Effectiveness of Virtual Reality in Participatory Urban Planning

A Case Study

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ABSTRACT

In urban planning, 3D modeling and virtual reality (VR) provide new means for involving citizens in the planning process. For municipal government, it is essential to know how effective these means are, to justify investments. In this study, we present a case of using VR in a municipal process of civic participation concerning the redesign of a public park. The process included co-design activities and involved citizens in decision-making through a ballot, using 3D-rendered versions of competing designs. In co-design, 3D-modeling tools were instrumental in empowering citizens to negotiate design decisions, to discuss the quality of designs with experts, and to collectively take decisions. This paper demonstrates that, in a ballot on competing designs with 1302 citizens, VR headsets proved to be equally effective compared to other display technologies in informing citizens during decision making. The results of an additional, controlled experiment indicate that VR headsets provide higher engagement and more vivid memories than viewing the designs on non-immersive displays.

By integrating research into a municipal process, we contribute evidence of cognitive and engagement effects of using 3D modeling and immersive VR technologies to empower citizens in participatory urban planning. The case described in the paper concerns a public park; a similar approach could be applied to the design of public installations including media architecture.

Author Keywords

Participatory design; virtual reality; urban planning; civic engagement.

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1 INTRODUCTION

In a participatory society, authorities share responsibilities with citizens and civil communities [13,37] in many domains, such as health care, safety, social security, and urban planning and the organization of public spaces. City governments are looking for optimal ways to improve the infrastructure for public participation [6,10] using new technologies to support this. The municipality of The Hague collaborated with The Hague University of Applied Sciences in an activity of participatory design to find evidence of the effectiveness of Virtual Reality technology in participatory urban planning processes.

Virtual Reality (VR) devices such as 3D-rendering headsets and smartphones have become accessible to a broad audience, increasing their potential utility beyond specialist settings. Thanks to their immersive nature, VR headsets can provide a tool for supporting decision-making processes in architecture and urban planning, by virtually placing the observer in the context of the design. 3D rendering in such processes has evolved from expert systems to participatory systems, in which the public is given the opportunity to experience the envisioned design through an immersive visualization [9,20,39,40]. Experimental research suggests that VR can increase public participation in such processes [9,17] and provide a sufficiently realistic experience to make judgements on the quality of the presented content, instead of paying attention to rendering artifacts.

The municipality of The Hague incorporated 3D rendering and VR technology in the participatory re-design of a public park in a neighborhood with approximately 13,500 residents. The municipality defines four levels of participation: consultation, advice, co-production, and co-decision [16]. These levels formed the backbone for a co-creative process that, although initiated and facilitated by the municipality, was owned by the residents. The intention of the municipal district director and the neighborhood manager was to stimulate a sense of ownership in residents and engage them in a do-it-with-others (DIWO) activity regarding the development of the park in their neighborhood [7].

The participation process can be summarized as follows, with the participation levels shown in italics:

1. Call for participation – *consultation*

All residents in the neighborhood received an invitation to send suggestions regarding the park to the neighborhood manager and/or to partake in a workgroup for co-designing the revamp of the park.

2. Co-creation workgroup – *co-production*

The workgroup of citizens engaged in a series of intensive co-design sessions with experts from the municipality, making use of 3D modeling, leading to three high-quality designs for the park.

3. Public ballot – *co-decision*

The three variant designs were submitted to voting by all neighborhood residents. The residents were allowed to view the proposed designs using a variety of display technologies.

4. Final design – *co-production*

The city's landscape architect and the workgroup co-produced the final detailed design, based on the winning variant.

This paper reports on research tapped into phases 2 and 3 of the process. These phases provided a vessel to investigate the effectiveness of VR technology in participatory urban planning. Specifically, we were interested in the following research questions that mainly relate to phase 3, the public ballot:

RQ 1. How does VR technology affect the residents' engagement with the decision-making process regarding the park?

RQ 2. Does immersive VR technology provide a cognitive benefit in decision making compared to non-immersive display technologies?

Display technologies available in the ballot were a paper map, a smartphone, a tablet, a personal computer, or a VR headset. Except for the paper map that showed 2D plans, all technologies used the same 3D model to display the designs.

Relating to RQ 1, we define engagement from two perspectives: 1) citizens' engagement with the overall participatory decision-making process as conducted by the municipality; 2) citizens' engagement with the presentation of the three designs for the park. The first perspective, regarding the overall participation process, was measured during the ballot. The latter perspective, engagement with the presentations, gives an indication of how well the medium captures citizens' attention during their personal decision-making process. In addition to the experiment during the ballot, we conducted a controlled experiment to quantify the experiential differences between immersive and non-immersive presentations.

Relating to RQ 2, the cognitive benefits were examined by studying the citizens' perception of the differences between the variants designed for the park. During the ballot, we collected data about the voters' *confidence* about their perception. In the controlled experiment, we investigated the *actual* perception by measuring the participants' recollection of what they had seen.

The paper is structured as follows. Section 2 discusses related work and section 3 introduces the co-design process. Section 4 then discusses the first experiment, executed during the ballot, and section 5 reports on the second experiment in the controlled laboratory study. Sections 6 & 7 present our discussion and conclusion respectively.

2 RELATED WORK

In the past few decades, the role of citizens in relation to government has evolved considerably from political representation towards active, civic participation in policy-making by the end of the 20th century. The 'participation society' from the beginning of this century is now evolving into a 'do-democracy' where citizens' initiatives shape government responses and actions [19]. De Waal discusses political-philosophical perspectives on citizenship and how citizenship is changing as a consequence of the introduction of smart city technology. He defines the republican perspective, that combines individual freedom with collective responsibilities, as opposed to the libertarian perspective, that focuses on individual rights and minimal mutual responsibilities [37,36].

Arnstein, already in the 1960's, introduced the concept of a citizen participation ladder, as a form of classifying as well as critiquing different styles of governance and participation settings [3]. Foth defines four stages of evolution of the relationship between city government and citizens, with government in roles evolving from administrator to collaborator and citizens evolving from residents to co-creators [13]. Creighton defines participation as "the process by which public concerns, needs, and values are incorporated into governmental and corporate decision-making" [8]. Engaging citizens to participate in public decision-making processes can foster creativity and generate fresh ideas [23], while resulting in strong citizen commitment to related changes [3,21].

Practice teaches that effective collaboration between citizens and professional decision-makers requires a middle-out approach [15]. Top-down approaches tend to place decision-makers at the center of the process and do not generally lead to genuine engagement. Bottom-up initiatives, e.g. taken by community groups, may be seen by decision-makers as illegitimate or substandard and therefore get disregarded. A middle-out process integrates top-down objectives with bottom-up interests and involves stakeholders in all stages of the decision-making process.

Visual communication can effectively support processes of collective decision-making and communicating about such decisions. It can offer a common language in an easily accessible medium and thus reduce barriers for public engagement, allowing participants to become more literate about planning processes [38]. 3D visualizations in urban design have long targeted professional users, such as architects, urban planners, and landscape designers [25,35], but are increasingly used for participatory urban planning as well [1,2]. Visualizations in 3D and VR are used in public consultation processes [20,39], allowing the public to interactively access information in 3D models and leave comments and suggestions for modifications. VR has been demonstrated a suitable means, technologically, to facilitate public participation in urban decision-making [20]. Visualizations also offer opportunities to bring evidence into the decision-making process, informing citizens about environmental issues [40] and consequences for, e.g., daylight and shadow [9].

The present technology of smartphones allows for sufficiently realistic VR experiences, making the technology suitable for large-scale participatory design and assessment of design proposals [5,22,27]. Experimental applications have suggested that VR and interactive 3D visualizations on mobile devices help improve citizens' understanding and increase public engagement [17].

Immersive VR has been suggested to be beneficial for recalling items seen during the virtual experience, especially in multisensory VR environments [11,26]. As an example, Harman, Brown, and Johnson [18] made an experiment to compare recall ability between a VR headset and a computer monitor, and found that people were able to remember more information if they were using the VR headset. However, also contradictory evidence has been presented [4,14], suggesting that increased immersion may have a counterproductive effect for recall. Possible explanations are limited cognitive capacity and mediated arousal, which have been hypothesized to affect recall negatively [4].

3 CO-DESIGN PROCESS

In the beginning of the process, the municipality published a call to the residents for attending an information session with municipal experts. Over 70 residents attended the event, where municipal experts explained possibilities and limitations of what could be achieved in the park, both technically and budgetary. The residents were invited to write up their ideas for the park, which resulted in over 60 written suggestions.

A workgroup of 25 residents from the neighborhood was formed in the event, including males and females from various ethnic backgrounds and age groups, reasonably representative of the neighborhood's population. The workgroup collaborated with municipal experts to generate three designs for the park in three co-design sessions.

In the first session, the workgroup transformed the residents' written suggestions into a comprehensive list of ideas. Based on this list, the neighborhood manager made a set of puzzle pieces for the different zones of the park. Characteristics for each zone were derived from the list of ideas.

In the second session, the workgroup used the pieces of the puzzle to create five compositions for the park. The workgroup members individually prioritized the list of ideas by distributing 20 points between the listed items. These activities enabled the workgroup members to develop a vision for their ideas and choices. The group then formed three teams that each created a design draft for the park. The three drafts were then elaborated by a municipal landscape architect to generate more detailed initial designs.

In the third co-design session, each team discussed their design for the park (see Figure 1) and improved it using a digital 3D modelling system, Sketchup, which was operated by an expert (see Figure 2). This enabled the three teams to comment on and modify the initial designs and instantly visualize their new ideas in the 3D modelling environment.

Figure 1. One of the three teams discussing their design using 2D plans.

Figure 2. One of the three teams discussing their design with the landscape architect (left) and interacting with an expert (sitting behind the computer) as he was modelling their design in 3D.

The co-design sessions resulted in three variant proposals for the revamp of the park. The differences between the three proposals concerned the layout of the pathways in the park and the kind and density of vegetation (e.g., flower beds, hedges). The differences also concerned larger elements, such as playgrounds, activity areas (e.g., skate park, basketball ground, fitness equipment), and outdoor furniture. Two of the three proposals removed an existing service building; one proposal added a new bandstand in the park.

4 EXPERIMENT 1: PUBLIC BALLOT

4.1 Method

With the three designs, a public ballot was conducted among the residents of the neighborhood. The ballot period spanned 3 weeks. The main aim of the municipality was to let residents vote for their favorite among the three designs. This also provided a platform to investigate the effects of using VR technology in the decision-making process.

4.1.1 Participants

The municipality sent a written invitation for the ballot to all residents of the area (approximately 13,500) and advertised it online and through a poster campaign. As a result, 1302 residents participated in the ballot. The voting was entirely anonymous and demographic data of the participants was not collected in order to minimize any barriers for participating in the voting. The only personal information recorded was postcode; this was recorded in order to calculate the distance of the park from the home of the resident.

4.1.2 Setup and Technology

Photorealistic 3D rendering was used to visualize the three prospective design variants for the park. The rendering was done for three fixed locations in the park and the rendering engine supported navigation similar to Google Street View (see Figure 3), i.e., supporting rotation of the point of view and discrete transitions from one vantage point to another.

The 3D-rendered park variants were viewable with a range of devices. A Web-based interface allowed participants to view the designs on their personal computer, smartphone, or tablet. This possibility was enabled to support remote voting, e.g., from home. A voting-support team was active during the ballot period in over twenty public locations in the neighborhood in and around the park. The voting-support team presented the designs either with a VR headset or using a 2D paper map detailing the design variants. The paper map was used as a baseline in the study.

4.1.3 Procedure

The procedure was slightly different for participation through the voting-support team vs. participating independently using personal devices. With the voting-support team, the three variants were presented in a fixed order (A-B-C), whereas for unassisted voting the participants were free to display the variants in any order as many times as they wanted on their own device. The team assisted in two types of voting sessions, offered to residents as a choice: using paper or using the VR headset. The team was instructed to guide the viewing of the three variants, by operating the VR headset for navigation between vantage points and variants, and by answering questions that residents might have. An assisted voting session lasted on average approximately 6 minutes using the VR headset and 3 minutes using the paper map.

After viewing the variants, either unassisted or assisted by the team, the residents could vote for their preferred proposal. Voting took place through a form on the district's official website, where voters could first view the three variants – using their preferred device – and then cast their vote. The voting-support team also carried tablets to allow residents to vote immediately after viewing the designs via the VR headsets or on paper (see Figure 4).

In addition to the voting, the participants were asked to answer a short questionnaire after reviewing all the variants. The questionnaire contained questions related to the confidence of the vote, perceiving differences between the design variants, importance of the park for the voter, and willingness to recommend the voting to others. It was a strategic decision to keep the questionnaire short in the ballot in order to maximize the number of responses in the participatory decision-making process.

4.1.4 Data

Table 1 summarizes the main data collected in the ballot. Voters' willingness to recommend others to vote was used to determine the Net Promoter Score (NPS) for the voting procedure. The NPS is a measure, often used in marketing research, for customers' engagement with a brand or product [32]. We used this measure to determine citizens' engagement with the overall decision-making process regarding the park, as initiated by the municipality.

The questionnaire also gave the voter the opportunity to write a motivation with their vote, which informed the district officials about the perceived pros and cons of the three variants for the park.

Figure 3. Visualization and navigation of the designs as shown on computer screens.

Figure 4. Residents viewing the variants of the park using the VR headset (left) and paper plans (right), with the voting-support team.

Variable	Scale
Confidence of the vote	0 – 10 (not at all confident – 100% certain)
Confidence about having perceived the differences between the variants	0 – 10 (very few differences – differences very clear)
The importance of the park to the voter	0 – 10 (not at all important – very important)
The voter's willingness to recommend others to vote	0 – 10 (not at all willing – certainly willing)

Table 1. Main variables for the questionnaire in the ballot.

4.2 Results

4.2.1 *Engagement with the process (RQ1)*

At the end of the voting period, 1302 residents had submitted valid votes and completed forms. In earlier work, the research results regarding the NPS were published [24] and showed that the engagement with the voting-process in this case was in line with the average appreciation for municipalities in The Netherlands. No correlation was found between the importance of the park to voters and their engagement with the process. The data showed that voters using the 2D paper maps were significantly less willing to ask others to vote as well, compared to users of smartphones and users of the VR headset. Voters using their own computer were significantly less willing to recommend than smartphone users, but no significant difference was found between the VR headset and the smartphone [24].

These results from the ballot questionnaire answer RQ1 from the first perspective we mentioned earlier: regarding citizens' engagement with the overall decision-making process. The second perspective, citizens' engagement with the presentation, using VR as opposed to other display techniques, required an additional, more detailed and controlled study in experiment 2.

4.2.2 *Cognitive benefits (RQ2)*

Analyzing the data from the ballot questionnaire, the voters' confidence of their vote did not relate to the vote they casted (for design variant A, B, or C), nor to the device they used to view the variants. Voters' confidence of being able to perceive the differences between the variants for the park was also not related to their actual vote.

(I) Device	(J) Device	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
Paper	Computer	.568	.251	.157	-.12	1.25
	Tablet/iPad	.764	.354	.198	-.21	1.73
	Smartphone	1.342*	.255	.000	.65	2.04
	VR headset	-.200	.228	.905	-.82	.42
VR headset	Paper	.200	.228	.905	-.42	.82
	Computer	.768*	.206	.002	.21	1.33
	Tablet/iPad	.964*	.324	.025	.08	1.85
	Smartphone	1.543*	.211	.000	.97	2.12

*. The mean difference is significant at the 0.05 level.

Table 2. Mean differences for the variable 'Differences perceived' in the ballot.

There were significant differences between the devices used, with respect to the voters' self-reported ability to see the differences between the variants (see Table 2). Voters that viewed the plan with the VR headset or with the 2D paper maps – thus voters that were approached and assisted by the voting-support team – were significantly more confident of having been able to see the difference than voters viewing the plans unassisted using their own devices. The assistance by the voting-support team, that was instructed to answer questions about the different designs, seems to be the factor of importance here, not the type of device used for viewing the designs. The mean difference for the variable 'Differences perceived,' between assisted and unassisted voting sessions was relevant and significant at -1.056, BCa 95% CI [-1.360, -.752], p = .000.

Regarding the perceived differences between the three designs, the short questionnaire in the ballot only addressed the voters' *confidence* about perceiving the differences. Further study was needed to examine the *actual* perception of differences, which we did in experiment 2.

5 EXPERIMENT 2: LABORATORY STUDY

5.1 Method

Due to the unassisted voting opportunity, it was not possible to control the contextual circumstances during the ballot, which might have had an effect on the results. A laboratory study was conducted to assess in detail the differences between immersive and non-immersive VR regarding perceived differences between the presented designs and engagement with the presentation medium. The controlled study was conducted in two public locations in the city.

5.1.1 *Participants*

76 participants (32 female) were recruited for the experiment. The participants were recruited randomly from the location of the experiment. 42 of these participants used the VR headset to display the park designs, while the other 34 viewed the designs on a laptop computer. None of the participants had participated in the public ballot.

5.1.2 *Setup and Technology*

The same VR headset that was used in the ballot was used in the laboratory study. For comparison, a laptop computer was used to display the 3D rendering on a 2D screen. Other devices such as smartphones, tablets, and paper maps were not addressed in the laboratory study. The main aim was to compare an immersive VR headset with a non-immersive representation, and it was deemed sufficient to do this comparison between the headset and a conventional laptop screen.

The study was conducted in two locations in the city, relatively far from the park itself in order to eliminate the importance of and familiarity with the park from the experiment. The locations were selected to be public indoor spaces with other people present in the environment. The purpose of having background noise and activity around the participant was to study the immersive quality of the VR headset as well as potential distraction effects.

5.1.3 *Procedure*

The procedure was similar to that in the ballot with the voting-support team. Each participant was instructed to view the different designs either with the VR headset or with a laptop. For the VR headset, the experiment conductor controlled the vantage point in a fixed order. The participant was allowed to view the VR-rendered park from each vantage point as long as they wanted and were encouraged to rotate their head to see the entire park. When they were ready to move to the next vantage point and subsequently to the next variant design, they expressed this to the experiment conductor. Participants who viewed the designs on a laptop were instructed to follow the same fixed order, but this was not enforced and these participants switched more freely between the vantage points and variants. The experiment conductor did not offer any further clarifications or answers to questions about the park design variants.

After the viewing, the participants were presented with an extended questionnaire. The questionnaire was tuned to measure memory and recall of objects in the park and differences between the variants. The first part of the questionnaire asked the participants to write down as many objects as they remembered seeing (Free recall). The second part contained questions about the voting experience and the voting itself. The third part presented the participants with a checklist of 22 items (verbally described, e.g., 'a gazebo'); the task was to check whether the participant had seen each item in variant A, B, and/or C (Recall accuracy).

Variable	Scale
Free recall	number of objects listed by the participant
Recall accuracy	0 – 10 (10 = perfect recall)
Confidence of the vote	1 – 5 (not confident at all – 100% certain)
Confidence about having perceived the differences between the variants	1 – 5 (very few differences – differences very clear)
Immersion in the 3D environment	1 – 5 (not immersed at all – very immersed)
Translocation to the park	1 – 5 (no translocation at all – felt like in the park completely)
Concentration	1 – 5 (not concentrated at all – completely concentrated)

Table 3. Main variables for the laboratory study.

5.1.4 *Data*

Table 3 presents an overview of the main data collected during the laboratory study. The participants' capability to remember what they had seen was measured in two ways: (1) by counting the number of objects they were able to write down (Free recall); and (2) by a Recall accuracy score calculated from the checklist of 22 items. This score is representative for how accurately the participant remembered the presence of each item in each of the variants. Mistakes, such as remembering the item but not the variant in which it was present, led to a lower score. A score of 10 represents perfect recall of all items in all variants (which never occurred).

The questionnaire also included questions for measuring the level of immersion experienced by participants and their feeling of having been translocated to the park as opposed to being at the experimentation location. Finally, the questionnaire asked participants how well they could concentrate on viewing the park designs.

5.2 Results

5.2.1 *Engagement with the decision-making (RQ1)*

The data from the lab study clearly shows that participants were significantly more engaged by the VR experience than by navigating the 3D renderings on the computer screen. For each of the three variables 'Immersion,' 'Translocation,' and 'Concentration,' there is a significant advantage for the VR headset (see Table 4). None of these variables could be related to gender or age groups (under 25, 25-49, 50+).

Variable	Mean difference
Immersion	-.697, 95% CI [-1.250, -.145], p = .014
Translocation	-1.755, 95% CI [-2.326, -1.184], p = .000
Concentration	-.821, 95% CI [-1.243, -.398], p = .000

Table 4. Mean differences between Laptop and VR headset, for variables Immersion, Translocation, and Concentration.

Regarding session duration, there was no significant difference between the VR headset and the computer (299 and 275 seconds, respectively). On average, the sessions with the laptop were not significantly overestimated, but those with the VR headset were. Interestingly, the overestimation was found only in male participants: the mean overestimation of the VR session duration by males was 32.7% CI [15.214, 51.026], p = -.024; by females it was 3.7% and not significant.

In terms of engagement, the results are clear: in all the engagement dimensions, the VR headset outperformed the laptop computer.

5.2.2 *Cognitive benefits (RQ2)*

The laboratory study confirmed that the VR headset did not significantly induce more self-reported confidence in the participants' decision, compared to the laptop. Participants' confidence of being able to perceive the differences between the variants for the park was also not related to their actual vote.

No significant mean difference in the recall accuracy was observed between the laptop and the VR headset. However, the mean of the number of objects participants listed in the free recall task was 6.24 for the laptop and 8.02 for the VR headset. The mean difference is significant: -1.789, BCa 95% CI [-3.237, -.340], p = .016. In other words, compared to using a laptop for viewing the 360˚ images of the park, the VR headset allowed participants in the lab experiment to better recount what they had seen, but when measuring their recall accuracy in the recall test, there is no significant difference between the two devices.

6 DISCUSSION

The results of this research provide insight into the effectiveness of VR technology in involving the larger public in participatory urban planning. Regarding the first research question about citizens' engagement with the decision-making process, two conclusions can be drawn. First, in the co-design process, the application of 3D modeling was instrumental for the workgroup to see and reflect upon their designs, resulting in instant design iterations. Instant visualization in 3D brings ideas to life and fuels creativity, both in professional designers/planners and untrained participant citizens, particularly so when designs can be interactively changed during the co-design sessions. The activity of visualization helps participants to assess and reflect deeper on the spatial properties and qualities of their ideas. It facilitates comparisons of alternative designs and places these, literally, into the larger urban context. Being able to immediately review design alternatives in 3D contributed positively to the engagement of the workgroup.

Second, the results of the controlled laboratory study indicate that the participants using immersive VR experienced higher levels of engagement than the participants with non-immersive VR when viewing alternative designs for the park. This result is very important for the municipality in deciding whether to invest in using immersive VR technology to stimulate citizen participation: engaged voters can be argued to be less prone to external distractions during the decision making and to be more committed to make informed decisions. We can conclude that using 3D rendering and VR technologies is fruitful to enhance civic participation, as previously demonstrated [24] and discussed also by Gill and Lange [17].

The data analysis showed a significantly higher engagement in voters that used a Smartphone to view and assess the designs. This may either indicate that the device used influences the engagement level or that Smartphones users are more likely to engage with local policy. Both possibilities are hard to substantiate from the research results. The data shows no indications that the outcome of the voting was biased by the device used to view and assess the designs.

Interestingly, regarding the second research question about cognitive benefits of immersive VR, increased engagement did not result in higher confidence of the vote nor better ability to account for differences between competing designs. The results of the laboratory study show that people who used the VR headset were able to remember more items in the park than people who used the laptop. There was, however, no difference in the recall accuracy between the two devices. This indicates that viewing the designs on the VR headset resulted in more vivid, but not more accurate, memory than viewing the designs on the laptop. Considering the fact that the VR headset outperformed the laptop in terms of immersion, translocation, and concentration, it seems that the higher level of immersion with the VR headset might have helped the participants with the free recall of items, which is in line with previous results [18]. However, based on the results, immersion was not helpful regarding the recall accuracy. The list of 22 items to recall was, admittedly, rather long, so the high cognitive demand of the task combined with the immersive experience might have hindered the recall accuracy [4,14].

The controlled experiment corroborates the finding from the ballot regarding the effect of the voting-support team on perceiving differences between different designs. In the ballot, the VR headset and paper maps were used with the voting-support team, who were not only assisting the voting but were also available to answer any questions the voters had. It is possible that this discussion influenced the confidence in perceiving differences between the designs. Since no significant difference between the VR headset and the laptop was found in the controlled experiment, the assistance by the team is a probable explanation for these differences in the ballot. This result suggests that while technology can be utilized for informed decision making in a participatory process, interacting with municipal representatives during the decision making can provide further insight into the decision to be made.

6.1 Limitations

There are four main methodological limitations in the study, First, as discussed above, the presence of the voting-support team during the ballot seemed to influence the comparison between the technologies. While this can be seen as biasing the voters in terms of their confidence in perceiving the differences between the designs, it is important to remember that the main aim of the municipality was to get as many votes in as possible. We rectified this bias by conducting the controlled laboratory experiment, which eliminated the effect of the voting-support team from the comparison.

Second, the questionnaire during the ballot was limited in scope due to the aim of easy voting. This implied that we were not able to include questions related to immersion, demographics, and details of perceived differences between the designs. While this data could have provided further insight into how people perceived the VR technology in the voting, we were still able to sufficiently investigate immersion and perceived differences in the controlled experiment.

Third, to simplify the viewing of the three designs with the VR headset, they were always presented in the same order (A-B-C). Thus, the results do not account for possible order effects. We did not control in which order people viewed the variants in the unassisted voting, nor how many times they looked at each variant from each vantage point. However, this approach did not have a statistically decisive influence on the outcome of the ballot itself and it is unlikely that it had an effect on the key measures of our study. Willingness to recommend the voting, perceived differences between the variants, and level of immersion can be argued to be relatively robust against order effects.

Finally, while qualitative data was collected through interviews and observations during the sessions of the workgroup in phase 2 of the participation process, the research presented in this paper focused solely on collecting quantitative data in the public ballot in phase 3. Interactions between the voting-support team and the public were observed, but not methodically enough to allow conclusions to be drawn.

7 CONCLUSION

The presented case study investigated the effectiveness of VR technology in participatory urban planning, in the context of a municipal decision-making process. The results suggest that there are several benefits in using VR headsets with 3D rendering in such a process. First, immersive VR provides higher engagement than using 2D presentation technologies, indicating stronger potential in eliciting participation. Second, immersive VR results in more vivid memory of the viewed content than computer monitors, which may be important in terms of making informed decisions. Third, the effect of human interaction should not be neglected in decision-making processes harnessing engaging technologies. Finally, the experiments provide the kind of evidence that municipal governments need to decide about investments and the design of participatory planning processes.

The participatory design project had an important social impact on the neighborhood. The resulting design closely reflects the needs and wishes of the inhabitants near the park. The municipality's decision to involve all inhabitants, in response to discontentment about the park, has also contributed to the relationship between the neighborhood and the municipal government. Citizens showed an increased and genuine interest in the local urban development and felt invited to partake in the decision-making. In this way, the renewed park and the process of its realization contribute to the social cohesion in the neighborhood and a shared responsibility to maintain its social and physical qualities. Did the participatory design and the voting procedure lead to a better design for the park? In the opinion of the municipal officials involved, the actual value in a project like this is determined not merely by the quality of the resulting design, but by the quality of the public support for its outcome. The social and managerial impact of the participation project is discussed in more detail in earlier work [24].

Due to the nature of the municipal decision-making process, there were some methodological limitations in the large-scale field study during the ballot. These limitations were rectified through an additional controlled experiment to ensure experimental validity. The field study and the controlled experiment complemented each other and resulted in findings that could not have been obtained without conducting both experiments. Therefore, we can conclude that when conducting research as an additional component in a design process of a municipality, it is important to conduct additional experiments to shed more light on the obtained insights.

7.1 Future work

From our observations and evaluations with the voting-support team, we learned that many voters said, after voting, that they would like to be able to participate in a more nuanced manner than just choosing between the three options given. They had suggestions to make and ideas to explore for modifications of the proposed designs. Ball et al. [5] stress that mutual understanding between planners and stakeholders is a prerequisite for successful participatory design. For mutual understanding to happen, there must be a public dialogue about urban plans, stakeholder needs, and consequences of design decisions [5]. Facilitating such dialogues and co-design activities for the larger public calls for a much subtler approach, where the effectiveness of visual communication is combined with tools for dialogue, design exploration, collective construction of meaning, and of shared understanding. Future work on this topic would have to address the design of such tools and to explore the delicate balance between meaningful interactions and public accessibility of what could potentially become a very complex collaborative design environment. Prior to this kind of development, more qualitative research is needed to gain insight into the social factors that bind participants, both professional and untrained, in co-design projects.

The increasing availability of VR and AR technology, including on common Smartphones, is lowering the threshold for setting up and managing this technology in projects with public participation. For municipalities it is essential to increase the level of citizen-engagement in decision-making processes and media technology proves to be a very appealing way to do this. The municipalities' interest in using VR and other digital media for this purpose, leads to two speculations regarding media architecture. First, in addition – or alternative – to VR, other digital media can be utilized to facilitate citizen engagement and offer valuable capabilities. For instance, using public displays as discussed by, e.g. [12,28–31,33,34], may be suitable to prompt public debates about alternatives in decision-making processes. Second, participatory processes will play an increasing role in decision-making, also regarding the design and realization of media installations in public spaces. The process presented in this paper can be applied in such cases and our conclusions may help optimize the social and managerial effects and the acceptance of the outcome.

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