SocialSlider: Changing the Transparency of Avatars

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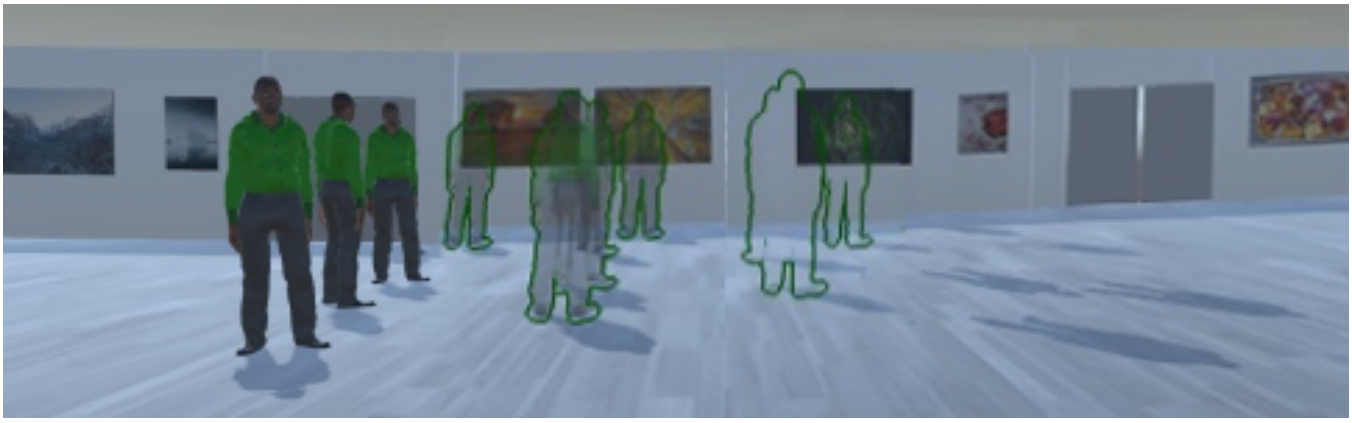

Figure 1: *SocialSlider* allows to fade out avatars in social VR, which is here happening from left to right. Left: avatars are visible. Center, left: avatars are half transparent and mainly visible through an outline. Center, right: avatars are fully transparent and only visible through an outline. Right: Avatars are invisible. Only their shadows can be seen. The transparency of avatars can be discretely and continuously changed. In this paper, four techniques to select the avatars that shall be faded in or out are implemented and evaluated.

ABSTRACT

Due to the growing number of users, social virtual reality can get crowded. As we sometimes prefer to be only surrounded by friends or more enjoy empty galleries to have a better view, we designed *SocialSlider*: an interaction technique that allows us to manipulate other avatars' transparency. We implemented *SocialSlider* with two transparency control modes and four avatar selection techniques: (1) select a single avatar, (2) select all, (3) select a co-located group, or (4) select a semantic group, such as unknown users. Through a user study, we found that (A) The concept of *SocialSlider* is appreciated and promising to overcome issues of crowded VR, such as occlusion. (B) The avatar's level of transparency can affect their perceived co-presence. Thus, we show that fading avatars' visibility is a beneficial technique in multi-user VR with benefits beyond avoiding occlusion, such as controlling the felt privacy or the experience of being social.

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CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Computer supported cooperative work**; *Interaction techniques.*

KEYWORDS

Virtual Reality, multi-user VR, social VR, occluded view

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1 INTRODUCTION

Similar to the real world, public places in social virtual reality (VR) are places of communication, collaboration, and social interaction. Although research on multi-user (or social) VR has a long history [5, 7, 8], social VR applications, such as AltspaceVR[1] or

[1] https://altvr.com/

Mozilla Hubs[2], still cause issues that limit the quality of social interaction within such systems. If many users, for example, share the same virtual space, it can get crowded very quickly, which causes occlusion, a distraction from content, and more difficult interest management [12, 21]. Crowded VRs, moreover, are challenging regarding users' awareness management [14, 22], which is necessary to reduce the amount of information to a level a user can perceive and to ensure that important information for decision making is still received [17]. From the physical world, we know that in crowded areas, persons may feel uncomfortable and stressed because their intimate space is violated [18]. What density of people is perceived as comfortable and when discomfort occurs varies from person to person and is, among other things, culturally determined [19]. In this respect, it is difficult to prevent discomfort caused by crowding by setting a fixed number of people for an area. One solution might be to enable the users to decide for themselves when it is too crowded and to allow them to change the situation without having to leave the place themselves. This is an approach that we follow in this paper.

We explore using a slider to manipulate the visibility of dedicated virtual bodies. We implemented a *SocialSlider* that allows the user to change the transparency of single or multiple avatars and thus, enables the users to decide on their own which information, in particular, which co-users, are relevant for them and should be visible. Individual avatars can be (temporarily) hidden or made semitransparent. To separately select avatars for transparency change we used gestures as they are the way to point at people and thus represent natural user interfaces [34]. Comparing these gesture-based selection techniques in a user study showed that (1) the general concept of changing avatars' transparency is appreciated, and (2) transparency can affect the perceived co-presence.

2 RELATED WORK

Like in physical reality, observing objects in VR is often hampered through other objects or avatars occluding the view. Previous work aiming to overcome occlusion issues proposed viewpoint changes as well as techniques making occluding objects and avatars transparent to allow for seeing through them.

2.1 Viewpoint Change

In the domain of training and collaborative work, a large body of work explored the possibility to get the view of a co-user to see what they see [1, 10, 15, 20, 30, 33, 36] as well as accessing the view of a third-person perspective camera, mainly to observe oneself for learning physical skills [11, 16, 24, 27]. While the listed view-sharing examples happen in a collaborative situation, accessing the view of an anonymous bystander or a stranger would cause privacy issues or violate intimacy.

Piumsomboon et al. [28, 29] allowed mixed reality co-users to scale themselves up into a giant or shrink down into a miniature to get different perspectives of a collaboration set-up and to get a non-occluded view at objects that were hidden before.

Reinhardt et al. investigated the possibility of walking through other avatars, which as a side effect also eliminates the occlusion of these avatars [31].

[2]https://hubs.mozilla.com/

While viewpoint changes require changing the own avatars' location or perspective, VR also allows changing the transparency of objects or avatars in the own view, which allows for maintaining the own position and perspective.

2.2 Transparency

Argelaguet et al. [2] investigated multi-user pointing with see-through techniques to avoid collision and at the same time to improve collaborative interaction tasks when inter-user occlusion problems in multi-user VR occur. While here see-through techniques are applied to objects, *SocialSlider* aims at see-through techniques applied to avatars.

When Zhang and Furnas investigated interactions in multiscale social VRs, they used transparent avatars with an outline to distinguish between far-away, resized avatars and semi-transparent avatars. They used this representation as it is easy to understand and could "reduce the area of blocked views" [37]. *SocialSlider* uses transparency as well but enables users to decide by themselves if and when avatars should be transparent or semi-transparent.

Benford et al. raised the idea to use translucence to symbolize the partial presence of a user: Users can see by the level of transparency whether they have another user's attention or if it is an abandoned avatar [6]. We use the concept of partial presence in a different way. In *SocialSlider*, users can decide which avatars they want to pay attention to and how much co-presence they want to perceive from a self-selected co-user.

Coffin and Hollerer [13] investigated a technique that allows a user to look through obscuring objects in arbitrary 3D graphics scenes. To control this form of virtual x-ray vision, the user interactively cuts holes in the obscuring geometry. To see occluded objects, *SocialSlider* uses transparency manipulation as well, but instead of cutting out shapes, *SocialSlider* changes the transparency of entire models, respectively for single or multiple avatars.

In summary, transparency has been applied to avatars, but previous work did not explore the opportunity to enable the user to manipulate the transparency of co-users' avatars explicitly.

3 EXPERIMENT

We conducted an experiment to proof the concept of our proposed *SocialSlider* technique and to evaluate the usability of its four different avatar selection methods.

3.1 Experiment Design

In our experiment, we explored the general concepts of *SocialSlider*. Furthermore, we investigated the usability of the four *selection techniques* and of the two *control modes* of transparency manipulation (discrete mode to switch transparency on or off and continuous mode to fade transparency in and out) using a 2x4 within-subjects design. The *selection techniques* were (1) selecting individual avatars, (2) selecting all, (3) selecting a co-located group, and (4) selecting a semantic group based on their member's shared attribute, e.g. avatars we do not want to be with in one VR. A semantic group could be (pre)defined by creating a list of friends/colleagues/followers as known from social media. Assuming that their avatars should remain visible, all other avatars belong to the semantic group of non-friends that can be selected.

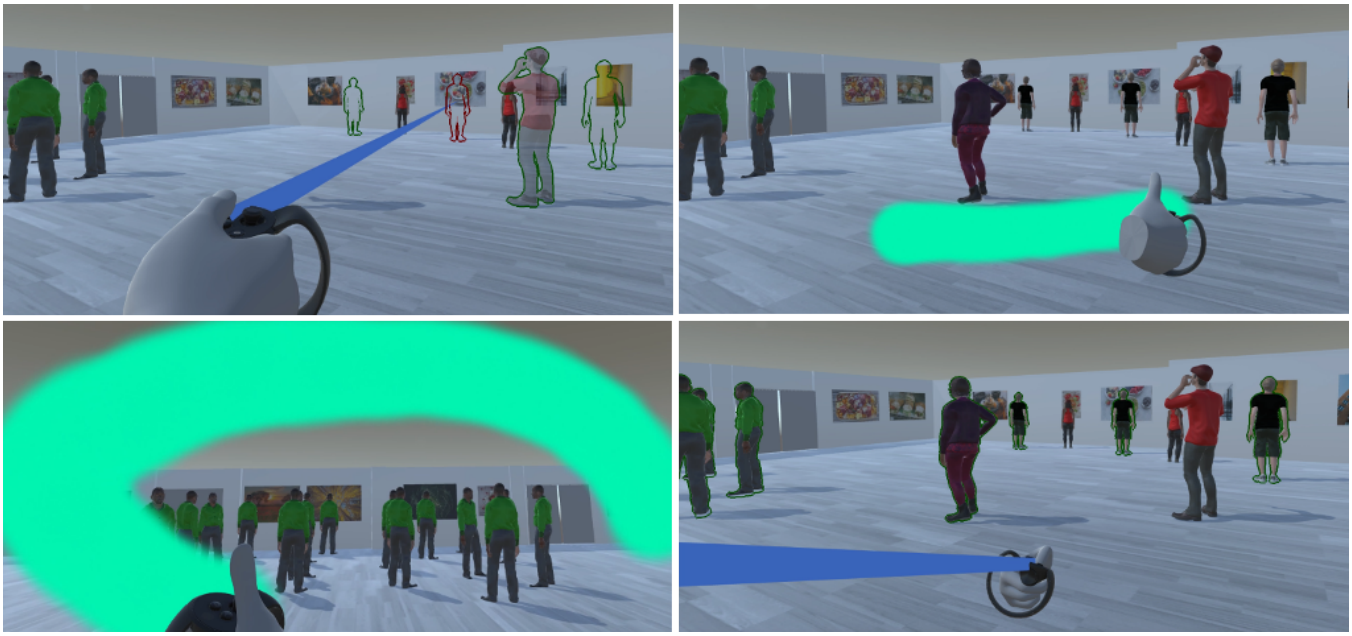

Figure 2: Selection techniques: top left: selecting a single avatar, top right: selecting all, bottom left: selecting a co-located group, bottom right: selecting a semantic group

3.2 Measurements

The general concept of *SocialSlider* was evaluated through the semi-structured question:

- What do you think in general about the idea of manipulating the transparency of avatars in multi-user VR?

Usability of the design variations of *SocialSlider* implemented through different *selection techniques* and *control modes* were measured with the System Usability Scale (SUS) questionnaire [9]. To better understand the SUS ratings, additional qualitative feedback on the advantages and disadvantages of both *control modes* and the four *selection techniques* was gathered by the following semi-structured questions:

- What made the control mode of transparency more or less useful?
- What made the interaction technique more or less useful?

3.3 Participants

The experiment was conducted with 24 participants (7 female, 17 male) with an average age of 28.167 (SD = 4.320). The participants aged between 20 and 38 years had different backgrounds of experience with using VR. One participant declared that they had never used VR before, 13 participants reported a rare use of VR, whereas 10 participants reported that they use VR at least once a month.

3.4 Apparatus

As experimental environment, we used a virtual exhibition (see Figure 2) with several avatars (built with the avatar generator from devops [3]): In total there were 43 non-animated avatars in the virtual environment representing remote users. Participants explored *SocialSlider* in the virtual environment (VE) and applied it in our 2x4 designed controlled experiment. One participant at a time and the investigator were the only people physically present, so there was no possibility of a physical collision with other users.

The VE was developed with Unity3D[4] (Version 2018.2.18f1) and the Oculus SDK version 1.28, OVR Plugin 1.29. We used an Oculus Rift as a head-mounted display (HMD), 2 Oculus touch controllers, and the Oculus tracking sensors. Our PC was equipped with an Intel i7 processor, 16 GB RAM, GeForce 1080 graphic board, and Windows 10.

3.4.1 Selection Techniques. The *selection techniques* were realized through commonly established mid-air gestures performed with the Oculus touch controllers.

Selecting a single avatar was realized through a mid-air pointing gesture using a raycast from the controller to a single avatar. Such hand-held raycasting has widely been used due to its intuitiveness and ease of use [4]. The ray was activated by pressing the B-button of the right controller. When successfully pointed, the selection was confirmed by pressing the A-button of the right controller. We used a laser-pointer metaphor to visualize the raycast, which was a blue line beginning at the virtual index finger of the user's right hand. As a combination of hand-held raycasting and highlighting of the hit objects is a precise pointing technique [35], *SocialSlider* uses a red outline to show avatars that have been hit

[3] https://assetstore.unity.com/packages/tools/avatar-generator-81473
[4] https://unity.com/

by using an asset from cakeslice[5]. After confirming the selection, the outline changed to green (see Figure 2, top left).

Selecting all was done by drawing a green line in the air using the trigger button of the right controller with the right index finger (see Figure 2, top right). While no object targeting was required, the gesture was recognized using the recognizer from AirSig [6]. We used that gesture as it reminds at pointing at a larger and further away area while moving the hand from the left to the right of that area.

Selecting a co-located group was done by pointing at a group and drawing a green circle around the group while pushing the trigger button with the right index finger of the right controller (and again using the recognizer from AirSig). The selection was confirmed by releasing the button (see Figure 2, bottom left). Circling objects is a preferred technique for selecting multiple objects with a mouse [23]. Hence, we adapted that concept for the 3D space. As pointing is faster than a circling gesture and as circling selection time increases with increasing shape complexity [26], measuring task completion time (TCT) would lead to obvious results. Hence, we did not analyze TCT. The pointing and selecting feedback through colored outlines was realized similar to the single avatar selection.

Selecting a semantic group was done after the user activated the raycast by pressing the B-button of the right controller and had to point on themselves (see Figure 2, bottom right). The mental model behind that gesture design was thinking of "myself" to select "my" friends, and pointing at myself is an established and natural gesture for referring to oneself [3].

3.4.2 Controlling Transparency. Discrete and continuous control are the two major input modes in HCI with commonly known advantages when either switching between values or fading from one to another [25]. We implemented both, discrete and continuous control to change the avatar's transparency after selecting avatars with one of the described *selection techniques* by moving the thumb-stick of the controllers.

Discrete mode: Switching transparency on (or off) could be realized by the discretely interpreted thumb-stick move towards left (or right). To facilitate the selection of invisible avatars and to allow a sense of the total number of avatars in the room, the shadows of the avatars remain visible.

Continuous mode: A continuous transparency fading (with the possibility to stop and leave the avatars semi-transparent) could be done by moving the thumb-stick to the left to decrease transparency and to the right to increase transparency.

3.4.3 Task Visualization. Tasks were visualized through color codes (see Figure 2). The avatars with green shirts represent the co-located group, whereas the semantic group has red clothes (headdress, shirt). The avatars with violet clothes should be selected in the single avatar selection task. There was no special color for the selection of all avatars in the virtual environment because all avatars in the room are selected independently of the color of clothes.

[5]https://github.com/cakeslice/Outline-Effect
[6]https://github.com/AirSig

3.5 Procedure & Task

After welcoming the participants, a short introduction about the VR setup and the tasks was given. The virtual environment was shown on a screen, the color code and the tasks were explained followed by a short explanation about the use of the controllers. Afterwards, the participants signed a consent form and fill in the demographic questionnaire.

Due to our 2x4 design, each participant had to execute eight tasks, which were four selection tasks realized using two different modes (discrete, continuous). To avoid sequence effects, we used a Latin Square design for the order of the eight conditions.

The following four selection tasks were explained at the beginning of the experiment and repeated before the execution of the task:

- Select the co-located group represented by the green avatars and manipulate their transparency with the continuous/discrete control.
- Select single persons represented by violet avatars and manipulate their transparency with the continuous/discrete control.
- Select all your non-friends by pointing at yourself manipulate their transparency with the continuous/discrete control. Your Friends are the red avatars.
- Select all persons in the room by using the line gesture and manipulate their transparency with the continuous/discrete control.

The participants were allowed to look around and move in a square of 2m x 2m. As there was no time limit, the participants were instructed to remove the HMD when they finished the task and fill in the SUS questionnaire as well as two semi-structured questions each on advantages and disadvantages of the *selection techniques* and the *control modes*.

After completing all tasks, the users were asked about their general opinion on transparency manipulation.

4 RESULTS

We first analyzed the quantitative data using inferential statistics. Then we analyzed the qualitative data on the general concept of *SocialSlider*. Finally and to better understand the quantitative results, we analyzed the qualitative feedback on the within-subjects variables *selection technique* and *control mode*.

4.1 Quantitative Usability Data

For analyzing the quantitative usability data gathered through the SUS questionnaire, a Friedman test was used to indicate significant differences for the within-subjects variable *selection technique*. Due to the non-parametric data of the SUS questionnaire, we used the Wilcoxon Signed-Rank tests for post-hoc analysis with a Bonferroni correction applied. Based on the four conditions, this leads to a significance level of $p < 0.0125$ for the *selection techniques*. Furthermore, a Wilcoxon Signed-Rank test was used to indicate significant differences for the within-subjects variable *control mode*.

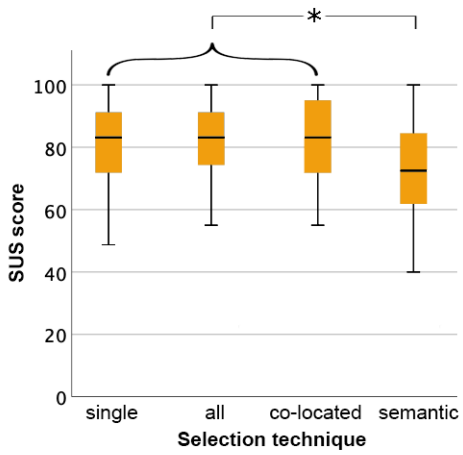

Figure 3: SUS score per selection technique

4.1.1 Selection Technique. Descriptive statistics led to the following median values for the SUS score: $Mdn_{\text{single}} = 83.125$, $Mdn_{\text{all}} = 83.125$, $Mdn_{\text{co-located group}} = 83.125$, and $Mdn_{\text{semantic group}} = 72.500$.

A Friedman test showed significant differences in the SUS scores between the different *selection techniques*, $\chi^2(3) = 11.910$, $p = .008$.

Post hoc analysis with Wilcoxon Signed-Rank tests revealed a statistically significant lower *usability* for *semantic groups* than for any other *selection technique* (*semantic groups* versus *single avatars*: $Z = -2.811$, $p = .005$), *semantic groups* versus *all*: $Z = -2.608$, $p = .009$, and *semantic groups* versus *co-located group*: $Z = -3.403$, $p = .001$).

No significant differences in the *usability* could be found between the three *selection techniques*: *single avatars*, *all*, and *co-located group* (*single avatars* vs. *all*: $Z = -.365$, $p = .715$, *single avatars* vs. *co-located group*: $Z = -1.262$, $p = .207$, and *all* vs. *co-located group*: $Z = -.672$, $p = .501$).

4.1.2 Control Mode. Descriptive statistics led to the following median values for the SUS score: $Mdn_{\text{descrete}} = 82.1875$, and $Mdn_{\text{continuous}} = 80.000$.

A Wilcoxon Signed-Rank test showed no significant differences for the *usability* between *discrete* and *continuous* ($Z = .065$, $p = .948$).

4.2 Qualitative Data

The qualitative data collected during semi-structured interviews was analyzed through axial coding. The categories were structured according to the general concept of the *SocialSlider* and our independent variables.

4.2.1 General Concept of SocialSlider. Through the question, *"What do you think in general about the idea of manipulating the transparency of avatars in multi-user VR?"*, we gained important insights into our general concept of the *SocialSlider*.

The majority of participants (23 of 24) rated the general idea of manipulating the transparency of avatars in multi-user VR positively. In particular, participants highlighted the benefits for crowded scenarios, such as those that can occur in social VR:

- *"I think it would be useful in crowded VR spaces." (P3)*
- *"I think that the option to make people transparent in VR is really useful, especially if it's really crowded in the room you stay, or you want to feel more "alone" with your friends who are there with you." (P5)*
- *"Great option for situations with a lot of avatars to get free sight on things that are hidden by avatars." (P6)*

Moreover, participants highlighted special benefits of *SocialSlider*, such as an increase of privacy (4), a decrease of occlusion (10), and a fast way to find friends in the crowd (3):

- *"It is a nice feature and will become more important with a higher number of users in the same VR-space. But I don't see why I would share the VR-space with strangers that I don't want to see (fade out). I would join a VR-session with friends, and then I think that I'd like to see them." (P1)*
- *"I think there are a lot of scenarios where it might be very useful to manipulate the transparency of avatars. Sometimes you need to see more of the room to get the whole scenario, or it might just be too crowded to feel comfortable. There might be important information to be hidden behind avatars, and those avatars might not be helpful or needed in any way." (P16)*
- *"Very interesting concept. Especially, being able to quickly select and find an important group (friends) can be very helpful in crowded areas." (P13)*

As interesting side aspect of *SocialSlider*, the ability to change the presence level of an avatar through their transparency was highlighted:

- *"From a social point of view, changing their transparency lets the room keep full but at the same time make them not so important like completely present avatars." (P12)*
- *"A continues variation of transparency is more useful to get half transparency as well to get the whole impression of the room but not feeling alone." (P6)*

4.2.2 Non-intuitive Gesture Design and Ergonomic Issues. Our qualitative data provides more detailed insights about the worst rating of pointing at oneself to select a semantic group.

In general, the concept of being able to *select a semantic group* was perceived to be beneficial stated by thirteen participants, for example:

- *"The interaction technique to select a semantic group seems very useful for a scenario in which you want to be just with your friends, so it's nice to have an easy and fast way to achieve this." (P16 semantic continuous).*
- *"It's a quick way to change the scene into a somewhat private scene for you and your buddies." (P4 semantic discrete)*, and
- *"Toggling not friends makes room for socializing with friends fast." (P12 semantic discrete).*

A major criticism of our participants refers to the gesture design not being intuitive and feeling awkward when pointing a laser beam at themselves. Nine participants stated that the selection techniques were hard to use as not being intuitive, i.e.:

- *"It's very cumbersome to mark yourself." (P4 semantic continuous)*,
- *"Pointing at myself is a weird gesture and feels unnatural." (P2 semantic continuous)*, and

- *"Harder to use and not intuitive to point at yourself." (P5 semantic discrete).*

Moreover, five of our participants named ergonomic issues, and three participants described that they feel uncomfortable when they performed the selection technique.:

- *"The self-pointing was a bit hard to do (physically) because of the controller and the tracking." (P1 semantic discrete)*
- *"Weird to point the laser-pointer to myself and difficult to handle with the controller, unnatural hand movement" (P9 semantic discrete)*
- *"uncomfortable feeling when bringing the laser pointer closer to yourself." (P14 semantic continuous)*

Contrary to the other gesture designs that were found intuitive, the semantic group control was perceived to need to be learned as it is not immediately obvious (9).

- *"It is not obvious to point at yourself to highlight your friends." (P7 semantic discrete)*
- *"I think the gesture to select a semantic group by pointing at myself is not very self-explanatory and intuitive to use. But there is nothing wrong with the idea of selecting a semantic group." (P16 semantic continuous).*
- *"Pointing at oneself might create the wrong associations" (P12 semantic discrete)*

4.2.3 Manipulation of Transparency as Presence Cue. Transparency had either to be manipulated through discrete control realized through a single thumb-stick move towards left or right or via continuous control interpreting the level of thumb stick position change (towards left or right). While it is commonly known that discrete control is faster than continuous control [25], we found no statistically significant differences in the control modes' usability. However, the qualitative data analysis gave us deeper insight into how the transparency change effects the perception of presence of the users represented by partly or completely faded out avatars.

Discrete mode: In contrast to the advantages of continuous control for the sense of presence, there have been several social and co-presence disadvantages named by participants for discrete control.

Five participants highlighted that the invisibility of the avatars has a negative effect on perceived co-presence, and the feeling of a crowd is lost when avatars are invisible, for example:

- *"It's getting hard to tell how many avatars are around there if a lot of them are not visible (or just by their shadows)." (P6 single continuous)*, and
- *"Turned off avatars can easily be forgotten." (P13 all discrete).*

Accordingly, two participants mentioned appearing loneliness and a less social experience, such as:

- *"You feel somewhat lonelier/it makes the experience less social." (P20 all continuous)*

As a consequence of the loss of co-presence, the "empty" virtual environment when using *SocialSlider* was mentioned to be appropriate for a kind of private mode by one participant:

- *"It's a quick way to change the scene into a somewhat private scene for you and your buddies." (P4 semantic discrete)*

Continuous mode: Thirteen out of 24 participants stated that they preferred the continuous mode for the ability to control transparency and mentioned several social aspects as reasons for this, such as allowing to be surrounded by self-selected people and changing into a more private atmosphere.

- *"It is useful for keeping / letting a certain group of people be there..." (P12 co-located continuous)* and

Three participants indicated that distinctive levels of transparency could clarify distinctive levels of social interconnectivity. Four participants mentioned that semi-transparent avatars lead to a decreased feeling of co-presence, which can be very useful for having control about being not (or less felt) surrounded by people (or their avatars) we do not want to be with:

- *"Faded avatars are still visible but not as present as non-faded." (P13 single continuous)* and
- *"The transparency mode allows different states of avatars or social connection. Choosing specific avatars, that one does not want to talk to but remember that they are still there, seems like a use case that makes sense. (P12 single continuous).*

The benefit of semi-transparent avatars, mentioned by six participants, is to keep the impression of a crowd without having a limited view, exemplary explained as follows:

- *"Getting an empty room really quickly, but having the possibility to see almost invisible people to make the room feel less empty but still being able to see everything." (P5 all continuous)* and
- *"Good for getting a better view but still have the feeling of staying with other people inside a room." (P24 co-located continuous).*

5 DISCUSSION

In the following, we discuss our results, in particular the benefits of the general concept of *SocialSlider*, interesting side-effects on co-presence, and the poor usability of the gesture of pointing at oneself to select a semantic group. We also include the limitations and outline future work.

5.1 SocialSlider Advantages

The general concept of *SocialSlider* was appreciated and found beneficial for various reasons. Besides reducing crowding in social VR, *SocialSlider* allows users to look at objects behind avatars, which is in line with previous work [2]. In contrast to previous work, we enabled the user to control other avatars' transparency, which was appreciated as it empowers users to change the social setting in VR and, for example, create a private atmosphere by fading everybody out but one's friends. (Please note that this concept was appreciated, while the according gesture was not.)

The highlighted ability to fade out the avatars of users reduces the feeling of being with them in the same VR. Such co-presence reduction can be valuable to create a private atmosphere and allow the users to get into a privacy mode which ensures that the interactions and conversations are only perceptible for the chosen group. Co-presence reduction could also be used to prevent discomfort through intimacy violation, e.g., when a remote co-user's avatar gets into our intimate proximity zone [18]. Moreover, *SocialSlider*

could be used to intentionally avoid collision with other avatars of remote users without the need to change the own motion path as visual support of walk-through locomotion techniques [31]. On the other hand, if the users are physically co-located, the avatars should stay at least semi-transparent to avoid collision in the physical world.

5.2 Transparency & Co-presence

As stated before, participants commonly reported an effect of transparency on co-presence. Similar to transparency affecting co-presence, Reinhardt and Wolf had shown that the feeling of being with another person in VR (co-presence) decreases with the ability to walk through their virtual body [31].

Our results suggest: The more transparent an avatar is displayed, the fewer users might perceive their co-presence. That could be used to (A) create a more private atmosphere (through fading out avatars one does not want to be with) (B) decrease overcrowding, but (C) if all avatars are faded out, one might feel lonely in social VR. The effect of transparency on co-presence has not been explored yet and hence, is a novel way to design for usable social VR. Thus, it is worth to be further and more systematically investigated, which we plan in future research.

5.3 Limitations & Future Work

While most of our gestures were following established mid-air gesture design, the gesture to select a semantic group by pointing at oneself lacks usability due to ergonomic issues.

The reason for the usability issue might be the handheld controller which extends the hand and lengthens the forearm. As a consequence, the controller might collide with the user's upper body when pointing at oneself. Hence, improvements of that gesture design to implement the *SocialSlider* concept are recommended.

In addition to examining in more detail the effect of transparency manipulation of avatars on co-presence and the plausibility illusion [32], it would be useful to use the density of people in the room as a variable to determine at what state a VE is considered to be overcrowded and whether higher density of people increases the frequency of use of the *SocialSlider*. Furthermore, it could be tested whether a more realistic representation of the avatars through natural movement or auditory content has an influence on the use of the SocialSlider.

Future work could test the *SocialSlider* for different scenarios, such as creating a private mode for one-to-one or one-to-many interactions in a crowded environment or evaluate it with pathfinding tasks. An evaluation with small groups could also be interesting.

6 CONCLUSION

In this paper, we introduced *SocialSlider*, a technique that empowers the user in multi-user VR to change the transparency of their co-users. We compared four techniques to select avatars whose transparency should be modified and found that: (A) The concept of *SocialSlider* is appreciated and promising to overcome crowded VR as it can reveal occluded views, protect intimate proximity zones, create a private atmosphere, e.g. with friends, and even make users feel alone when all other avatars are invisible. (B) Our results let suggest that a transparency increase might decrease the perceived co-presence. Especially the last point has not been investigated yet and hence, hopefully inspires future research on avatar's transparency effects.

REFERENCES

[1] Judith Amores, Xavier Benavides, and Pattie Maes. 2015. ShowMe: A Remote Collaboration System That Supports Immersive Gestural Communication. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI EA '15)*. Association for Computing Machinery, New York, NY, USA, 1343–1348. https://doi.org/10.1145/2702613.2732927

[2] Ferran Argelaguet, Alexander Kulik, André Kunert, Carlos Andujar, and Bernd Froehlich. 2011. See-through techniques for referential awareness in collaborative virtual reality. *International Journal of Human-Computer Studies* 69, 6 (2011), 387 – 400. https://doi.org/10.1016/j.ijhcs.2011.01.003

[3] Michael Argyle. 2013. *Bodily communication.* Routledge.

[4] Marc Baloup, Thomas Pietrzak, and Géry Casiez. 2019. RayCursor: A 3D Pointing Facilitation Technique Based on Raycasting. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3290605.3300331

[5] Steve Benford, John Bowers, Lennart E. Fahlén, Chris Greenhalgh, and Dave Snowdon. 1995. User Embodiment in Collaborative Virtual Environments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '95)*. ACM Press/Addison-Wesley Publishing Co., USA, 242–249. https://doi.org/10.1145/223904.223935

[6] Steve Benford, John Bowers, Lennart E Fahlén, Chris Greenhalgh, and Dave Snowdon. 1995. User embodiment in collaborative virtual environments. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 242–249.

[7] Steve Benford, Chris Greenhalgh, and David Lloyd. 1997. Crowded Collaborative Virtual Environments. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems* (Atlanta, Georgia, USA) *(CHI '97)*. Association for Computing Machinery, New York, NY, USA, 59–66. https://doi.org/10.1145/258549.258588

[8] Steve Benford, Chris Greenhalgh, Tom Rodden, and James Pycock. 2001. Collaborative Virtual Environments. *Commun. ACM* 44, 7 (July 2001), 79–85. https://doi.org/10.1145/379300.379322

[9] John Brooke. 1996. SUS: A quick and dirty usability scale.

[10] Amine Chellali, Isabelle Milleville-Pennel, and Cédric Dumas. 2013. Influence of Contextual Objects on Spatial Interactions and Viewpoints Sharing in Virtual Environments. *Virtual Real.* 17, 1 (March 2013), 1–15. https://doi.org/10.1007/s10055-012-0214-5

[11] Philo Tan Chua, Rebecca Crivella, Bo Daly, Ning Hu, Russ Schaaf, David Ventura, Todd Camill, Jessica Hodgins, and Randy Pausch. 2003. Training for Physical Tasks in Virtual Environments: Tai Chi. In *Proceedings of the IEEE Virtual Reality 2003 (VR '03)*. IEEE Computer Society, USA, 87.

[12] E. F. Churchill and D. Snowdon. 1998. Collaborative virtual environments: An introductory review of issues and systems. *Virtual Reality* 3, 1 (01 Mar 1998), 3–15. https://doi.org/10.1007/BF01409793

[13] C. Coffin and T. Hollerer. 2006. Interactive Perspective Cut-away Views for General 3D Scenes. In *3D User Interfaces (3DUI'06)*. 25–28. https://doi.org/10.1109/VR.2006.88

[14] Dawei Ding and Miaoling Zhu. 2003. A model of dynamic interest management: interaction analysis in collaborative virtual environment. In *Proceedings of the ACM symposium on Virtual reality software and technology*. 223–230.

[15] Maximilian Dürr, Rebecca Weber, Ulrike Pfeil, and Harald Reiterer. 2020. EGuide: Investigating Different Visual Appearances and Guidance Techniques for Egocentric Guidance Visualizations. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Sydney NSW, Australia) *(TEI '20)*. Association for Computing Machinery, New York, NY, USA, 311–322. https://doi.org/10.1145/3374920.3374945

[16] Susan R. Fussell, Leslie D. Setlock, and Robert E. Kraut. 2003. Effects of Head-Mounted and Scene-Oriented Video Systems on Remote Collaboration on Physical Tasks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Ft. Lauderdale, Florida, USA) *(CHI '03)*. Association for Computing Machinery, New York, NY, USA, 513–520. https://doi.org/10.1145/642611.642701

[17] Benedikt Gollan, Michael Haslgrübler, and Alois Ferscha. 2016. Demonstrator for Extracting Cognitive Load from Pupil Dilation for Attention Management Services. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct* (Heidelberg, Germany) *(UbiComp '16)*. Association for Computing Machinery, New York, NY, USA, 1566–1571. https://doi.org/10.1145/2968219.2968550

[18] Edward T. Hall. 1966. The Hidden Dimension.

[19] Edward T. Hall, Ray L. Birdwhistell, Bernhard Bock, Paul Bohannan, A. Richard Diebold, Marshall Durbin, Munro S. Edmonson, J. L. Fischer, Dell Hymes, Solon T.

Kimball, Weston La Barre, J. E. McClellan, Donald S. Marshall, G. B. Milner, Harvey B. Sarles, George L. Trager, and Andrew P. Vayda. 1968. Proxemics [and comments and replies]. *Current anthropology* 9, 2/3 (1968), 83–108.

[20] Thuong N. Hoang, Martin Reinoso, Frank Vetere, and Egemen Tanin. 2016. Onebody: Remote Posture Guidance System Using First Person View in Virtual Environment. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction* (Gothenburg, Sweden) *(NordiCHI '16)*. Association for Computing Machinery, New York, NY, USA, Article 25, 10 pages. https://doi.org/10.1145/2971485.2971521

[21] Mojtaba Hosseini, Steve Pettifer, and Nicolas D. Georganas. 2002. Visibility-Based Interest Management in Collaborative Virtual Environments. In *Proceedings of the 4th International Conference on Collaborative Virtual Environments* (Bonn, Germany) *(CVE '02)*. Association for Computing Machinery, New York, NY, USA, 143–144. https://doi.org/10.1145/571878.571901

[22] Mojtaba Hosseini, Steve Pettifer, and Nicolas D Georganas. 2002. Visibility-based interest management in collaborative virtual environments. In *Proceedings of the 4th international conference on Collaborative virtual environments*. 143–144.

[23] J. C. Jackson and R. J. Roske-Hofstrand. 1989. Circling: A Method of Mouse-Based Selection without Button Presses. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '89)*. Association for Computing Machinery, New York, NY, USA, 161–166. https://doi.org/10.1145/67449.67483

[24] Matthew Kyan, Guoyu Sun, Haiyan Li, Ling Zhong, Paisarn Muneesawang, Nan Dong, Bruce Elder, and Ling Guan. 2015. An Approach to Ballet Dance Training through MS Kinect and Visualization in a CAVE Virtual Reality Environment. *ACM Trans. Intell. Syst. Technol.* 6, 2, Article 23 (March 2015), 37 pages. https://doi.org/10.1145/2735951

[25] I. Scott MacKenzie, Abigail Sellen, and William A. S. Buxton. 1991. A Comparison of Input Devices in Element Pointing and Dragging Tasks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New Orleans, Louisiana, USA) *(CHI '91)*. Association for Computing Machinery, New York, NY, USA, 161–166. https://doi.org/10.1145/108844.108868

[26] Sachi Mizobuchi and Michiaki Yasumura. 2004. Tapping vs. Circling Selections on Pen-Based Devices: Evidence for Different Performance-Shaping Factors. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vienna, Austria) *(CHI '04)*. Association for Computing Machinery, New York, NY, USA, 607–614. https://doi.org/10.1145/985692.985769

[27] Takayuki Nozawa, Erwin Wu, Florian Perteneder, and Hideki Koike. 2019. Visualizing Expert Motion for Guidance in a VR Ski Simulator. In *ACM SIGGRAPH 2019 Posters* (Los Angeles, California) *(SIGGRAPH '19)*. Association for Computing Machinery, New York, NY, USA, Article 64, 2 pages. https://doi.org/10.1145/3306214.3338561

[28] Thammathip Piumsomboon, Gun A. Lee, and Mark Billinghurst. 2018. Snow Dome: A Multi-Scale Interaction in Mixed Reality Remote Collaboration. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI EA '18)*. ACM, New York, NY, USA, Article D115, 4 pages. https://doi.org/10.1145/3170427.3186495

[29] Thammathip Piumsomboon, Youngho Lee, Gun Lee, and Mark Billinghurst. 2017. CoVAR: A Collaborative Virtual and Augmented Reality System for Remote Collaboration. In *SIGGRAPH Asia 2017 Emerging Technologies* (Bangkok, Thailand) *(SA '17)*. ACM, New York, NY, USA, Article 3, 2 pages. https://doi.org/10.1145/3132818.3132822

[30] Lauriane Pouliquen-Lardy, Isabelle Milleville-Pennel, François Guillaume, and Franck Mars. 2016. Remote collaboration in virtual reality: asymmetrical effects of task distribution on spatial processing and mental workload. *Virtual Reality* 20, 4 (01 Nov 2016), 213–220. https://doi.org/10.1007/s10055-016-0294-8

[31] Jens Reinhardt and Katrin Wolf. 2020. Go-Through: Disabling Collision to Access Obstructed Paths and Open Occluded Views in Social VR. In *Proceedings of the Augmented Humans International Conference* (Kaiserslautern, Germany) *(AHs '20)*. Association for Computing Machinery, New York, NY, USA, Article 15, 10 pages. https://doi.org/10.1145/3384657.3384784

[32] Mel Slater. 2009. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences* 364, 1535 (2009), 3549–3557.

[33] S. Valin, A. Francu, H. Trefftz, and I. Marsic. 2001. Sharing viewpoints in collaborative virtual environments. In *Proceedings of the 34th Annual Hawaii International Conference on System Sciences*. 12 pp.–.

[34] Daniel Wigdor and Dennis Wixon. 2011. *Brave NUI World: Designing Natural User Interfaces for Touch and Gesture* (1st ed.). Morgan Kaufmann Publishers Inc., San Francisco, CA, USA.

[35] Nelson Wong and Carl Gutwin. 2014. Support for deictic pointing in CVEs: still fragmented after all these years'. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*. 1377–1387.

[36] Ungyeon Yang and Gerard Jounghyun Kim. 2002. Implementation and Evaluation of "Just Follow Me": An Immersive, VR-Based, Motion-Training System. *Presence: Teleoperators and Virtual Environments* 11, 3 (June 2002), 304–323. https://doi.org/10.1162/105474602317473240

[37] Xiaolong Zhang and George W Furnas. 2002. Social interactions in multiscale CVEs. In *Proceedings of the 4th international conference on Collaborative virtual environments*. 31–38.