Improving distance learning with holograms

Otte van Dam
Supervisors: Bibeg Limbu, Marcus Specht
EEMCS, Delft University of Technology, The Netherlands

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1 Abstract

Previous studies have found that there is a strong correlation between the social presence of a teacher and perceived performance of students, and that an increased cognitive load decreases the effectiveness in problem solving. The objective of this study was to find out to what extend holograms can be used to improve the social presence of the teacher and reduce the cognitive load within distance learning. This was done by recording a lecture and using that recording to represent the teacher in different ways: a zoom lecture with a small video of the teacher on the slides as a control group, slides with the head of the teacher on a telepresence robot, slides with the teacher on a holographic screen and a lecture in a VR environment. 22 participants filled in questionnaires about the social presence and cognitive load after attending one of the 4 lecture types. The small number of participants made it hard to find any significant differences between the lecture groups while using non-parametric tests but the medians hinted that the VR lecture improved the social presence of the teacher compared to the zoom lecture and the telepresence robot lecture reduced the cognitive load compared to the zoom lecture.

2 Introduction

Students felt their performance while learning was negatively influenced by teaching going online during the covid-19 pandemic (Stevens, 2020). The students felt that their performance was suffering from the distance lectures and felt a lack of interaction.

(Tu & Mcisaac, 2002) found that a higher level of online interaction occurs with a higher level of social presence. (Paredes & Vazquez, 2019) also found a strong correlation between social presence and perceived performance, making it important to find ways of improving social presence in distance learning.

(Paredes & Vazquez, 2019) compared the social presence of a holographic teacher lecture to that of a traditional lecture but found no significant differences. Traditional lectures are however not part of distance learning. This study will compare the social presence of a teacher within distance learning by comparing a zoom lecture with holographic lectures such as a lecture with a holographic display or a lecture in a VR environment.

When using a fully immersive VR environment, the cognitive load can increase significantly (Grant Frederiksen et al., 2020). It is however important to decrease the amount of cognitive load for students since (Sweller, 1988) found that an increased cognitive load, decreases the effectiveness in problem solving.

Previous research studied the cognitive load a lot when presenting information on for instance slides or websites. There has been no research done to the effect of the teachers' representation on cognitive load

To close the gaps in knowledge mentioned in the paragraphs above, the following research questions are used:

- *'How can holograms be used in distance learning to enhance teachers' presence, when students are in the same class room but the teacher is distant?'*

- *'How can holograms be used in distance learning to decrease the cognitive load of a lecture, when students are in the same class room but the teacher is distant?'*

3 Background

This section will give some definitions that will be used during the paper that might differ from what other people would use as definition. Some knowledge that will is used from previous research about key topics

in this paper will be discussed . Lastly, it will also give some background about HoloLearn for who this research is done.

This paper makes use of the following definitions:

- **Hologram:** A representation of a human in an environment,where the human will be part of the environment it is represented in.
- **Distance Learning:** A teacher teaching to students from another physical location.

3.1 Social Presence

Social presence was first defined by (Parker, Short, Williams, & Christie, 1978). This research will use the following definition of social presence: "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." defined by (Kreijns, Kirschner, Jochems, & van Buuren, 2010). A lot of studies, including (Kreijns et al., 2010), (Gunawardena, 1995), (Tu, 2002) and (Mazgaj, D'Amato, Elson, & Derrick, 2021), used a questionnaire to measure social presence.

3.2 Cognitive Load

The cognitive load theory was developed by (Sweller, 1988) as, the amount of working memory of the brain is used. Cognitive load consists of three types of load:

- **Intrinsic:** The intrinsic load what first defined by (Chandler & Sweller, 1991) as the difficulty of a specific topic, such as a math equation where the load of a problem is the similar for a specific problem.
- **Extraneous:** Extraneous load was also defined by (Chandler & Sweller, 1991). It is the load associated with the representation of information to a learner. A square can for instance be represented by text but also by a figure.
- **Germane:** Germane load is defined by (Sweller, van Merrienboer, & Paas, 1998) and is the load associated with the permanent storage of information in the brain.

3.3 HoloLearn

HoloLearn is a research project from the Centre for Education and Learning, a collaboration of: the University Leiden, TU Delft and Erasmus University Rotterdam. The project aims to stimulate richer social interaction in online/distance education between students and teacher by making use of holograms at TU Delft (*HoloLearn*, 2020). All software made by the project is made by students of TU Delft.

4 Methodology

This section will explain in detail, how the experiment is carried out. It shows the experiment is a valid experiment and it will help others that want to reproduce the experiment.

4.1 Participants

Only participants that are fluent in English are allowed to participate and most of them will be students from the TU Delft. These participants will all be gathered by the research group itself. There will be a 10 euro bol.com voucher for the participants. There will be around 4 different lectures, the aim is to have 5-10 participants for every lecture which makes a total of 20-40 participants. We aim for as many participants as possible and we will divide them equally over the lectures.

4.2 Apparatus

The experiment will be carried out with 4 different lecture types, that use 4 different kinds of technology.

4.2.1 Zoom Lecture

The control group of the experiment is a zoom lecture. Students will be seated in a class room where a recording of a teacher will be played on a big screen as can be seen in figure 1.

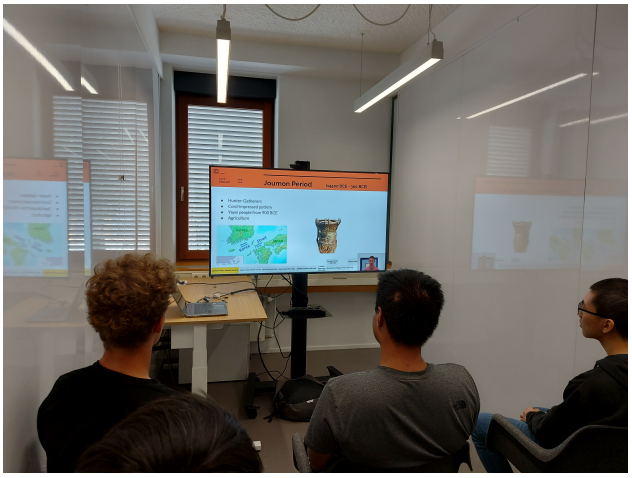


Figure 1: The research team watching the Zoom lecture.

A zoom lecture is chosen for the control group instead of a traditional lecture since the study focuses on distance learning lectures. For the recording of the zoom lecture a Kinect camera is used (*Azure Kinect DK â Develop AI Models*, 2022), just as in all the other lectures. This video will placed over a recording of the slides just as in a normal zoom lecture.

4.2.2 HoloDisplay

The experiment will use a screen with a projection of the teacher on it. The teacher will be recorded with a Kinect Azure camera (*Azure Kinect DK â Develop AI Models*, 2022). This camera does not only record a regular picture video but also a depth video. Pixels that are to far away from the camera on the depth video will be turned black in the picture video. What is left is the teacher and possible object the teacher would like to show with a black background. This video is projected on a big transparent screen. On this screen a foil is applied that diffuses the light from the projector. Since a projector does not project black light only the teacher will be projected on the screen which the students can see. The students can see through the screen on places where nothing is projected, giving the illusion that the teacher is part of the environment. A picture of the result can be found in figure 2. It was created by HoloLearn (more information on HoloLearn in section 3.3).

Figure 2: The research team watching the HoloDisplay lecture.

4.2.3 VR-Lecture

One lecture will be held in Virtual Reality. Students will sit together in a room with next to each other while wearing a VR-headset. This set up can be seen in figure 3.

Figure 3: The research group in the VR set-up.

During the experiment the participants were also wearing headphones, which were not available when making this picture.

Students will be placed on 1 of the 5 available seats in a 3D-environment that contains a model of a classroom. The environment is created using ThreeJS (*Three.js - JavaScript 3D library*, 2020), a Javascript based 3D library. In the environment a teacher will be placed at the front of classroom behind a desk. The slides (if any) will appear behind the teacher as can be seen in figure 4.

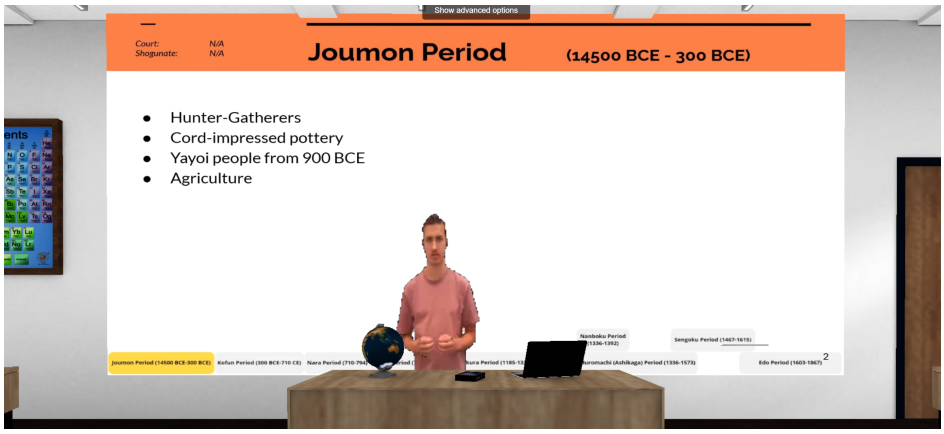


Figure 4: A teacher in the 3D environment together with the slides.

When other students pick a seat in the classroom, a 3D model will appear in the place where that student is seated as can be seen in figure 5.

Figure 5: A model representing another student in the environment.

This model will rotate just as the student is rotating in real life. Participants will be wearing a Oculus Go headset (*Oculus Go | Features*, 2018), an older VR headset from 2018. For the teacher in the environment the recording for the HoloDisplay is used. The black background is however removed and made transparent. The environment was made by HoloLearn (more information on HoloLearn in section 3.3).

4.2.4 Telepresence Robot

The telepresence robot is a robot made out of a IPad on top of a Segway that can drive itself. On the IPad the face of the teacher will be displayed. The face will be cut from the recording that is used in the zoom

lecture. The telepresence robot will stand in front of a screen where the slides are displayed as can be seen in figure 6.

Figure 6: The research team watching the telepresence robot lecture.

4.3 Materials And Measures

During the experiment both social presence and cognitive load were measured. A questionnaire was used for both.

4.3.1 Social Presence

To measure the teachers' presence, a Likert-scale questionnaire was used that measures the feeling that the participants are dealing with a 'real' physical person instead of a virtual teacher. After considering questionnaires from: (Tu, 2002), (Gunawardena, 1995), (Weidlich, Kreijns, Rajagopal, & Bastiaens, 2018) and (Biocca, Harms, & Gregg, 2001), the questionnaire from (Weidlich et al., 2018) was chosen. The questionnaire contained questions that were most applicable to a recorded lecture with no interaction between the teacher and the students. It originally made for a group of persons instead of one, it has therefor been altered on every question. For instance a question in the original questionnaire was *"It feels as if all my fellow students are 'real' physical persons"*, which was turned into *"It feels as if the teacher is a 'real' physical person"*. Participants could chose between 5 answers ranging from 'Strongly disagree' to 'Strongly agree'. Questions about the presence of the student itself have been removed since the teacher is a recording so their will not be any interaction. The used questionnaire can be found in appendix A

4.3.2 Cognitive Load

The cognitive load will be measured with a one question questionnaire that measure how much effort the students had to give to learn the subject. The questionnaire is created by (Paas, Ayres, & Pachman, 2008). The original question is altered a bit to fit the current set-up. The seven possible answers have stayed the same. The original question was "In solving or studying the preceding problem I invested" with answers going from "very, very low mental effort" to "very, very high mental effort". The altered questions is "In studying the Japanese history until 1603 I invested" with the same possible answers.

4.4 Procedure

Participants were randomly divided over the lectures upon arriving. When all participants were present, they received a pre-exam about the content. When all pre-exams were handed in, the participants watched one of the 4 types of lectures. After the lecture, participants got a post-exam and some questionnaires on paper to fill in about the lecture they just watched. Once a participant was done with the exam and questionnaire, they were told to leave.

4.5 Design

The study is between-subjects, where 4 different groups are being compared. Participants only followed one of the four lectures since the teacher explains theory that the students did not have before. If the students would know the theory, it might be a less intense lecture which could effect the perceived presence of the teacher or cognitive load. The four different groups consist of:

- **Control group:** A zoom lecture (section 4.2.1).
- **Treatment groups:** A hologram lecture with the HoloDisplay (section 4.2.2), a VR lecture in a 3D environment (section 4.2.3) and a lecture from a telepresence robot (section 4.2.4).

4.5.1 Independent Variable

The independent variable is the representation of the teacher. In the control group, the teacher will represented in a video which looks identical to a zoom lecture. In the treatment groups, the teacher will be represented on the HoloDisplay, in the VR environment or on a telepresence robot.

4.5.2 Dependent variables

The dependent variables is the social presence of the teacher and the cognitive load of the lecture. The social presence and the cognitive load are expected to be dependent on the representation the teacher.

4.5.3 Confounding variables

The social presence of the teacher and the cognitive load of the lecture do not only depend on the representation of the teacher. There multiple variables that it depends on. By keeping these the same as much as possible for both the control group and the treatment group, the effect of other variables will be mitigated. The following variables will be controlled:

- **The teachers' presentation:** The teacher will be giving one presentation, this presentation will be recorded for all the lectures at the same time. Every mistake the teacher makes will be in all lectures and will therefor not influence the dependent variables.
- **Participants' knowledge of the subject:** All the participants will have no previous knowledge about the subject before the lecture. If a participant would have previous knowledge, the lecture could be less intense for the participant which could influence the social presence of the teacher or the cognitive load of the lecture. If all students start with no knowledge influence will be mitigated. The given lecture will be about Japanese history before 1603 which is not common knowledge for people not from Japan. To ensure that by coincidence there is not somebody that happens to know something about the subject, a pre-exam is used to check the previous knowledge of the participants.

5 Results

This section will show the results of the experiment explained in section 4. The data consists of answers from questionnaires about social presence and cognitive load. 22 participants were divided over 4 lecture

types: 6 participants for the Zoom and HoloDisplay lectures and 5 participants for the telepresence robot and VR-lecture. Since the sample size is so small, normality can not be assumed ((Field, 2018)) and since transformation can not deal with this issue, a non-parametric test is used (Morgan, 2017). There are 4 different types of lectures that are being compared and the samples are not related since the study is a between subject study, therefor a Kruskal-Wallis test is used.

5.1 Social Presence

The questionnaire used to measure the social presence of the teacher consists of 9 questions with a Likert-scale (section 4.3.1). The mean of all 9 questions is used for the Kruskal-Wallis test. The test did not find a significant change in social presence between any of the 4 lecture types, $H(3) = 5.916$, $p = 0.116$. There are however differences in the medians as can be seen in the boxplots in figure 7.

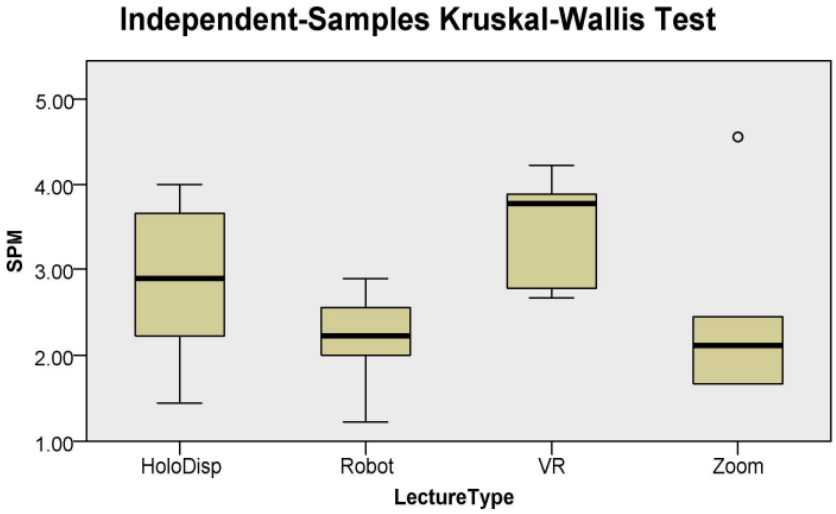


Figure 7: Social Presence Mean (SMP) for every lecture type.

The boxplots show differences between the social presence medians of the lecture types. The lowest score is for the zoom lecture with a median of 2.11, followed by the telepresence robot lecture with a median of 2.22. The 2th highest is of the HoloDisplay with a median of 2.885. The highest social presence median is of the VR lecture with an median of 3.78.

When looking at the 9 sub-questions of the social presence questionnaire, a significant difference can be found in sub-question 7: "*In this learning environment the lecturer feels so 'real' that I almost believe we are not virtual at all*" between the VR and Zoom lecture: $H(3) = 8.730$, $p = 0.033$. In other sub-questions no significant difference were found.

5.2 Cognitive Load

The questionnaire used to measure the cognitive load is a one question questionnaire with a 9-step scale (section 4.3.2). The answer will give 1 to 9 points for the question, which is used for the Kruskal-Wallis test. The test did not find any significant differences in cognitive load between the different lecture types. There are however differences in medians which can be seen in the boxplots in figure 8.

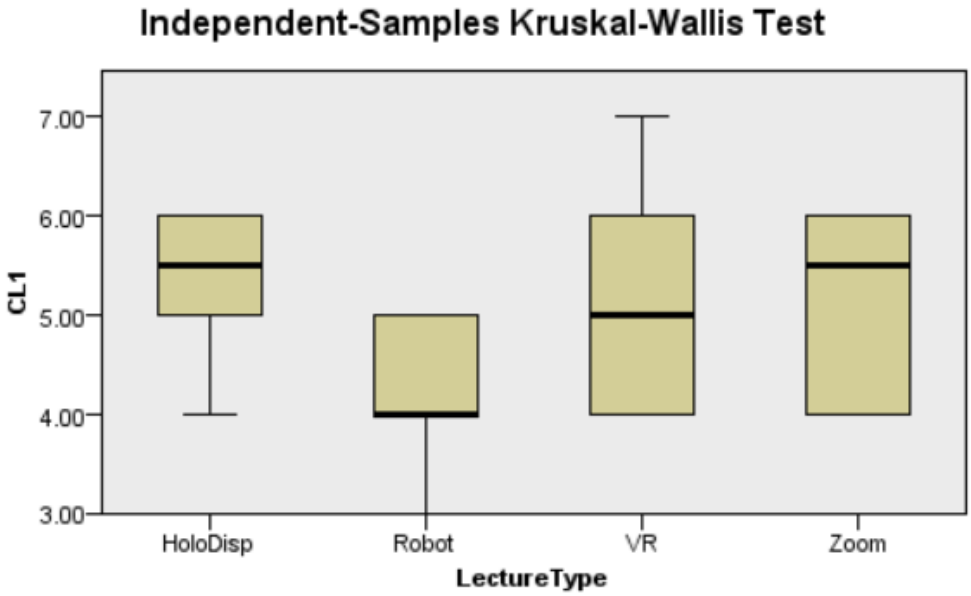


Figure 8: Cognitive Load (CL) for every lecture type.

The boxplots show different medians for all lecture types:

- **Zoom:** 5.5
- **HoloDisplay:** 5.5
- **VR:** 5
- **Telepresence Robot:** 4

6 Responsible Research

When working with human participants you have to be very careful that you are being ethical. The research group was very aware of this during the whole research. The following was done during the project in terms of responsibility:

- **Data Collection:** All data collected of the participants were collected on paper and stored in a locked closet. This ensured that no data of participants could be leaked. All the stored data do not contain any information that can lead to the participants.
- **Reward for participating:** All participants received a reward for participating in the research. The reward given is a 10 euro bol.com voucher and their participation took around hour. Since students get around 15 euro per hour as a Teaching Assistent, students would not feel obliged to participate because they really need the reward.
- **Covid-19:** During the research all local guidelines from the RIVM were followed.

- **Reproducibility:** All software that is used during the project is from HoloLearn. Their Github is a public Github and can be found online (van Dam, Milliken, Quin, Trasberg, & Ordonez, 2022). All other materials used in the experiment can be found in this paper except the recordings of the teacher. The recording can however be made with the public Github of HoloLearn. It does not matter that the recording is different as long as the same recording is used for all lectures given.

7 Discussion and Limitations

The research was very limited in the amount of participants per lecture type. With a total of 22 participants for 4 lecture types there are 5.5 participants per lecture type. It is very hard to find any significant difference with a sample size of 5 or 6. This can be seen with the Kruskal-Wallis test and the boxplot of the social presence means. Even with a big difference in medians (2.11 for the zoom lecture and 3.78 for the VR lecture) there is no significant difference. It does hint towards a difference which could be found with a higher sample size.

There is also a noticeable difference in the medians for the cognitive load. The lowest load was at the telepresence robot with a median of 4 and the highest loads were at the HoloDisplay and zoom lectures with a median of 5.5. A possible cause is well explained by one of the participants about the HoloDisplay:

"Most information is on the slides, with a teacher next to it, you have to divide your attention over 2 screens. The teacher can be a bit distracting."

Another limitation was the available VR headsets. The headsets used during the experiment were Oculus Go headsets. The headsets are very lightweight and old headsets. They are limited in processing power, do not fill the view of our eyes completely and do not track the translation of the headset. Current day headsets would improve the processing power and fix the other issue but were sadly not available in the numbers that were needed and the application would not able to run on them yet.

To keep all lectures the same and handle technical difficulties all lectures were recorded lectures. This limits the interaction between the participants and the teacher. In other studies, interaction was a big part of the social presence. Some lecture types might have a better way of interacting which could change the social presence compared to others.

8 Conclusion and further work

It is hard to draw any real conclusions from the experiment since it is very limited by the sample size of every lecture type. The data collected did show some interesting differences but not significant enough for such a small sample size. Since all the work of setting up the experiment is already done and still available to use, I would recommend HoloLearn to continue the study with more participants. The data can be added to the data from this study if everything is kept the same. With a sample size of 10 students per lecture type, a significant difference might be found in terms of social presence and cognitive load.

Further research could also be done to investigate the difference in social presence when the teacher is live teaching and can respond to the audience and answer some questions. There might be a difference in how well the technologies handle questions and interactions with students.

A Questionnaire Social Presence

1. Social Presence

For each statement put **X** in the appropriate box.

1. In this learning environment, it feels as if we are face to face.

						I
Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

2. In this learning environment, it feels as if I deal with a 'real' person and not with an abstract anonymous person.

Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

3. In this learning environment, I can form distinct impressions of my lecturer.

Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

4. In this learning environment, I imagine that I can really 'see' the lecturer to be in front of me.

Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

5. In this learning environment, the lecturer feels so 'real' that I almost believe we are not virtual at all.

Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

6. In this learning environment, it feels as if the lecturer is a 'real' physical person.

Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

7. In this learning environment, it feels as if the lecturer and I are in the same room.

Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

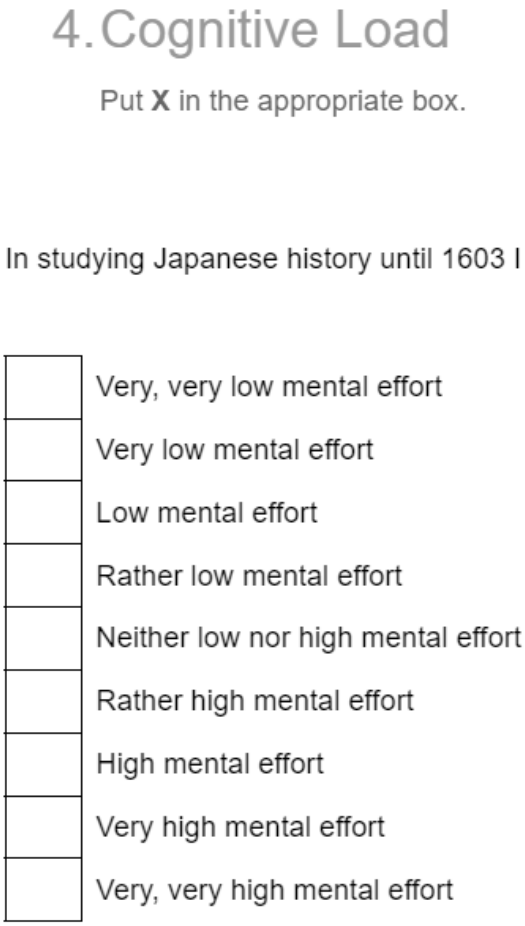
8. In this learning environment, it feels as if the lecturer and I are in close proximity.

Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

9. In this learning environment, I strongly feel the presence of the lecturer.

Totally Disagree	Disagree	Somewhat Disagree	Neither Disagree nor Agree	Somewhat Agree	Agree	Totally Agree

B Questionnaire cognitive load



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