Instructor Presence and Learner Response: Analyzing Learning Gain, Cognitive Load, Visual Attention and Affective States in Video and Metaverse Environments

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Abstract

This research explores the impact of different learning delivery modes, across video and virtual space via the metaverse, on student responses such as learning gain, visual attention, cognitive load, and affective states. Utilizing eye-tracking technology and facial expression analysis, this study examines the effect of instructor presence, both physical and in avatars, in educational videos and virtual environments, including individual and group lectures. The experimental design includes video-based learning and metaverse settings, where the instructor and other learners' presence is manipulated to measure their effects on the learners' cognitive and emotional responses. The mode of instructor presence appears to significantly impact learning outcomes, cognitive load, affective state, and attention, according to preliminary data. These findings underscore the potential of sophisticated educational technology to improve learning outcomes. This study closes essential gaps in the literature and provides valuable information for improving teaching strategies in technologically enhanced learning environments.

Keywords

Learning gain, Cognitive load, Eye-tracking technology, Facial Expression

1. Introduction

Technological developments, increasing student demands, and new research on successful teaching approaches all contribute to the evolution of teaching and learning. As these changes continue, educators must stay flexible and adaptable, seeking new ideas and strategies to improve student learning and success. Suitable learning resources, delivery styles, and environments assist students to attain their learning goals [1]. Learning resources can be offered in a variety of ways. One option is to use video as the primary medium. Furthermore, the metaverse has become a model of a learning environment in which both the lecturer and the students can be virtually present in the same space. As a result, video is an effective medium, and the metaverse is a modern learning environment where instructors and students can virtually interact.

Video-based learning (VBL) has become more popular recently, with many students taking online courses [2][3]. Moreover, in this cutting-edge period, studying the metaverse is garnering more and more attention. Metaverse education is becoming an essential and exciting educational trend. It is considered a platform for sustainable education free of time and space barriers [4]. In the metaverse, the lecturer and the learners can be virtually present in the shared learning environment. However, the effect of the instructor's physical and learner presence in the videos and virtual environments like the metaverse has not yet been extensively researched, especially the impact of instructor and learners' presence on learners' responses, such as learning gain, visual attention and cognitive load (eye tracking measures), and affective state (valence and arousal).

The project examines how the instructor's and other learners' presence in different learning delivery methods, such as videos and metaverse, affects learners' learning gain, visual attention, cognitive load (eye tracking measures), and affective state (valence and arousal). Detecting learners' responses will involve selected instruments and technologies.

2. Problem Identification

Many previous studies have discussed the effects of learning delivery and environment on learners. Other studies have focused on eye tracking and other body measurement tools. However, how “presence” in video materials and the metaverse impacts learners, such as understanding, cognitive load, visual attention, and affective state, has yet to be studied. Previous research on the effect of presence focused on learning gain; in this research, we also intend to measure cognitive load (using various measure instruments) and affective state dynamics.

Video-based learning has become more familiar, although its effectiveness in learning and usability needs

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to be better understood [5]. Moreover, the merits and limitations of each video lecture type for learning have yet to be thoroughly investigated [6]. Regarding the extent of learning, [7] found that students taught through videos (e.g., YouTube) obtained considerably more significant learning gains on the post-test than those who never thought about using videos. Further studies are needed on teacher presence (real human and avatar) versus slides and voice only in learning videos.

In addition, the metaverse is a breakthrough in education. The effect of the metaverse shared learning environment (with and without other students) on learning needs deeper investigation.

It is challenging to find prior work comparing the effect of instructor and learners' presence in lecture videos and the metaverse on students' affective states, eye-tracking measures, and learning gain. Hence, measuring the effect of instructors' and learners' presence in different learning delivery modes and learning environments is novel.

Finally, using body measurement tools for learning purposes, such as eye-tracking technology and facial expression recognition, warrants further investigation. From the problem related to technology-enhanced learning above, we formulate some research questions into two different experiments.

2.1. Research Question of Experiment 1 (Video Experiment)

The research questions for video experiments are as follows:

1. How does an instructor's physical presence in a learning video affect learners' learning gains and cognitive load (measured by eye-tracking) compared to the instructor's complete absence from the video?
2. How does an instructor's physical presence in a learning video affect learners' learning gains and cognitive load (measured by eye-tracking) compared to the instructor's presence as a virtual avatar?

2.2. Research Question of Experiment 2 (Metaverse Experiment)

The research questions for metaverse experiments are as follows:

3. How does the shared virtual presence of instructors and learners (i.e., co-presence) in the metaverse, where the student only sees the lecturer (individual lecture), evoke more pleasant emotions (higher valence) and more intense emotions (higher arousal) compared to a scenario where the student can also see other students (group lecture)?
4. How does a group lecture, where students can see both the lecturer and other students, affect learners' learning gains compared to an individual lecture, where the student only sees the lecturer?

3. Current Knowledge and Hypothesis

A word's representation becomes more complex when a gesture is added [8]. In contrast, [9]found that gestures contribute to listening comprehension and communication effectiveness. Gestures help the speaker to organize their thoughts [10]. Videos featuring the presence of a teacher can significantly improve academic achievements and raise cognitive loads compared to those that do not include a teacher [11]. However, in our experiment, we locate the central content/slide and lecturer position separately. This is possibly a different result from the previous study since the student can split their focus and miss critical information on the slide when focusing on the lecturer's gesture. Moreover, some answers to the question can only be seen on the slide without being mentioned by the lecturer.

On the other hand, as a compensating technique, speakers and listeners can use gestures during communication and thinking, interacting with people's cognitive dispositions [12]. The gesture might have drawbacks to learning, making the instructor's explanation seem more complex. Besides, learners need to switch their attention from the topic to the lecturer back and forth. From those prior works, we can formulate some hypotheses (H).

H1: The lecturer's presence in the video leads to lower learning gain than in the non-lecturer presence video.

H2: The lecturer's presence in the video leads to a higher cognitive load than in the non-lecturer presence video.

A digital representation of a person in a virtual setting is called an avatar. An avatar's appearance and behaviour can be more superficial than a real human's. Avatar-based teachers are more attractive than face-to-face [13], which can be designed to have fewer gestures. Besides, Avatar-based instructors can enhance the sense of presence and instructing satisfaction. [14] discovered that participants using avatars learned substantially more while memorising pairs of letters.

Using avatar lecturers or teachers in virtual settings can improve learning by providing students an interesting, immersive, and enriching educational experience [15], [16]. Avatars may be helpful when students are more comfortable communicating with a virtual avatar or when the subject contains delicate or possibly painful issues.

H3: The instructor's presence as an avatar in the learning video leads to more significant learning gain than their physical presence.

H4: The instructor's virtual presence as an avatar in the learning video leads to a lower cognitive load than the physical presence.

During learning sessions, students naturally experience a variety of affective states [17] [18]. [19] discovered that social presence influenced the impact of agent behaviour on valence and arousal during virtual presentations. The physical and social environment can affect students' affective experiences while learning. Higher valence and arousal are usually fostered in a positive, supportive, and inclusive learning environment.

[20] contends that distractions can be minimised through independent learning. On the other hand, [21] asserts that group learning dramatically increases performance. Dividing up complex tasks is the whole idea of group learning [22].

Nevertheless, in our research, where there is no direct interaction among students, individual lectures are anticipated to provide a more concentrated virtual setting with fewer distractions. However, group lectures may create a more pronounced sense of presence in virtual learning environments.

H5: There is a statistically significant difference between the learner's level of valence and arousal during individual lectures (a student alone) and group lectures (a student with other students)

H6: The individual lecture leads to more significant learning gain than the group lecture.

4. Research Methodology

The research was conducted at Queen Mary University of London and involved 3rd-year Electronic Engineering and Computer Science students. The involvement is voluntary. There are two experiments. Experiment 1 (video) involved 33 participants, and Experiment 2 (metaverse) involved 20 participants. This ensures enough data is collected and a robust statistical analysis can be conducted.

4.1. Video Experiment Methodology

Eye-tracking Technology captured and measured participants' gaze and visual attention when learning. The data collected is analysed statistically to see the effects of various experimental conditions on fixations and pupil dilation, which are indicators of cognitive load [23], [24], [25]. The eye-tracker that we used is a single eye camera 120Hz Pupil Core eye-tracker from Pupil Labs https://pupil-labs.com/products/core (See figure 1).

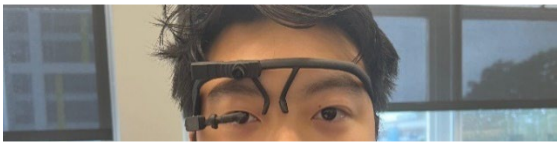

Figure 1: Pupil Core Eye Tracker by Pupil Labs

Before watching the videos, participants were asked to answer a knowledge test (pre-test Multiple Choice Questions) on the topic of the videos. After watching the videos, they were asked again to answer the same knowledge test (post-test) to measure learning gain. We modified a video from Lex Fridman about "Deep Learning": https://www.youtube.com/watch?v=O5xeyoRL95U. We cut the video into three parts, each about 5 minutes long (Topic A, B, and C). The videos contain some slide presentations (Topic A has 4, topic B has 6, and Topic C has five slides.

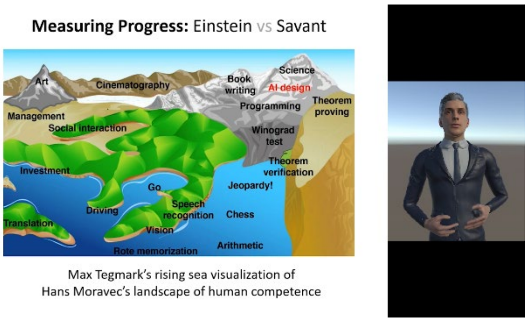

Figure 2: Video with avatar lecturer

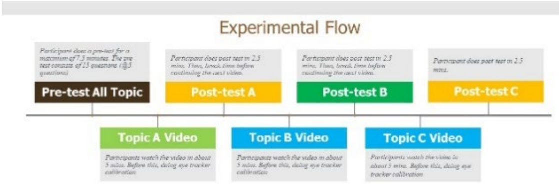

Figure 3: The Flow of Video Experiment

We randomized the order of the experimental conditions (no lecturer, lecturer presence, and avatar lecturer) to avoid any habituation effect. For example, the first participant starts watching videos using non-lecturer presence, while the second and third participants start using lecturer physical presence and avatar lecturer presence, respectively. Figure 2 shows an example of the video with the lecturer's presence as an avatar.

The experiment was about 60 minutes in total. The visual timeline can be seen in Figure 3.

4.2. Metaverse Experiment Methodology

We recorded the participant's faces when watching videos using an external camera. Participants' affective states were measured continuously in the 2D space of emotional valence (how pleased or unpleased) and arousal (the intensity of power activation of the emotion). We use an established system to detect the level of valence and arousal developed by Daeha Kim and Byung Cheol Song [26]. We recorded the faces of the participants and analysed them afterwards. The arousal scale ranged from 0 (not active) to 1, and the Valence scale varied from 1 (unpleasant facial expression) to 1 (pleasant) [27]. The Axis of valence and arousal can be seen in Figure 4.

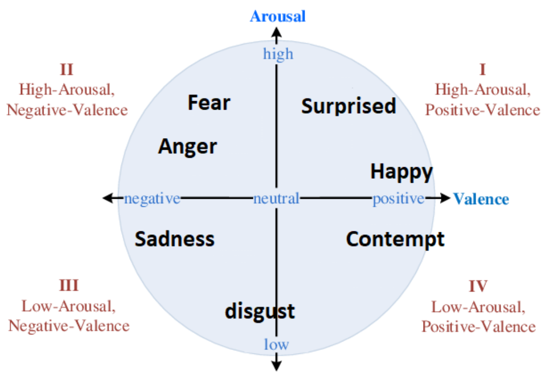

Figure 4: Two-dimensional valence-arousal Space for Emotions [28]

We also employed pre- and post-test questions and questionnaires to ask participants their opinions on their metaverse learning experience. We modified a video by Alexander Amini about "AI Bias and Fairness": https://www.youtube.com/watch?v=wmyVODy_WD8. In this experiment, we cut the video into two parts, each about 4 minutes long (Topic D and E).

The metaverse or virtual environment used was ENGAGEVR (https://engagevr.io); see Figure 5. This platform has many features that support teaching purposes, and the subscription price is affordable for everyone in the educational field.

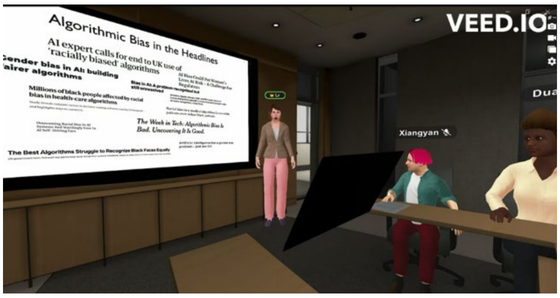

Figure 5: Engagevr Environment

The metaverse experiment took about 50 minutes. The visual timeline can be seen in Figure 6.

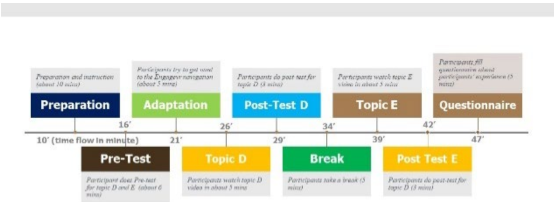

Figure 6: The Flow of Metaverse Experiment

5. Potential Contribution

This research explores the impact of video materials and the metaverse on students' understanding, cognitive load, and affective states, enhancing our knowledge of how these environments affect learning. It addresses gaps in earlier studies, which mainly looked at learning improvements, and points out that while video-based learning is more common, its effectiveness still needs more exploration. The study also guides creators of educational videos to help improve the quality of their content.

Furthermore, the metaverse emerging as a new educational platform opens new possibilities and difficulties. This study aims to evaluate the utility of advanced techniques such as eye-tracking technology and facial expression recognition for monitoring students' mental load and emotional states, which will provide more in-depth insights into their experiences during various learning activities. It focuses on the influence of teacher and student presence in different educational settings, providing fresh perspectives on how it affects learning gain, visual attention, cognitive load, and affective states.

6. Discussion

Some researchers study the effect of presence in learning videos, while others explore how shared learning space impacts learning. [29] investigates the effect of lecturer presence in videos using interviews only as a research method. The interview method has drawbacks because it is subjective. Meanwhile, several tools related to human response measurement can be used, such as eye-tracking technology and facial expression recognition [30] [31] [32]. Eye-tracking seems particularly beneficial for studying mental processes [33]. Thus, it is necessary to investigate the effect of teacher presence on eye-tracking measures when studying using videos.

On the other hand, due to the rapid development of artificial intelligence, automatic recognition of facial expressions has been intensively studied in recent years [34]. Emotion recognition through facial expression detection is one of the essential fields of study for human-computer interaction [35]. However, more researchers currently focus only on discreet emotion. At the same time, the dimensional model is more effective than the discrete model in providing a nuanced and continuous representation of emotional experiences because it focuses on measuring intensity along the dimensions of valence and arousal instead of classifying emotions into distinct categories. The API system developed by Daeha Kim and Byung Cheol Song [26], used in this research, is beneficial because it can detect learners' affective states during learning in the metaverse.

The chosen methodology is appropriate for filling the research gap because combining tests, eye tracking, facial expression recognition, and questionnaires is a comprehensive method for collecting data on numerous aspects of the student experience. The test permits the measurement of learning gain. Eye tracking allows the objective measurement of participants' pupil diameter and visual attention, revealing their cognitive processes. Facial expression recognition adds another layer of objective data by documenting participants' affective states, allowing for a more in-depth comprehension of their emotional experiences. The questionnaire will enable participants to give subjective assessments based on their expertise when studying using a virtual environment (metaverse).

7. Current Data Analysis

7.1. Video Experiment Analysis

We have successfully gathered data from 33 participants using knowledge tests and eye-tracking measures.

7.1.1. Learning Gain of Video Experiment

From the pre-test and post-test results, we calculate the learning gain using this formula [36]

$$c = \begin{cases} \frac{\text{post-pre}}{100-\text{pre}} & \text{post} > \text{pre} \\ \text{drop} & \text{post} = \text{pre} = 100 \text{ or } 0 \\ 0 & \text{post} = \text{pre} \\ \frac{\text{post}-\text{pre}}{\text{pre}} & \text{post} < \text{pre} \end{cases}$$

We will compare the learning gain across three different conditions. In examining the influence of a lecturer's physical presence on students' learning gains, we perform statistical analysis to see the difference between no lecturer presence on the video vs. lecturer physical presence, lecturer physical presence vs. lecturer presence as an avatar, and no lecturer presence vs. presence as an avatar.

Besides that, it is essential to know the correlation between learning gain and gaze transition. Transition is switching gaze activity from 1 Area of Interest (AOI) to another, back and forth. We aim to examine the correlation between learning gain and gaze transition between the two AOIs across all conditions (AOI 1 is the main content/slide area, and AOI 2 is the presenter/lecturer area).

7.1.2. Pupil Diameter

The output from eye tracking measures gives us information about the participant's pupil diameter. By measuring pupil diameter or pupil dilation, we can link to the cognitive load of the participant during learning [23], [24], [25]. The participants watched all videos under three conditions (no lecturer presence, lecturer physical presence, and lecturer presence as an avatar), so comparing which conditions gave them more pupil dilations was interesting.

To assess whether significant differences exist in pupil diameter under three different conditions, we conducted a series of statistical comparisons among no lecturer presence on the video vs. lecturer physical presence, lecturer physical presence vs. lecturer presence as an avatar, and no lecturer presence vs. presence as an avatar.

Knowing the correlation between pupil diameter and learning gain is also important. We want to explore this relationship across three conditions. Moreover, we want to see the correlation between pupil diameter and gaze transition between the two AOIs across all conditions.

7.1.3. Comparison of Time Spent on Hotspot Looked by Participants in the Slides and the Number of Gaze Transition

Figure 7: Example Hotspots on the Slide

To assess attention allocation, we calculated the percentage of time participants spent focusing on designated hotspots in a slide presentation. These analyses were designed to determine how the physical presence of a lecturer influenced participant interaction with the content, as highlighted by the hotspots on the slides. Figure 7 shows an example of a hotspot on the slide visualization.

7.2. Metaverse Experiment Analysis

7.2.1. Valence and Arousal

We have collected data from 20 participants. We compare valance and arousal levels between conditions in this experiment (Individual Lecture vs. Group Lecture). The result will be linked with the learning. For example, how do participants' valance and arousal levels have meaning to their learning?

7.2.2. Learning Gain of Metaverse Experiment

We calculate the learning gain from the pre and post-test scores and compare the results between two conditions (individual vs group lecture) to see if there is a significant difference.

7.2.3. Questionnaire

After learning on metaverse, participants were asked to give their opinions to compare individual and group lectures. We analyse their responses, which is valuable in capturing how virtual environments give a sense of presence. The questionnaire results can be combined with the facial expression data to gain comprehensive analysis.

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