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Immersive Virtual Spacewalking in Stakeholder Workshops: The Effect of Immersive, BIM-driven Design and Interaction Tools on Human Sense of Presence

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ABSTRACT

In this mixed methods field study, we explored the effect of gradually enhanced visual details and naturalistic implementation in virtual apartments on perceived presence. Furthermore, we recorded the usability of virtual interaction mechanism, and which virtual interaction mechanism could be remembered after the data collection phase. In three workshops, planned BIM data of two different types of apartments were put into a virtual environment. We optimized the virtual apartments for an immersive virtual reality walkthrough and developed interactive tools for exploring the virtual apartments. We found a significant lower values in presence subscales when the visual details where intermediate, compared to low and high visual details. This may show a possible connection with the uncanny valley phenomenon. Also, further limitations of the study are discussed, and an outlook of possible further research is suggested.

Keywords: Immersive virtual reality, Presence, Building information modell

INTRODUCTION

Over the last decade, the use of Building Information Modelling (BIM) has become increasingly widespread to manage the growing complexity of construction projects. As a result, project managers are facing new challenges in managing stakeholders in BIM projects, as the BIM concept is still relatively new to many of the stakeholders (Leśniak et al., 2021). The introduction of BIM has brought new and complex activities into the already complex process of project management, resulting in a radical change in the working practices of project managers and in the working practices of the project stakeholders (Li et al., 2021). Besides the purely technical advantages of better planning and manipulating data, plans, etc. used to get the best possible visualization of the future, human factors are at least as, if not more, important when looking into the future. Immersive virtual reality (VR) can transform

virtual plans into a walkable world, so that different stakeholders (architect, builder, tenant, etc.) can walk through the same flat without the need for specialist expertise in understanding building plans (Schiavi et al., 2022). This same mental picture of the e. g. apartment can now have an impact on decision-making processes and shorten the time to final judgement. At the same time, different aspects of interior design can be explored (size effect, furnishing, etc.).

What evidence is there that VR in BIM can be useful for the stakeholder process? Dinis et al. (2021) succeeded in improving project communication for stakeholders through a new workflow that combined laser scanning and virtual reality in the context of building information modeling (BIM) and provided an alternative approach for defining expected requirements, qualities, and specifications. Building on this, Ventura et al. (2018) were able to show that the creation of a process map depicting all the necessary phases and activities to be considered for the effective implementation of immersive VR to assess design intent with clients and end users was possible. The study by Abbas et al. (2000) revealed otherwise. Thereby, no significant improvement could be observed in the quality of discussion, richness of communication, and openness in the process with VR compared to face-to-face communication. In addition, face-to-face communication achieved slightly better values, which in turn means that immersive reality must be improved in order to better represent realistic interactions. In this case, the used interaction methods and VR induced presence (illusion of the state or fact of being present, as with others or in a place) seems to play an important role as it has been previously described (e.g., for social presence research see Greenwald et. al., 2017). In our mixed methods field study, we wanted to know which interaction mechanisms play an important role in the immersive virtual world and whether the sense of presence (illusion of place) is changed by the virtual design of rooms.

METHODS

In three workshops, planned BIM data of two different types of apartments were put into a virtual environment (UNITY3D). We optimized the virtual apartments for an immersive virtual reality walkthrough and developed interactive tools for exploring the virtual apartments. In the first workshop (W1) we aimed to assess and demonstrate the sense of space of the planned apartment. In the second workshop (W2) we focused on the texturing (W2) and in the third workshop (W3) we demonstrate the kitchen & wet room variants. Form W1 to W3 the visual details and naturalistic implementation of the virtual apartment were gradually enhanced (see Figure 1).

The participants were tenants, building owners, architects, and employees from the local building office. Their experience in virtual reality varied from none to a lot of experience. There were different tasks and goals for each workshop. Beside discussions, there was at least one VR-experience session per workshop, where participants would experience the virtual room in groups of two, with tasks specific to the session. A virtual

Figure 1: From top (W1) to bottom (W3) the visual details and naturalistic implementation of the virtual apartment were gradually enhanced.

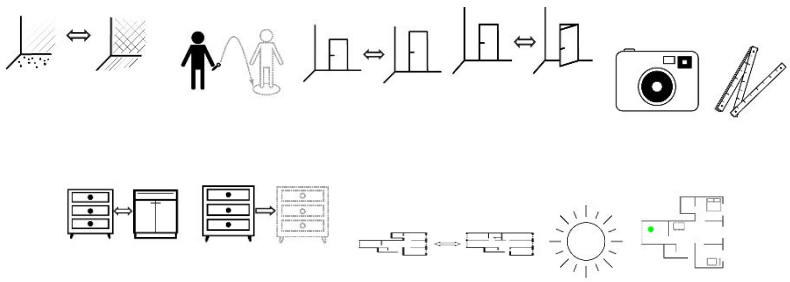

Figure 2: Interaction options from top left to bottom right: Close door, Open door, Teleport, Change texturing, Measure size/length, Take photo, Swap furniture, Move furniture, Change floor; Change sun position, Mini map.

tablet allowed participants to interact in various ways in virtual space and a mini map simultaneously enabled orientation in the virtual apartment (see Figure 2).

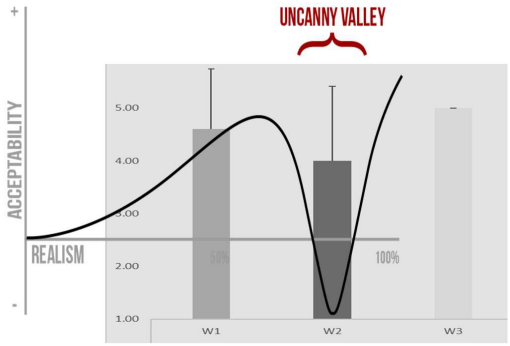

Figure 3: The mean values of several subscales of the PLBMR were reduced in the second workshop.

This was done with three HTC VIVE pro headsets (one per group) with one person experiencing in the virtual world and the other spectating the first-person view from on a 75" screen. After some time, they swapped medium and the person who was in the virtual world now watched from outside. We recorded the following data during the workshop: technical affinity with TA-EG (Karrer et al., 2009), usability with UEQ-S (Schrepp et al., 2017) and sense of presence with PLBMR (Frank & Kluge, 2014). Additionally, the participants were interviewed several weeks after the workshops with half structured interviews: Over all workshops a dataset of N = 13 participants could be archived and evaluated. Descriptive and non-parametric statistics were calculated with SPSS 21. The coding of the interviews was done with MAXQDA.

RESULTS

Quantitative Data Analysis

We found a heterogeneous group in the scales for technical affinity. Regarding the importance of the tools, we found that not all tools were remembered in the interviews. The teleport function was retrospectively remembered most often, followed by changing/moving furniture, changing the floor and textures, and the mini map. The overall usability rating in the UEQ-S was good and the most important finding was a significant less sense of presence (PLBMR) in workshop 2 with $p > .05$, cohens' $d=.21$ (see figure 3) which led us to the assumption of a possible uncanny valley effect (see discussion).

Qualitative Data Analysis

In the retrospective view of the participants qualitative data from the interviews, showed positive and negative aspects of immersive virtual reality as a supplemental tool:

Regarding the positive aspects, object can be viewed differently and in greater depth, from which a rethinking and a basis for discussion can arise.

Original comment: "This discussion, I mean we then came to this story via details, e.g., of the facility, and whether we would have discussed these

details of the facility based purely on the plans in this way I don't know. And above all, that it was then also just very transparent for both of them, that is, visible."

Also, people from outside the field can be more easily involved in decision-making processes. Original comment: "It is of course very advantageous that you can experience the dimensions before the start of construction and can also communicate with them, i.e., just now for our participation process, that we could take people with us, I found that very, very positive and helpful, because of course the people can then also transport their experiences in their environment."

Regarding the negative aspects, some people noticed that body or other reference points for size estimation were missing/ lighting conditions, textures and colors not realistic enough. Original comment: "What gives you the scale a little bit is the eye level where you have in the model. That shows you something like I'm this tall. But you don't have any other... You can't see your own body in the room, for example. That would perhaps be another step, that one, that one perhaps moves a kind of an avatar in there. (...) Or I think it's very important to be able to judge a room, you have to be able to estimate the size of the room. You can do that through the textures, through the details, where you know how big a window handle is. (...) Or right now if you know about furnishings, if you know: Ah this is the size of a chair, then the room is so and so big." Also, the discussion did not take place at the same time as viewing. Original comment: "And it was extremely difficult to have such a discourse afterwards, because in virtual reality everyone was alone, actually. But you would discuss as a group. But if you discussed it afterwards, so you sat down at the table afterwards and would discuss."

The biggest advantage that the workshop organizers identified was reduction in the time it takes to submit a building application. Original comment: "If we had not used VR, we would still be arguing for 2 years. ()".

DISCUSSION

The introduction of BIM resulted in a radical change in the working practices of project managers and in the working practices of the project stakeholders (Li et al., 2021). This change should be carried out in a way that most stakeholders should feel comfortable with. As we saw in the data, the usability ratings were good, but some interviews showed that a reduction in complexity may be a further improvement, since not every feature was remembered or needed in the virtual room (Schiavi et al., 2022). The decrease in sense of presence in the second workshop show a possible connection with the uncanny valley phenomenon. In other research areas e.g. robotics, the term "uncanny valley" demonstrates the phenomenon that, after a certain point, as a robot's human likeness increases, familiarity with and empathy toward the robot decreases, unless human likeness is at a very high level (Mori, 1970). In interaction design this effect was demonstrated before in different case studies by McMahan et al. (2016). As we cannot describe any causalities in this field study, we are only able to describe this phenomenon, which could be important when validated in controlled experiments. If this effect

is validated, then it can be that the own presence feeling is changed by the visualization, which was conditioned by the topic of the workshop. Whether this then has an influence on the assessment, communication, etc. of the participants can only be clarified by further studies. Beside this missing causality in this filed study as a main limitation of the study we could show the advantage of VR as tool for creating a collective mindset for what is being planned. Even though VR has not yet reached the best maturity level, we are optimistic that future technological developments will address the user's problems to further improve the experience in the stakeholder management process in the construction project.

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