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Asymmetric communication in virtual reality: designing for presence, effectiveness, and enjoyment.

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Abstract. This paper investigates the design of multi-user virtual reality (VR) communication and collaboration, focusing on asymmetric VR where one user is immersed in the virtual environment while the other interacts from the external world. Through an exploratory user study (n=16), we examine how users experience different asymmetric VR communication methods and how these experiences inform the design of effective communication systems. We identify key factors that influence the effectiveness of different styles of asymmetric VR communication and highlight the benefits and limitations of these styles. Our thematic analysis of the participants' responses and experiences sheds light on the importance of considering communication methods and their impact on users' experiences in asymmetric virtual environments. Our study provides insights into how communication methods can be designed to enhance presence, social presence, communication effectiveness, and enjoyment. These findings can inform the design and development of more engaging and effective asymmetric communication methods for multi-user collaboration.

Keywords: Virtual reality, Asymmetric virtual reality, Collaboration.

1 Introduction

Communication and collaboration are important activities in multi-user virtual reality. These activities typically occur with both users wearing head-mounted-displays and experiencing equal levels of immersion in the virtual environment. An alternative approach is asymmetric virtual reality, where one user (the VR user) is immersed in the virtual environment, while the other (non-VR user) interacts with them from the external world. In such a setup, the VR user and non-VR users often communicate and collaborate on a shared task. Asymmetric communication has been seen in the context of games [16, 17, 18], research [1, 2, 3, 12], and commercial applications.

How asymmetric communication is implemented has been shown to affect numerous user-related factors. These include the immersed user's sense of presence [5, 4, 6], enjoyment [3], and autonomy [12], as well as the social dynamic that exists between the two users [12]. In this paper, we complement existing works by comparing how users react to different implementations of asymmetric communication. Unlike prior works, which have typically focused on a single method at a time, we seek to investigate multiple interaction methods in the same study. By examining how users respond to a range of interaction methods, we aim to provide a more nuanced understanding of the

strengths and limitations of various approaches, as well as insights into how different methods can be combined and integrated to enhance the effectiveness of communication and collaboration in asymmetric settings. Furthermore, by using the same set of users for all interaction methods, we can control for individual differences and contextual factors that may impact users' experiences and provide a more direct comparison of the methods under investigation.

In our exploratory user study (n=16), we investigated how users experienced and perceived different asymmetric communication methods. A thematic analysis revealed key themes related to sense of presence in the virtual environment, communication effectiveness, and social presence. Each theme is explored and illustrated with relevant participant quotes. Based on these themes, we provide design suggestions for implementing asymmetric VR communication and discuss trade-offs such as communication effectiveness versus enjoyment and presence in the virtual environment versus social presence. This examination of identified themes and ensuing design recommendations offers insights for informed decision-making regarding the selection and implementation of asymmetric communication methods.

2 Literature review

Literature on asymmetric virtual reality features numerous examples of asymmetric communication styles. Here, we explore several prominent approaches. These approaches serve as inspiration for the design of our study.

Direct verbal communication is commonly used in asymmetric VR. In such a setup, the non-VR and VR users interact directly through spoken word. This style of communication can be remote [14, 1, 11] or co-located [3]. During remote communication the non-VR user's voice is heard through the headset, while co-located verbal communication has both users sharing the same physical space and no additional hardware is necessary.

How to represent the non-VR user in the virtual environment during communication has been explored in various works. Forms of embodiment range from full body avatars [14, 1] to abstract representations [2, 6]. For instance, Ibayashi et al.'s DollhouseVR system represents the non-VR user as a giant floating hand pointing at objects in the virtual environment [2]. In Koller's work on treating patient's fear of public speaking in VR, the non-VR user, a trained psychiatrist, can take over virtual audience members at will in order to communicate with the immersed patient as they practice delivering a speech [1].

Non-verbal asymmetric communication methods have also been explored. One important function of non-verbal communication is pointing (directing the user's attention to objects in the virtual environment). Kumaravel et al. highlighted this style of communication as being a primary activity in asymmetric VR [10]. Approaches to directing the VR user's attention include Duval & Fleury's work on representing a non-VR user's 2D pointer input as a 3D ray in the virtual environment for the VR user to see [7], Oda et al.'s use of spatial annotations such as 3D arrows [8], Ibayashi et al.'s aforementioned giant pointing hand, and having external text messages appear on a diegetic virtual

screen [6]. Peter, Horst, & Dörner compare two approaches to directing user’s attention using non-verbal communication: highlighting objects using a diegetic beam of light, and outlining objects with white glowing borders [4]. We follow a similar approach in our study.

Several works have discussed user-related factors relating to asymmetric VR, showing that how users experience and perceive asymmetric communication is highly affected by how it is implemented. For instance, Gugenheimer et al. showed how the design of an asymmetric communication method can have an impact on the user’s perceived dominance in the interaction [12]. Likewise, Wang et al. found that having the non-VR user appear in the virtual environment served as a social affordance, indicating that two-way verbal communication is now possible [9]. They also pointed out that this seemed to shift the user’s attention from the virtual scene to the social interaction. This in turn relates to the concept of presence, the experience of “being there” in a virtual environment [19, 21]. Several works have broken presence into sub-components: spatial and social presence [19, 20, 22]. We use a similar distinction in this work.

In this work, we compare several styles of asymmetric communication based on the features discussed here. Participant comments reflected several user-related factors discussed in these prior works, as well as introducing new unexplored dynamics.

3 Methodology

The communication methods implemented in our study incorporated various design features from prior literature, including disembodied verbal communication, embodied verbal communication, and non-verbal communication. Based on these features, we implemented 6 communication methods:

Co-located speech with no hardware: This method involves the user speaking with other users who are physically in the same location, without the need for any additional hardware such as headsets or microphones. The communication is based on the user’s physical presence and their ability to project their voice to the other users.

Remote speech that the user heard through their headset: This method involves the user hearing speech from other users who are in a remote location, through their VR headset. The speech is transmitted to the user’s headset through directional speakers and spatial audio.

Walkie-Talkie: In this method, the user communicates with the moderator through a virtual Walkie-Talkie. The user needs to press a button to speak. While the communication is two-way, the user must initiate the interaction by answering the beeping Walkie-Talkie or by picking it up and making a call to the moderator.

2D video feed similar to a Skype call: This method involves the user communicating with other users through a 2D video feed, similar to a Skype call. The user can see the non-VR user’s face and hear their voices, but the non-VR user is not fully immersed in the VR environment. A similar method was described in [5].

Outlines: This method uses white glowing outlines around objects of interest to guide the user’s attention. The outlines serve as a non-verbal form of communication

and are used to draw the user's attention to specific objects or areas in the VR environment. A similar method was described in [4].

Beam of Light: This method involves a beam of light shining through a window and guiding the player's attention to objects of interest. The beam of light serves as a non-verbal form of communication, similar to the outlines, and is used to draw the user's attention to specific objects or areas in the VR environment. It was intended to offer a more "lifelike," less gamified nonverbal approach compared to Outlines. A similar method was described in [4].

3.1 Study design

We conducted a user study (n=16) to investigate how users experience and perceive different implementations of asymmetric VR communication. Participants solved a series of puzzles in a virtual environment designed as a rustic cabin in the mountains. Each puzzle used a different asymmetric communication method, inspired by prior literature and including both verbal and non-verbal methods. The puzzles included arranging lettered blocks in the correct order based on clues in the virtual cabin, finding numbered cards in the cabin, and finding a hidden key in the cabin. Feedback was collected from participants and post-session interviews were conducted to explore their thoughts and perceptions. The study followed a within-subjects design, with each participant trying out all six communication methods. The communication methods were counterbalanced between sessions. Each session lasted between 20-40 minutes. The participants played the role of the VR-user, while the researchers played the role of the non-VR user in all six tasks. One of the two researchers carried out five of the six conditions remotely, while the other remained in the room with the participant and carried out the co-located condition. A backend tool similar to the VRGuides system described by Peter, Horst, & Dörner [4] was implemented for running the sessions and controlling the remote communication methods. The virtual environment was implemented in the Unity game engine, and hardware included an HTC Vive Pro 2.0 headset and a VIVE Wireless adapter for untethered movement in the virtual environment.

3.2 Data analysis

All interviews were audio-recorded, transcribed, and analyzed using a thematic analysis approach. During this process, the researchers began with a close reading of the interview transcripts, noting important or interesting passages. These were then labeled with codes based on their content. As more codes emerged, patterns and connections began to emerge between them. For example, when looking at the codes related to the user's sense of presence in the VR experience, the researchers noted that many users talked about feeling fully immersed in the environment and feeling like they were actually present in the virtual world. These codes were then grouped together and a theme of "sense of presence" emerged. In total, 92 codes were identified, which were structured into 4 overarching themes: sense of presence, communication effectiveness, social presence, and user preference. These themes were then used to inform the development of design drivers for asymmetric VR communication methods.

4 Findings

The themes that emerged during our analysis of participant interviews are described here.

Sense of presence in the virtual environment: When discussing the theme of sense of presence in relation to the different asymmetric VR communication methods, we found that some methods led to a greater sense of immersion and presence in the virtual environment than others. For example, users described feeling more present and engaged when using methods that involved non-verbal cues: *“Yeah it was quite nice when everything was so quiet. I could hear the bird which I didn’t hear before. And the fire. And at some point I was feeling like I should sit down at the table. And the window! The window scene was... I know it was VR, but I almost felt like ‘uuuu it’s cold.’”* (P5); Another user described it by stating *“Collaboration was nice, it was fun talking to someone, but when I was looking for clues by myself, I definitely paid more attention to what was in the cabin and explored it a bit more than I had earlier.”* (P4); Although users received less instruction and guidance during these portions of the session, leaving them to figure out the puzzles for themselves with subtle environmental cues wasn’t necessarily a bad thing, as it shifted their attention from the social interaction to the virtual environment. This attention-shifting is similar to Wang et al.’s description in [9].

Communication effectiveness: Our analysis of user interviews revealed that certain types of asymmetric VR communication methods were perceived as more effective for communicating information than others. In particular, methods that involved direct speech allowed for efficient back-and-forth between the VR and non-VR user. Most participants found this direct verbal communication to be useful: *“The most helpful was the audio, I needed clues for the whole puzzle.”* (P7); *“I felt like I had this constant companionship, and I wasn’t bothering you by asking questions”* (P8). On the other hand, we found that it was somewhat common for users to not immediately notice or understand the non-verbal cues (Outlines, Beam of Light): *“I initially assumed it was part of the environment.”* (P9); *“At first I didn’t understand that it was helping me, but I enjoyed it once I did.”* (P5); *“Wait, is this a hint?”* (P10); *“Are you turning that light on?”* (P4); *“That glowing outline would have been very easy to miss, if I hadn’t been looking for all the possible places a key is supposed to go. I saw it out of the corner of my eye.”* (P6).

Interestingly, the communication effectiveness of certain communication methods also influenced the power dynamic between the participant and non-VR user acting as the moderator. Whereas the other communication methods were initiated by the non-VR user, the Walkie-Talkie relied on the participant answering before dialogue began. Several users talked about a temptation to not answer: *“You offered me the option of making contact at one point, calling me on the Walkie-Talkie... and I was so tempted to not do that, because I want to figure this out on my own.”* (P14); Others actually did ignore the incoming calls: *“Yeah, yeah, I know, I know, but I’m not gonna. I can do it by myself.”* (P8); One participant described using it at their discretion when they needed help: *“Ok I’m getting too impatient, I need to give you a call. Got any hints for me?”*

Over.” (P11). This shift in power is similar to Gugenheimer et al.’s concept of dominance in the interaction [12].

Social presence and collaboration: Social presence emerged as a key theme in our analysis of user interviews. Users reported that some methods facilitated a sense of social presence and connection with the external user far more than others. During the non-verbal cues, participants often described themselves as being “alone.” Even though the Outlines and Beam of Light helped guide them through their respective puzzles, participants often did not conceptualize this as a social interaction, but rather, as part of the gameplay: *“Oh that’s true, it didn’t feel like that. I thought it was part of the design of the game. Like you’re playing a game and certain objects blink. It’s very different to talking to someone about how to solve this puzzle”* (P8); *“I didn’t realize it was a cue from you guys, I thought it was just me being smart.”* (P12).

Moving from non-verbal to verbal, participants reported appreciating the straightforward nature of direct verbal communication, although this too was often treated as more of a gameplay element than a social interaction: *“Whereas your voice through the headphones felt like it was part of the game.”* (P3); *“Just speaking to me through the headphones feels like a video game, like a narrator.”* (P11); *“I thought it was like in a military environment, you just receive commands from the headset, you don’t talk back to the headset.”* (P12).

When switching to the two most visually apparent communication methods, the Walkie-Talkie and 2D Video Call, participant’s descriptions of the interactions immediately shifted to focusing on the social element. Discussing the Walkie-Talkie, participants reported: *“I’d say the Walkie-Talkie one was probably the most immersive. It’s like you’re somewhat in that virtual environment talking to me. That’s how I felt.”* (P11); This was even more apparent with the video feed, where the non-VR user appeared on screen: *“When you showed up on the screen that was a bit different because then I had, you, I was very aware of your presence at that time.”* (P8); *“You were present, not with me in the cabin, but on the screen in the cabin, so you were there.”* (P1); *“I felt very connected, I think it’s like having a phone call versus a Skype call, you feel more connected with the person and more immersed.”* (P14); *“You’re getting that feedback that someone is listening to you that I didn’t get with the other ways.”* (P12).

User preference: User preferences emerged as an important theme in our analysis. Users reported that their individual communication styles and preferences influenced their perceptions of the different methods. For example, most participants commented on the Beam of Light positively: *“It was helpful and subtle, not directly telling me to do something. It was nice to be helped like that.”* (P4); Others found it to be too obvious, or even condescending: *“It was funny but annoying at the same time. It was like yeah, you won’t solve this, let this holy light guide you to your next piece.”* (P10); *“Yeah, it was more undermining in a sense.”* (P2); Similarly, reactions to Co-Located Speech were mixed and depended on the individual user. Some participants found the guidance generally useful and did not think much about it: *“It felt the same [as remote voice], just a voice.”* (P9); Others did not: *“You being in the same room but not interacting with me through the environment but actually just talking to me, and not even through headphones, to me that was... the least believable”* (P1); *“I guess that it was a reminder about the real world, that you’re talking to me from the real world, whereas with others*

it felt like you were in that world with me.” (P4); “You talking right next to me, that didn't really... I didn't want to have that in the experience. If I could have chosen, I would rather be without that.” (P14).

User preferences also came into play when reacting to the 2D video call. While that communication method fostered the most social presence, some participants found that it was too much social presence: *“Seeing your face... I felt like instead of creating closeness it felt like I was under some onus to take help, so I'd rate it lower.” (P8); “You'd rather just hear a voice in that space. It's kind of weird, like oh don't come see me, I'm in this... this cabin now, don't intrude on my experience.” (P3); “It felt like you're being watched. But then again I guess you were watching the whole time anyways. But yeah that definitely felt like, like you were watching everything I was doing, and it felt weird.” (P11);* These comments echo the sentiments of Willich et al.'s participants in [5] when reacting to a similar communication format.

Sometimes, individual's ways of interpreting the design of communication methods were quite amusing. One participant described the disembodied Co-Located voice as follows: *“Yeah, that was also like the godly voice. [laughing] Because at first the light lights up the right place, and then there's this like, like, older male voice, you know, stereotypical god with a beard, something like that. [laughing] It's a nice cabin we have here, really high up!” (P10);* Another participant associated the 2D Video Call with horror movie connotations, saying: *“It was straight from the Saw movies, you weren't the helper in my mind anymore, you were the captor.” (P10).*

5 Discussion

As we have seen, the design of asymmetric communication methods can have a strong impact on the user experience. Based on the themes that emerged from the analysis of our interview data, we derived design drivers for implementing effective asymmetric VR communication methods. Design drivers can be thought of as specific goals or outcomes that inform the design and implementation of asymmetric VR communication. As you will notice, these design drivers can either work in unison or detract from each other. These design drivers are:

Creating a sense of presence in the virtual environment: The design of asymmetric communication can enhance the user's sense of presence in the VR environment to increase immersion and engagement. Low-distraction communication methods such as non-verbal pointing allow the user to retain their focus on the virtual environment's sounds, props, and tasks. We also observed that communication methods with less social presence can encourage users to pause and think through things more, rather than immediately seeking advice.

Fostering social presence: Asymmetric communication methods can be designed to promote social presence and enhance the feeling of being in a shared space with the non-VR user. This can be achieved by incorporating communication into the virtual environment itself, rather than using disembodied methods. Additionally, allowing for continuous two-way verbal communication between the VR user and non-VR user, and

providing social affordances such as the Walkie-Talkie that beeps when activated, can enhance social presence.

Maximizing communication effectiveness: Asymmetric communication methods should be designed to support task performance and minimize distractions when social and environmental presence are secondary objectives. In such a case, clear and direct communication methods are preferred to minimize confusion and errors. For example, direct two-way verbal communication can be effective in supporting task performance and maximizing communication effectiveness.

Increasing enjoyment: Promoting enjoyment and engagement with the virtual environment can be another important design driver for asymmetric communication. Designing communication methods that fit well with the virtual environment's theme and setting can enhance the user's overall enjoyment, even if it may not maximize communication effectiveness.

The design drivers discussed here may be more or less important depending on the context and specific goals of the VR experience and should be weighed carefully.

6 Limitations and future research

One potential limitation of this study is that it was conducted in a laboratory setting, which may not be representative of the real-world use of asymmetric communication methods in VR. Participants may have behaved differently than they would in a natural environment, which could affect the results. Additionally, the small sample size and the use of the same two moderators for all sessions could introduce bias into the study. Furthermore, the puzzles used in the study were designed to be similar in nature and difficulty, which may not accurately reflect the range of tasks that users may encounter in VR applications. Finally, it should be noted that the study focused solely on the user's subjective experiences and did not measure objective metrics such as task completion time or accuracy.

7 Conclusion

Our study compared six approaches to asymmetric VR communication. These approaches were based on common design styles in asymmetric VR literature. A thematically analysed was conducted to understand how participants experienced our asymmetric communication approaches. We found four design drivers (creating a sense of presence in the virtual environment, fostering social presence, maximizing communication effectiveness, and increasing enjoyment), which the designer of asymmetric VR should balance and prioritize based on the goals of the VR experience.

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