# Enhanced Auditoriums for Attending Talks in Social Virtual Reality


Tim Weissker
RWTH Aachen University
Aachen, Germany
weissker@vr.rwth-aachen.de

Leander Pieters
RWTH Aachen University
Aachen, Germany
leander.pieters@rwth-aachen.de

Torsten Kuhlen
RWTH Aachen University
Aachen, Germany
kuhlen@vr.rwth-aachen.de

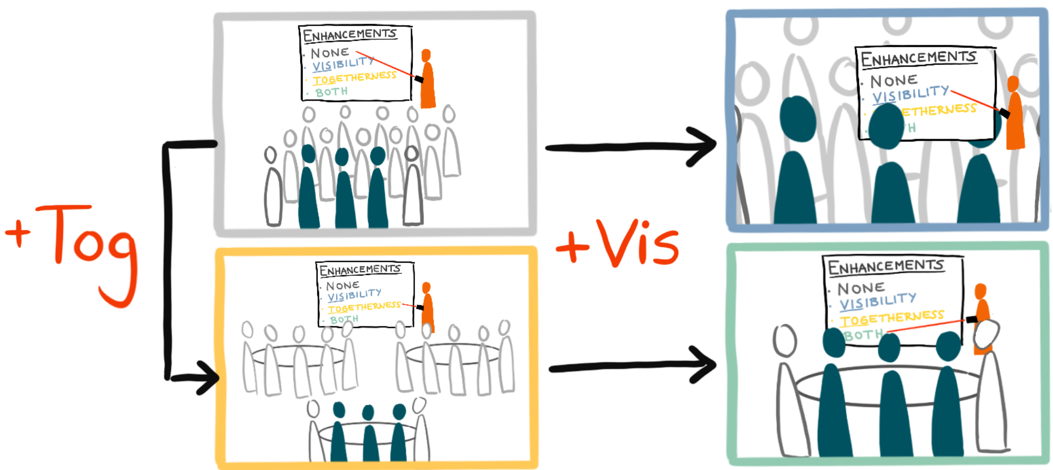




**Figure 1: We compared virtual talk attendance with head-mounted displays in four different auditoriums based on the presence or absence of two orthogonal features to improve the visibility of the presentation ($Vis$) and the feeling of togetherness ($Tog$). *Top Left:* Conventional row-based seating layout without enhancements. *Top Right:* Row-based seating layout with a copy of the stage per user to improve visibility. *Bottom Left:* Group table arrangement to improve the feeling of togetherness. *Bottom Right:* Group table arrangement with a copy of the stage per table to improve both visibility and the feeling of togetherness.**


## ABSTRACT

Replicating traditional auditorium layouts for attending talks in social virtual reality often results in poor visibility of the presentation and a reduced feeling of being there together with others. Motivated by the use case of academic conferences, we therefore propose to display miniature representations of the stage close to the viewers for enhanced presentation visibility as well as group table arrangements for enhanced social co-watching. We conducted an initial user study with 12 participants in groups of three to evaluate the influence of these ideas on audience experience. Our results confirm the hypothesized positive effects of both enhancements and show that their combination was particularly appreciated by audience members. Our results therefore strongly encourage us to rethink conventional auditorium layouts in social virtual reality.



## CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**.




*CHI EA '23, April 23–28, 2023, Hamburg, Germany*



ACM ISBN 978-1-4503-9422-2/23/04.
https://doi.org/10.1145/3544549.3585718

## KEYWORDS

Virtual Reality, Head-Mounted Display, Multi-User, Virtual Presentations, Audience Experience, Social Interaction

**ACM Reference Format:**
Tim Weissker, Leander Pieters, and Torsten Kuhlen. 2023. Enhanced Auditoriums for Attending Talks in Social Virtual Reality. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems (CHI EA '23), April 23–28, 2023, Hamburg, Germany*. ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3544549.3585718


## 1 INTRODUCTION

In recent years, several social gatherings and events have been moved to online spaces. While traditional 2D video conferencing systems are still the most prevalent choice, social virtual reality systems using head-mounted displays aim to provide a more immersive and therefore natural meeting experience by having participants interact as avatars within a shared 3D virtual environment [13, 14]. A particularly relevant use case of these systems for the scientific community is the realization of academic conferences, where researchers from around the globe gather to present papers, discuss their results, and expand their network. Prior work has reported on mostly positive participant feedback on academic conferences in social virtual reality when a real-world gathering is infeasible, stating that interactive sessions like poster discussions and breakout sessions worked particularly well [12, 25]. However, participant attitudes towards attending frontal presentations in virtual environments have been more reserved, with several users preferring classic video streams over the immersive experience [1, 7, 12]. Based on these results, we argue that the exact replication of real-world auditorium layouts in virtual reality as done in previous virtual conferences is not the best choice to promote a satisfactory experience for the audience. In this paper, we therefore propose possible solutions for two common issues typically associated with large virtual auditoriums. First, we suggest a miniature representation of the presenter and their slides in the proximity of viewers to overcome visibility problems when sitting far away from the stage. Second, we suggest the use of round group tables for enhanced co-watching and fostering social exchanges after the presentation. To evaluate our ideas, we conducted an initial user study with 12 participants, who attended virtual presentations together in groups of three. In summary, our work led to the following contributions:

- the introduction of mechanisms to improve presentation visibility and to support social groups in virtual auditoriums
- the results of an initial user study confirming the effectiveness of our enhancements as well as providing insights into their application in an exemplary use case

While using academic conferences as a prominent use case of virtual talk attendance, the implications of our results likely extend to other presentation scenarios as well. They strongly encourage to rethink conventional auditorium layouts in social virtual reality in order to make presentation attendance more convenient and valuable.

## 2 RELATED WORK

Academic conferences are an integral part of scientific exchange, where researchers from around the world gather to share and discuss progress in their discipline. Apart from the mere exchange of prior research results, a central benefit of meeting at a single venue is the opportunity to socialize, which forms new academic relationships, strengthens existing ones, and therefore provides the basis for future collaborations [1, 7]. However, the need to travel to a conference venue somewhere in the world is increasingly criticized because of the high carbon footprint, financial outlay, and logistical issues related to the attendees' personal life [1, 12, 19]. Moreover, travel might not be possible at all during an economic crisis [7] or pandemic [1, 15]. Several prototypical events have therefore explored academic conferences supplemented by or based entirely on online formats. Beyond basic textual exchanges via chats and mailing lists [10] as well as classic 2D video conferencing tools [4, 19], collaborative virtual environments (CVEs) like *Second Life* embody all participants as avatars in a three-dimensional virtual space [5], which allows for simulating the experience of walking around a conference venue and talking to nearby participants via an audio connection [7, 10, 21]. Modern social virtual reality (social VR) systems like *AltspaceVR* and *Mozilla Hubs* also allow users to join using a head-mounted display [13, 14], which makes the experience more immersive and enables enhanced gestural communication via the tracked movements of the headset and the controllers [1, 12, 15, 25].

Prior work has shown that users of CVEs and social VR systems tend to assume proxemic [24, 25] and communicative patterns [22] known from the real world. As a result, several previous academic conferences in these systems were rated positively for providing a more direct and expressive meeting experience than conventional conferencing solutions, which was especially beneficial for interactive sessions like poster discussions [7, 12], breakout rooms [25], and network building [1, 7]. However, user feedback regarding the attendance of frontal keynote or paper presentations in virtual environments typically tended to be more reserved, despite them being rated as one of the most relevant activities at a conference in general [1]. At the IEEE VR 2020 conference, for example, the live streaming platform *Twitch* was rated significantly more appropriate for attending conference talks than the social VR platform *Mozilla Hubs* [1]. Comparing the reports of several prior virtual events, attending conference talks in virtual environments appears to come with two central limitations:

**Limited Visibility** In many systems, the visibility of the slides and the speaker of a talk is limited compared to watching a live stream on the desktop. While earlier systems reported issues with the graphic resolution of the slides themselves [7], visibility is also impaired by being in a faraway viewing position like the back row of a virtual auditorium. As a result, it was reported that users often attempted to navigate around to improve their viewing angle onto the virtual presentation [12, 25], which can create socially challenging situations for the presenter as well as distractions for other attendees.

**Limited Feeling of Togetherness** Attending conference talks is often a social experience in itself, in which peers enjoy joining sessions together and discussing the content afterwards [4, 7]. However, the limited field of view in virtual environments as well as the navigation needs arising from the above-mentioned visibility problems disrupt the feeling of attending the talk together. This is because users are often not able to observe the reactions, postures, and gestures of their peers, which is a key requirement for successful social viewing experiences [20]. Furthermore, the often used row-based auditorium designs are poorly suited for interpersonal exchanges after the presentation [15].

To approach these limitations in an early desktop-based CVE, the performance discussed by Benford et al. duplicated the speaker's avatar to improve visibility and offered separate viewing rooms for private discussions during the performance [2]. Inspired by these early approaches, our work in this paper explores novel ideas to enhance visibility and to support social groups for presentations in modern social virtual reality systems.

## 3 NOVEL AUDITORIUM DESIGNS

We developed four virtual auditorium designs for attending classic slide-based presentations in social virtual reality, which are based on the presence or absence of two orthogonal features in an attempt to improve the visibility of the presentation ($Vis$) as well as the feeling of togetherness ($Tog$). Each design can therefore be described by a two-part shorthand like $Vis \times \overline{Tog}$, in which a horizontal bar indicates that the corresponding feature was not included in this design. A visual overview of all four designs from a conceptual viewpoint is given in Figure 1 and will be detailed in the following. The concrete instantiations of these concepts for our user study are shown in Figure 2 and will be detailed in Section 4.


**Figure 2: In our user study, participants attended one short prerecorded talk in each of the four auditoriums as a group of five (three participants and two simulated users). In each talk, the presenter (orange shirt) introduced a specific type of animal to the audience of about 155 listeners. The listeners other than the participants were simulated to create comparable experiences across conditions. After each talk, participants were asked to discuss their main insights gathered in the talk.**

$\overline{\textbf{Vis}} \times \overline{\textbf{Tog}}$ This auditorium design serves as the baseline without any enhancements in terms of visibility and togetherness. The audience is arranged in a typical row-based seating layout, which is oriented towards the stage on which the presenter explains their slides. Similar virtual replications of real-world auditoriums were seen at prior conferences in CVEs and social VR systems [7, 15].

$\textbf{Vis} \times \overline{\textbf{Tog}}$ This auditorium design also follows a row-based seating layout, but it adds an individual miniature representation of the slides and the presenter's avatar in front of each viewer. This idea is inspired by the World-in-Miniature (WIM) and Voodoo Doll techniques, which provide copies of relevant objects or areas of interest for inspection and manipulation [17, 23]. In the context of talk attendance, we expect a miniature copy of the stage in the proximity of each viewer to improve the visibility and therefore the understanding of the presentation. To prevent cluttering the environment with a separate miniature for each viewer, we propose that only the miniature belonging to a particular user should be rendered to them while the others can be abstracted by a static proxy geometry.

$\overline{\textbf{Vis}} \times \textbf{Tog}$ This auditorium design features circular group tables scattered across the room instead of row-based seating, where each table offers a given number of chairs oriented towards a single frontal stage. This idea is inspired by the *horseshoe* formation people tend to assume in the real world to interact with each other while simultaneously observing something in the distance [11]. In the context of talk attendance, we expect that this seating layout improves the sense of togetherness since the emotions and reactions of the peers can be perceived more easily. It also provides a good basis for discussions after the presentation.

$\textbf{Vis} \times \textbf{Tog}$ This auditorium design is a combination of the group table layout with an individual miniature representation of the stage situated at each table. We expect this layout to ensure proper presentation visibility while simultaneously fostering social observations and exchanges with the peers. However, depending on the position and size of the miniature, different seating positions in this layout may come with different viewing angles on and therefore perspective distortions of the miniature. While presenting differently rotated miniatures for each viewer could be a solution to this issue, the introduced inconsistency between group members would also hinder the interpretability of deictic gestures. For our work of this paper, we therefore decided to favor a consistent representation of the miniature for all group members. Nonetheless, similar to the $Vis \times \overline{Tog}$ auditorium, we suggest that the miniatures of the other tables should be abstracted by a static proxy geometry.

# 4 INITIAL USER STUDY

We conducted an initial user study to get a first impression on the effectiveness of our auditorium designs and their influence on audience experience during talks. For this purpose, we invited participants in groups of three and asked them to listen to and discuss short presentations within the described auditorium settings.

## 4.1 Participants

Overall, 12 participants (8 male, 3 female, 1 unknown) between 21 and 58 years of age ($M = 35.1, \sigma = 15.99$) took part in the study. Seven of them claimed to have a technical profession while the other five mentioned non-technical backgrounds. To reduce a potential novelty bias in our sample, we ensured that prior knowledge regarding virtual reality was balanced, with only half of the participants using a head-mounted display for the first time.

## 4.2 Experimental Setup

The hardware setup of our study involved three workstations with *HTC Vive Pro 2* head-mounted displays and controllers in separated areas of our lab. Each system was calibrated to cover a separate quadratic interaction space of 2m x 2m, with a chair in the middle allowing to sit down while attending the presentations. All three systems shared five wall-mounted base stations 2.0 as tracking references. The workstations were connected to each other via standard Ethernet connections to a central router, which enabled a proprietary *Unity* application based on *Netcode* to synchronize the virtual environment across all machines with a low latency. This software system represented each user with virtual head and hand geometries based on the measured tracking data (see presenter in Figure 2), which allowed for basic gesturing as in several commercial systems [14]. Navigation beyond head movements was enabled by teleportation with a parabolic selection ray [18]. To support basic non-spatialized verbal communication via the built-in headphones and microphones of the head-mounted displays, all workstations were also connected to a separate *Mumble* server[1]. The virtual environment was rendered on each machine at the native resolution of the head-mounted display at 2448x2448 pixels per eye and an update rate of 90Hz.

## 4.3 Experimental Design

The user study employed a within-subjects design with four conditions, in which participant groups experienced instantiations of the four auditorium designs introduced in Section 3. The order of conditions followed a balanced Latin Square design to prevent systematic carryover effects. For the purpose of this study, we took particular care to make conditions as comparable as possible. The two row-based and the two table-based auditoriums featured 154 (11 rows with 14 seats each) and 155 seats (table-based, 31 tables with 5 seats each), respectively. These were mostly filled with virtual agents since recruiting and overseeing an equivalent number of participants for the study was infeasible to administer. The agents' representation as low-polygonal full-body meshes (see audience in Figure 2) differed to the one used for the real user's avatars described above to facilitate differentiation. The agents also featured different animation cycles indicating their attention towards the stage in order to make the scene appear more realistic. To further increase comparability in the two $Vis$ conditions, we scaled the miniatures to occupy the same visual angle when viewed from a central position, with the slides covering approximately 75° of the horizontal field of view. However, some smaller fluctuations were introduced due to the tracked head movements of participants as well as the different seating positions in $Vis \times Tog$. A screenshot of each auditorium is shown in Figure 2.

## 4.4 Task Procedure and Measurements

Participants came to our lab in groups of three and signed a consent form. They were then accompanied to the three separate head-mounted displays in our lab and introduced to the application in a tutorial scene. In particular, they were shown each other's avatars as well as how to navigate the virtual space by teleportation. Since we deemed a group of three users rather small for the joint exploration of an academic conference, participants were also introduced to two special virtual agents and instructed to treat them as if they were part of their peer group. Participants were then brought to the first auditorium and asked to teleport to their assigned seats as indicated by a floating arrow, where their two peer agents were already waiting. The assigned seats were identical for auditoriums featuring the same seating layout and had the same distance of approximately 30m to the stage for a comparable experience between the two seating layouts. Participants were then assisted to sit down on the provided real-world chair and asked to watch a speaker give a 2.5-minute scientific presentation on a particular type of animal (European otter, dik-dik, red panda, or quokka). This presentation was prerecorded to maximize comparability across participants. After the speaker concluded, participants were asked to discuss for two minutes about what they considered the most interesting insights of the presentation. Afterwards, they took their head-mounted displays off and individually filled in:

- Three custom questions regarding the visibility of the presentation, in which participants were asked to rate the readability of text on the slides, the clarity of images on the slides, and the observability of the stage and speaker on a scale from 1 (very bad) to 7 (very good).
- The subscales *Co-Presence*, *Attentional Allocation*, *Perceived Affective Understanding*, and *Perceived Behavioral Interdependence* of the Networked Minds Measure to quantify these concepts underlying social presence between 1 (negative) and 7 (positive) [3, 9]. These subscales were selected since we expected the largest differences for them and aimed to keep the total number of questions manageable for participants.

This procedure was repeated for the remaining auditoriums. While the presentations focused on different animals to keep the discussions engaging, they followed the same strict structure of presenting a fact sheet, an image, and a final remarkable fact about the corresponding animal. The order of presentations was the same for all groups, which means that the counterbalancing of auditoriums prevented a systematic assignment of a particular auditorium to a particular presentation. After all four conditions were completed, participants provided a final preference ranking of the auditoriums by ordering them from 1 (best experience) to 4 (worst experience).

## 4.5 Hypotheses

Based on our intentions of improving the visibility and the sense of togetherness during presentations in social VR, we formulated the following hypotheses before the experiment as a prerequisite for inferential statistical analyses:

$H_1$**:** The $Vis$ auditoriums will lead to better scores on the visibility questions than the $\overline{Vis}$ auditoriums.

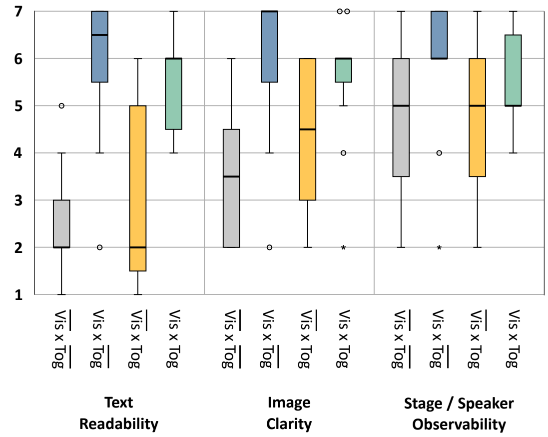
$H_2$**:** The $Tog$ auditoriums will lead to better scores on the social presence subscales than the $\overline{Tog}$ auditoriums.

$H_3$**:** The $Vis \times Tog$ auditorium will receive the highest preference rankings overall.

## 4.6 Results

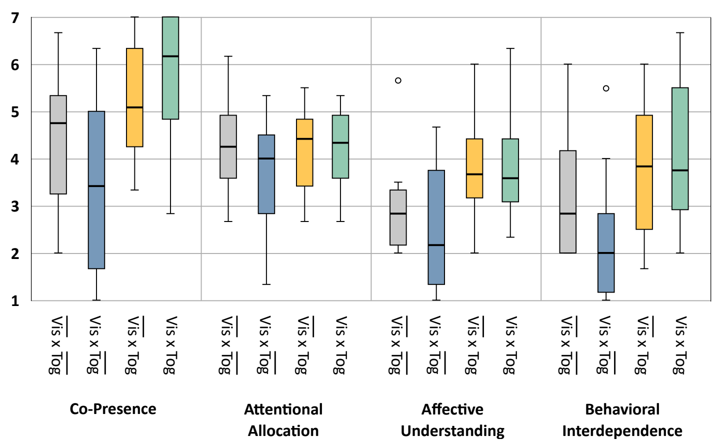
Based on our hypotheses, we analyzed our data using *IBM SPSS Statistics*. For inferential testing, we decided to run 2x2 factorial repeated-measures ANOVAs to study the main and interaction effects of the $Vis$ and $Tog$ enhancements on the respective dependent variables. Since meta analyses in prior work have shown that ANOVAs are rather robust with respect to small sample sizes, non-normal data distributions, and ordinal data [16], we consider this choice appropriate based on the lack of a non-parametric counterpart for factorial repeated-measures designs [8, p.555]. Since both factors only involved two levels, the assumption of sphericity does not apply to our study design. In addition to test statistics and p-values, we also report the effect sizes $\eta_p^2$ and apply the threshold

[1]https://www.mumble.info/




| | Main Effect of $Vis$ | | | Main Effect of $Tog$ | | | Interaction Effect | | |
|---|---|---|---|---|---|---|---|---|---|
| | $F(1, 11)$ | $p$ | $\eta_p^2$ | $F(1, 11)$ | $p$ | $\eta_p^2$ | $F(1, 11)$ | $p$ | $\eta_p^2$ |
| Text Readability | 55.730 | **< 0.001** | **0.835** | 0.010 | 0.923 | 0.001 | 2.125 | 0.173 | **0.162** |
| Image Visibility | 22.568 | **< 0.001** | **0.672** | 0.560 | 0.470 | 0.048 | 11.560 | **0.006** | **0.512** |
| Stage / Speaker Visibility | 7.237 | **0.021** | **0.397** | 0.250 | 0.627 | 0.022 | 3.143 | 0.104 | **0.222** |

**Figure 3: Score distributions and inferential test results for the custom questions on presentation visibility ($N = 12$ per boxplot) on a scale from 1 (very bad) to 7 (very good). Significant p-values and large effect sizes are highlighted in bold.**




| | Main Effect of $Vis$ | | | Main Effect of $Tog$ | | | Interaction Effect | | |
|---|---|---|---|---|---|---|---|---|---|
| | $F(1, 11)$ | $p$ | $\eta_p^2$ | $F(1, 11)$ | $p$ | $\eta_p^2$ | $F(1, 11)$ | $p$ | $\eta_p^2$ |
| Co-Presence | 0.494 | 0.497 | 0.043 | 18.641 | **0.001** | **0.629** | 8.304 | **0.015** | **0.430** |
| Attentional Allocation | 2.701 | 0.129 | **0.197** | 0.653 | 0.436 | 0.056 | 4.661 | 0.054 | **0.298** |
| Affective Understanding | 1.855 | 0.200 | **0.144** | 9.715 | **0.010** | **0.469** | 1.298 | 0.279 | 0.106 |
| Behavioral Interdependence | 3.655 | 0.082 | **0.249** | 6.601 | **0.026** | **0.375** | 13.085 | **0.004** | **0.543** |

**Figure 4: Score distributions and inferential test results for the tested subscales of the Networked Minds Measure ($N = 12$ per boxplot). Ratings with reversed question wording were changed after the experiment to obtain an overall score from 1 (negative) to 7 (positive). Significant p-values and large effect sizes are highlighted in bold.**

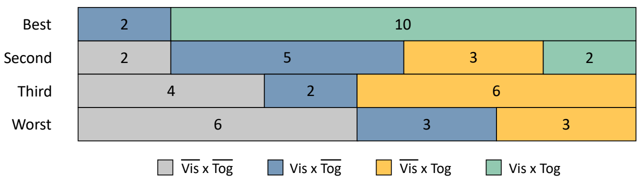



**Figure 5: Preference ranking submitted by participants after attending a talk in each of the auditoriums. The size of the bars and the enclosed numbers indicate the frequencies with which the auditoriums were placed in each rank.**

values of 0.01, 0.06, and 0.14 to distinguish between small, medium, and large effects, respectively [6, pp. 285-287].

*4.6.1 Presentation Visibility ($H_1$).* The distribution of scores as well as the results of the conducted ANOVAs on the three questions regarding presentation visibility are given in Figure 3. We observed significant positive main effects of $Vis$ on all three scores with large effect sizes. All main effects of $Tog$ were non-significant. The interaction effect was only significant for the clarity of images, with the benefits of $Vis$ over $\overline{Vis}$ being smaller under the influence of $Tog$. Nonetheless, the effect sizes of all three interactions were large, indicating a similar trend.

*4.6.2 Social Presence ($H_2$).* The distribution of scores as well as the results of the conducted ANOVAs on the four subscales of the Networked Minds Measure are given in Figure 4. We observed significantly positive main effects of $Tog$ on all scales but *Attentional Allocation* with large effect sizes. While all main effects of $Vis$ were non-significant, we still observed large effect sizes on all scales but *Co-Presence*, indicating lower scores when the $Vis$ enhancement was present. The interaction effects were significant for *Co-Presence* and *Behavioral Interdependence* with large effect sizes, with the benefits of $Tog$ over $\overline{Tog}$ being stronger under the influence of $Vis$. A similar trend is indicated by the large interaction effect size of *Attentional Allocation* despite its statistical non-significance.

*4.6.3 User Preference ($H_3$).* The distribution of preference ranks is visualized in Figure 5. We summed the ranks up to form an overall preference score per auditorium, in which a lower result represents a higher preference. The best rank sum was obtained for $Vis \times Tog$ (14, median rank: 1), followed by $Vis \times \overline{Tog}$ (30, median rank: 2) and $\overline{Vis} \times Tog$ (36, median rank: 3). The worst rank sum was obtained by $\overline{Vis} \times \overline{Tog}$ (40, median rank: 3.5).

## 4.7 Discussion

The large main effects of $Vis$ on the perceived readability of text, clarity of images, and observability of stage / speaker indicate that a miniature representation of the stage is a valuable addition to improve visibility issues associated with conventional auditoriums ($H_1$). However, the large effect sizes regarding the interaction of both enhancements also point towards slight visibility detriments when the $Tog$ enhancement was used as well. This is likely due to the fact that the group table arrangement leads to different viewing angles among group members as well as more visual space being reserved for the peers than in row-based seating, which can also occasionally be distracting. Nevertheless, the large main effects of $Tog$ on the perceived feeling of co-presence, affective understanding, and behavioral interdependence indicate that the group table arrangement also offers additional valuable social awareness cues that strengthen the feeling of attending the talk together rather than alone ($H_2$). The large effect sizes for the main effect of $Vis$ and the interaction effect on selected subscales also reveal that a miniature representation of the stage for each user in a row-based auditorium, similar to the individual screens in an airplane, is detrimental in terms of the social dimension, making the experience more isolated than in a conventional auditorium. Overall, the benefits of both the $Vis$ and $Tog$ enhancement in combination were highly appreciated and led to the best preference ratings by far ($H_3$). The worst preference ratings were obtained for the conventional auditorium layout, which provides a strong motivation to consider alternatives for presentation scenarios in social virtual reality.

## 4.8 Design Guidelines for Virtual Auditoriums

Based on our survey of related work as well as the results of our user study, we formulated two initial design guidelines for auditoriums in social virtual reality:

**Visibility** Auditoriums in social virtual reality should give each audience member a clear view onto the presenter and their slides, for example by placing the relevant content at a close distance and without large perspective distortions.

**Togetherness** If social constructs lead to talk attendance as a group, auditoriums in social virtual reality should facilitate monitoring the reactions and emotions of the others to increase social presence, for example by choosing circular instead of linear seating layouts.

We see these guidelines as a first step towards improving talk attendance in social virtual reality, which serves as a basis to be built upon and extended in future work.

# 5 CONCLUSION AND FUTURE WORK

Social virtual reality systems have the potential to improve upon several of the limitations associated with large auditoriums. In this paper, we focused on the use case of academic conferences to derive first ideas to improve the visibility of a presentation for every viewer as well as the sense of togetherness when attending as a group of peers. The results of our user study regarding these enhancements were very positive and underline the importance of conducting further research into making presentation attendance more convenient and therefore valuable to the viewers. Beyond academic conferences, we are convinced that our presented ideas have the potential to be beneficial for other use cases like business or teaching presentations as well. As a result, future work will validate our insights in different contexts with more participants in larger groups, longer and more complex presentations, and alternative ideas of rethinking conventional auditorium designs. This will lead to more specific guidelines for designing presentation scenarios in social virtual reality. Furthermore, the analysis of social presence with more realistic avatars involving eye and face tracking remains subject to future work. Altogether, we believe that with further research, gatherings in social virtual reality may eventually become an appealing alternative to their physical counterpart.

# REFERENCES


[1] S. J. Ahn, L. Levy, A. Eden, A. S. Won, B. MacIntyre, and K. Johnsen. 2021. IEEEVR2020: Exploring the First Steps Toward Standalone Virtual Conferences. *Frontiers in Virtual Reality* 2 (2021), 648575. https://doi.org/10.3389/frvir.2021.648575

[2] S. Benford, G. Reynard, C. Greenhalgh, D. Snowdon, and A. Bullock. 2000. A Poetry Performance in a Collaborative Virtual Environment. *IEEE Computer Graphics and Applications* 20, 3 (2000), 66–75. https://doi.org/10.1109/38.844374

[3] F. Biocca, C. Harms, and J. Gregg. 2001. The Networked Minds Measure of Social Presence: Pilot Test of the Factor Structure and Concurrent Validity. In *4th Annual International Workshop on Presence*. Media Interface and Network Design Labs, East Lansing, MI, USA, 9 pages.

[4] B. Brown. 2020. Notes on Running an Online Academic Conference or How We Got Zoombombed and Lived to Tell the Tale. *Interactions* 27, 4 (2020), 16–21. https://doi.org/10.1145/3406108

[5] E. F. Churchill and D. Snowdon. 1998. Collaborative Virtual Environments: An Introductory Review of Issues and Systems. *Virtual Reality* 3, 1 (1998), 3–15. https://doi.org/10.1007/BF01409793

[6] J. Cohen. 2013. *Statistical Power Analysis For the Behavioral Sciences* (2nd ed.). Routledge, United Kingdom. https://doi.org/10.4324/9780203771587

[7] T. Erickson, N. S. Shami, W. A. Kellogg, and D. W. Levine. 2011. Synchronous Interaction among Hundreds: An Evaluation of a Conference in an Avatar-Based Virtual Environment. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada). Association for Computing Machinery, New York, NY, USA, 503–512. https://doi.org/10.1145/1978942.1979013

[8] A. Field. 2013. *Discovering Statistics using IBM SPSS Statistics* (4th ed.). SAGE Publications, United Kingdom.

[9] C. Harms and F. Biocca. 2004. Internal Consistency and Reliability of the Networked Minds Measure of Social Presence. In *7th Annual International Workshop on Presence*. Universidad Politecnica de Valencia, Valencia, Spain, 7 pages.

[10] M. L. W. Jones. 2000. Collaborative Virtual Conferences: Using Exemplars to Shape Future Research Questions. In *Proceedings of the Third International Conference on Collaborative Virtual Environments* (San Francisco, California, USA). Association for Computing Machinery, New York, NY, USA, 19–27. https://doi.org/10.1145/351006.351009

[11] A. Kendon. 2010. *Spacing and Orientation in Co-present Interaction*. Springer, Berlin, Heidelberg, 1–15. https://doi.org/10.1007/978-3-642-12397-9_1

[12] D. A. Le, B. Maclntyre, and J. Outlaw. 2020. Enhancing the Experience of Virtual Conferences in Social Virtual Environments. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*. IEEE, USA, 485–494. https://doi.org/10.1109/VRW50115.2020.00101

[13] Q. Liu and A. Steed. 2021. Social Virtual Reality Platform Comparison and Evaluation Using a Guided Group Walkthrough Method. *Frontiers in Virtual Reality* 2 (2021), 668181. https://doi.org/10.3389/frvir.2021.668181

[14] J. McVeigh-Schultz, A. Kolesnichenko, and K. Isbister. 2019. Shaping Pro-Social Interaction in VR: An Emerging Design Framework. 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/10.1145/3290605.3300794

[15] M. Mulders and R. Zender. 2021. An Academic Conference in Virtual Reality? Evaluation of a SocialVR Conference. In *2021 7th International Conference of the Immersive Learning Research Network (iLRN)*. IEEE, USA, 6 pages. https://doi.org/10.23919/iLRN52045.2021.9459319

[16] G. Norman. 2010. Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education* 15, 5 (2010), 625–632. https://doi.org/10.1007/s10459-010-9222-y

[17] J. S. Pierce, B. C. Stearns, and R. Pausch. 1999. Voodoo Dolls: Seamless Interaction at Multiple Scales in Virtual Environments. In *Proceedings of the 1999 Symposium on Interactive 3D Graphics*. Association for Computing Machinery, New York, NY, USA, 141–145. https://doi.org/10.1145/300523.300540

[18] Aniruddha Prithul, Isayas Berhe Adhanom, and Eelke Folmer. 2021. Teleportation in Virtual Reality; A Mini-Review. *Frontiers in Virtual Reality* 2 (2021), 7 pages. https://doi.org/10.3389/frvir.2021.730792

[19] G. Roos, J. Oláh, R. Ingle, R. Kobayashi, and M. Feldt. 2020. Online conferences – Towards a new (virtual) reality. *Computational and Theoretical Chemistry* 1189 (2020), 112975. https://doi.org/10.1016/j.comptc.2020.112975

[20] S. Rothe, A. Schmidt, M. Montagud, D. Buschek, and H. Hußmann. 2021. Social viewing in cinematic virtual reality: a design space for social movie applications. *Virtual Reality* 25, 3 (2021), 613–630. https://doi.org/10.1007/s10055-020-00472-4

[21] S. Shirmohammadi, S.-Y. Hu, W. T. Ooi, G. Schiele, and A. Wacker. 2012. Mixing Virtual and Physical Participation: The Future of Conference Attendance?. In *2012 IEEE International Workshop on Haptic Audio Visual Environments and Games Proceedings*. IEEE, USA, 150–155. https://doi.org/10.1109/HAVE.2012.6374455

[22] H. J. Smith and M. Neff. 2018. Communication Behavior in Embodied Virtual Reality. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada). Association for Computing Machinery, New York, NY, USA, 12 pages. https://doi.org/10.1145/3173574.3173863

[23] R. Stoakley, M. J. Conway, and R. Pausch. 1995. Virtual Reality on a WIM: Interactive Worlds in Miniature. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA). ACM Press/Addison-Wesley Publishing Co., USA, 265–272. https://doi.org/10.1145/223904.223938

[24] L. M. Wilcox, R. S. Allison, S. Elfassy, and C. Grelik. 2006. Personal Space in Virtual Reality. *ACM Transactions on Applied Perception* 3, 4 (2006), 412–428. https://doi.org/10.1145/1190036.1190041

[25] J. Williamson, J. Li, V. Vinayagamoorthy, D. A. Shamma, and P. Cesar. 2021. Proxemics and Social Interactions in an Instrumented Virtual Reality Workshop. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan). Association for Computing Machinery, New York, NY, USA, 13 pages. https://doi.org/10.1145/3411764.3445729