Studying the Effects of Educative Holographic Projections in VR Environment.

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Abstract

This study aims to examine the implications of bringing holographic projections – based on the TU Delft's project "HoloLearn" – into VR environment. With the spiked interest in remote communication caused by COVID-19, the demand for more immersive virtual conference software grows. And as Virtual Reality as a product becomes more affordable and practical for end-users, there is a room for researching the combination of two technologies. In particular, the implications holograms in VR have on the lecturer's social presence and user's exhaustion & fatigue. Hence, we designed a between-subject experiment intended to measure the audience's perception of the lecturer's social presence and user's exhaustion & fatigue between setups with Zoom, screen based holograms, and holograms in VR. A total of 17 participants, 5-6 per group, undertook an academic lecture in different formats and filled in a survey about their experience. The results concluded little to no statistically significant difference between researched groups on social presence and exhaustion & fatigue.

Keywords: Social Presence Measure · Holograms in Virtual Reality · Zoom Fatigue

1 Introduction

A huge part in the learning experience is taking communication. While we rarely think of what really makes this experience of good quality, with COVID-19 pandemic people started realising the inefficiencies of the modern online communication channels, such as Zoom™, Skype™, Teams™, and alike.

The technologies, however, are progressing. And what has been once thought as scientific fiction is now part of our lives. At TU Delft, Dr. Bibeg Limbu (Limbu, 2020) has been developing HoloLearn (Holographic Learning) project with the aim to stimulate richer social interactions in online/distance education between students and teachers by making use of holograms. In addition, another technology that is now being closely watched for the purposes of education is Virtual Reality (Cooper, Park, Nasr, Thong, & Johnson, 2019). Especially, since VR can now be considered as an affordable and practical product for general masses.[1]

Individually, these topics are being extensively researched, especially in the recent years. For example, Nai Li and David Lefevre (Li & Lefevre, 2020) researched their HVC technology (Holographic Videoconferencing), a technology similar to HoloLearn's. The surveyed attendees showed a strong belief that it enhances presenters' degree of teaching presence and attendees' engagement in the sessions, compared to simple 2D video channels.

[1]Meta Quest 2 is a notorious example of a VR headset with a price tag of just €349 that provides a good image and head tracking quality, hand tracking capability and does not need a PC to run.

However, the matter in combination is poorly researched. The literature study showed an open spot in the knowledge of implications of the holograms in Virtual Reality. This area has great potential for future of education and how we experience learning. Hence, this is motivation of the study, which led to the formulation of the main research question:

RQ. How do holograms placed in Virtual Reality affect the perception of teachers' social presence?

The following hypotheses were hence derived:

H1. The combination of HoloLearn and VR technologies leads to the increased perception of the lecturer's social presence.
H2. VR leads to the decreased level of Zoom fatigue in the communication episode.

The *H1* deems relevant according to the findings of Credence Baker (Baker, 2010) who concluded that the instructor's presence is a significant predictor of student affective learning, cognition, and motivation. Social presence, in turn, is well defined by Kreijns K. et al. (Kreijns, Kirschner, Jochems, & Van Buuren, 2011), and states that "social presence is the degree of illusion that others appear to be a "real" physical persons in either an immediate (i.e., real time/synchronous) or a delayed (i.e., time-deferred/asynchronous) communication episode".

The *H2*, in its turn, comes from a rapid emersion of the term "Zoom fatigue" during COVID-19. Robby Nadler (Nadler, 2020) in his paper argues that Zoom fatigue is not as much about the physical intensiveness of the computer screens, but rather limitations and challenges that computer-mediated communication has in relation to interpersonal interactions. Virtual Reality is much more immersive experience, compared to modern video conference software, hence is expected to decrease the level of Zoom fatigue. Nevertheless, there are still limitations in interpersonal interactions that can cause Zoom fatigue in VR.

This research designs a quantitative study using independent measures experiment design. The aim is to explore the implications of combining HoloLearn and VR technologies in regards to hybrid learning. For this, a pre-recorded lecture is shown to participants in different formats.

The experiment's independent variable is the representation of the lecturer. In particular, Zoom session (control group), telepresence robot (fig. 1), HoloDisplay (fig. 2), and HoloVR (Hologram in Virtual Reality; fig. 4) are available.

The dependent variables, in turn, are represented by the social presence of the lecturer as well as Zoom fatigue experienced by the attendees as defined earlier.

There is a also a controlled variable in the form of the lecture itself. The lecture is pre-recorded, and the topic is intentionally chosen to be distant from the common knowledge. In the end, it is a 15 minute lecture on Japanese history before year 1603.

2 Methods

The experiment is organized in cooperation with 4 other researchers of HoloLearn group. This means that the experiment contains material for 5 studies in total, and some of it might be irrelevant for this study specifically. For example, telepresence robot setup is not of interest of this paper. In addition, Procedure chapter mentions Pre-Tests and Post-Tests, which are also out of scope of this paper. The study describes procedure in full as a matter of full transparency and reproducibility of the experiment as is.

2.1 Participants

The experiment studies relation between 4 groups (Zoom, telepresence robot, HoloDisplay and HoloVR) and has at least 5 participants per group. The participants are mostly bachelor students of Computer Science & Engineering at Delft University of Technology in their third year of education. The participants are fluent in English, since the measurement tool is the questionnaire in English. Each participant receives a voucher in amount of 10 euro for an online store Bol.com as a reward for participation.

Group	Participants No.
Zoom	6
Robot	5
HoloDisplay	6
HoloVR	5

Table 1: The distribution of participants over groups.

2.2 Apparatus

The entire system is based on developments of HoloLearn. For all groups, this research relies on open-source software available on Github in *hololearn-project/hololearn* repository.

As for the hardware, the Zoom setup requires the least amount of specialized equipment. In order to record the lecture, a simple web-camera suffices. For the presentation itself, the venue is equipped with a large conference screen.

The telepresence robot is a two-wheel controlled videoconferencing robot with iPad mounted at the top that is meant to stream face of the person. In the experiment, Double 2 is used; a robot produced by Double Robotics, as seen in the figure 1.

Figure 1: A telepresence robot Double 2 (Double Robotics).

HoloDisplay produces a screen-based hologram as seen in the figure 2. HoloDisplay is by itself a piece of equipment, a frame with half-transparent glass in it. HoloDisplay also makes use of the projector to project hologram onto it. The projector must not be mounted, so it can be positioned well in relation to HoloDisplay. Moreover, in order to record lecture for it, HoloDisplay relies on Kinect, a motion sensing input device produced by Microsoft. It uses depth sensor to remove background from the recording.

Figure 2: A screen based hologram, HoloDisplay.

The HoloVR setup uses Oculus GOs as VR headsets, each having headphones to isolate sound. In this research, the setup is limited by 5 headsets, so only 5 participants can simultaneously watch the lecture. As well as in HoloDisplay, HoloVR setup uses Kinect in order to record the lecture and remove background from the video. Hence, in this experiment, HoloVR uses the same recording as HoloDisplay.

2.3 Procedure

Briefing

The experiment is scheduled for 2 days: Zoom and Robot setups on Day 1, and HoloDisplay and HoloVR on Day 2.

Participants are asked to come to the venue at a pre-defined time on one of the days. They are met by the researches and led to the briefing room. When all participants arrive, one of the researches reads aloud a small briefing on what the research is about and what rights participants have.

Before the experiment starts, all participants have to read and sign the informed consent form. It also contains all information relevant to the participants, such as purpose of the study, data management plan, procedure and contacts.

Following the consent form, the participants receive a pre-test to assess their knowledge of the topic before the lecture itself. The pre-test has a sticky note with the participant code to uniquely identify and later match the tests and the survey, while keeping the participant anonymous. The code consists of a 1-digit number and a letter to identify the setup (Z = Zoom, R = Robot, H = HoloDisplay, V = HoloVR). The participants are instructed to keep this note during the experiment. After the pre-tests are filled, the participants are instructed to go into one of the rooms corresponding to the letter in their code to watch the lecture.

Lecture

Each group is subjected to the same pre-recorded lecture, but in different formats. The way how all setups are arranged can be seen in the figure 3.

Figure 3: The setups arrangement: Zoom (top-left), robot (top-right), HoloDisplay (bottom-left), HoloVR (bottom-right).

For Zoom-alike session, the participants enter the room and get seated together in front of the large screen. When ready, a Zoom meeting with pre-recorded lecture begins on the screen.

For telepresence robot session, the participants enter the room and get seated together in front of the large screen and the robot itself. When ready, a pre-recorded lecture begins, where face of the lecturer is streamed on the robot, and the slides are on the large screen.

For HoloDisplay, the participants enter the room and get seated together in front of HoloDisplay. When ready, a pre-recorded lecture begins on HoloDisplay.

Finally, for the VR session, the participants enter the room and get seated together. Each participant puts on a VR headset with headphones. When ready, each VR headset starts a pre-recorded lecture. The figure 4 gives a better understanding on how the lecture looks from inside the virtual reality. Moreover, Tristan Quin in his 2021 paper goes in greater details on how HoloLearn builds 3D environment and how it can enhance this experience even further (Quin, Limbu, Beerens, & Specht, 2021).

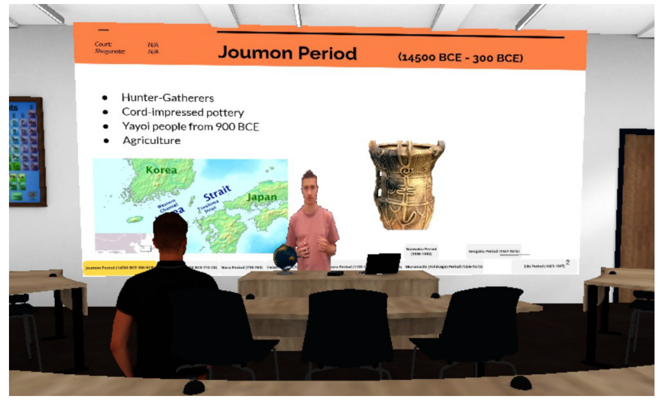

Figure 4: The view of the participant in Virtual Reality during the lecture.

Post-Test & Survey

After the lecture, each group gets to the room with tables. First, they have to fill in the post-test to assess the knowledge after having the lecture watched. When done, the participants need to fill in the survey that contains experience-related questions, including ones from Social Presence measure (Kreijns et al., 2011) and ZEF scale (Fauville, Luo, Queiroz, Bailenson, & Hancock, 2021). The participants are instructed to include the participant code on both papers.

When finished, the participants get the voucher reward and are free to leave.

2.4 Materials & Measures

This research uses existing measurement tools in evaluating the variables. Considering strict constraints in time and human-resources allocated to the research, this way was deemed the most appropriate for this study.

Social Presence

As mentioned in Introduction, the study uses the definition of social presence offered in 2011 paper by Kreijns, Kirschner, Jochems, & Van Buuren. A more recent paper that Kreijns co-authored (Kreijns, Weidlich, & Rajagopal, 2018) takes it a step further and proposes a tool that measures social presence, based on the same definition. This tool, hence, was considered as the most applicable for use. The tool is a 10-item social presence measure that uses a Likert scale with 5 rating scale steps; 1 = disagree, 2 = somewhat disagree, 3 = neither disagree or agree, 4 somewhat agree, 5 = agree. As claimed by authors, all items are aligned with the Rasch Measurement Model.

Originally, this tool is being used to measure social presence within a student group. Thus, items include phrases such as ”my fellow students”. In this research, however, the interactions are happening between a student and a lecturer. In order to accommodate this difference, the items in the measure are modified, so to replace occurrences of ”students” and alike, with ”teacher” related alternatives. Due to applied change, 1 item lost its meaning and is no more valid for this study. In particular, the item referred to ”all of my fellow students feel that I am a ’real’ physical person”. This item does not contribute to the study and cannot be evaluated by the participant in the experiment's setup, because it would mean what the recorded lecturer feels about the participant. Hence, the item was removed. The resulting 9-item tool used in the experiment can be seen in the table 2.

Nr.	Item
	In this learning environment ...
SP01	... it feels as if we are a face to face group
SP02	... it feels as if I deal with 'real' persons and not with abstract anonymous persons
SP03	... I can form a distinct impression of the lecturer
SP04	... I imagine that I really can 'see' the lecturer to be in front of me
SP05	... the lecturer feels so 'real' that I almost believe that we are not virtual at all
SP06	... it feels as the lecturer is a 'real' physical person
SP07	... it feels as the lecturer and I are in the same room
SP08	... it feels as if the lecturer and I are in close proximity
SP09	... I strongly feel the presence of the lecturer

Table 2: An adjusted social presence measurement tool based on Kreijns et al. from 2018.

Zoom fatigue

Zoom fatigue is a fairly new concept that emerged during the COVID-19 pandemic. In 2021, a group of researches presented a tool that they called a Zoom Exhaustion & Fatigue Scale (ZEF Scale) (Fauville et al., 2021). The researches developed 49 items survey that later was reduced to 15 items over 5 constructs. The research includes an elaborate validation study on 2724 respondents.

This tool was in the end chosen to be used in this study due to shared definition of Zoom fatigue, high level of validation quality, as well as shared references to Nadler (Nadler, 2020).

As well as the tool used for measuring social presence, ZEF scale makes use of a Likert scale with five rating scale steps; 1 = Not at all, 2 = Slightly, 3 = Moderately, 4 = Very to 5 = Extremely. The paper adds, however, two frequency questions (marked with asterisks) that are scaled from 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often to 5 = Always. The resulting set of questions used in the experiment can be seen in table 3.

Construct	Nr.	Item
General Fatigue	ZEF01	How tired do you feel after video conferencing?
	ZEF02	How exhausted do you feel after video conferencing?
	ZEF03	How mentally drained do you feel after video conferencing?
Visual Fatigue	ZEF04	How blurred does your vision get after video conferencing?
	ZEF05	How irritated do your eyes feel after video conferencing?
	ZEF06	How much do your eyes hurt after video conferencing?
Social Fatigue	ZEF07	How much do you tend to avoid social situations after video conferencing?
	ZEF08	How much do you want to be alone after video conferencing?
	ZEF09	How much do you need time by yourself after video conferencing?
Motivational Fatigue	ZEF10	How much do you dread having to do things after video conferencing?
	ZEF11	How often do you feel like doing nothing after video conferencing? *
	ZEF12	How often do you feel too tired to do other things after video conferencing? *
Emotional Fatigue	ZEF13	How emotionally drained do you feel after video conferencing?
	ZEF14	How irritable do you feel after video conferencing?
	ZEF15	How moody do you feel after video conferencing?

Table 3: Survey questions for the ZEF scale (Fauville et al., 2021).

Limitations

The aforementioned tools have particular limitations. For example, Kreijns et al. (Kreijns et al., 2018) admit that they cannot state their Social Presence measure to be invariant with respect to asynchronous and synchronous media, as they administered the survey with the raw social presence measure only to students in collaborative learning settings that use asynchronous communication media. Moreover, they cannot state that the tool is invariant for men and women as well as the study the students were enrolled in.

There are multiple limitations to Zoom Exhaustion & Fatigue scale (Fauville et al., 2021) as well. For example, Fauville et al. see the five dimensions of the scale highly correlate with one another. Thus, they are likely to be dependent. They also recommend future work to be done on different context of video conferencing (work, social, etc) as well individual differences (ethnics, gender, culture, etc).

Taking into account these limitations, the tools are still seen applicable to the context of this research. Limitations, although relevant for consideration, are within the acceptable level of risk.

3 Results

The results obtained from the experiment are analysed using Kruskal-Wallis test (Kruskal & Wallis, 1952) with significance level $\alpha = 0.05$. Considering that the data contains 3 groups, small sample size (5-6 per group) and the samples are independent, Kruskal-Wallis test is the most appropriate non-parametric option.

The representative value per subject, as seen in the table 4, is calculated by applying Kruskal-Wallis test to sum of Likert scale items of the participant for this subject.

According to the results, the groups do not have statistically significant difference neither in Social Presence, nor in Zoom Exhaustion & Fatigue scales.

Subject	H	p-value
SP	3.7773	0.1513
ZEF	1.4367	0.4876

Table 4: Kruskal-Wallis test on Likert scale surveys for Social Presence and Zoom Exhaustion & Fatigue scales.

Although the results do not imply statistically significant difference, further analysis is performed for better understanding of the underlying data. For example, the figure 5 represents the average score per question between groups in Social Presence measure. In the figure, a trend is seen; ascending average score from Zoom to HoloDisplay to HoloVR in most of the items. Same analysis for Zoom Exhaustion & Fatigue scale can be seen in the figure 6, but it doesn't give any consistent trends. Worth noting that besides negligible significance, the averages in the figures can be interpreted as statistical errors due to small sample size. Thus, these figures should not be considered reliable, but yet can be useful in interpretation.

There are a few items, if analysed individually, produce significant difference. In particular, in Social Presence it is item SP07 "In this learning environment it feels as the lecturer and I are in the same room" with $pvalue = 0.0342$. As seen in the figure 5, HoloVR scores significantly higher than the other groups. In Zoom Exhaustion & Fatigue, however, items ZEF05, ZEF06, and ZEF11 (see table 3) are worth noticing. The p-values are $0.0593, 0.0232, 0.0495$, respectively.

4 Discussion

The data produces statistically insignificant difference between the researched groups. Hence, the Kruskal-Wallis test's null hypothesis – in the case of this study states that the Likert score sums for these groups are all equal – cannot be rejected. This test was chosen as the most appropriate tool given the constraints this study is subjected to (in terms

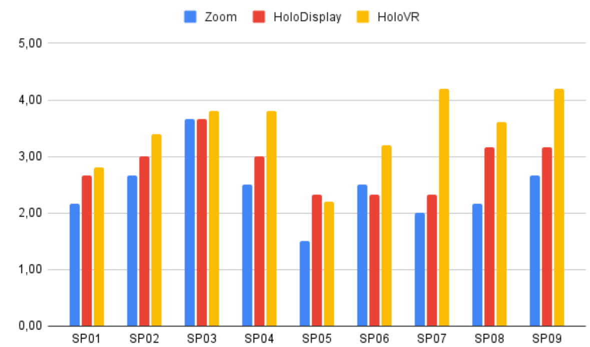

Figure 5: The average Likert score per question in Social Presence scale.

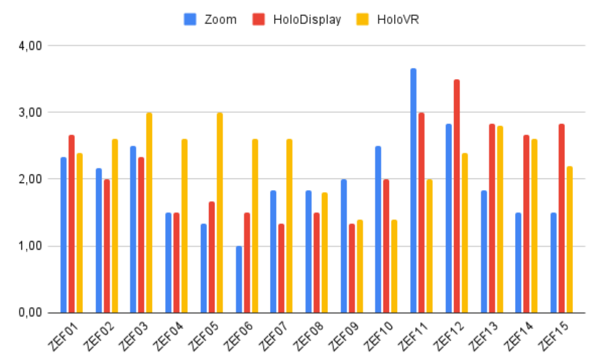

Figure 6: The average Likert score per question in Zoom Exhaustion & Fatigue scale.

of time, human-resources, etc). However, considering the nature of the tools, quantitative study over larger sample with parametric tests could produce more reliable results for consideration.

Nevertheless, the results show significant difference in multiple items if analysed individually, as mentioned in the chapter 3 and seen in figures 5 & 6. For example, in Social Presence, there is SP07 "In this learning environment it feels as the lecturer and I are in the same room" with $pvalue = 0.0342$, and much higher average score in HoloVR group as seen in the figure 5. This deviation can be explained by the focus of the item on "the same room". As can be seen in the figure 4, the participants of HoloVR group are, in fact, present in the same – although virtual – room as the lecturer. While other items measure the degree of "physical" presence or proximity, which are fairly subjective feelings, SP07 is practically true for HoloVR participants, hence scored higher.

Zoom Exhaustion & Fatigue has a few deviations itself. In particular, ZEF05 and ZEF06 with p-values $0.0593, 0.0232$, respectively. While ZEF05 is not within the significance level, it is quite close to it. Both ZEF05 and ZEF06 come from the same construct, "Visual Fatigue". The items are also fairly close in the meaning, where ZEF05 "How irritated do your eyes feel after video conferencing?" and ZEF06 "How much do your eyes hurt after video conferencing?". As seen in the table 6, HoloVR scores significantly higher on these items, compared to other groups. Considering the nature of HoloVR, these results can be justified. The setup for Virtual Reality requires a VR headset with lenses and screens right in front of eyes, in very close proximity. Moreover, the model of the headset used in this experiment, Oculus GO, is upto this point outdated and produces low quality image with visual artifacts. Thus, it is justifiable that the participants find this setup significantly more irritating on eyes, compared to Zoom or HoloDisplay, where participants sit on a considerable distance from the screen. Another significant reason can be absence of prior experience with the VR technologies. Considering that VR is still an uncommon technology, a lot of people did not have prior experience with it, which can lead to irritation as a first time occurrence.

ZEF11 "How often do you feel like doing nothing after video conferencing?" also showed significant difference in individual analysis. In particular, Zoom and HoloDisplay setups scored well above HoloVR as seen in the figure 6. Nevertheless, there are no clear reasons on why. One of the speculative reasons, however, is the excitement participants had after they experienced VR possibly for the first time. As the technology is new and interesting, this could lead to a higher desire to interact with outside world. One can only speculate the reasons on this deviation, so further research into it should be performed.

5 Responsible Research

This research was conducted in accordance to all regulations and recommendations imposed by the TU Delft Human Research Ethics Committee (HREC). The research has undergone the approval of HREC. The elaborate Data Management Plan was supplied to ensure safety of the obtained data as well as high level of privacy for the participants. Only the data needed directly for the research was recorded and stored securely. Minimum of personal information was requested. Where possible, the data was anonymised.

The participants had to read and sign the consent form. The form included detailed information about the experiment's procedure and how the data will be used. The form also included an explicit statement regarding the right for the participants not to answer the questions or to stop the experiment at their will.

This paper describes to great details each step of the study to ensure its reproducibility. Any changes to the existing models are reasoned and explicitly stated (e.g., changes to social presence measurement tool based on Kreijns et al. from 2018; see chapter 2.4). Any data manipulations are openly reasoned in the paper. All these steps ensure transparency of the study's methodology and its results. In its turn, this aims to increase reliability of the paper.

6 Conclusions and Future Work

The aim of this research was to explore the implications of combining HoloLearn and VR technologies in regards to hybrid learning. In particular, the interest was in the areas of social presence and Zoom fatigue. For this, an independent measures experiment was designed, where a pre-recorded lecture was shown to participants in different formats. The researched groups (Zoom, HoloDisplay and HoloVR) contained 17 participants in total.

The hypothesis derived for this research had not been justified. The results showed little to no statistically significant difference between the groups in general. The combination of HoloLearn and VR technologies does not necessarily lead to the increased perception of the lecturer's social presence. Moreover, VR does not necessarily lead to the decreased level of Zoom fatigue in the communication episode.

However, a few items showed significant difference in individual analysis. Firstly, the participants from HoloVR group showed higher feeling of the presence of being in the same room as the lecturer. Secondly, HoloVR has also been perceived as much more eyes irritating than the other setups.

As part of recommendation for the future research in this area, the technological stack should be upgraded to modern standards, and be able to produce higher quality experience. Instead of Oculus GO, a more modern headset shall be used to produce higher quality imagery. HoloLearn software stack should be improved, so to avoid visual artifacts after applying background removal scripts. HoloVR environment should include better quality 3D models and rendering techniques. All of this might lead to results different from this research's as the experience that the participants will be subjected to is comparable to our expectations of user-ready product.

As has already been mentioned, this study is subjected to strict constraints with respect to time, human-resources and used equipment. For this reason, the experiment processed groups with 5 or 6 people only, and further analysis is handled by non-parametric tools. However, the future work could explore further into quantitative research over larger sample and parametric tools to produce more reliable analysis of the results. Such research could further ensure diversity of the groups.

The measurement tools, used in this paper, have their own limitations. Thus, it is up to future research to ensure that the tools are kept up-to-date and any new discoveries or improvements to the tools are taken into account.

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