig. 3) show that the technology was easy to use and that participants would use HMD VR technology. Also results for negative effects (nausea, dizziness and disorientation) are good, most reported negative effects are reported for orientation. In the workshop with professionals we also included questions about the interactive functionalities added after the workshops with citizen. Bird view was perceived most useful followed by manipulating the environment and answering questionnaires in the VE. The 3D model was criticized in terms of its level of detail not being realistic enough. Positively noted were interaction mechanisms such as taking snapshots, planting trees or moving buildings.

[13] http://unity3d.com/

[14] http://www.bahnhof-hard-fussach.at/

Participants suggested to use VR to experience proposed urban development projects where no buildings exist yet or to experience the city from other people's – for example a child's – perspective.

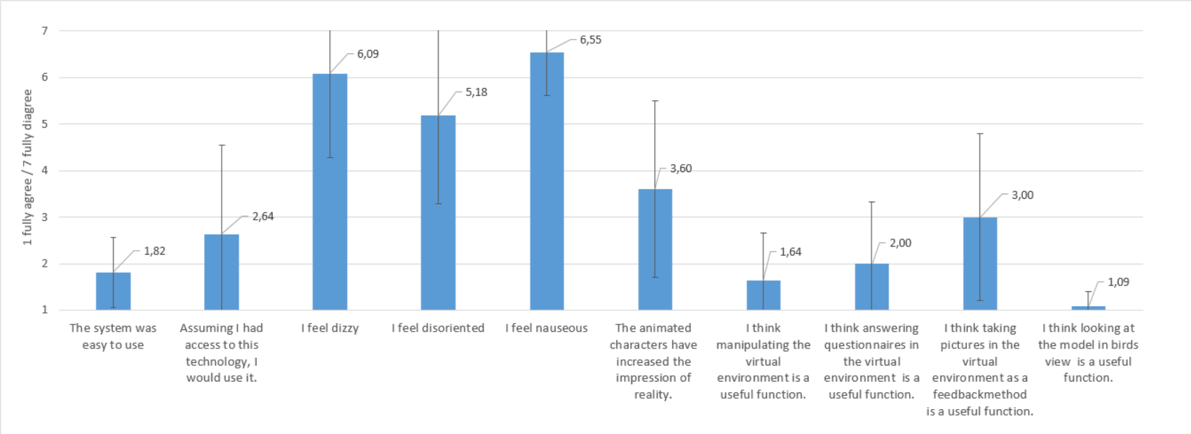

Fig. 3 The participants mean answers in the questionnaires for fully immersive VR through HMD

Handheld VR (360 Degree Renderings) – Tablet was rated as easy to use and participants stated that they would use such a technology (Fig. 4). Participants also stated that handheld VR could be useful for an overview over large-scale urban development projects that are complex in nature and not yet built. The integration of Gamification elements (people giving information within the VE, etc.) was stated as opportunity to make the model livelier. It was also noted that a wayfinding system within the VE could be necessary for orientation.

Handheld AR – Tablet was rated as easy to use with similar values as head-mounted AR (Fig. 4). Participants noted a potential for on-site communication of yet to be built projects. It was noted that AR technology can be a good complement for printed plans and that various planning stages could be communicated. It was stated that a better quality and calibration of the 3D model could improve interaction with citizens.

Headmounted AR – Microsoft HoloLens was rated as easy to use, like the handheld AR. Noticeable is the fact that AR HoloLens had the lowest rating for all three technologies when asked if participants would use such a technology (Fig. 4). Participants noted the potential of this application as complement to printed plans / information materials. Wearing the HMD was experienced as heavy on the head. The light conditions were experienced a challenge for the application in an open-space setting.

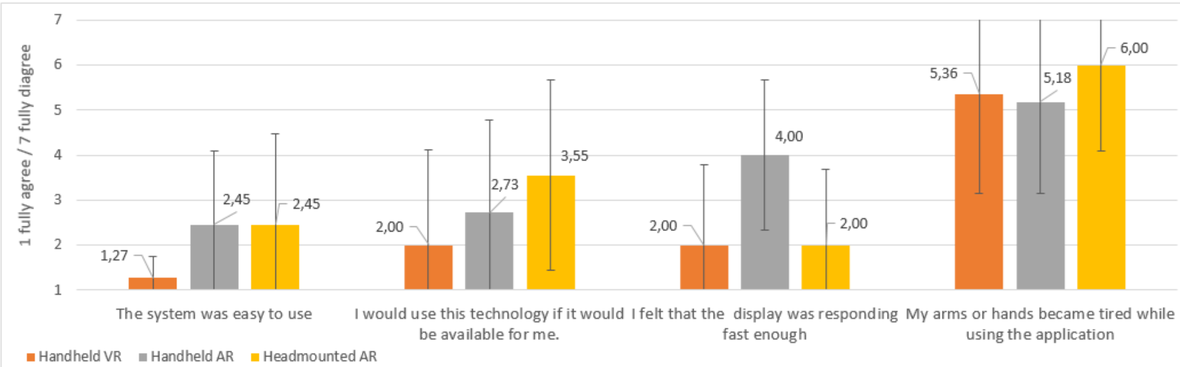

Fig. 4 The participants mean answers in the questionnaires for handheld VR and AR

Opportunities and threats for application of AR and VR technology in participation processes were derived from a concluding discussion in the expert workshop.

The expert group noted that the assignment of the technology and the project stage must be clearly defined when such technologies are being used. Experts agreed that VR and AR can complement existing dialog formats but also agreed that VR and AR technology should be used to combine the transformative experience with established participation formats. The group named large-scale and complex urban development as well as infrastructure projects as good examples for AR and VR application. Regarding logistics it was questioned if enough people can be handled by support-intensive AR and VR applications. The spatial and temporal flexibility of (hand-held and web-based) AR and VR applications was stated as potential benefit to detach participatory processes in a spatial and temporal manner. As specific use case the expert group noted VR for experiencing a virtual model of an urban situation from the perspective of another person/user group (children, elderly, other traffic participants, etc.). Such a change of perspective could be helpful for resolving conflicts in participation processes. In regard to AR the group acknowledged the potential of in-situ applications, especially 1:1 scale models displayed on-site.

The group also discussed that the application of VR and AR in participation processes can help to reach new target groups. In terms of a collaboration between experts, politicians and administration, AR and VR may be used to better imagine a proposed project and thereby developing more assurance and constituency for a (controversial) project. A decentralized application (via smartphone application or website) of AR and VR could engage the broader public in participation processes. To reach more diverse target groups it would be necessary to integrate more comprehensive interaction and feedback mechanisms that are easy to use and specific to the issues that are dealt with in the respective participation process. It was stated that the documentation and replicability of user feedbacks is crucial for (public) participation processes.

Gamification or storytelling can be possible strategies to improve the engagement of participants with the VE and to give feedback more effortlessly. In contrast, it was stated that a mere gamification approach may endanger the integrity of the participation process when it is considered as being too playful.

An important question in the discussion was how much the realistic representation of the virtual environment influences the quality of the feedback and the degree of engagement. During user tests a „blank“ 3D model was experienced as too boring whereas too much depth of detail in the VE could raise (false) expectations amongst participants in participation processes. This poses higher requirements for 3D modelling and an extension with audio to achieve a certain level of immersion.

5. Conclusions

At this stage of the research project VR-Planning we state that AR and VR technologies are promising additions to the toolbox of participatory planning methods, yet, several aspects remain unclear related to logistics, cost, benefits, interaction or immersion. From our initial workshops described in this paper we propose several innovations to be explored for the use of AR and VR in participatory processes and put forward that AR and VR technology can – if applied in a context-sensitive and complementary manner to existing participation methods – raise inclusivity and efficiency of participation processes.

In terms of *innovation* AR and VR technology can bring the aura of "new" technology to established participation processes. Nevertheless, it will be important to critically assess the cost and benefit of such an integration because the mere integration of technology will not per definition raise the quality of participation processes. In particular, new methods need to be introduced to collect and analyze feedback in order to make VR and AR a real support and improvement of participatory processes. Some ideas that emerged during the workshops will provide an opportunity to design new participation formats and the VR-Planning team will work on drafting proposals for such formats during the remaining project.

The initial VR-Planning workshops indicate that AR and VR technology could potentially increase the *inclusion* of participation processes. Mainly young people and technology-oriented target groups appear to be attracted by AR and VR technology. An open question is how VR and/or AR can be used to reach groups that are often underrepresented in participation processes today. A specific question remains the inclusion of older people who are not familiar with innovative technologies such as AR and VR applications. In relation to target groups we can already put forward that with different technologies different target groups can be addressed and different ranges are possible. Applications for smartphone and tablet will allow for a large coverage while head-mounted displays will be used to interact with small groups and in in-depth investigations where an increase of collaboration possibilities will be required.

Regarding *efficiency* the question if AR and VR can make participation processes more efficient cannot be clearly answered at this point. There are strong hints that such technologies lead to a better understanding of proposed (spatial) designs but many questions remain to be discussed. Our initial workshops have shown that the costs for logistics and servicing of AR and VR technologies used in participation processes are substantial. To the contrast of low-tech methods most VR and AR applications today require some level of technical knowledge which is not necessarily present with all facilitators of participation processes. In consequence, the workload for participation processes appears as double (for moderation and for technology support). Future research and innovation must focus on making VR and AR technology easier to use.

We can point out potential for improvement and the use of AR and VR provides valuable impulses regarding the increase of interest in the participation process, the better spatial understanding of a proposed planning as well as accompanying effects. This gives an indication that AR and VR provide an intuitive way of involvement and generally lead to clarity and better understanding of public infrastructure or street design projects. This lays a foundation for inclusive, efficient and sustainable planning towards a solution accepted by the parties involved.

We expect more in-depth results in the future workshops where we will study AR and VR in participatory planning processes within real world examples in Styria (Kapfenberg) and Vienna (Seestadt Aspern) to entail a strong cooperation between citizens, professional planners and representatives of the public administration.

Acknowledgements

This work has been partially funded by the Austrian Federal Ministry for Transport, Innovation and Technology (bmvit) in the “Mobilitaet der Zukunft” programme under grant number 860210 (“VR-Planning”). The authors would like to thank the project partners for their valuable work and contribution as well as for their effort.

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