SocialSlider: Changing the Transparency of Avatars affects their Co-Presence

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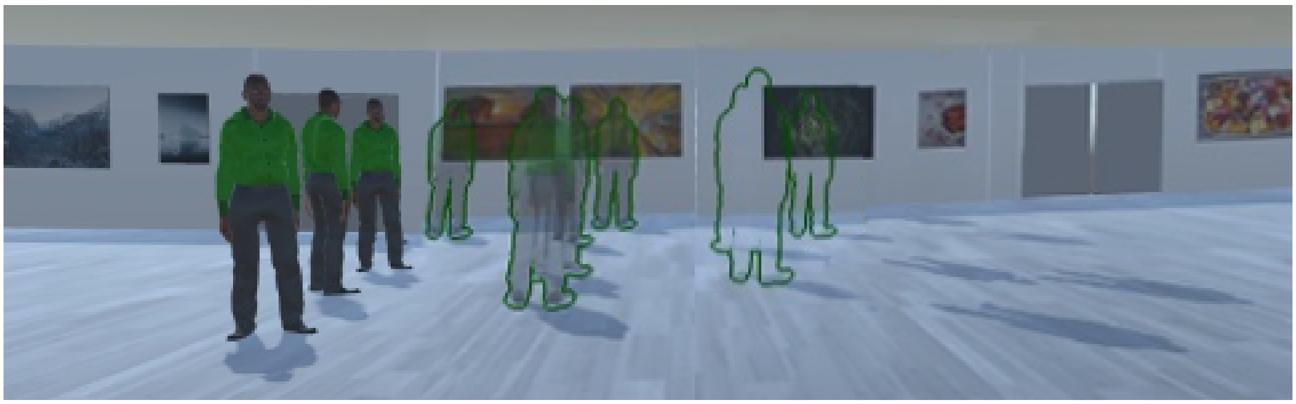

Figure 1. SocialSlider allows to fade out avatars in social VR, which is here happening from left to right. Left: avatars are visible. Center, left: avatars are half transparent and mainly visible through an outline. Center, right: avatars are fully transparent and only visible through an outline. Right: 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 constantly growing number of users, social virtual reality (VR) can be overcrowded. As we sometimes prefer to be only surrounded by close friends or as we more enjoy empty galleries to have a better view, we introduce *SocialSlider*: an interaction technique that allows us to fade avatars' visibility and to make them transparent. We implemented *SocialSlider* with four techniques to select avatars that shall be made invisible or faded out: (1) select a single avatar, (2) select all, (3) select a group of avatars standing together, 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 crowded VR. (B) The level of transparency of avatars affects their perceived co-presence. (C) Pointing at oneself is a gesture of poor usability as it lacks ergonomics.

Author Keywords
Virtual Reality, Multi-user VR, Social VR, Occluded View

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

INTRODUCTION
Although research on multi-user (or social) virtual reality (VR) has a long history [4, 6, 7], social VR applications, such as AltspaceVR[1] or Mozilla Hubs[2], still cause issues that limit the quality of social interaction within such systems. Similar to the real world, public places in social VR are places of communication, collaboration, and social interaction. But if many users share the same virtual space, it can get crowded very quickly, which causes occlusion, a distraction from content, and more difficult interest management [11, 18].

Concepts to solve problems of overcrowded social VR differ a lot for VR where co-located users share both, a virtual and a physical space [22, 30] versus social VR shared by remote users. Last allows for overcoming physical laws, such as going through [29] and seeing through [2] virtual objects and virtual bodies.

This paper explores using a slider to manipulate the visibility of dedicated virtual bodies. Hence, we design *SocialSlider* that allows the user to change the transparency of single or multiple avatars. Comparing different techniques to separately select

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

avatars for transparency change in a user study showed that (1) the general concept of *SocialSlider* is appreciated, (2) less common selection gestures lack usability, and (3) transparency affects co-presence.

RELATED WORK

Related previous work investigated concepts aiming to overcome issues of overcrowded VR, in particular occluded view.

Issues in Overcrowded VR

A large body of research investigated social VR applications and the most diverse issues that arise from them. Crowded VRs are challenging regarding users' awareness management [13, 19]. Awareness management is necessary to reduce the amount of information to a level a user can perceive and to ensure that important information is still received. Without this reduction of information, the users' cognitive load will increase due to filtering the relevant information from the overloaded environment. Interaction techniques, like the *SocialSlider*, might help to enable users to decide on their own which information, in particular, which co-users, are relevant and should be visible.

Overcoming Occlusion and Improving Visibility

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.

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, 9, 14, 17, 28, 31, 33] as well as accessing the view of a third-person perspective camera, mainly to observe oneself for learning physical skills [10, 15, 21, 25]. 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. [26, 27] 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 setup 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 [29].

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.

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 multi-scale 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" [34]. *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 [5]. 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 [12] 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.

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.

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.

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 [8]. 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:

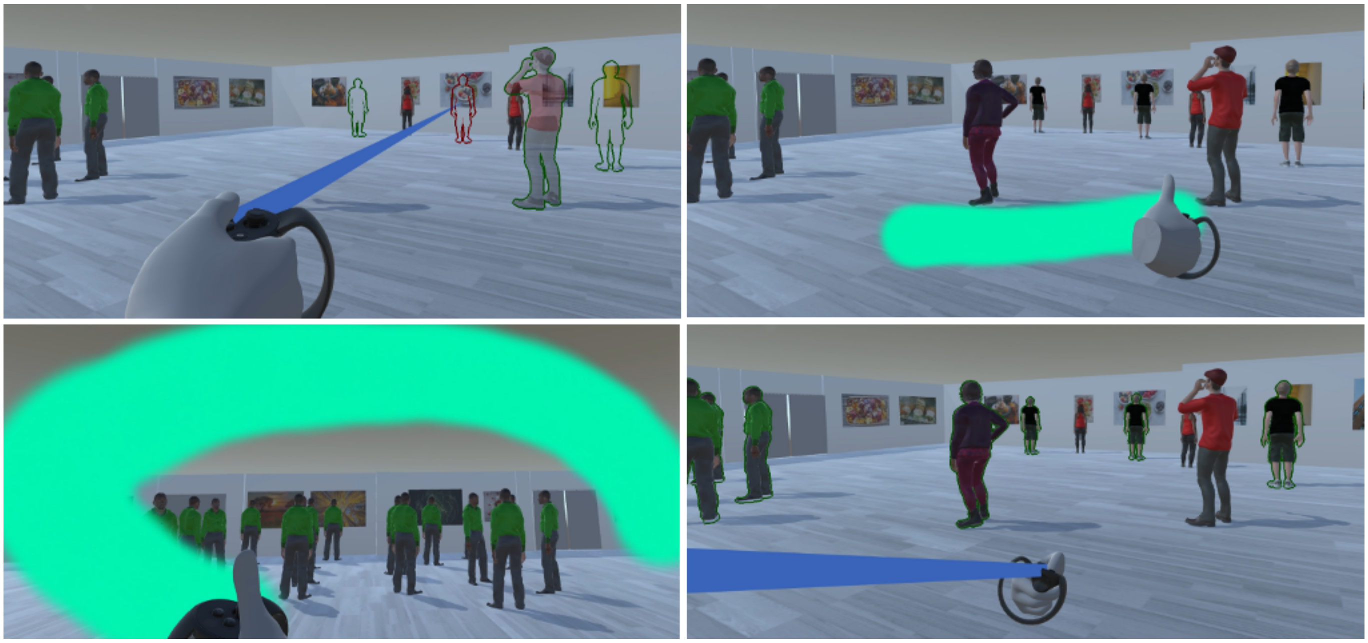

Figure 2. Selection techniques: top left: selecting a single avatar, top right: selecting all, bottom left: selecting a co-located group, bottom right: selecting a semantic group

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

- What made the interaction technique more or less useful?

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.

Apparatus
As the experimental environment, we used a virtual exhibition (see Figure 2) with several avatars (built with the avatar generator from devops [3]). Participants explored *SocialSlider* in the virtual environment (VE) and applied it in our 2x4 designed controlled experiment.

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.

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 [3]. 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 [32], *SocialSlider* uses a red outline to show avatars that have been hit 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

[3] https://assetstore.unity.com/packages/tools/avatar-generator-81473
[4] https://unity.com/
[5] https://github.com/cakeslice/Outline-Effect
[6] https://github.com/AirSig

was confirmed by releasing the button (see Figure 2, bottom left). Circling objects is a preferred technique for selecting multiple objects with a mouse [20]. 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 [24], 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.

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 [23]. 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.

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 from the color of clothes.

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. To avoid the carry-over effect, we used a Latin Square design for the order of the eight conditions.

After completing the task with each *selection technique* in combination with both *control modes*, the SUS questionnaire as well as two semi-structured questions each on advantages and disadvantages of the *selection techniques* and the *control modes* were answered by the participants. After completing all tasks, the users were asked about their general opinion on transparency manipulation.

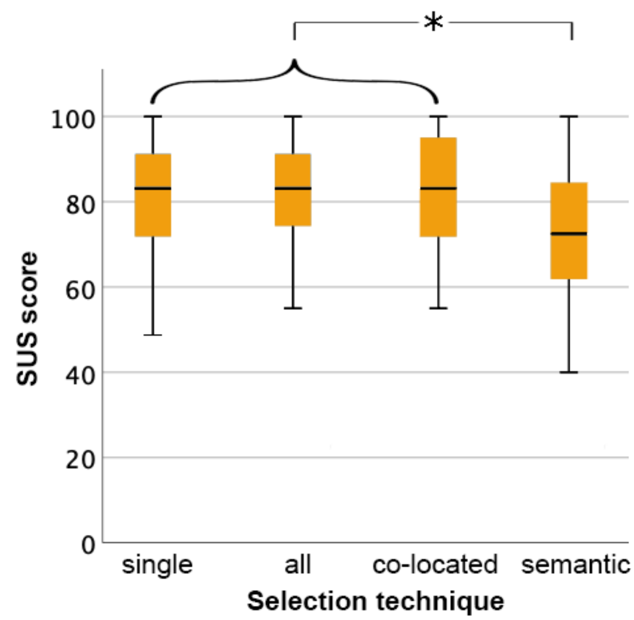

Figure 3. SUS score per selection technique

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*.

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*. Post-hoc analysis with Wilcoxon Signed-Rank tests was conducted with a Bonferroni correction applied, resulting in a significance level of $p < 0.0125$. Furthermore, a Wilcoxon Signed-Rank test was used to indicate significant differences for the within-subjects variable *control mode*.

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*: $Z = -.672$, $p = .501$).

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* ($Z = .065$, $p = .948$).

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.

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 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)*

Non-intuitive Gesture Design and Ergonomic Issues

Our qualitative data provides more detailed insights about the worst rating of pointing at oneself to fade 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).*
- *"Its 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.:

- *"Its 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)*

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 [23], 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 the 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:

- *"Different impression and atmosphere of the room when unknown people are invisible." (P6 semantic continuous).*

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 follow:

- *"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).*

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.

SocialSlider Advantages

The general concept of *SocialSlider* was appreciated and found beneficial for various reasons. Besides reducing overcrowding 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 cannot only be valuable to create a private atmosphere but it could also be used to prevent discomfort through intimacy violation, e.g., when a co-user's avatar gets into our intimate proximity zone [16]. Moreover, *SocialSlider* could be used to intentionally avoid collision with other avatars without the need to change the own motion path as visual support of walk-through locomotion techniques [29].

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 [29].

Our results indicate: The more transparent an avatar is displayed, the fewer users perceive their co-presence. That can 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. That finding is novel and worth to be further and more systematically investigated, which we plan in future research.

Pointing at Oneself

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.

CONCLUSION

In this paper, we introduced *SocialSlider*, a technique that empowers the user in social 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) A transparency increase of avatars causes a decreased perceived co-presence. (C) Pointing at oneself when holding a controller is a gesture of poor usability as the hand extension can cause ergonomics issues.

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