VR Collaboration in Large Companies: An Interview Study on the Role of Avatars

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ABSTRACT

Collaboration is essential in companies and often physical presence is required, thus, more and more Virtual Reality (VR) systems are used to work together remotely. To support social interaction, human representations in form of avatars are used in collaborative virtual environment (CVE) tools. However, up to now, the avatar representations often are limited in their design and functionality, which may hinder effective collaboration. In our interview study, we explored the status quo of VR collaboration in a large automotive company setting with a special focus on the role of avatars. We collected interview data from 21 participants, from which we identified challenges of current avatar representations used in our setting. Based on these findings, we discuss design suggestions for avatars in a company setting, which aim to improve social interaction. As opposed to state-of-the-art research, we found that users within the context of a large automotive company have an altered need with respect to avatar representations.

Index Terms: Human-centered computing—Collaborative and social computing——Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods;

1 INTRODUCTION

Collaboration in enterprises often requires traveling long distances, which is expensive and also not environment-friendly. With digitalization solutions, the use of VR hardware and software is increasing in large automotive enterprises. VR is useful in collaboration contexts to overcome the lacking interaction of conventional online conferences [37]. Here, human avatars have been studied in the domain of gaming [26] or social platforms [11]. However, a transfer to the context of enterprises has not been examined yet.

To fill this gap, we studied the impact of avatar-supported CVEs in the context of an automotive enterprise setting, as VR collaboration is already used in engineering tasks. For this purpose, we conducted an interview study with 21 key users. We use the term *key user* to refer to anyone whose job function includes using VR tools on a regular basis. Our semi-structured interviews aimed to shed some light on the status quo of avatar-supported CVEs used in enterprises. First, we wanted to grasp the key users' usage scenarios and working context in order to identify tool-related challenges *(RQ1)*. Second, we encouraged key users to express their experiences centered on social interaction with avatars and their preferences with regard to their self-representation *(RQ2)*.

Based on our findings, we indicate shortcomings of present avatar representations and formulate design suggestions for avatar-supported CVEs in enterprises. In short, our contributions are:

- An analysis of the current usage and experience of avatar-supported CVEs in an enterprise setting.
- A set of design implications for avatar-supported CVEs derived from our results.

With these contributions, we want to provide suggestions for VR practitioners to improve avatar-supported CVEs and to enable more successful collaboration.

2 BACKGROUND AND RELATED WORK

Our work primarily focuses on avatar-supported CVEs in an enterprise setting including VR head-mounted displays (HMDs) with VR controllers and Augmented Reality (AR) HMDs. Hence, it is important to note how people perceive social interaction and virtual human representations [28], as certain forms of avatars have an impact on the social entity [19]. Notably, behavioral information such as facial expressions and gaze have a unique role, as the level of realism can be increased [34].

2.1 Telepresence and Social Interaction

In immersive CVEs, it is important to give users the feeling to be in the same room with a common goal [21]. Thus, users need to notice a given incentive [24] to shape social interaction. Here, the full potential of visualization to increase self-awareness, as well as the presence of other participants has not yet been exploited [27]. Altering aspects of the virtual avatar might have effects on interaction and relationships in a number of contexts, especially with defined roles for leaders and followers [33]. However, in the area of non-verbal information on social interaction, there are still open research questions that arise with new technologies [6].

Non-verbal behavior is important to communicate feelings or attitudes towards users and is more important than verbal signals alone [4]. Baker et al. [3] established a heuristic to describe intentional and non-intentional communication, thus, simplifying interpersonal correspondence. It should be emphasized that hand gestures alone are not enough to understand a remote user sufficiently [38] as non-verbal communication also includes facial expressions.

2.2 Impact of Avatar Representation

Social interaction and the sense of embodiment of avatars hold a significant matter on shaping communication and co-presence [16] as well as user engagement [12] in CVEs, thus, increasing the sense of inhabiting the virtual world [1]. Even though researchers [40] found that virtual characters improve the value of social cognition in CVEs, avatars varied considerably with regard to fidelity and movement conformity. As social interaction tends to be determined

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Table 1: Key questions used for guiding the open-ended interviews focusing on two main topics. *RQ1*: What is the usage context of avatars used in CVEs (tool-related)? *RQ2*: What are users' needs and challenges with regard to avatars (avatar-related)?

Tool-related questions *(RQ1)*	**Avatar-related questions *(RQ2)***
• What is your role in using CVE tools and which tools do you use?	• How do you interact with other participants socially?
• How do users differ in terms of previous VR experience?	• What do you like/dislike about current avatar representations?
• How do you collaborate, co-located and distributed?	• How do you perceive other users/yourself in a CVE session?

by the avatar quality in terms of behavioral realism [14], body ownership [25] and trust [15], it is important to address reasons for this certain impact.

Users who embody a less detailed avatar experienced greater social interaction compared to users with full-bodied avatars [20]. It stays unclear whether the results are based on self-representation or interaction with others. On the other hand, research has shown that visually realistic avatars affect the subject feeling of presence [25] in terms of consistent motion representation.

Some researchers emphasize the importance of trust in CVEs as the basis for social interaction. For instance, users feel more trust towards a human-like avatar [22] and are comfortable when in presence of likewise [15]. Yet, the latter fail to address ideal avatar requirements. Other researchers argue that self-perception is as important as perception of others for being social in CVEs, thus, stress to provide personalized avatars [39] as extended possibilities to express oneself while increasing social interaction [9]. Nevertheless, it should be visible to users that their behavior matches what they are doing as well as how their actions might affect the environment.

3 Method

In our study, we conducted semi-structured interviews with enterprise users to better understand their daily working routines with avatar-supported CVEs. Our research goal was to characterize the scope of key users' challenges when working with avatar-supported CVE tools. We collected data from 21 participants, which we then analyzed by *open* and *axial coding* [7]. This methodological approach enabled us to gain insights into the practices, tasks, and context from the broad data collected.

3.1 Participants

We interviewed 21 key users (15 male & 6 female) with a mean age of 40 years (25 - 60 years) from 3 companies with a total of 8 different corporate departments. All companies are based in the automotive industry. Our respondents carry different roles in their use of CVE tools. These include being a session moderator, developer or engineer. The professional experience of the surveyed participants ranged from being in their first year of work to more than 10 years. Further, participants rated their experience with VR tools as follows: advanced beginner: 1, competent: 7, proficient: 4, expert: 9. The respondents were contacted by email. In addition, a written call was distributed in an internal forum.

3.2 Interviews

The interviews were done individually. We started each interview with a brief introduction to the purpose of this study: understanding daily routines with CVEs and the challenges of using the available avatars to communicate and collaborate with other participants. Each interview lasted between 35 and 65 minutes.

Each semi-structured interview was conducted using a catalog of key questions, summarizing our *RQs* (see Table 1). To understand avatar-supported CVE tools and their context currently used within the company *(RQ1)*, we first asked questions with regard to the tool in general to get an insight into the status quo. We identified different stakeholders and distinguished distinctive domain tasks of expertise. To interpret how key users collaborate in the CVE, we inquired questions to describe the existing avatar representations and then specify how current collaboration in CVEs takes place *(RQ2)*.

3.3 Analysis

The interviews were audio recorded with the respondents consent and then transcribed. Extensive notes were written during each interview. To analyze this data, we leveraged an iterative open and axial coding approach [7]. Our results culminated in Figure 1.

4 Users and Usages of Avatars in CVEs

We found that users differ widely in their usage of VR tools. We also inquired the CVE tools that key users work with to show their prevalent virtual environment. Here, we found three different existing tools (see Fig. 2) as well as a couple of additional tools that were named twice or less often. After defining the domain tasks, we outline four different user types we identified (see Fig. 1) to understand situations in which avatar-supported CVEs are used.

4.1 Domain Tasks

Our VR key users work within the context of an enterprise in the automotive industry. In general, existing VR hubs are used and supervised by staff that assists users with setting up their specific tool environment. A VR hub consists of all devices needed to conduct a CVE session with peers, co-located or distributed. We identified five domains that users work in when using CVEs to carry out specific engineering tasks (see Fig. 1, *Domain Tasks*).

Requirement Validation focuses on confirming the correctness and completeness of all requirements in the development process.

Data Viewing is an integral part of the development process. Compared to traditional 2D screens or printouts, immersive VR environments provided a viewing experience that is closer to the final hardware result in terms of perception of scale and space.

Ergonomics directly affects the ergonomic quality of the final product. With VR, it is possible to slip into the role of distinct customers to discuss various hardware features and concepts as early as possible from the customers' point of view.

E-Learning, in a CVE, enables users along the development and manufacturing line to understand upcoming tasks and challenges before facing actual hardware in early development stages.

Assembly Planning addresses issues during the hardware manufacturing process. Based on virtual data, buildability of parts and feasibility of assembly lines were examined, as well as securing layouts for shop floors.

4.2 Avatars in CVE Tools

We asked interviewees about tools they were using to work in avatar-supported CVEs. We observed three common VR tools interviewees mentioned (see Fig. 1, *Tools*) and exclude tools mentioned only twice or less often. In general, these tools are primarily used in early phases and adopted for different use cases. The mostly used tools are shown in Figure 2. Overall, users are represented by robot-like avatars with a name tag over their heads or cardboard goggles. These avatars are regarded as low-fidelity representations by the key users. Most often, interviewees emphasized the difficulty to distinguish between users and the peril of recognizing another user in the environment as the representation is rarely visible.

4.3 User Types

As interviewees varied widely in their domain expertise, we classified key users into four types that we identified during our analysis

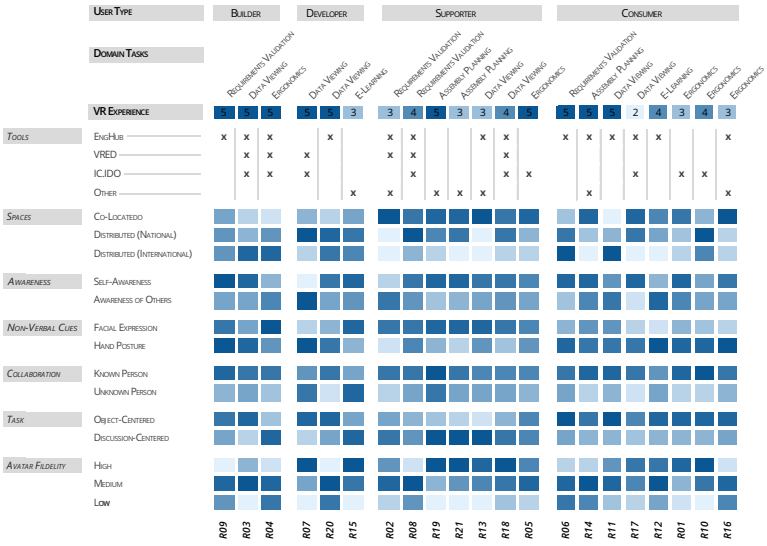
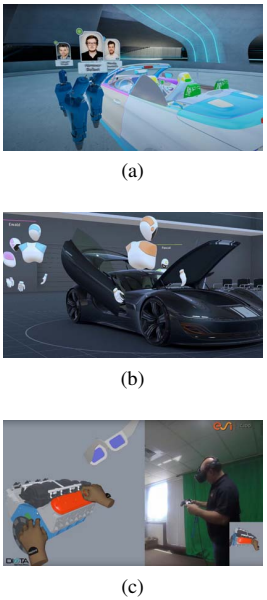


Figure 1: The matrix displays interviewees grouped by user types and domain tasks. Beneath, the self-rated VR experience is given. For each interviewee, their used tools are assigned. Based on answers given to questions regarding RQ1 and RQ2 (see Table 1), we collected the identified codes and reclassified them to highlight special fields of interest for each interviewee. Therefore, we took the value of each code frequency per interview to evaluate the sequential coloring based on saturation for each row (*lowest code frequency*: light blue to *highest code frequency*: dark blue).



(a) (b) (c)

Figure 2: Screenshots of most used CVE tools by key users. (a) Engineering Hub[1] with robot-like avatars and labels. (b) VRED[2] with robot-like avatars. (c) IC.IDO[3] with cinema-like goggles and virtual hands.

process (see Fig. 1, *User Types*). These refer to their knowledge regarding VR environments, the influence on peers and the degree of involvement when establishing and improving VR tools.

Consumers typically enjoy working with VR, when it is easy to use. They emphasize issues regarding limited possibilities to express yourself and perceive others. *Consumers* mostly collaborate with familiar peers (6 of 8 *consumers*) (see Fig. 1, *Collaboration*). Users in this group mostly work on object-centered tasks collaboratively (see Fig. 1, *Task*), meaning users look at a specific 3D model. In general, a discussion rarely emerges.

Supporters are characterized by helping *consumers* to work with their VR tools. *Supporters* recommend tools to their peers and have the role of a multiplicator. 6 of 7 *supporters* would choose a medium- or high-fidelity avatar, meaning a higher degree of realism and anthropomorphism. Unlike *consumers*, *supporters* described their virtual sessions as mostly discussion-centered. Generally, 3D models are present, yet, discussions are the focal point.

Developers inherit all traits of the *supporters*. However, they additionally build their own concepts based on feedback through *consumers* and *supporters*. They look at specific use cases, focusing on developing user concepts to help build and improve VR tools and experiences in general. However, they are in need of reliable reproducibility of avatar behavior to discuss problems and improvements.

Builders inherit all traits of *supporters* as well. They build specific plugins for VR tools based on needs *supporters* and *developers* report. Builders have the highest self-rated VR experience. Typically, they consider matters that may not be apparent to others based on their knowledge and observations. They have a high demand for avatar customization to increase their immersion even further.

[1]https://www.daimler-protics.com/ - Engineering Hub
[2]https://www.esi-group.com/products/virtual-reality - IC.IDO
[3]https://www.autodesk.com/products/vred/overview - Autodesk VRED

5 Analysis of Interview Results

Based on our study with 21 key users, we present our qualitative observations gained from semi-structured interviews. By exhaustive coding whilst the analysis, we were able to create a matrix containing the most interesting pieces of our categorized data (see Fig. 1). With regard to *RQ1* and *RQ2*, we present the current usage context of our key users of avatar-supported CVEs. With a wide variety of different observations, we characterize the VR tools and domain tasks that conclude on our four identified user types (see Fig. 1).

5.1 User Awareness

Awareness is a well-known determinant for collaborative tools in general [36]. Thus, in terms of CVEs, it is important to be aware of people that are together with you in the CVE to increase the feeling of being there. Accordingly, we report results on avatar fidelity, recognizability of the representation as well as characteristics of self-representing avatars and the awareness of others.

Avatar Fidelity. Usually, additional hardware is necessary to use the full potential of VR/AR systems. Thus, we asked interviewees about the desired fidelity opposed to technological constraints, for instance, when supplemental equipment is needed. All interviewees refrained from using additional equipment that is attached to the body, like motion capturing suits or complex VR gloves. Most would find these setups interesting, but too cumbersome in an easy-to-use organizational context, when wanting to swiftly join a session.

14 of 21 key users tended to use less realistic avatars implying a less complex setup. Yet, half of them suggested being open for high-fidelity avatars, if that meant using no additional hardware. Interviewees favor medium-fidelity avatars for various reasons. Some wanted to feel disconnected from the virtual self, not wanting to have an exact copy in the CVE, but a representative. Additionally, 7 of 21 interviewees wanted the freedom to individualize their avatar, as they fear an automatically created caricature. It would make them feel uncomfortable inhabiting such a virtual representative.

"I think it is even more pleasant. Stylizing or abstracting creates a little distance to reality instead of just leaving your photo on it." (R11)

However, 14 of 21 interviewees emphasized the imminence of not being taken seriously when adopting a cartoonish avatar wishing for humanly avatars for everyone. We identified that this is the mostly mentioned reason why key users disapprove low-fidelity avatars.

Recognizability and Self-Representation. Awareness of users seems to be related to the recognizability of the representations. 85% of interviewees reported on how the avatar should resemble their real life selves in a certain way, making it recognizable. This is especially relevant when interacting with yet unfamiliar co-workers. While most (90%) key users reported knowing their virtual counterpart before collaborating virtually, 12 of 21 noted to have already collaborated with entirely unknown counterparts. In this case, robot-like avatars were making it harder to familiarize.

17 of 21 interviewees indicated that a self-representing virtual avatar is important to gain trust and feel comfortable in a virtual session in general, but highlighted that it would only have an increased value when using an avatar for the first time. Further, we asked to describe the ideal avatar. Some interviewees then emphasized the importance to have an appealing avatar for their counterparts representing their best visual features. Especially, when collaborating with unfamiliar peers, 12 of 21 interviewees indicated the significance of a satisfying self-avatar, as opposed to sessions with already familiar peers (7 of 21).

"I only create the avatar for my counterpart not for myself, as I do not see it anyway. That means I would always design my avatar from as I would like to be perceived by my counterpart. That is how I actually do it with my real body." (R08)

We observed that users who are using avatar-supported CVEs for the first time think they see their own avatar when actually seeing the avatar of their counterpart. This matter highlights the relevance of being introduced to your virtual self in order to get the chance to acquaintance with your avatar and raise confidence.

"Some users do not understand that you need the VR controllers and HMD to appear in the virtual session as yourself. For instance, many think that a robot avatar [counterpart] in the virtual scene is their own, when it is not. (R03)"

5.2 Social Behavior in Virtual Environments

Research indicates that real-world social phenomena can be transferred into virtual environments [2]. Key users also mentioned situations where they felt uncomfortable as well as core aspects for communication and social interaction.

Inconvenient Situations in Virtual Behavior. Awkward or uncomfortable situations based on user behavior may also arise in CVEs. We observed that 4 of 21 interviewees have been in situations that made them feel uncomfortable. However, they indicated that the other participant not implicitly had the intention to do so. For instance, inconvenient situations arose, when a user came into proximal distance entering the personal zone.

"You strive for what you know from the real world. It is actually uncomfortable when someone is too close to you. Then you move, just to have some distance." (R05)

16 of 21 interviewees reported that potential bystanders in the real world make users wearing an HMD uncomfortable, too. In general, it is not possible to see who or how many peers are with you in the same space and what they are doing, thus, increasing insecurity. Furthermore, we observed this phenomenon is not limited to co-located collaboration as some interviewees implied the desire to see who is attending a CVE session in distributed sessions.

"I want to see who in India is wearing the HMD and that there are two bystanders. So I know if it is a one-to-one or one-to-many relationship." (R02)

Communication. We observed that the aspiration for specific communication modalities varied between use cases. Most of the tools used VR controllers to visualize hand positions in form of virtual controller models, but no tool supported facial expressions in any form. Thus, we visualized user answers with regard to the importance of non-verbal cues and task focus (see Fig. 1, *Task & Non-Verbal Cues*). Overall, facial expression is essential when having discussion-centered CVE sessions and gets less important in object-centered CVE sessions (see Fig. 1, *Task & Non-Verbal Cues*). Interviewees reported, when having emotional discussions, users are missing coequal face-to-face encounter (13 of 21) as well as social interaction. They seek to have an indicator of the current state of mind with micro-expressions of their counterpart to interpret specific statements. 16 of 21 interviewees emphasized that hand postures are more important in most of their object-centered use cases. Realistic proportions and correct hand transformations are necessary to point at specific spots, making sure to have a mutual understanding instead of describing verbally where to look.

"In many cases, it is important to see if I can get somewhere with my hand. If it looks somehow realistic, is not important. The fact that you can put your hand in specific parts and see if you can get past at all, that would definitely help a lot." (R04)

Although interviewees privileged hand posture over facial expression, 7 interviewees who favored hand posture (from 15 of 21) emphasized additional benefit from facial expressions in any form, as their use cases gradually shifted, thus, motivating the significance of both modalities for satisfying CVE session.

Social Interaction and Relationship Formation. Current tools limit socializing during sessions (17 of 21 key users). If users already know how their counterpart acts in the real world, they transfer this behavior onto the avatar, making it easier to communicate, thus, continuing the real world relationship. Still, missing facial expression and body posture make it difficult to judge a persons' state of mind. 16 of 21 key users reported on the value of socially expressive avatars, as they help to overcome the gap of current avatar visualizations and to increase perception of feelings and behaviors.

"You focus on your counterpart. There are only a few ways to know if someone is happy or not. Right now, it's just a doll." (R16)

6 Design Suggestions

Through interviews and observations, we gathered background information about our key users within an automotive enterprise setting and their respective challenges. Understanding their background and needs is integral for designing avatar-supported CVEs that ultimately aim to support their day-to-day use. We found that contrary to avatar-supported CVEs for entertainment, tools with business purpose need to consider different use-case contexts and various social hierarchy conditions. Thus, our insights highlight the fact that key users within an automotive enterprise setting have different needs with respect to avatar-supported CVEs than presented by across-the-board research.

6.1 Social Aspects for Communication

As discussed before, the benefit of virtual collaboration lies in the interaction between peers. Thus, we reflect on social aspects that should be considered for successful and proper communication.

Intensify Social Interaction by Allowing Non-verbal Cues. As a means to intensify social interaction, we propose to *consider non-verbal upper-body cues equally*. Users' state-of-mind within a virtual environment is not conveyed through facial expression alone, but body language as well [8]. Still, users efficiently compensate for missing social cues [34]. This may lead to the inability of judging specific statements through one of our key users who was not able to distinguish between joking or being serious. Here, it is crucial to pay attention to the actual benefit of each cue, hence, we advise to

carefully apply expressive avatars to the key users' specific needs regarding use cases, while still supporting socializing in VR.

We can confirm that avatars can improve social presence and the overall VR experience [33]. Here, the level of interactional realism is as important as emotional expressiveness [10] for influential and meaningful social interaction. Interviewees described social interaction as a clear need to judge a peer's state of mind. Currently, this is hardly possible, except if users in a session are familiar with each other. Yet, this is often not the case. Here, interaction concepts that highlight a users' state of mind in a novel way might be promising. Concepts like emotes or emojis [41] might also proof beneficial, but haven't been applied or researched in organizational VR yet.

Consider Behavioral and Hierarchical Aspects. As the virtual representation becomes more complex, we propose to *embed guidelines to prevent improper behavior*. With research indicating that real-world behavior can be transferred into virtual environments [2], we observed that inconvenient situations, such as invading personal space, indeed influence the respective user. Some users even feel uneasy if they are too close to other virtual participants in the CVE. Thus, proxemics need to be observed carefully, as users embodying avatar movements in VR feel violations of personal space more intense [5]. Here, perception of avatars is critical to understand social dynamics in CVEs and potential ethical risks [30]. Thus, we strongly support the claim of using social norms theory to form behavioral rules for CVEs. Interpersonal dynamics, based on standing in the company, experience or familiarity between peers, shall not be disturbed by either improper avatar design and behavior. Peers would not want to risk accidentally displaying improper demeanor towards higher-ups that are present in a meeting.

Improve Attitude towards CVEs. To communicate the benefits of virtual representations we propose to *prepare users for the experience*. The degree of immersion is an often unseen benefit by users that are not yet familiar with VR. Thus, using the immersive character to increase acceptance of a user towards CVE tools and the feeling of presence [31] is a key for a satisfying VR experience. Increasing the engagement in a CVE helps raise acceptance towards the technology. However, specifying influence factors for immersion and presence to build up acceptance still needs to be considered [29]. Some of our key users described a changing attitude towards CVEs by peers that were voluntarily introduced to the technology, helping them to accept its benefits. Here, we also stress the importance of being introduced to your avatar, in order to raise trust and confidence in your representation and to help overcome doubts.

6.2 Consider Avatars of all Participants

Not only social aspects need to be considered, but also the actual representation of peers within a CVE. These are critical for a successful introduction of virtual avatars in an organizational environment.

Foster Familiarity. We propose to *raise awareness through personalized avatars*, of others as well as yourself. VR itself has the potential to enhance mutual awareness as opposed to conventional technologies [35] and bridge the gap between the perception of avatars of familiar and unfamiliar peers. The less familiar a peer, the more relevant it is to properly identify the person behind the virtual avatar. We identified that interviewees want to use an avatar, that in some way is recognizable as their own. This confirms Freeman et al. [11], who considered creating and crafting your own avatar as a challenging way to experience avatars in CVEs. Our interviews further indicate that frequent customization might be counter-productive for day-to-day use, as users would have trouble to recognize each other. This might also occur, if a peer is virtually represented in a drastically caricatured manner. Hence, we advise to set limits and boundaries for customization.

Determine Avatar Fidelity. To increase familiarity we propose to *keep avatar fidelity consistent*. Research shows a correlation between avatar fidelity and self-esteem [17]. However, we could not confirm nor disprove this finding, as we did not survey this type of information. We found that key users would accept lower avatar fidelity, if that means they would not have to use an additional hardware setup. Users tend to choose their avatars' visual fidelity based on different properties [23], as realism for avatars in work communication is nuanced. Opposed to Freeman et al. [11], we observed that many interviewees wished for a medium-fidelity avatar resembling their selves without being a too realistic one-to-one copy. This preference for medium-fidelity avatars with a high movement conformity is in line with results indicated by Gamelin et al. [13].

Involve Bystanders. To improve workspace awareness and immersion, we propose to *include bystanders in the virtual experience*. An often overseen factor we identified is the need for visualizing potential bystanders and their behaviors. We confirm the findings of researchers that highlight the need of systems for a partner environment [18]. CVE tools used in the company and most VR-based consumer applications exclude bystanders from the overall experience, although it was reported to strongly increase the feeling of insecurity of the HMD wearer. Users tend to feel uncomfortable if they do not know who is in the virtual or physical space around them. Thus, we advise to involve bystanders through camera and sound, as even simplified representation methods might already produce significant improvements of comfort and security [32].

7 Limitations

Before we conclude, we would like to discuss some of the limitations of our current research. First, saturation of theory given our sample size does not necessarily imply generalizability of our results. Future studies with larger sample sizes and populations that are more varied should empirically validate our findings through more confirmatory methods, such as surveys or experimental designs. Second, our intention is not to advocate for any specific avatar representation in organizational CVEs. Instead, we simply emphasize that stakeholders of tools need to be embedded in the development process of introducing enhanced avatar-supported CVEs in organizational contexts. Finally, our practical recommendations are based solely on comments of our key users and the implications we have drawn require additional scrutiny to determine, if they are viable solutions for CVE processes in organizational contexts.

8 Conclusion and Future Research

In this interview study, we examined the usage of avatar-supported CVE tools and the users' experiences in an organizational setup. We analyzed our data with an iterative coding process and structuring to gain insight into those aspects. Based on our findings, we derived design suggestions for avatar representations within organizational CVEs. We would like to note that these recommendations are not intended to represent concrete guidelines, but are intended to point out directions for future work that must be looked into more deeply.

There are a number of directions for future research that are implied within our design suggestions. First, we plan to continue our observational field work to see whether our implications are conferrable to an expanded group of users. Second, we will continue to explore different dimensions of avatar-supported CVEs as guided in our discussion. We are particularly interested in getting a better understanding of the required avatar fidelity in organizational settings and address shortcomings of non-verbal cues for current virtual avatars. Here, we will develop prototypes that provide examples of avatars with different fidelities to investigate how our key users perceive distinctive representations in a CVE. Overall, we want to help closing the gap between research and practice in a meaningful manner from both ends.

References

[1] S. A. Aseeri and V. Interrante. The influence of avatar representation and behavior on communication in social immersive virtual environ-

ments. In *Proc. IEEE Conf. on Virtual Reality and 3D User Interfaces (VR)*, pp. 823–824. IEEE, 2018.

[2] L. A. Baccon, E. Chiarovano, and H. G. MacDougall. Virtual reality for teletherapy: Avatars may combine the benefits of face-to-face communication with the anonymity of online text-based communication. *Cyberpsychology, behavior and social networking*, pp. 158–165, 2019.

[3] K. Baker, S. Greenberg, and C. Gutwin. Heuristic evaluation of groupware based on the mechanics of collaboration. In *Int. Conf. on Eng. for Human-Computer Interaction*, pp. 123–139. Springer, 2001.

[4] G. Bente, S. Rüggenberg, and N. C. Krämer. Social presence and interpersonal trust in avatar-based, collaborative net-communications. In *Proc. of the Int. Workshop on Presence*, pp. 54–61, 2004.

[5] L. Blackwell, N. Ellison, N. Elliott-Deflo, and R. Schwartz. Harassment in social virtual reality. *Proc. of ACM Conf. on Computer Supported Cooperative Work (CSCW)*, pp. 1–25, 2019.

[6] W. Buxton. Telepresence: Integrating shared task and person spaces. In *Proc. of Graphics Interface*, pp. 123–129. Canadian Information Processing Society Toronto, Canada, 1992.

[7] K. Charmaz. *Constructing grounded theory: A practical guide through qualitative analysis*. sage, 2006.

[8] T. J. Dodds, B. J. Mohler, and H. H. Bülthoff. Talk to the virtual hands: Self-animated avatars improve communication in head-mounted display virtual environments. *PloS one*, 2011.

[9] D. Economou, I. Doumanis, L. Argyriou, and N. Georgalas. User experience evaluation of human representation in collaborative virtual environments. *Personal & Ubiquitous Computing*, pp. 989–1001, 2017.

[10] M. Fabri and D. Moore. The use of emotionally expressive avatars in collaborative virtual environments. *Virtual Social Agents*, 2005.

[11] G. Freeman, S. Zamanifard, D. Maloney, and A. Adkins. My body, my avatar: How people perceive their avatars in social virtual reality. In *Proc. ACM Conf. Human Factors in Computing Systems (CHI)*, pp. 1–8. ACM, New York, NY, USA, 2020.

[12] R. Fribourg, F. Argelaguet, L. Hoyet, and A. Lécuyer. Studying the sense of embodiment in vr shared experiences. In *Proc. IEEE Conf. on Virtual Reality and 3D User Interfaces (VR)*, pp. 273–280, 2018.

[13] G. Gamelin, A. Chellali, S. Cheikh, A. Ricca, C. Dumas, and S. Otmane. Point-cloud avatars to improve spatial communication in immersive collaborative virtual environments. *Personal and Ubiquitous Computing*, pp. 1–18, 2020.

[14] M. Garau, M. Slater, V. Vinayagamoorthy, A. Brogni, A. Steed, and M. A. Sasse. The impact of avatar realism and eye gaze control on perceived quality of communication in a shared immersive virtual environment. In *Proc. ACM Conf. Human Factors in Computing Systems (CHI)*, p. 529–536. ACM, New York, NY, 2003.

[15] C. George, M. Eiband, M. Hufnagel, and H. Hussmann. Trusting strangers in immersive virtual reality. In *Proc. Conf. on Intelligent User Interfaces Companion*, pp. 1–2, 2018.

[16] M. Gerhard, D. Moore, and D. Hobbs. Embodiment and copresence in collaborative interfaces. *International Journal of Human-Computer Studies*, 61(4):453–480, 2004.

[17] G. Gorisse, O. Christmann, S. Houzangbe, and S. Richir. From robot to virtual doppelganger. In *Proc. Int. Conf. Advanced Visual Interfaces (AVI)*, pp. 1–5. ACM, 2018.

[18] J. Gugenheimer, E. Stemasov, J. Frommel, and E. Rukzio. Sharevr. In *Explore, Innovate, Inspire*, pp. 4021–4033. Association for Computing Machinery Inc. (ACM), New York, NY, 2017.

[19] J. D. Hart, T. Piumsomboon, L. Lawrence, G. A. Lee, R. T. Smith, and M. Billinghurst. Emotion sharing and augmentation in cooperative virtual reality games. In F. F. Mueller, D. Johnson, and B. Schouten, eds., *Proc. ACM Conf. Human Factors in Computing Systems in Play (CHI Play)*, pp. 453–460. ACM, 2018.

[20] F. Herrera, S. Y. Oh, and J. N. Bailenson. Effect of behavioral realism on social interactions inside collaborative virtual environments. *PRESENCE: Virtual and Augmented Reality*, 27(2):163–182, 2020.

[21] P. Isenberg, N. Elmqvist, J. Scholtz, D. Cernea, K.-L. Ma, and H. Hagen. Collaborative visualization: Definition, challenges, and research agenda. *Information Visualization*, 10(4):310–326, 2011.

[22] D. Jo, K.-H. Kim, and G. J. Kim. Effects of avatar and background representation forms to co-presence in mixed reality (mr) tele-conference systems. In *ACM Trans. Graphics (Proc. SIGGRAPH Asia)*, pp. 1–4. 2016.

[23] A. Kolesnichenko, J. McVeigh-Schultz, and K. Isbister. Understanding emerging design practices for avatar systems in the commercial social vr ecology. In *ACM Designing Interactive Systems (DIS)*, p. 241–252. ACM, New York, NY, USA, 2019.

[24] J. Lacoche, N. Pallamin, T. Boggini, and J. Royan. Collaborators awareness for user cohabitation in co-located collaborative virtual environments. In *Proc. ACM Symp. on Virtual Reality Software and Technology*, pp. 1–9, 2017.

[25] M. E. Latoschik, D. Roth, D. Gall, J. Achenbach, T. Waltemate, and M. Botsch. The effect of avatar realism in immersive social virtual realities. In *Proc. of ACM Symp. on Virtual Reality Software and Technology*, pp. 1–10, 2017.

[26] I. J. Livingston, C. Gutwin, R. L. Mandryk, and M. Birk. How players value their characters in world of warcraft. In *Proc. of ACM Conf. on Computer Supported Cooperative Work (CSCW)*, pp. 1333–1343. ACM, New York, NY, 2014.

[27] S. Lukosch, M. Billinghurst, L. Alem, and K. Kiyokawa. Collaboration in augmented reality. *Proc. of ACM Conf. on Computer Supported Cooperative Work (CSCW)*, 24(6):515–525, 2015.

[28] K. F. MacDorman and H. Ishiguro. The uncanny advantage of using androids in cognitive and social science research. *Interaction Studies*, 7(3):297–337, 2006.

[29] J. Mütterlein and T. Hess. Immersion, presence, interactivity: Towards a joint understanding of factors influencing virtual reality acceptance and use. In *Proc. Adoption and Diffusion of Information Technology (SIGADIT)*, 2017.

[30] K. Nash. Virtual reality witness: exploring the ethics of mediated presence. *Studies in Documentary Film*, pp. 119–131, 2018.

[31] M. M. North and S. M. North. A comparative study of sense of presence of virtual reality and immersive environments. *Australasian Journal of Information Systems*, 20, 2016. doi: 10.3127/ajis.v20i0.1168

[32] J. O'Hagan and J. R. Williamson. Reality aware vr headsets. In *Proc. of ACM Int. Symp. on Pervasive Displays*, pp. 9–17, 2020.

[33] T. Piumsomboon, G. A. Lee, J. D. Hart, B. Ens, R. W. Lindeman, B. H. Thomas, and M. Billinghurst. Mini-me: An adaptive avatar for mixed reality remote collaboration. In *Proc. ACM Conf. Human Factors in Computing Systems (CHI)*, pp. 1–13, 2018.

[34] D. Roth, J.-L. Lugrin, D. Galakhov, A. Hofmann, G. Bente, M. E. Latoschik, and A. Fuhrmann. Avatar realism and social interaction quality in virtual reality. In *Proc. IEEE Conf. on Virtual Reality and 3D User Interfaces (VR)*, pp. 277–278. IEEE, 2016.

[35] H. Salimian, S. Brooks, and D. Reilly. Mp remix: Relaxed WYSIWIS immersive interfaces for mixed presence collaboration with 3d content. *Proc. of ACM Conf. on Computer Supported Cooperative Work (CSCW)*, pp. 1–22, 2019.

[36] K. Schmidt. The problem with awareness': Introductory remarks onawareness in CSCW. *Proc. of ACM Conf. on Computer Supported Cooperative Work (CSCW)*, pp. 285–298, 2002.

[37] K. Schuster, K. Gross, R. Vossen, A. Richert, and S. Jeschke. Preparing for industry 4.0–collaborative virtual learning environments in engineering education. In *Engineering Education 4.0*, pp. 477–487. Springer, 2016.

[38] T. Teo, G. A. Lee, M. Billinghurst, and M. Adcock. Hand gestures and visual annotation in live 360 panorama-based mixed reality remote collaboration. In *Proc. of the Australian Conf. on Computer-Human Interaction*, pp. 406–410, 2018.

[39] T. Waltemate, D. Gall, D. Roth, M. Botsch, and M. E. Latoschik. The impact of avatar personalization and immersion on virtual body ownership, presence, and emotional response. *IEEE Trans. on Visualization and Computer Graphics*, pp. 1643–1652, 2018.

[40] X. Wang, J. Laffey, W. Xing, K. Galyen, and J. Stichter. Fostering verbal and non-verbal social interactions in a 3D collaborative virtual learning environment: a case study of youth with Autism Spectrum Disorders learning social competence in iSocial. *Edu. Tech. Research and Development*, pp. 1015–1039, 2017.

[41] Z. Zhao, F. Han, and X. Ma. Live emoji: A live storytelling vr system with programmable cartoon-style emotion embodiment. In *IEEE Int. Conf. on Artificial Intelligence and Virtual Reality (AIVR)*, 2019.