The Effect of Presence and Appearance of Guides in Virtual Reality Exhibitions

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ABSTRACT

Virtual reality (VR) enables users to experience informal learning activities, such as visiting museum exhibitions or attending tours independent of their physical locations. Consequently, VR offers compelling use cases by making informal learning and education accessible to a broader audience and simultaneously reducing the carbon footprint. For many learning activities, the presence of a human guide is essential for participants' experience. The effect of the presence of a guide and its appearance in VR is, however, unclear. In this paper, we compare a real-world guide with a realistic, an abstract, and an audio-only representation of a virtual guide. Participants followed four multimodal presentations while we investigated the effect on comprehension, presence, co-presence and the perception of the guide. Our results show that even a realistic presentation of a guide results in significantly lower co-presence, humanness, and attractiveness compared to a human guide. Qualitative results and participants' feedback indicate that having no visual representation of the guide helps to focus on the content but can reduce the connection with the guide.

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CCS CONCEPTS

• **Human-centered computing** → **User studies**; **Virtual reality**.

KEYWORDS

Virtual reality, VR, Virtual avatar, Presence, Co-Presence, Uncanny valley effect.

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1 INTRODUCTION

VR provides users with access to environments that are inaccessible, far away, expensive or dangerous to visit independent of their location and current time [41]. Consequently, it enables broader access to informal learning activities, such as visiting a museum exhibition or attending tours. In the real world, many people do not frequently participate in this kind of activities because of the required preparation time, transportation, financial costs, and sometimes limited quality of guides and tutors [41, 54]. By providing access to informal learning activities for a broader population, VR not only contributes to reducing the carbon footprint but also has the potential to increase the accessibility for visitors with special cognitive and physical needs [40, 41]. Furthermore, VR can bring additional benefits to informal learning activities. Previous work showed that VR grabs and holds the attention of learners, supports the interaction with the virtual learning environment, more accurately illustrates some processes and is highly motivating [34].

Visiting exhibitions is a common informal learning activity [17]. Presenting an exhibition in VR can provide solutions to the limitations of real-world exhibitions [25]. Because of the lack of space or fragility of exhibition artifacts, it is not always possible to present them. However, VR can not only help to overcome these challenges but also allow to interact with exhibition content directly and to observe it from various viewpoints. Furthermore, VR enables to reconstruct and demonstrate environments and artifacts that are only partly preserved, have been lost or destroyed [52]. There are usually only a few possibilities for visitors to interact with artifacts and learn new information about them in traditional exhibitions [38]. The visitors learn in exhibitions by reading labels or booklets with information or listening to audio guides. In contrary to human-guided exhibitions, these possibilities are not personalized and do not answer visitors' questions about the exhibition content.

Learning from human guides can offer advantages over learning from computer-based guides. Current computer-based guides cannot convey subtle cues through facial expressions, body language, conversational cues, or the simple use of dialogue [24]. However, Bulu [10] found that social presence is essential for learners to be more satisfied with the virtual world experience. On the other hand, VR offers exciting opportunities for intelligent guiding systems [44]. In a virtual exhibition environment, visitors can benefit from following a virtual guide, listening to it, asking questions and receiving responses. Furthermore, through personalized virtual guides for individuals and groups, VR exhibition visitors can experience time-independent guided tours. In a VR exhibition, a visitor and a virtual guide can collaborate, interact and communicate in nonverbal ways which are not always possible in traditional exhibitions as a single guide typically gives a tour for a larger group of attendees. Furthermore, VR guide can be responsive and context-sensitive by tracking visitors' visual attention and physical movements.

VR allows an extensive variety of representation of the virtual exhibition guide. Previous work showed that visual presence and appearance of virtual avatars affect social behavior, interaction in the virtual environment, and the motivation to engage with VR content [4, 5, 7, 33]. However, it is unclear how guides for VR exhibitions should be designed. Therefore, we conducted a user study with 20 participants to investigate the effect of the presence and visual appearance of the virtual guide in VR exhibition on comprehension of the exhibition content, presence, co-presence, and the uncanny valley effect. We compared a real-world guide with a realistic, an abstract, and an audio-only representation of a virtual guide in a VR exhibition setting. Results show that having even a realistic virtual guide in a VR exhibition results in lower attractiveness, co-presence, and humanness than the real-world guide. Furthermore, we found that participants can focus better on the content without a visual representation of the guide, but it reduces the connection with the guide.

2 RELATED WORK

Our work focuses on investigating the presence and appearance of virtual guides in VR exhibition settings. Thus, the work is positioned between research highlighting the benefits of virtual guides in inform virtual exhibitions and learning in virtual exhibitions, and research dedicated to the effects of too realistic representations that can elicit uncanny sensations.

Virtual Exhibitions and Presentations

Both physical and virtual museum exhibitions should fulfill the functions of inspection, research, communication, documentation, and storage [26]. While virtual museum exhibitions have the advantage of easing storage as well as the inspection and research of exhibited or archived artifacts [59], they lack information detail [53] and communication [11, 35] when being compared with their physical equivalents.

Social interaction among exhibition visitors has an impact on their overall exhibition experience [28]. Various systems have been built to connect virtual and real exhibition visitors. Brown *et al.* presented a mixed reality system that allows a virtual and a physical exhibition visitors to share their museum visit experience in real time [9]. The study with the system showed that participants could retain many of the attractions of a traditional shared exhibition visit. Further previous work investigated systems supporting co-visiting experiences to explore the combination of traditional and digital media in the visitor experience [19], comprehension of the heritage [23], peer-to-peer information exchange [18], or cultural heritage experts for co-located collaboration [8].

In addition to the described positive effect of social interaction on content engagement, virtual exhibitions can also enhance the informal learning experience through supporting virtual guides. While virtual tours can be automatically created [14, 16, 32, 36, 57], virtual tours simply presenting virtual objects and descriptions of them do not reach the fullest potential of stimulating engagement amongst the audiences [37]. Narratives can strongly reinforce the visitors learning and understanding of the content in a physical exhibition [45]. Since social interaction is the key to reinforcing learning [28], guiding avatars are a promising approach to reduce the lack of offered exhibition functions [26] that virtual exhibitions still suffer.

Agents are digital models driven by computer algorithms [3]. While agent-based exhibition and tour guides have been introduced to create engaging exhibition experiences, users have been unsatisfied when the design of the agent restricted the questions they could ask [43]. Moreover, agents are beneficial for navigation aid. However, the expectation as information aid seems to be hard to meet because of the lack of personalization capabilities. As an example, adapting the given explanations based on what the user had already heard or proposing different tours in the case of multiple visits has been missed in agent-based guides [13]. When comparing the user experience of an agent-based guide with a human guide, the latter's performative function and the personal engagement with groups and individuals were perceived as something that cannot be replicated by an agent [42].

Previous work suggests that humans could be better guides than agents [42]. It might be supported through human guides' ability of spontaneous in-situ response to visitors' questions. Furthermore, human guides can use the non-verbal communication of their body pose, which supports verbal explanations in teaching [55]. On the other hand, avatars as being virtual representations of humans can also answer questions spontaneously in-situ and take advantage of non-verbal communication to support their verbal explanation. The use of avatars strongly contributes towards collaboration, awareness, interaction and communication [15].

Effects of Realism in VR

Presence of virtual guides can affect learning [46]. The design of anthropomorphic virtual guides can significantly impact on the motivation to engage with museum content as avatar realism was shown to have a significant effect on the presence and co-presence [27, 47]. An increase in human behavior realism, such as gaze, can cause an increase in co-presence [1]. However, adding visual features of a face can negatively effect mediated communication and cause self-disclosure [58]. Bailenson *et al.* [3] proposed a hybrid realism solution for avatar realism that maintains high co-presence without lowering self-disclosure and which would be beneficial for distance learning applications. Baylor [5], on the other hand, pointed out that the appearance of the agent as a social model is a critical factor for its success and that providing a social model from the same in-group as the user is generally advantageous. Furthermore, a human-like voice with appropriate and relevant emotional expressions has an impact on learner motivation and engagement with the learning material [6]. Moreno *et al.* [30] showed that learners outperformed on the retention test and problem-solving transfer when the speech of the desktop-based pedagogical agent was presented as an audio rather than on-screen text. Moreover, they found that presenting the pedagogical agent either as a fictional agent or as a video of a human face does not affect the learning experience. George *et al.* [21] investigated three instructor representations using the head-mounted display on social presence and task performance. The instructor representations were audio-only, abstract avatar and a webcam representation, which was the rendering of the input of a camera, capturing the instructor, on a flat surface in the virtual environment. The results showed that webcam representation increases social presence while decreasing task performance. Oppositely, audio only representation resulted in the least social presence and the highest task performance.

The mismatch between an avatar's gender, appearance, and physical body and one's physical reality has been shown to affect social communication preferences and behavior in virtual public spaces [20, 29]. Banakou and Chorianopoulos showed that users with more elaborate avatars had a higher success rate in their social encounters, and female users spoke more frequently with male avatars when using an attractive avatar which indicates a self-confidence effect induced by the appearance of the personal avatar [4]. Interestingly, co-presence was found to decrease with an increasing mismatch between the appearance and behavioral realism of an embodied agent versus one's physical reality [2].

While high levels of realism can help to engage with content and increase presence and co-presence, they can also have adverse effects on the VR experience. The uncanny valley effect can occur at high levels of realism and when a human-like character looks almost but not perfectly real [12, 31, 50]. Even subtle differences of virtual characters compared to real humans can cause feelings of discomfort, eeriness, and even repulsion. Similar feelings occur when own avatar does not look like the own body [49, 50, 56]. Researchers assume that a perceptual mismatch occurs when multiple features are atypical or have inconsistencies in their realism [12, 51]. Thus, when animations, textures, and models in 3D are inconsistent in virtual realism, the effect can also occur with own and to others' avatar in VR [56].

Summary

Virtual exhibitions have the potential to enhance the exhibition visit experience. While avatars are a promising approach for learning and engaging with content when being in a virtual exhibition, it remains unclear how such an avatar should be designed. A high degree of behavior and form realism is the base for mimic and gestures which are nonverbal supporters of verbal communication. However, an increase in realism can lower self-enclosure in learning and could even create an unpleasant guide caused by the uncanny valley effect.

3 METHOD

To assess the effect of the presence of a guide and its appearance in VR exhibition and to compare the experience with the real world, we conducted a controlled experiment. Therefore, we prepared a real world and a VR exhibition room. The room in VR was the 3D model of the one in the real world (see Figure 2). For the study, we developed four short presentations both for the real world and VR. The presentations were conceptually similar but introduced different content. To present content with different modalities, we

Figure 1: Composers' busts and paintings including them used as stimuli in the real and virtual conditions.

selected four classical music composers: Johann Sebastian Bach, Frédéric François Chopin, Franz Peter Schubert, and Pyotr Ilyich Tchaikovsky. For each presentation, as modalities we used a bust of the composer, a short piece of music of the composer ("Christ lag in Todesbanden", "Prelude Opus 28, Number 7", "Der Erlkönig", and "1812 Overture", respectively) and a painting showing the composer in the historical context (see Figure 1). Furthermore, for each presentation, we prepared a speech describing the life and work of the corresponding composer for the guide. The texts of the speeches had on average 198.5 (SD = 8.66) words. For the study, we varied the presence and the appearance of the guide in VR. In these presentations, the guide was presented as a realistic avatar (*VR-Realistic*), an abstract robot (*VR-Abstract*), or only by audio (*VR-audio*).

Participants

We recruited 20 participants (9 female) through our university's mailing lists. Their age was between 19 and 31 (M = 23.3, SD = 3.45). Most had a background in IT and were university students. Twelve had experience with VR (60%). Except for one participant, all but one (95%) indicated that they were not acquainted with any informal learning environment in VR. Participants received 10EUR for taking part in the study.

Study Design

We systematically varied the realism of the human guide resulting in a within-subject design with a single independent variable Guide. The independent variable has four levels: *Real*, *VR-Realistic*, *VR-Abstract*, and *VR-Audio*. We assessed the effects of the four conditions on several dependent variables. After experiencing each condition, participants were asked to fill questionnaires. To assess the effect of the conditions on social presence in VR and the affinity to the guide, participants filled the co-presence questionnaire by Poeschl and Doering [39]. The perceived humanness, attractiveness, and eeriness were measured using the uncanny valley effect questionnaire by Ho and MacDorman [22]. Additionally, we used the group presence questionnaire (IPQ) to assess the perceived realism and the feeling of the presence of our participants [48]. We also measured comprehension of heard speeches by using five multiple-choice questions with four possible answers. We ensured that the texts used in the presentations and their questions had a similar complexity through a pilot study with six participants. Moreover, participants were asked to give qualitative feedback on each condition.

Apparatus

To conduct the study, first, we prepared an exhibition room in our lab. We used whiteboards to give a feeling of a room with white walls. We placed a pedestal, a bust and a painting in the room as seen in figure 2. Furthermore, we created a 3D model of the room for the VR conditions. A research assistant was coached to present the virtual artifacts and played a guide wearing a black jacket and pants. We generated the realistic 3D representation from pictures of her by using FaceGen Pro [1] and DAZ3D [2]. Both the model and skeleton are based on the Genesis 8 model in DAZ3D. We used the animated model of a robot for the less human-like representation [3]. For conditions in VR, we recorded the research assistant's motion for each presentation using OptiTrack's full-body tracking system. In the real world condition, our research assistant played the guide by herself. We used Unity 3D (Version 2018.2.16) to create the VR conditions. As further apparatus, we used a high-performance PC running Windows 10 and an HTC Vive as a head-mounted display (HMD). In all except the *VR-Audio* condition, the guide was staying in the same position and showing once the bust and the painting by lifting the arm on the corresponding direction during the presentations.

Procedure

During the study, four presentations, one in the real world and three in VR, were shown to each participant. We counterbalanced the order of *Guides* and presentations using a Latin square design. After we introduced the purpose of the study, participants signed a consent form and answered questions about their demographics and technology familiarity. We then introduced the used apparatus, helped participants to wear the HMD and told them to stand in front of the exhibition. In the *Real* condition, participants did not wear the HMD. During the conditions in VR, participants were

[1] https://facegen.com
[2] https://www.daz3d.com
[3] https://assetstore.unity.com/packages/3d/characters/robots/space-robot-kyle-4696

Figure 2: Rooms in *Real, VR-Realistic, VR-Abstract,* and *VR-Audio* conditions.

wearing HTC Vive. At the beginning of the study, each participant was informed about the comprehension tests, asked to pay attention to the guide's speech and to be as accurate as possible when answering the questions. At the beginning of each presentation with a visual guide, the guide showed the bust of the corresponding composer and later the painting to catch the participant's attention.

During the presentations, participants observed the exhibition items, listened to the guide's speech and a piece of music by the corresponding composer while standing two meters away from the guide which was marked on the floor. After each presentation, participants took off the HMD if they were wearing it, answered five comprehension questions and filled in the questionnaires. During this time the research assistant changed the bust and the painting of the composer to the next ones. Afterward, participants continued with the remaining conditions. The study took about 50 minutes per participant.

4 RESULTS

For the study, each participant experienced one presentation per condition. Comparing the comprehension scores (see Figure 4), a Friedman test revealed no significant effect of Guide, $\chi^2(3)$=3.181, p = .365.

To reveal the main effect of Guide on the subscales of the Uncanny Valley questionnaire (Figure 3) as well as presence (Figure 5), we applied Friedman tests as the assumption of normality had not been confirmed. Pairwise post hoc comparisons using the Wilcoxon signed-rank test using Bonferroni correction were conducted if applicable.

There was a statistically significant effect of Guide on perceived humanness, $\chi^2(3) = 48.045$, $p < .001$. Post hoc test showed statistically significant difference between *Real* ($M = 6.51$, $SD = 0.903$) and *VR-Realistic* ($M = 2.68$, $SD = 1.145$), *Real* and *VR-Abstract* ($M = 2.18$, $SD = 0.87$), and *Real* and *VR-Audio* ($M = 3.72$, $SD = 1.262$, all $p < .001$). Furthermore, we found statistically significant differences between *VR-Abstract* and *VR-Audio* ($p < .001$) as well as between *VR-Audio* and *VR-Realistic* ($p = .047$). There was a statistically significant main effect of *Guide* on perceived eeriness, $\chi^2(3) = 8.862$, $p = .031$. However, post hoc test could not reveal any statistically significant difference between the conditions. Comparing the attractiveness scores, we found a main effect of *Guide* on perceived attractiveness, $\chi^2(3) = 31.23$, $p < .001$. Post hoc test revealed statistically significant difference between *Real* ($M = 5.388$, $SD = .186$) and *VR-Realistic* ($M = 4.113$, $SD = .191$, $p < .001$), *Real* and *VR-Abstract* ($M = 4.238$, $SD = .151$, $p < .001$), and *Real* and *VR-Audio* ($M = 4.538$, $SD = .118$, $p < .001$).

There was a statistically significant main effect of Guide on general presence, $\chi^2(3) = 8.285$, $p = .04$, and on experienced realism, $\chi^2(3) = 11.677$, $p = .008$. Post hoc test of the general presence scores could not reveal any statistically significant difference between the conditions. Post

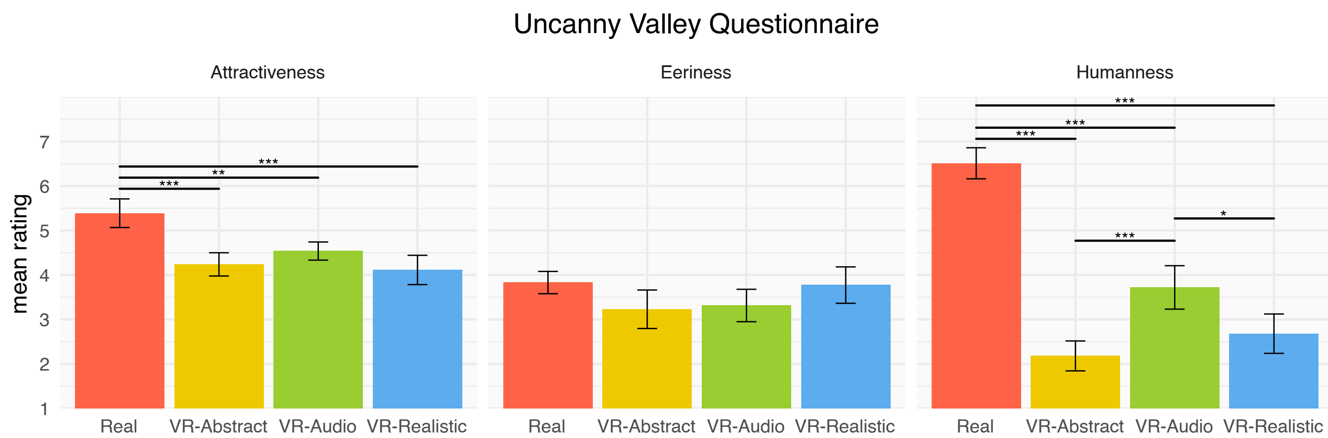

Figure 3: Subscales of the Uncanny Valley questionnaire for all conditions. With * p < 0.05, ** p < 0.01, and *** p < 0.001 and all others are not significant.

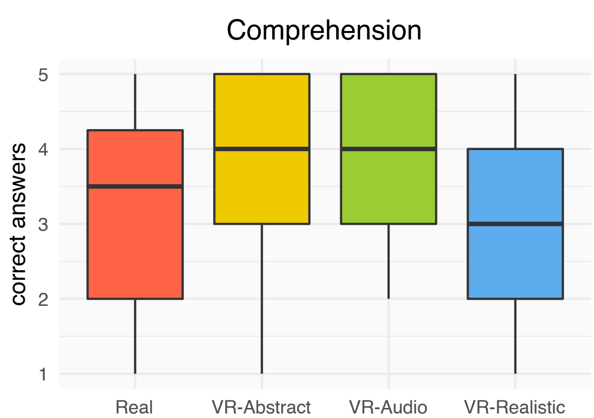

Figure 4: Box plot of correct answers in the comprehension test.

hoc test of the realism scores showed significant differences between *Real* ($M = 4.475$, $SD = 1.498$) and *VR-Abstract* ($M = 2.975$, $SD = .935$), as well as between *Real* and *VR-Realistic* ($M = 2.888$, $SD = .776$, all $p < .01$).

Assumed violations of normality among the co-presence scores were tested using Shapiro-Wilk's test and showed no significances (all $p > .099$). Mauchly's test indicated that the assumption of sphericity had not been violated, $\chi^2(3) = .740$, $p = .378$. Thus, a repeated measures ANOVA was conducted and showed a statistically significant main effect of the *Guide* on co-presence, $F(3, 57) = 42.627$, $p < .001$. Post hoc test using Bonferroni correction revealed statistically significant differences between *Real* ($M = 5.31$, $SD = 0.181$) and *VR-Realistic* ($M = 3.053$, $SD = 0.208$), *Real* and *VR-Abstract* ($M = 2.727$, $SD = 0.209$), and *Real* and *VR-Audio* ($M = 2.533$, $SD = 0.253$) (all $p < .001$). Figure 5 shows the co-presence scores for all conditions.

At the end of the study, each participant gave feedback on each condition. 70% of the participants reported that they learned the most in the *VR-Audio* condition. They explained that there was "no distraction" (P1, P3, P7, P9, P10, P12, P16, P17, P18, P20) in this condition, and it was "easy to concentrate on the guide's speech" (P10, P13). Four participants learn the most during the *VR-Abstract* condition. The explanation was the "lack of natural movements" (P6, P18) in the abstract avatar, which was the reason for the distraction in *VR-Realistic* condition. On the other hand, P19 stated: "the abstract guide was not a lot of distraction, but [it] was something to capture my attention." One participant indicated that "the facial expressions and gestures of the guide resulted in distraction" (P20) during the conditions with both realistic and abstract guides. Furthermore, participants mentioned that the guide in the *VR-Abstract* condition did not distract because "it almost felt like a third object presented in the museum" (P1) and "it was possible to disregard it after some time" (P8). 8 participants mentioned that the guide in the *VR-Realistic* was uncanny. P2, P8, and P15 indicated learning the most in the real-world condition and missed the "eye contact" of the guide during the conditions in VR.

5 DISCUSSION

In this paper, we investigated the effect of the presence and appearance of a virtual guide on the experience of a virtual exhibition. The comprehension scores for the conditions *VR-Abstract* and *VR-Audio* were slightly higher than for the *Real* and *VR-Realistic*. However, the difference between them was not statistically significant. The results suggest that the appearance of the guide might have a negligible effect on

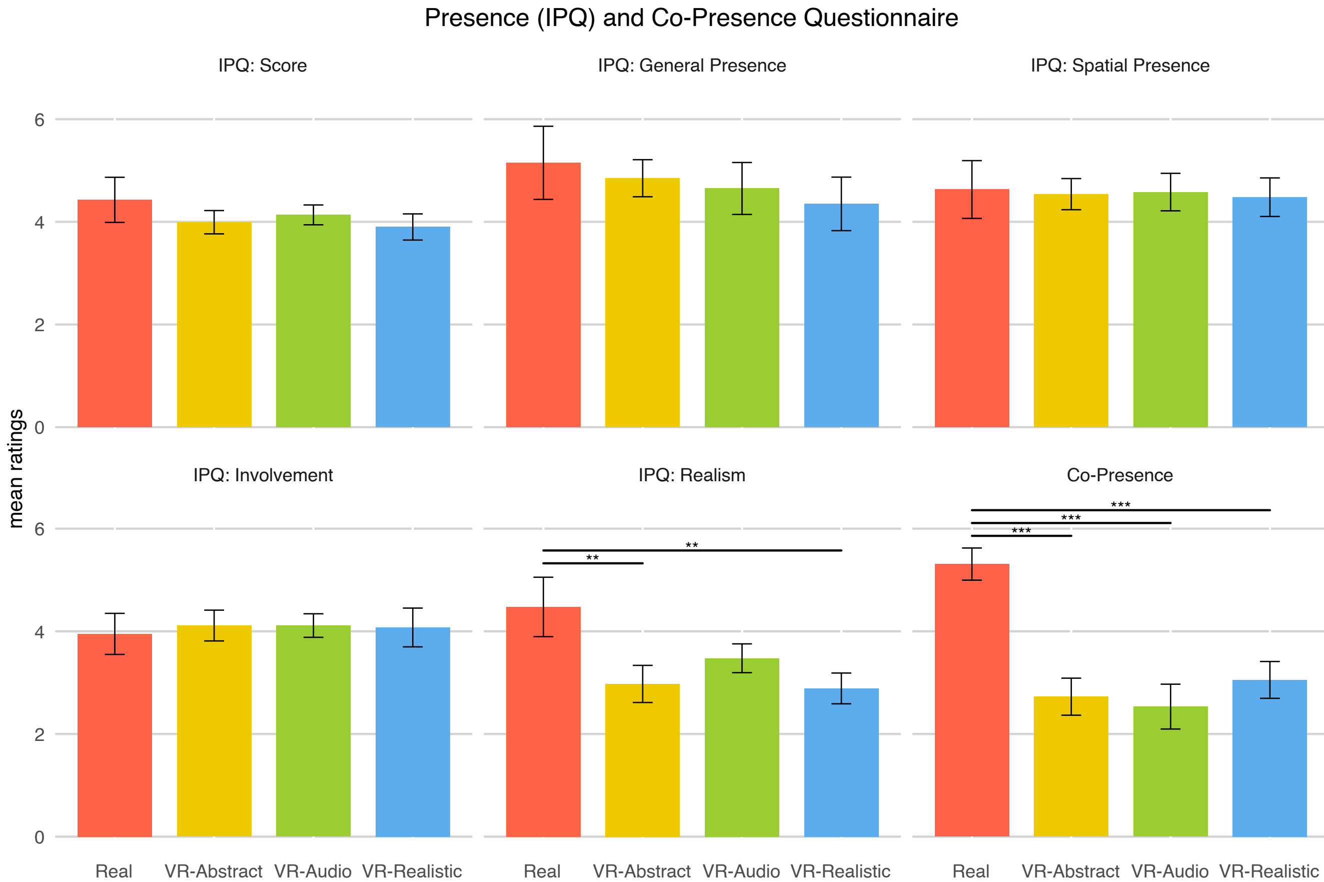

Figure 5: Presence scores and subscales of the IPQ and the Co-Presence questionnaire for all conditions. With * p < 0.05, ** p < 0.01, and *** p < 0.001 and all others are not significant.

the learning outcome. The result is in line with the related work that shows that displaying a pedagogical agent either as a fictional character or as a video of a human face does not affect the learning experience [30]. On the other hand, participants' feedback revealed that the guide in the *VR-Audio* condition was the most favorite one following the one in the *VR-Abstract* condition. These representations of the guide were less distracting than the visual guides. It could be further explained with the fact that participants were familiar with the audio guides as they are commonly used in exhibitions.

Both the sense of presence and co-presence were significantly affected by our conditions. Considering the VR conditions only, we found that perceived realism using an avatar was higher than using only audio. Regarding the uncanny valley effect, post hoc analysis could not reveal between which conditions in VR perceived eeriness was different. As ratings of the perceived eeriness in the *Real* as well as in the *VR-Realistic* condition was at a similar level, we assume that potential effects of the uncanny valley are negligible. Interestingly, perceived humanness of our VR conditions was higher when only audio was presented, which indicates that voice realism was also rated and part of the virtual experience. This fact should be taken into account when using artificial voices in virtual exhibitions, for example.

The co-presence score was the highest for the *Real* condition followed by the *VR-Realistic* condition. The results showed that affinity to the guide was higher in the real-world condition than in VR. The co-presence score in *VR-Realistic* was slightly higher than in *VR-Abstract* condition but not statistically significant. Interestingly, participants indicated that they could ignore the abstract guide and consider it as an object in the exhibition despite its movements. This is supported by the comprehension tests, in which the abstract and the audio guide showed similar results. Nevertheless, as co-presence was lowest using an audio guide, we assume that a visual virtual guide – either in a realistic or abstract style – can have a positive effect on the feeling of co-presence during a virtual exhibition and contribute to the satisfaction of participants of informal learning activities [10].

6 LIMITATIONS

While we showed that the representation of the guide has significant effects on participants' experience, the study has a number of limitations. In the study, the same human guide presented the content to all participants. We modeled the guide of the *VR-Realistic* condition after the human guide and used audio recordings from the same person. Therefore, we assume that potential effects caused by the specific human guide are canceled out. We conducted the study in the lab without distractions from the surrounding environment or other people. In the study, only one person was attending the presentation at a time as this is the most common presentation used in existing VR museums and exhibitions. In an actual exhibition, it is sometimes noisy, and there are often people next to the exhibited artifacts. As people often attend to this kind of activities in groups, future work should investigate the effect of virtual guides in multi-user VR environments.

Our results showed that in VR exhibitions, participants prefer to use audio-only guides than visual guides to learn more. Related work also showed that users' task performance is higher when they receive audio instruction rather than the instruction from visual instructors [21]. For the study, we used the museum exhibition setting. However, similar settings with a guide or a tutor are common for several activities, such as tours or classrooms. Despite the similar setup, participants might need to perform different tasks in these activities. For example, in a classroom setting a participant might need to repeat the same action after seeing the virtual tutor performing the action. In this case, a virtual tutor might outperform an audio-only alternative. Furthermore, audio-only representation of a guide might be difficult when there is a lot of background noise. However, future research is required to investigate the effects of virtual guides and to create realistic human guides without an uncanny effect.

7 CONCLUSION

We investigated the effect of the presence and appearance of a virtual guide in the virtual exhibition and compared it with the real-world equivalent. We studied how the representation of the guide (human guide, realistic virtual guide, abstract virtual guide, and audio guide) affects comprehension of the guide's speech, perceived presence, co-presence, and the uncanny valley effect. We found that the appearance of a guide might have a negligible impact on learning outcome. However, the audio guide was the most favorable for the learning purpose since there was a low distraction. For the audio guide, the perceived realism and humanness were higher than the other representations in VR. However, the results showed that presenting an avatar for a guide can have a positive effect on the feeling of co-presence during a virtual exhibition. We suggest future work to investigate creating realistic human guides for VR without an uncanny effect causing distraction.

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