Training in IVR: Investigating the Effect of Instructor Design on Social Presence and Performance of the VR User

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Figure 1: We tested 3 IRs and 2 tasks: (A) shows the *avatar* during the memory task - VR user had to memorize a sequence of button presses, (B) the *webcam* during the object finding task, and (C) the *sound-only* design without visual representation of the instructor. In the object finding task, VR users' were shown an image (c1) of the object they had to find on the table.

ABSTRACT

We investigate instructor representations (IRs) in the context of virtual trainings with head mounted displays (HMD). Despite the recently increased industry and research focus on virtual training in immersive virtual reality (IVR) , the effect of IRs on the performer (VR user) has received little attention. We present the results of a study (N=33), evaluating the effect of three IRs - webcam, avatar and sound-only - on social presence (SP) and performance (PE) of the VR user during task completion. Our results show that instructor representation has an effect on SP and that, contrary to our assumption based on prior work, it affects performance negatively.

CCS CONCEPTS

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

KEYWORDS

Instructor design, Immersive Virtual Reality, Social Presence

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1 INTRODUCTION & BACKGROUND

Virtual Reality (VR) has established itself as a training tool for use cases where real world alternatives were found to be too expensive, dangerous and impractical. For example, in military training for shooting tasks [37] and in the industry to introduce workers to complex machinery [8, 24]. Many of these scenarios use an instructor-performer setup. In this type of interaction, the instructor provides orders to the VR user, the majority of communication is one-directional - instructor to performer -, and roles are not interchanged during interaction.

Prior work on instructor-performer tasks investigated instructor representations (IRs), such as avatars and video, but only within specific use cases, on a 2D screen (e.g., military) [7, 18, 38] or across devices with varying degrees of immersiveness (e.g., 2D vs. 3D representation [1]). It did not evaluate whether different IRs within the same level of immersiveness (3D vs. 3D), result in differences with regard to social presence (SP) and performance (PE).

Although, there are varying definitions, generally prior research refers to spatial *presence* as a subjective measure of how "real" the virtual world is perceived in comparison to the real world (RW). In contrast, *immersion* is the objective evaluation of the technological capabilities of a given VR experience (e.g., field of view)[36]. Similarly, there also exists the concept of *social presence*, which measures the perception of interacting face to face with another real person [4, 20]. Prior work has confirmed that the general existence of other people in close proximity [27], communication, awareness and interaction [12] increase SP, however, it has failed to investigate whether there are differences depending on the design of the representation and its effects on PE in immersive virtual reality (IVR) in an instructor-performer scenario.

Selverian et al. analysed the influence of SP and spatial presence on learning effects – confirming a positive effect [34]. Although, we do not directly review learning effects, an increase in SP depending on IR, may coherently also shed light on its influence on

PE. The latter has been a recurring topic of research [12, 18, 19, 30], however, prior work focused on the effects spatial presence may have on PE rather than solely investigating SP's effect on PE. The latter was reviewed by Tauer et al.[40], who analysed the effects of cooperation and competition on PE, and found that both contribute positively to it. Similarly, different IRs also enable varying degrees of cooperation and competition, therefore implying that IR may have an effect on PE.

Based on the above mentioned gap in prior work on IRs in virtual trainings and its effect on SP and PE, we completed a user study (N=33). We present the results and discuss design implications for future applications. We evaluated three IRs for interaction between a person in the RW (instructor) and a VR user (performer): (a) sound-only, (b) avatar and (c) webcam. We let participants complete two abstract tasks, needing varying requirements on intellectual abilities. An object finding and a memory task; both resembled to examples from prior work.

We found conflicting results between participants' perceived SP towards IRs and their task PE. Although, communicating with visual representations (e.g., webcam and avatar) of the instructor were found to be more enjoyable and of high SP, PE was significantly lower in comparison to the sound-only representation. Our findings support designers and developers, working on IVR training systems, to make informed decisions when choosing IRs.

2 DESIGN CHOICES BASED ON PRIOR WORK

In order to investigate the influence of IR during interaction in IVR, we relied on prior work to create six different types of instructor-performer scenarios. To cover a wide variety of representations and maximize the generalizability of our findings, we chose three IRs and two types of collaborative tasks (3x2)[1].

2.1 Instructor Representation

Research implies that the choice of IR influences success metrics for interaction in virtual reality, such as SP [10, 15, 28] and task PE [2, 3, 41]. We focus on instructor-performer interactions, such that each participant only takes on one role – the instructor, as the main communicator, and the performer, who mostly acts upon request.

Based on prior work on interaction in IVR, we highlight objects that the instructor refers to [11] and our implementation allows head and hand movements that perfectly mimic instructions [14, 17]. We compare two visual [& sound] IRs, namely avatar and webcam, against a baseline, sound-only IR. Below we detail the influence of prior work on our choices.

2.1.1 Avatar. A virtual IR that interacts naturally within VR. Prior work has shown that it increases user engagement [26], subsequently leading to an increased PE [31]. It took the form of a robot, as prior work confirmed their success in learning applications [22], the positive effect they have on SP and their ability to manipulate the world that they are embedded into [21]. The design of the robot avatar is largely based on the works of Di Salvo et al.[13], who identified factors, such as eye position and size that increase the attractiveness. Body movement from the instructor was mapped 1:1 to the avatar, enabling the selection of virtual objects.

[1]Our intention is not to explore all possible VR scenarios in this preliminary work but focus on prominent ones based on prior work.

2.1.2 Webcam. In this variant, we rendered the input of a camera, capturing the instructor, on a flat surface in the virtual environment. Prior work in video-mediated collaboration suggests that situating the collaborator in a shared media space, for example a virtual environment, improves the interaction [39]. Since particle clouds that render a person's shape and movement into a virtual scene, similar to holographic representations [6] and holoportations [29], have high technological demands, the webcam solution was found to be a more economically achievable solution for the foreseeable future. Alghamdi et al. [1] revealed the positive effect webcam illustrations have on SP when comparing their placement in 2D monitors vs. HMDs. Bente et al. [7] compared avatar images against a video representation of the instructor, however they could not confirm any significant findings in regards to SP.

In line with Greenwald et al.'s finding, we placed the webcam texture in a fixed place in the environment [14]. They found out that this placement would allow the webcam texture to be perceived similar to a television or computer screen- something subjects could be expected to recognize from real life.

2.1.3 Sound. In this baseline condition, the performer communicated with the instructor without visual IR. $sound_{\text{rep}}$ was defined to be a superset of the visual choices, such that incremental differences due to the visual representations could be measured. Additionally, $sound_{\text{rep}}$ reflects existing instructor-performer scenarios, such as in the case of helplines, where instructions are provided over the phone for desktop applications.

2.2 Collaborative Tasks

Based on prior work [20, 32] that suggests the usage of varying tasks to observe the relation of presence and PE, we defined a memory-heavy and an object finding task. Although there were differences in how the tasks were performed depending on the IR, we designed the tasks to be completed in the same manner.

2.2.1 $task_{memory}$. In the memory task, participants were shown a sequence of button presses which they had to remember. The first round started with the instructor clicking one button. This was increased by +1 button for each round with consistent timing between the button presses. The performer had to repeat the instructors actions, after memorizing the sequence. This action was done repeatedly until the performer made a mistake. In all IRs, the objects in IVR were highlighted upon mention by the instructor and when touched by the VR user. This was coordinated by the instructor through a keyboard for $webcam_{\text{rep}}$ and $sound_{\text{rep}}$ and within IVR itself for $avatar_{\text{rep}}$.

2.2.2 $task_{object}$. In the object finding task, the instructor directed the performer to select an object from the table with the aid of a graphics (Fig. 1, c1)– as quickly as they could. This was done until 75 objects were selected. Highlighting of VR objects and instructor coordination was the same as for $task_{\text{memory}}$.

Based on the principle of tangible user interfaces [9], we created synchronized distributed physical objects in the RW (e.g., a physical yellow button that could be touched, a paper with a green cross on black paper that could be held up) for the $webcam_{\text{rep}}$ (see Fig. 2, B), which were displayed to the user.

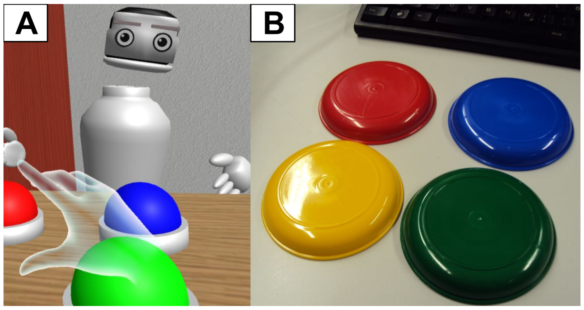

Figure 2: (A) Users' virtual [transparent] hands for object manipulation. (B) For *webcam*, we created tangible RW objects that the instructor used to show which buttons to press.

Most related work was either centred on non-VR applications [7, 38], compared 2D vs. 3D interaction [1] or used another structural model than the one of instructor-performer tasks [19, 27, 35]. Contrary to prior work on IRs for social interaction, we investigate the influence of three different IRs solely within immersive VR with an HMD and their effect on SP and task PE. Based on the above mentioned literature, we derived the following hypotheses:

H1 SP and PE in IVR is affected by IRs.

H2 IRs with a high SP result in an increased PE for the VR user.

3 EXPERIMENT

To test our hypotheses, we completed a lab study (*N*=33).

3.1 Apparatus

Virtual reality experiences were developed with Unity 3D and C#, and the study was completed with an Oculus Rift HMD. Network functionality was implemented with the help of Photon Unity Networking [2]. The update frequency of the webcam texture was set at 30 fps, to save update time, and the picture quality was that of a 25% compressed JPG. Participants were able to see their own pair of Oculus Touch Controllers as transparent blue hands - the default setting for Oculus HMDs (see Fig. 2, A). Voice chat was implemented using the software Skype. We created a virtual room (see Fig.1), where instructor and performer could meet to collaborate.

3.2 Study Design

3.2.1 Independent Variables. *task* (within-subjects variable): Participants had to complete two tasks. (1) $\mathit{task}_{\text{memory}}$, where they had to remember a sequence of buttons, and (2) $\mathit{task}_{\text{object}}$, which involved selecting one object at a time. Instructions were provided by the instructor for both tasks, such that participants could repeat the task. Instructor Representation (*IR*) (between-subjects variable): We evaluate three virtual representations (rep) of the RW instructor: (1) $\mathit{avatar}_{\text{rep}}$, a 3D character displayed in the virtual world, (2) $\mathit{webcam}_{\text{rep}}$, a real-time video feed, and (3) $\mathit{sound}_{\text{rep}}$, with no visual IR and commands were consistent with the other representations.

3.2.2 Dependent Variables. We captured *social* and *spatial presence*, as well as *workload* through standardised questionnaires–igroup Presence [33], SP questionnaire [4] on an *IR* level, and NASA TLX on a *task* level. [16]. Notably, questionnaires were adapted to address the varying IRs and the likert scales for spatial and social presence questionnaires were aligned, for easier completion and comparison. *Performance* was measured individually for each task. For $\mathit{task}_{\text{memory}}$, the length of the sequence was recorded and for $\mathit{task}_{\text{object}}$, we added up the time it took to select each object. Qualitative results (e.g., unstructured remarks on the difficulty of the game) were video recorded and coded post-experiment. We added three questions by Tauer et al. [40], to investigate perceived level of effort to succeed and cooperation & competition towards the different IRs, as they also influence PE and SP indirectly.

[2]https://www.photonengine.com

3.3 Procedure

The study started by giving participants an introduction to the tasks and the goal of their participation. Subsequently, they had to provide consent before completing a demographics questionnaire, followed by an introduction and training to VR. In the training scene, participants could see all tasks for the main study and were encouraged to familiarize themselves with the controllers and the input methods without focusing on performance. The experimenter provided feedback and guidance during the training. This lasted until participants communicated that they were proficient with the input methods. Next, the main part started, where participants had to complete the tasks for one pre-defined IR. Once the main setup had loaded, the experimenter went into another room to take on the role of the instructor - this allowed us to focus on the results of the performer in the analysis. At this point, the instructor confirmed with the performer that *they* will be providing instructions for all tasks and that the communication via Skype - built into the VR scene - was working. The instructor would provide a short scripted summary of each task before they started providing instructions. Participants were then advised on how PE was measured for each task and given the opportunity to ask questions. The [counterbalanced] order for *task* was setup prior to the study, thus participants would get the next task ($\mathit{task}_{\text{memory}}$ or $\mathit{task}_{\text{object}}$) displayed in VR as soon as the previous one finished. Note, that after each task, a workload questionnaire was asked and after completion of both tasks spatial and social presence was gathered through questionnaires.

3.4 Participants

Participants (*N*=33, 14 female) were recruited through a university mailing list and their average age was 24 (SD=5.8). Majority of participants were students (66%) who were familiar with VR (72%). Four participants had no experience with VR and one had a red-green blindness, which had no effect on the statistical analysis.

4 RESULTS

There were no outliers and a scatter-plot review revealed no correlations between the individual data sets (SP vs. PE vs. workload). Table 1 provides an overview of the results.

4.1 Social & Spatial Presence

A Kruskal-Wallis H test showed that there was a statistically significant difference in SP score between the three IRs, $H(2) = 7.63, p = 0.02$, with a mean rank SP score of 11.91 for $\mathit{sound}_{\text{rep}}$, 16.00 for

Table 1: Summary of results: (a) SP questionnaire (Scale 1-5, 5=high SP) [5] , (b) Length of remembered sequence measuring PE, (c&d)+(f&g) Tauer et al.[40] questionnaire (10-point scale, 10=high) to measure cooperation and competition , (e) Time (in sec) taken to find objects to measure PE -note that higher values mean a worse PE, (h) Workload (W) [16].

	(a)	$task_{\text{memory}}$			$task_{\text{object}}$			(h)
		(b)	*(c)*	*(d)*	*(e)*	*(f)*	*(g)*	
sound	3.09	12.73	1.09	1.91	139.54	1.64	2.09	7.5
avatar	3.45	11.55	4.45	3.73	142.67	2.45	2.91	5
webcam	3.93	8	2.82	4.45	147.13	3.18	4.64	4

$avatar_{\text{rep}}$ and 23.09. for $webcam_{\text{rep}}$. Qualitative results highlighted uncertainty in regards to $avatar_{\text{rep}}$. "I did not perceive it as another person but instead as a "character" lacking personality." (P3) . Contrary to this statement, another participant stated that the avatar had given the (P14) "feeling of another person and was preferable over a 'pseudo human' design". One participant wondered whether the avatar was human controlled at all until late in the application, where he reported it became clear.

Spatial presence (Scale 1-5, 5=high) showed no significant differences: 3.33 for $avatar_{\text{rep}}$ and 3.4 for $webcam_{\text{rep}}$ & $sound_{\text{rep}}$.

4.2 Performance

Overall, we did not find any significant differences in regard to task PE between the IRs. However, as table 1 shows, in $sound_{\text{rep}}$ participants performed slightly better across both tasks, followed by $avatar_{\text{rep}}$ and $webcam_{\text{rep}}$. A Kruskal-Wallis H test for $task_{\text{memory}}$ revealed a significant difference in regard to *PE* (number of items in a remembered sequence) between two IRs, $H(1) = 5.39, p = 0.02$, with a mean rank score of 14.68 for $sound_{\text{rep}}$ and 8.32 for $webcam_{\text{rep}}$.

However, questionnaire results investigating competition and cooperation - which we assumed to influence PE positively- revealed the highest scores (10-point scale: 10=high) for $webcam_{\text{rep}}$- most cooperative and competitive -, followed by $avatar_{\text{rep}}$ and $sound_{\text{rep}}$. This order (webcam highest, sound lowest) is the same as the order of the three IRs when comparing their SP scores.

4.3 Workload

The overall mean workload from the NASA TLX questionnaire data, showed no significant effects. However, further analysis in form of a Kruskal-Wallis H test in regard to the perception of *performance* - a subset of the NASA TLX data - showed a significant difference, $H(1) = 6.59, p = 0.01$, with a mean rank score of 15 for $sound_{\text{rep}}$ and 8 for $webcam_{\text{rep}}$. This means that participants who were subjected to $sound_{\text{rep}}$ perceived to have worked significantly harder than those that were exposed to $webcam_{\text{rep}}$.

5 DISCUSSION

In the context of an instructor-performer scenario in IVR, we confirmed our assumption based on prior work, which is that the representation of the instructor influences SP and task PE. However, contrary to prior work, we could not find any correlations between SP, task PE and workload.

As suggested by prior work by Cruz et al. [12], the IR that enables the most communication and interaction, namely (1) webcam, was perceived to have a significantly higher SP than (2) avatar and (3) sound. In alignment with prior work [40], our data also confirmed a higher perceived cooperation and competition for the first two representations when compared to sound-only. Contrary to our assumption, although PE was indeed influenced by IR, the order was reversed, such that participants performed best within (1) sound, followed by (2) avatar and (3) webcam. Thus, our data suggests that representations supporting an increased SP, such as webcam, do not directly infer high PE. Adversely, sound - with low SP - resulted in the highest PE and webcam - with high SP - with the lowest.

Additional data, investigating workload during task completion, highlighted that participants perceived to have worked significantly harder when the instructor was only present in form of sound rather than webcam. Although, this suggests that visual representations of the instructor seem to decrease the workload required to complete a task, it also resulted in a decreased PE for webcam and avatar IR. Our findings suggests that designers and developers are facing a trade-off between SP and PE, when deciding on the IR for their IVR training system. Use cases where an increased PE is more important than SP (e.g., military shooting tasks), may choose a sound-only representation. However, as workload is also higher within this representation, we only propose this for tasks that are short-timed. Similarly, we propose a visual representation for use cases where SP outranks PE (e.g., customer support). As workload is lower, PE may also last longer – to be investigated further in future work.

Finally, our data indicates that participants were indecisive about the avatar representation, as it did not result in any significant differences but rather remained in a constant second place. This was confirmed by the qualitative feedback, where some participants noted that they were unsure about whether the avatar was a human or a machine, although we specifically communicated that it was a human collaborator. It may be argued that IRs where it was clear that a human was present, such as webcam, resulted in lower PE as the motivation to perform was higher in IRs, where it was not visually apparent that a human was acting as an instructor. Similar approaches are reviewed in prior work, which suggests that we are primed by appearances [23, 25]. Designers of future applications may decide to use a robot-looking avatar when they want to increase PE whilst maintaining the advantages of a visually represented instructor, such as a high SP.

6 CONCLUSION AND FUTURE WORK

In the context of an instructor-performer interaction in IVR, we investigated the effect of IRs on on SP and PE. Our results show that (1) IR has an effect on SP and PE and that, contrary to our assumption based on prior work, (2) it affects PE negatively. Thus, representations yielding high SP result in lower PE by the VR user. Additionally, although visual representations are designed to increase the PE, they seem to have the opposite effect, such that users perceived to have worked harder in the sound-only representation, which is in alignment with the lower PE in the non visual - webcam and avatar - representations. We could not confirm any significant differences between the different types of abstract tasks, however future work may review whether SP affects PE between industry specific tasks. Additionally, it would be interesting to see how PE will develop in a long-term task.

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