Zoom Plus? An Experimental Study on a Virtual Classroom with More Natural Face Interaction and Its Effect on Videoconferencing Fatigue

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Abstract In the last two years, there has been a massive use of videoconferencing tools for distance learning all over the world. However, a feeling of fatigue has been found among students when they learn on those videoconferencing tools. Researchers have proposed multiple problems in the online interaction with several human faces that may contribute to the videoconferencing fatigue (VCF), and made calls for corresponding empirical examinations. To close this research gap, this study aims at investigating whether VCF can be reduced if we change the unnatural interaction with multiple faces on videoconferencing tools. An innovative videoconferencing tool FRAME was adopted to enable participants to look around to see more faces selectively, rather than seeing all faces simultaneously, and an experiment was conducted where participants had an online lecture in Zoom and FRAME and receive fatigue and stress-related measurement and learning effectiveness measurement for comparison between the two tools. Results showed that the distance learning in FRAME led to a significantly higher level of stress and less satisfaction than learning in Zoom. This tool effect was believed to be caused by the functionality and usability issues of FRAME as a distance learning tool, and implications were discussed for future research and policy making in distance education.

Key words Videoconferencing fatigue, Zoom fatigue, distance education, videoconferencing, COVID-19 pandemic

Introduction

In the last two years, the global COVID-19 pandemic triggered a huge shift in education over the world, from face-to-face physical learning in the classroom towards online learning at home (Brady & Pradhan, 2020; Schneider & Council, 2021). Hundreds of countries have closed schools and universities (hereafter referred to as educational institutions) and adopted nationwide online forms of learning, making distance learning suddenly become the norm (Bui et al., 2020; Kristóf, 2020). To cope with the difficulties of teachers and students being at different locations, educational institutions implemented videoconferencing tools and used them as a substitute for traditional classroom teaching during phases of lockdowns. Even when no lockdowns were effective, videoconferencing tools were, and still are, widely-used in education (Lockee, 2021; Roberts, 2009). Commonly used tools include Zoom, Skype, and Microsoft Teams, with Zoom becoming especially popular during the pandemic (Kristóf, 2020). A recent study shows, for example, that in Indonesia, 82% of students use Zoom (Utomo et al., 2020). Extensive use of Zoom and similar tools is reported for many other countries too, including the United States (Toney et al., 2021), predominantly because videoconferencing resembles face-to-face interaction.

However, according to Peper et al. (2021), a majority of students reported distance learning on Zoom as being difficult compared to the in-person classes. Among many difficulties in distant formats, a feeling of fatigue has been found in students when they interact and learn on those videoconferencing tools. This

phenomenon has been termed videoconferencing fatigue (Ratan et al., 2021), or 'Zoom fatigue', named after Zoom, one of the most popular videoconferencing tools (Nadler, 2020). Drawing upon a recent paper which developed a definition based on twelve conceptualizations of the phenomenon, the author defines videoconferencing fatigue (hereafter referred to as VCF) as "somatic and cognitive exhaustion that is caused by the intensive and/or inappropriate use of videoconferencing tools, frequently accompanied by related symptoms such as tiredness, worry, anxiety, burnout, discomfort, and stress, as well as other bodily symptoms such as headaches" (Riedl, 2021, p. 5).

Researchers have examined the possible root causes of VCF and argued that it is not simply caused by students staring at their computer screen for too long a time, or "we would have heard of Facebook fatigue long ago" (Nadler, 2020, p. 2). Rather, researchers have proposed multiple problems in the interaction with several human faces that may contribute to the fatigue phenomenon (Bailenson, 2021; Peper et al., 2021; Wiederhold, 2020). However, empirical evidence is needed to confirm this theoretical assumption of VCF being strongly affected by the interaction with human faces. If the assumption holds true, we can expect to observe a reduced fatigue level by modifying the way people interact with human images on the videoconferencing tools in a good way.

Therefore, this study wants to investigate whether students' fatigue level in distance learning would be reduced if they could interact with human images in an optimized way on videoconferencing tools. To be more precise, in order to target the potential problems lying behind the VCF phenomenon, this study should modify the display of student images in a way such that a student will not view others' images as enlarged faces at a close distance all the time during the distance lecture. The optimization of videoconferencing tools may not only improve the learning quality and students' feelings during the pandemic period, but also benefit distance learning in the long term (Brady & Pradhan, 2020). Importantly, one obvious solution to the problem would be to turn off cameras; hence, the issue of other faces would not exist at all. However, because a feeling of immersion is critical to establish a reasonable "together-feeling" during joint interaction in online sessions, seeing other people, or other people's faces, during videoconferences is not per se adverse.

Related Work

Distance Learning

Distance learning has already existed for decades (Phipps & Merisotis, 1999; Sherry, 1995). During those years, the fast development of communication technologies provided different formats for distance learning, such as tapes, radio, telephone, recorded videos and interactive videos (Allen et al., 2004; Webster & Hackley, 1997). Thus, learning contents and instructions can be delivered in these formats among multiple sites, asynchronously (at disparate times; e.g., recorded videos) and synchronously (at the same time; e.g., telephone).

As an important part in modern education, distance learning has been closely examined on its effectiveness (Allen et al., 2004; Webster & Hackley, 1997). According Phipps and Merisotis (1999), there are three major aspects of learning effectiveness that the researchers have focused on—learning outcome, attitude and overall satisfaction. For learning outcomes such as course scores in distance learning, a meta-analysis found them no worse but slightly better than those in traditional learning (Allen et al., 2004). A survey (Hannay & Newvine, 2006) also confirmed this finding, with over half of the students stating that they achieved higher grades in distance learning compared to traditional learning. As for students' attitude, Hannay and Newvine (2006) found students' strong preference towards distance learning, mainly because the convenience of distance learning gives them more opportunities to balance their other commitments. Furthermore, students were found generally satisfied with their distance learning (Bray et al., 2008).

During the COVID-19 pandemic, when more programs transitioned from the face-to-face format to the videoconferencing format globally, students' attitudes towards distance learning were found overwhelmingly negative. In a recent study (Vandenberg & Magnuson, 2021), researchers found only 25% students enjoyed having their theory courses on Zoom and the proportion reduced to 11% when it came to their online practical courses. Specifically, more than half of the students reported they experienced psychological barriers such as stress and anxiety during the distance learning.

Causes of Zoom Fatigue

Overview of Theoretical Causes

Because of the massive use of videoconferencing tools for synchronous distance communication in the last two years all over the world, more people are experiencing fatigue symptoms, both mentally and physically (Massner, 2021). There has also appeared more research exploring the cause of these symptoms (Nadler, 2020), although the research is still in an early stage and has mostly dealt with theoretical causes rather than empirically proven causes (Fauville et al., 2021a). In 2021, Bailenson published an article that outlined four possible, yet empirically unproven, causes for VCF, including eye gaze at a close distance, cognitive load as users need to work harder to send and receive communicative signals, self-view (if one does not turn off the own videostream), and reduced physical mobility. Later that year, a conceptual framework was proposed by Riedl who analyzed the decrease in naturalness of videoconferencing if compared to face-to-face interaction and proposed a theoretical model integrating six root causes of VCF based on Kock's (2004, 2005) media naturalness theory. According to Riedl (2021), when compared to face-to-face communication, there is a decrease of naturalness in videoconferencing communication due to two reasons: (1) lack of information (caused by asynchronicity of communication even if it is in the milliseconds range, lack of body language, and lack of eye contact), which might lead to increased cognitive effort as the human brain seeks to compensate for lack of information through altered neuronal processing; (2) information overload (caused by self-awareness via one's own videostream, multitasking, and unnatural interaction with multiple faces), which could increase cognitive load also. Altogether, Bailenson (2021) and Riedl (2021) presented theoretical insights on *possible* causes of VCF (see Table 1 for an overview) and made calls for corresponding empirical examinations. The author emphasizes that both theoretical frameworks explicitly indicate that the interaction with several faces in videoconferencing constitutes a major possible root cause of VCF.

	Theoretical Arguments	Evidence
Unnatural Interaction with Multiple Faces / Eye Gaze at Close Distances	Videoconferencing tools make people stare at a grid of others nonstop for a long time and also perceive being directly stared at intensively, which might cause physiological arousal and stress (Bailenson, 2021; Riedl, 2021).	Eye contact is a threat signal for non-human primates and also humans typically avoid being the target of others' eye fixations (Harrod et al., 2020); being stared at was a significant predictor of Zoom fatigue (Fauville et al., 2021a).
Self-view/ Awareness	Videoconferencing tools make people see their real-time camera feed, which can trigger self-evaluation, increase self-focused attention, disrupt an automatic communication process and ultimately may come along with overall negative effects (Bailenson, 2021; Riedl, 2021).	Viewing the self-image could lead to negative effects (Fejfar & Hoyle, 2000), an increased self-consciousness and social anxiety (Ingram et al., 1988); self-view anxiety was a significant predictor of Zoom fatigue (Fauville et al., 2021a).
Asynchroni-city	Image and audio latency on videoconferencing tools might lead to increased cognitive load (Bailenson, 2021), and the human brain works harder to overcome the delay in videoconferencing in order to establish a perception of synchronicity (Riedl, 2021).	Brain research found evidence of frustration, stress, and increased arousal in participants who experienced computer response time manipulation (Hirshfield et al., 2014).
Lack of Body Language	The lack of body language might hamper people's rapid emotion perception and thus increases cognitive effort (Riedl, 2021).	The suppression of body language could harm the perception of excitement (Kock, 2005).

Lack of Eye Contact	Although people develop a feeling of being stared at on videoconferencing tools, there is no direct eye contact, which might harm the establishment of shared attention, reduce coordination efficiency, and thus increase cognitive effort (Riedl, 2021).	Inter-individual neural synchronization evidence has been found for shared intention during mutual eye contact in social interaction situations (Saito et al., 2010).
Cognitive Load	On videoconferencing tools, people produce and perceive extra nonverbal cues such as more dramatic nodding, which can increase cognitive load (Bailenson, 2021).	Producing and interpreting nonverbal cues was found to be a significant predictor of Zoom fatigue (Fauville et al., 2021a).
Multitasking	When having videoconference meetings, people often do other tasks, which could lead to stress and fatigue (Riedl, 2021).	Internet multitasking was related to stress and had effects on burnout and anxiety (Reinecke et al., 2017).
Reduced Mobility	People have to sit in front of cameras when having videoconference meetings (Bailenson, 2021).	Reduced mobility was found to be a significant predictor of Zoom fatigue (Fauville et al., 2021a).

Table 1. Overview of Possible Causes of VCF

Unnatural Interaction with Faces

This section focuses on the aspects of unnatural interaction with faces as a potential cause for VCF. Using videoconferencing tools, people usually view others' faces as the main visual information. According to Bailenson (2021), the size of faces we see in videoconferencing tools is generally larger than those we see in face-to-face communication, given the same total number of people (because in a physical room, large groups of people are spaced in different locations inside the room). The emphasized, enlarged human faces might theoretically lead to a threatening state in the viewer's brains and cause the release of stress hormones, and also make them feel fatigue (Wiederhold, 2020). Also, on videoconferencing tools like Zoom, in the default setting all the people's faces will be shown on the medium, requiring specific action from the viewer to change this visualization mode. Perceiving and gazing at so many human faces at the same time could also be a possible cause of an unnatural and tiring experience (Bailenson, 2021).

Furthermore, when people are communicating with others via conferencing tools, they often keep staring at a grid of others' faces to keep the communication going and to avoid missing nonverbal signals. In face-to-face communication, this is not the case. People scatter in physical space and also do not directly look at others nonstop, and in some cultures, direct gaze is even considered as impolite (Kleinke, 1986). Bailenson (2021) outlined two components related to the hyper eye gaze on videoconferencing tools: the prolonged gaze time and the enlarged faces. During videoconference meetings, since the tool is the only platform for communication, people usually stare at the grid of faces for a long time (e.g., for hours). Moreover, the faces have also been enlarged on the videoconferencing tools, when compared to the relative size at which they are observed in normal face-to-face communication. The larger perceived face size indicates closer distance when standing face-to-face and is related to more intimate interpersonal distance. It has been found that reduced distance between people comes along with less and shorter eye gaze (Argyle & Dean, 1965). However, on videoconferencing tools, the distance is close and perceived eye gaze is pronounced, which seems to be against the natural trade-off between distance and eye gaze. What follows is that coping with this unnatural hyper eye gaze could make people's eyes and brains feel stressed and exhausted (Bailenson, 2021; Peper et al., 2021; Riedl, 2021). This might further lead to the hampered learning experience found by Vandenberg and Magnuson (2021), where students reported stress and showed dissatisfaction towards distance learning on Zoom.

The issue examined in this research is well documented in practice too. For example, Morris (2020) argues in a Wall Street Journal article: "Images of framed heads of varying sizes are disconcerting, as are the giant faces of speakers. Audiences are particularly sensitive to images of people, especially when they are too big and too close" (p. 5). Ma (2020), in a blog on the Slack platform, confirms this view, writing that: "When was the last time you held unwavering eye contact with someone for an hour? If we're in a crowded elevator, we look at the floor. If someone close by is staring, we take a step back. We use different personal space

techniques to always maintain an appropriate level of intimacy—which fails to translate online when you're staring 'at a huge face inches from your own'" (p. 2). Thus, the theoretical argument made in the present paper is not only outlined in scientific publications (e.g., Bailenson, 2021; Riedl, 2021), but also in practitioner articles too, confirming the practical relevance of the issue.

Problem Statement

Knowing the existing problems of current videoconferencing tools is a precondition to effectively reduce, or even avoid, the fatigue caused by tool features as outlined by Bailenson (2021) and Riedl (2021). To optimize online meeting tools, one direction is to consider other mediums' features such as those from Virtual Reality (VR) and Augmented Reality (AR). In essence, VR and AR frequently use 3D human images and objects to create a meeting experience that is more similar to face-to-face communication than videoconferencing (Wiederhold, 2020). Some companies like Microsoft and Google are trying to turn people into 3D images in distance communication, but the cost-effectiveness of this solution for daily communication is not clear yet (Wiederhold, 2021). Another direction is to change the existing browser-based videoconferencing tools. Bailenson (2021) suggested that doing small changes to the traditional videoconferencing tools might already be sufficient to cope with the fatigue issue. For example, we can provide a limit of face size on Zoom to solve the enlarged face problem, or hide the self-view in our default Zoom setting. However, the efficacy of these proposed solutions has not been examined by empirical methods yet. A change that has already been done by the videoconferencing tool Microsoft Teams was to add the "Together mode", which enables users to view each other in a room setting rather than grids. Microsoft's internal testing showed a reduced isolation feeling (Epstein, 2020), but this change did not target the hypothetically fatigue-inducing problems such as seeing all faces (with possible perceived eye gaze) and a feeling of being stared at.

To close this research gap, the current study aims at examining whether VCF can be reduced by changing an important medium feature that (1) exists in traditional videoconferencing tools and (2) has been believed to be a major root cause of fatigue. Specifically, this study targets the medium feature "unnatural interaction with multiple faces" and investigates if changing it can reduce fatigue. This feature has been chosen among all the proposed fatigue-inducing features because it has been widely believed to be a major possible cause (see Bailenson, 2021 and Riedl, 2021) and there is a lack of empirical evidence to support this hypothesis (Fauville et al., 2021a). To change the unnatural interaction with faces which users typically experience in traditional videoconferencing tools, a key change is to limit the number of faces shown on the screen simultaneously. To enable this change, an innovative videoconferencing tool, FRAME (www.framevr.io), was adopted in order to provide an environment different from Zoom (www.zoom.us), differing in the way that students can look around to see more people rather than seeing all the faces at the same time. In FRAME, attendees can have their virtual avatars moving around in a virtual space, with their camera image displayed next to the avatar. When they walk to the front of another person's avatar, they could see that person's image. This way of face display is similar to the face interaction in real life, where people walk around and face each other to communicate, and thus the use of FRAME might potentially reduce the fatigue feelings of seeing faces shown on the videoconferencing tools. According to previous research, people seemed to experience more problems in videoconferencing sessions in group meetings compared to one-to-one communication, so more research on the group interaction is needed (Nesher Shoshan & Wehrt, 2021; Peper et al., 2021), which also constitutes the context of typical distance learning scenarios (teacher/professor and many students). Therefore, in this study the group meeting (group lecture) were adopted as the context of distance communication.

Figure 1. Zoom (Left) and FRAME (Right) Interfaces

Notes: **Zoom picture from dpa, cited after Sueddeutsche (https://www.sueddeutsche.de/digital/zoom-fatigue-videokonferenz-ermuedung-corona-1.4888670); FRAME picture from https://learn.framevr.io/.**

An experiment was conducted in which a group of students had a lecture either in Zoom or in FRAME. Sample interfaces of Zoom and FRAME are illustrated in Figure 1. It was hypothesized that students using FRAME, where others' faces could be seen flexibly by their choice instead of being continuously displayed in a grid format, would perceive less fatigue as well as less stress than those who use Zoom, and thus have a better learning experience.

Methodology

Participants and Task

The participants in this study were recruited through an online community on Meetup.com. The community had more than 1200 members and hosted online and offline lectures and guest talks regularly. The members were mainly young designers, developers and students at applied sciences universities in the Netherlands. They were expected to have moderate to high videoconferencing familiarity as a result of the heavily used distance communicating tools at their work/study during the COVID19-induced lockdowns. The experiment took place in a guest lecture given live (in real-time) in the videoconferencing format by one of the supervisors of this thesis research. The lecture was free and its topic was creative artificial intelligence. The attendees could volunteer to participate in this experiment and the lecture was in no way a requirement for or contributor to the curricular development of attending students. During the lecture, attendees (referred to as "students" in the rest of this paper) and the teacher were all located at different places. This study adopted a within-subject design. The lecture was split into two parts (the first half and the second half) that are given in sequence. Each part was given via one of the two videoconferencing tools. The same group of students therefore participated under both experimental conditions, namely using Zoom and FRAME. To consider possible order effects, the author randomly divided the students into two groups and made them have the distance class simultaneously on two different tools. As shown in Table 2, the first group of students had the first half of their lecture on Zoom (20 minutes), had a 5 minutes break, and then participated the second half via FRAME (additional 20 minutes). The other group of students had the first half of their lecture on FRAME, had a 5 minutes break, and then participated the second half via Zoom. Based on this procedure, possible carry-over effects could be considered in statistical analyses. According to previous research (Fauville et al., 2021a; Oducado et al., 2021), most people have a typical videoconference for approximately 45 minutes. Students in the same group were all in one virtual space (either Zoom or FRAME), asked to turn on their camera and able to see the teacher and other students' images.

	Experiment Group 1	Experiment Group 2
Introduction 5 mins	Introduction of the research and instructions; Sign the consent form and fill in the demographic survey	
First Half of the Lecture 20 mins	On Zoom	On FRAME
Questionnaire 5 mins	Fill in the questionnaire	Fill in the questionnaire
Break 5 mins	Break (switch room)	Break (switch room)
Second Half of the Lecture 20 mins	On FRAME	On Zoom
Questionnaire 5 mins	Fill in the questionnaire	Fill in the questionnaire

Table 2. Overview of the Experiment Procedure

Measurement

Before the experiment, participants filled in a short demographic survey asking for their age, gender, and videoconferencing experience. To examine whether participants have felt VCF during the lecture, the author measured their fatigue level after each half of the class. Considering the close relation between stress and fatigue illustrated in Bailenson (2021) and Riedl (2021)'s VCF theories and supported by previous research (see Massner, 2021; Vandenberg and Magnuson, 2021), the author also included stress as a measured variable. As shown in our proposed theoretical modal in Figure 2, the unnatural interaction with human faces on videoconferencing tools was modelled as the cause of increased fatigue and stress, and the latter two variables were hypothesized to lead to the harmed learning experience, shown as reduced learning outcome and satisfaction.

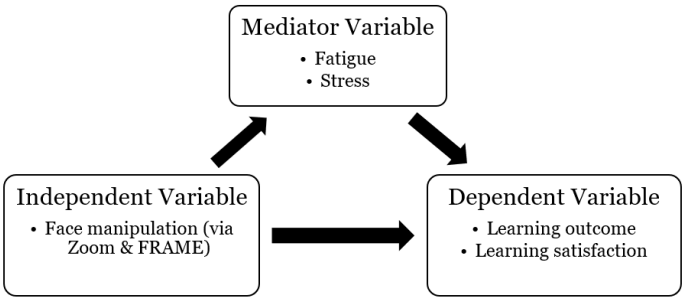

Figure 2. Theoretical Model of the Unnatural Interaction with Faces, VCF and Stress, and Learning Outcome and Satisfaction

After each half of the lecture, participants filled in a questionnaire that consisted of measurement for fatigue, stress, learning outcome, learning satisfaction and two open questions asking for participant's feedback. For fatigue measurement, the author administered Fauville et al.'s (2021b) Zoom Exhaustion & Fatigue Scale (ZEF Scale) to the participants after each half of the class. This 5-point Likert scale is based on a model of 5 factors (i.e., general fatigue, visual fatigue, social fatigue, motivational fatigue, and

emotional fatigue). General fatigue focuses on the general feeling of tiredness; visual fatigue focuses on visual symptoms; social fatigue focuses on the socially tired feelings and desire of being alone; motivational fatigue focuses on the reduced motivation to do things; emotional fatigue focuses on emotional symptoms. It comprises 15 items (see Appendix A) and constitutes a validated instrument to measure VCF (Fauville et al., 2021a; Oducado et al., 2021; Ratan et al., 2021). In the scale, the participants would choose from 1 to 5 (1 = "Not at all", 2 = "Slightly", 3 = "Moderately", 4 = "Very", 5 = "Extremely").

For stress measurement, participants filled in a five-item self-reported stress survey (see Appendix B). The survey was adapted from existing stress instruments (4 items from Cohen (1988)'s Perceived Stress Scale and 1 item from Tams et al. (2014)'s stress measure) with some adjustments to consider this research's novel context. For example, the words "in the last month" was changed to "during the distance learning just now" to directly capture the stress related to the experiment task (i.e., distance learning). The 5 items were on a 7-point scale ranging from strongly disagree to strongly agree.

Besides fatigue and stress levels, the participants' learning outcome and satisfaction was also measured to examine if a difference between Zoom and FRAME exists. The author used a quiz examining the participants' understanding about the lecture contents as the objective learning outcome. The quiz was designed by the lecturer based on the course contents and includes three statements for each half of the lecture. The participants had to judge if the statements were true or false. They could also choose "I'm not sure" if they were not sure about the correctness of the statements. Satisfaction was measured based on a two-item satisfaction survey, which was adapted from Bray et al.'s (2008) Distance Learning Questionnaire (DLQ). They developed these two items to measure students' satisfaction level in learning. Participants would choose between options ranging from 1-strongly disagree to 7-strongly agree. Items for the satisfaction measurement and quiz are listed in Appendix C and D. Additionally, there were two open questions asking if there were any significant issues that the participants experienced and if there were any thoughts that the participants would like to share regarding the video conference lecture experience; see Appendix E.

Hypothesis

Because of FRAME's advantage in reducing the number of faces and eye gaze that students perceive during the lecture, it was hypothesized that after having the online lecture in FRAME, students would have less fatigue, less stress, more satisfaction, and higher quiz performance if compared to having the lecture in Zoom. As shown in Figure 2, the author expected both (i) direct effects from the independent to the dependent variables and (ii) also a mediation effect via fatigue and stress.

Ideally, the possible difference in the scores between the two videoconferencing tools, Zoom and FRAME, could be explained by two different ways of interacting with human images on the two tools (i.e., on FRAME students would not continuously view others' images as enlarged faces at a close distance during the online lecture, while on Zoom they would). However, the navigation feature in FRAME might be a factor which cannot be fully controlled by the author and hence may affect the results. When using FRAME, participants could use the keyboard arrow keys to move, which might expend their cognitive resources and lead to a tiring feeling after the course. To limit the effect of this factor to the minimal level, participants were given a one-minute free movement period so that they could move themselves to a place that they wanted to be during the lecture, and after that, they were asked to stay at the same place until the end of the class on FRAME. The author deliberately made this experimental design decision as they observe a trade-off between ecological validity (defined as "the generalization of experimental findings to the real world outside the laboratory", Kihlstrom, 2021, p. 466) versus complete experimental isolation. In short, complete experimental isolation is hardly possible when real tools (here FRAME and Zoom) are used in the experiment. Yet, assuming that the empirical findings basically would support the theoretical model (Figure 2) in this study, future studies with a focus on experimental isolation should follow in the present study domain to complement the current investigation.

Data Analysis

After the experiment, statistical analysis was conducted to examine whether and to what extent the hypotheses hold true. For the fatigue measurement (i.e., ZEF scale), an overall ZEF score was calculated by

averaging all 15 items. Scores for each factor (i.e., general fatigue, visual fatigue, social fatigue, motivational fatigue, and emotional fatigue) were also calculated by averaging their related items according to Fauville et al. (2021b)'s model. Thus, there were the overall fatigue score, as well as general fatigue score, visual fatigue score, social fatigue score, motivational fatigue score, and emotional fatigue score. The scores ranged from 1 to 5 and the higher the score, the more fatigue the participants had. Regarding the stress, score of the fourth item was reversed due to inverted polarity of the score in relation to the others, and then all five items' scores were averaged to obtain an overall stress score. The higher the stress score was, the more stressed the participant felt. For learning satisfaction, scores of the second item were reversed due to inverted polarity of the score in relation to the first item, and then an average score (i.e., overall satisfaction) was calculated based on both items for each participant. The higher the overall satisfaction score was, the more satisfied the participant was. For the quiz, when the participant's answer was correct, a score of 1 was given to them. If their answer was incorrect or "I'm not sure", then the score was 0 for that quiz item. The total quiz score was the average score of 3 quiz items for each half of the lecture, ranging from 0 to 1. A higher quiz score means a better learning outcome. For the two open questions at the end of the questionnaire, the author read all the answers and analyzed them qualitatively.

Results

Demographics

Twenty-six people attended the online lecture experiment and 21 of them completed the whole experiment (on both Zoom and FRAME) and submitted all the questionnaires. Regarding the 5 participants who didn't complete the whole experiment, 4 of them didn't participate in the second half of the lecture or didn't answer the questionnaire after the second-half lecture; while 1 participant didn't participate in the first-half lecture or didn't submit the questionnaire for it, as shown in Table 3. No specific reason was known for their incomplete participation. One participant (#17) commented "I think the situation of having the experiment / lecture being done in the evening amount considerably to the amount of fatigue one will experience. In my personal situation I just had a dinner and had trouble not falling asleep" in the open question section in the questionnaire after having their first-half lecture on Zoom. It could be guessed that the participant dropped out perhaps because they felt sleepy and thus didn't want to continue. The other 4 participants didn't give any comments related to the incomplete participation in the questionnaire. In the following data analysis, these 5 participants' data were removed because the author wanted to analyze the data from participants who experienced both tools to examine the tool effect with minimized influence of individual differences among participants.

Participant ID	First Half of the Lecture	Second Half of the Lecture
14	On FRAME (data missing)	On Zoom
17	On Zoom	On FRAME (data missing)
20	On FRAME	On Zoom (data missing)
33	On Zoom	On FRAME (data missing)
43	On Zoom	On FRAME (data missing)

Table 3. Participant Dropout During the Experiment (N=5)

Among the 21 participants who completed the whole experiment, 10 of them had the first half of the lecture on Zoom and the second half on FRAME, while the rest 11 participants experienced the opposite order of videoconferencing tools. Their demographic results are shown in Table 4. In total, there were 12 males and 9 females. Their age ranged from 21 to 63, and the average age was 29. Their average familiarity level with video games / Zoom / FRAME / Other video tools was 1.57 / 1.62 / 0.05 / 1.90, respectively (0 = never; 1 = less than once a week; 2 = once or twice a week; 3 = three or four times a week; 4 = more than four times a week). Most of the participants had previous experience with Zoom or other videoconferencing tools. However, except one participant, all the other participants had never used FRAME before the experiment.

Categories	N	Percentage
Gender		

Female	9	43%
Male	12	57%
Other/Prefer not to say	0	0%
Age		
21-30	16	76%
31-40	2	10%
41+	3	14%
Frequency: video games		
Never	7	33%
Less than once a week	6	29%
Once or twice a week	1	5%
Three or four times a week	3	14%
More than four times a week	4	19%
Frequency: Zoom		
Never	3	14%
Less than once a week	7	33%
Once or twice a week	8	38%
Three or four times a week	1	5%
More than four times a week	2	10%
Frequency: FRAME		
Never	20	95%
Less than once a week	1	5%
Frequency: other video-conferencing tools		
Never	2	10%
Less than once a week	6	29%
Once or twice a week	8	38%
Three or four times a week	2	10%
More than four times a week	3	14%

Table 4. Participants' Demographic Information (N=21)

Tool Effect on Fatigue and Stress

Overall, participants had mild- to moderate-level of stress (3.24 for FRAME condition and 2.44 for Zoom condition on a 7-point scale) and fatigue (2.37 for FRAME condition and 2.25 for Zoom condition on a 5-point scale). Paired samples t-test showed that compared to Zoom, online learning on FRAME led to significantly higher stress levels (t (20) = 2.22, p=0.04); see Figure 3. The average fatigue level (i.e., the overall ZEF score) for learning on FRAME was also slightly higher than learning on Zoom, but the difference was not statistically significant, as shown in Table 5.

Stress and Fatigue Scores	FRAME			Zoom			T-Test		
	N	Mean	SD	N	Mean	SD	t	df	P
Stress Score (Overall)	21	3.24	1.36	21	2.44	0.98	2.22	20	**0.04***
ZEF Score (Overall)	21	2.37	0.81	21	2.25	0.68	0.82	20	0.42
ZEF General	21	2.65	1.13	21	2.59	0.87	0.27	20	0.79
ZEF Visual	21	2.02	0.99	21	2.02	0.79	0.00	20	1.00
ZEF Social	21	2.30	0.94	21	2.24	0.97	0.32	20	0.75
ZEF Motivational	21	2.56	0.82	21	2.32	0.84	1.68	20	0.11
ZEF Emotional	21	2.30	0.95	21	2.10	0.66	1.23	20	0.23

Table 5. Fatigue and Stress Scores After Learning on Zoom and FRAME

***Notes:* ⋆ Significant at alpha of 0.05.**

Tool Effects on Learning Satisfaction and Outcome

As shown in Table 6, overall, participants had an above middle level of learning satisfaction (4.02 for FRAME and 5.21 for Zoom on a 7-point scale) and learning outcome (an average score of 0.57 for both Zoom and FRAME; 0 = incorrect answer and 1 = correct answer). The average quiz scores for FRAME-mediated learning and Zoom-mediated learning were the same.

Learning Satisfaction and Outcome	FRAME			Zoom			T-Test		
	N	Mean	SD	N	Mean	SD	t	df	P
Satisfaction Score (Overall)	21	4.02	1.78	21	5.21	1.06	-2.70	20	**0.01***
Quiz Score (Overall)	21	0.57	0.37	21	0.57	0.35	0.00	20	1.00

Table 6. Learning Satisfaction and Outcome After Learning on Zoom and FRAME

***Notes:* * Significant at alpha of 0.05.**

Compared to Zoom, distance learning on FRAME led to significantly less satisfaction (t (20) = -2.70, p = 0.01); see Figure 3. No statistical difference was found between the two tools in learning outcome (t (20) = 0.00, p = 1.00).

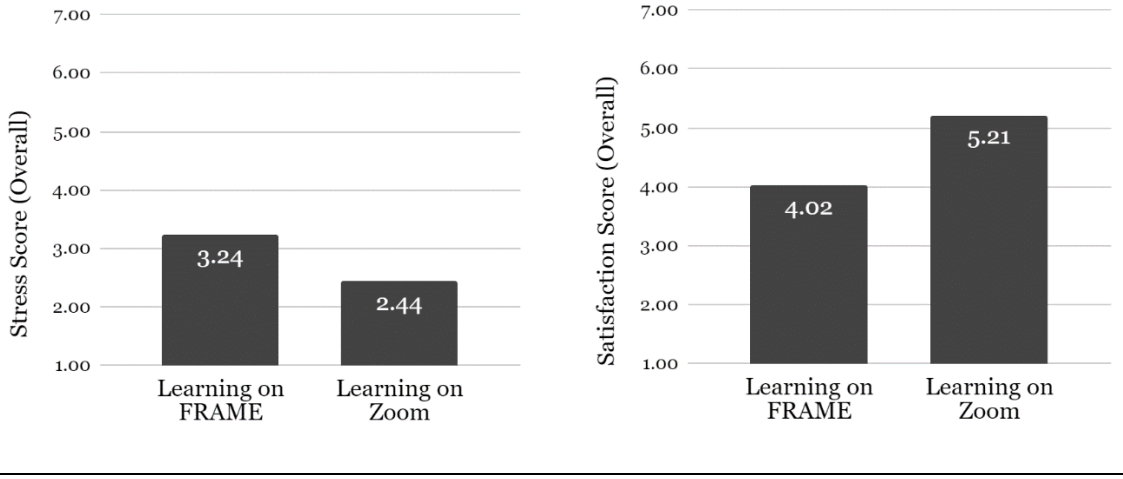

Figure 3. Difference Between FRAME and Zoom in Participants' Overall Stress (Left) and Learning Satisfaction (Right)

Mediation Analysis

In the hypothesis, it was assumed that the tool difference would cause differences in learning satisfaction and outcome, and be mediated by participants' fatigue and stress levels. From the results, we can see a statistically significant difference between Zoom and FRAME in participants' stress (no significant difference found for fatigue), as well as their learning satisfaction (no significant difference found for learning outcome). Although the tool effect might be caused by other factors rather than the face manipulation since learning on FRAME (fewer human faces displayed) turned out to lead to higher stress levels and less satisfaction than learning on Zoom (more human faces displayed), which is the opposite to our hypothesis, it's still worth exploring if the significant tool difference on the learning satisfaction is mediated by stress.

When combining all the participants' scores from both first-half and second-half lectures together, the mediation analysis (with tool as the independent variable, overall stress as the mediator, and overall satisfaction as the dependent variable) showed that the total effect between tool and satisfaction (p = 0.007) and the indirect effect (i.e., via stress; p = 0.045) were both statistically significant. The direct effect was not significant (p = 0.10); see Table 7. Therefore, it could indicate that the effect of the tool difference on the learning satisfaction was mediated by stress.

Mediation Analysis	Estimate	Std. Error	z-value	p	95% Confidence Interval	
					Lower	Upper
Direct effects (Tool→Satisfaction)	0.63	0.38	1.65	0.10	0.03	1.29
Indirect effects (Tool→Stress→Satisfaction)	0.56	0.28	2.00	**0.045***	0.06	1.21
Total effects (Tool→Satisfaction)	1.19	0.44	2.70	**0.01***	0.03	2.02

Table 7. Mediation Analysis Result

***Notes:* ⋆ Significant at alpha of 0.05.**
Delta method standard errors, bias-corrected percentile bootstrap confidence intervals, ML estimator.

However, when splitting the data into first-half and second-half lecture and conducting the mediation analysis on them separately, the indirect effect was no longer significant (first-half lecture: $p = 0.11$; second-half lecture: $p = 0.25$). For the first-half lecture, the total effect ($p = 0.004$) and direct effect ($p = 0.02$) were significant; while for the second-half lecture, neither the total effect ($p = 0.3$) nor the direct effect ($p = 0.63$) reached statistical significance.

Correlation Analysis

Correlation tests were conducted on fatigue, stress, learning satisfaction and outcome, as well as participants' previous experience with gaming and videoconferencing. A significant positive correlation between the overall stress score and overall fatigue score (both self-reported by participants on Likert scales) was revealed by Spearman's correlation test ($r_s = 0.50$, $p < 0.001$; Figure 4). Higher fatigue levels were correlated with higher stress levels, for both the FRAME-mediated learning ($r_s = 0.54$, $p = 0.01$) and Zoom-mediated learning ($r_s = 0.53$, $p = 0.01$).

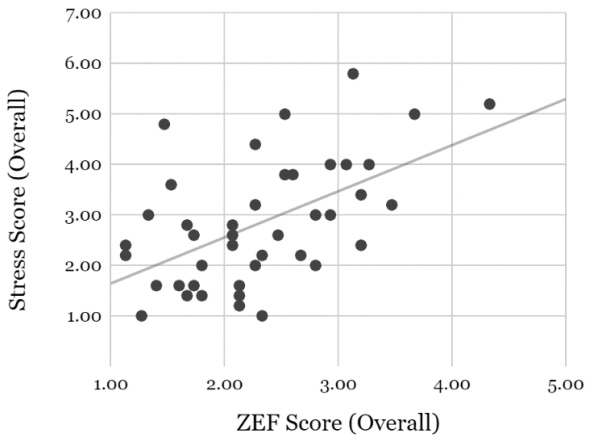

Figure 4. Correlation Between Stress and Fatigue (Zoom and FRAME Combined; N=42)

The overall stress score was also found significant negatively correlated with the overall satisfaction score ($r_s = -0.58$, $p < 0.001$), although when examining FRAME and Zoom separately, the correlation was only statistically significant for FRAME-mediated learning ($r_s = -0.62$, $p = 0.003$), not Zoom-mediated learning ($r_s = -0.41$, $p = 0.06$). For both the overall sample and the FRAME-meditated learning condition, higher stress levels were connected with lower learning satisfaction (see Figure 5).

Additionally, a negative correlation was found between the general fatigue level and the frequency of playing video games when participants had the lecture on FRAME ($r_s = -0.45$, $p = 0.04$) rather than in Zoom ($r_s = -0.28$, $p = 0.22$). General fatigue is one of the factors in the ZEF model and focuses on the general feeling of tiredness. When learning on FRAME, lower general fatigue was found correlated with higher frequency

of playing video games in the daily life (see Figure 5). The possible reason will be discussed in the Discussion and Conclusion part.

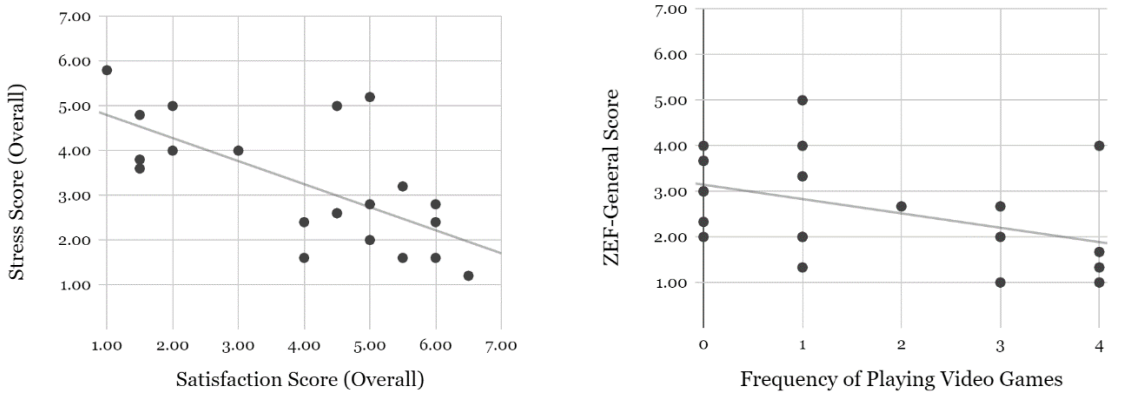

Figure 5. Correlation Between Stress and Satisfaction (Left); General Fatigue and Frequency of Playing Video Games (Right) for FRAME-Mediated Learning (N=21)

Notes: **Frequency of playing video game ranged from 0 to 4 (0 = never; 1 = less than once a week; 2 = once or twice a week; 3 = three or four times a week; 4 = more than four times a week).**

Time Effect

A comparison between the first-half and the second-half lecture was also conducted on the fatigue, stress, learning outcome and satisfaction scores. The general fatigue score was found significantly higher after the first half of lecture (*Mean* = 2.89; *SD* = 1.04) than after the second half (*Mean* = 2.35; *SD* = 0.89); t (20) = 2.70, p=0.01. After learning the first half of the lecture, participants experienced a stronger feeling of general fatigue if compared to the second half. Possible reasons will be discussed in the Discussion and Conclusion part. The author also examined this time effect for Zoom-mediated learning and FRAME-mediated learning separately, but results from ANOVA tests showed no significant difference of the general fatigue scores between the first-half lecture and second-half lecture (ps > 0.05 for both Zoom learning condition and FRAME learning condition).

Additionally, two-factor (2 x 2) ANOVA tests were conducted to examine if there were any interaction effects between time (first-half, second-half) and tool (Zoom, FRAME) on the general fatigue, visual fatigue, social fatigue, motivational fatigue, emotional fatigue, overall fatigue score, overall stress score, learning outcome and learning satisfaction. However, no significant interaction effect was found on these variables (all ps > 0.05).

Participant Feedback

In the questionnaire, two open questions were asked to participants after each half of the lecture, regardless of on which tool they had the lecture. For the question "**Did you experience any significant issues just now?**" asked after the online learning on Zoom, 20 out of 21 participants answered no issues or didn't answer this question. One of them commented "no, the conference with zoom went way better and was a more pleasant experience (than FRAME)" (Participant #08). The only participant who reported an issue said, "I was distracted by other tools around me (ex. iPad, my phone, etc)" (Participant #11).

When it comes to FRAME-mediated learning, only 7 out of 21 participants answered no issues or didn't answer this question. Three participants mentioned that FRAME crashed on their laptop. Answers include:

> *"Yes my entire browser crashed 3 times and also another program that was on" (Participant #8)*

"The tool crashed a couple of times in my browser so I had to log back in a couple of times" (Participant #22)

Four participants mentioned a problem of viewing the lecture slides on FRAME. They answered:

"In Frame, some people were standing very close to the slide, so they were blocking the view for the other participants" (Participant #12)

"This platform is not familiar with me at all. And due to other audience standing right in front of the screen, I was not able to concentrate on it" (Participant #27)

"It felt like I was either in the way of people's vision, or people were standing in the way. It's not so easy to get a clear view. It was also a bit hard to navigate." (Participant #37)

"I struggle to see the full powerpoint slides even though I tried to adjust the angle so many times…" (Participant #40)

Some participants also reported connection issues and problems in controlling their avatar in FRAME. One participant didn't point out a specific issue but commented:

"Frame doesn't feel very useful at least not more than just a normal zoom meeting" (Participant #36)

For the other open question "**Are there any thoughts you would like to share regarding the videoconferencing lecture experience just now?**", participants commented about Zoom that:

"(Zoom) was easier for me in terms of focusing on the lecture content. It was less stressful to participate in." (Participant #18)

"I was sometimes distracted by my phone" (Participant #31)

Regarding the videoconferencing lecture experience on FRAME, some participants had positive views:

"It was an interesting experience." (Participant #03)

"Liked it, VR is more free (in movement and image), just like real life." (Participant #35)

"it was nice that i could see the other participants' avatars. It made me feel that I was not alone and less stressed. Also, since I could not see the whole presentation (other avatars overlapped a bit), it somehow made me more focused on the presentation." (Participant #31)

However, more participants expressed relatively negative opinions about their videoconferencing lecture experience on FRAME:

"I think being able to move around in a virtual space like this is unnecessary and I think something like zoom just gets it straight to the point" (Participant #08)

"i found difficult to focus in FRAME" (Participant #09)

"Frame was very hard to get used to" (Participant #18)

"I have a feeling that I'm not a fan of Frame" (Participant #27)

"I think the idea of Frame is fun, but I don't think Frame is optimized at all." (Participant #19)

"I thought it was fun to walk around during the break, but otherwise distracting when I saw people move during the presentation" (Participant #37)

Discussion and Conclusion

In this study, it was hypothesized that reducing the number of human faces displayed on the videoconferencing tool during distance learning could help reduce the fatigue and stress that students

would experience in the videoconferencing lecture and thus lead to a better learning outcome and satisfaction. However, the results showed that when learning on FRAME, an innovative videoconferencing tool where attendees' faces can be seen selectively by moving and turning around in a 3D virtual environment instead of being shown in one grid on the screen, participants had significantly higher stress levels and lower learning satisfaction than learning on Zoom. This finding was the opposite to the hypothesis. To understand it, a key question is—why there were higher stress levels in FRAME-mediated learning?

A possible reason might be that although FRAME could reduce the number of human faces displayed during the lecture by allowing attendees to move around in a virtual classroom, the functionality of moving around and viewing learning-related information (such as the lecture slides) in a virtual space might introduce new factors related to stress into the learning experience. In participants' feedback in the questionnaires, issues of concentration and focus were mentioned. Participants reported that having other people's virtual avatars moving around during the online learning was distracting for them, and those people's avatars could easily block their view of the PowerPoint slides (shared by the lecturer and displayed as a standing screen in the FRAME space). As a result, participants were not able to see the slide contents clearly and some of them had to navigate or adjust their angle many times during the lecture to get a clear view of the slides. Additionally, a significant technical issue was found for FRAME-mediated learning. Participants reported that FRAME crashed for multiple times during the lecture and they had to log back to continue the lecture. Overall, they had the feeling that FRAME "doesn't feel very useful", "difficult to focus" and not optimized. One participant directly commented that Zoom was easier for them to focus on the lecture content and less stressful to participate in. Those participants' feedback suggested possible problems in FRAME's functionality and usability for online learning, which might cause the increased stress during the FRAME-mediated lecture.

When evaluating a product or tool, previous researchers have emphasized the role of functionality – whether the tool has the functions that users need. For tools adopted in learning, their functional use is very important (Tomczyk et al., 2020). A system with bad functionality would have negative influence on users' experience (Mathew et al., 2011; McNamara & Kirakowski, 2006) and potentially influence learning effectiveness (Wu et al., 2010). In the context of this research, participants' browser crashed when they were learning on FRAME and this technical issue could totally stop their learning. FRAME showed a deficit in functioning as a stable platform to provide learning contents. Different from functionality, usability focuses on whether the tool can help achieve users' goal with effectiveness, efficiency and satisfaction (Abran et al., 2003; McNamara & Kirakowski, 2006). Usability is regarded as an important quality indicator for interactive digital tools and a tool with poor usability can affect its functionality and cost users' efforts (Goodwin, 1987; Liu & Zhu, 2012). When learning on FRAME, users' avatar might stand too close to the shared screen of lecture slides and block other people's view of the slides. As a result, users had to move around in the virtual space to get a good view of the slides. During this process, they experienced difficulty in navigating, as well as in concentrating on the lecture. These issues suggest problems in FRAME's usability as a learning tool, since participants couldn't learn on FRAME with high effectiveness and satisfaction, as we can see from their feedback in the questionnaire. Participants' comments that they couldn't get used to FRAME and they weren't a fan of FRAME were also consistent with the Technology Acceptance Model (TAM) (Davis, 1985), which proposed that the perceived usefulness and perceived ease of use can affect participants' attitude and willingness of using a product. Usability was also believed to have direct impact on learning satisfaction (Liu & Zhu, 2012) and associated with stress (Heponiemi et al., 2019). In Heponiemi et al.'s research, high level of technical problems was found connected with high level of stress and psychological distress, while better functionality and usability was associated with lower stress. Higher stress levels were found associated with lower learning satisfaction for FRAME-mediated learning in our study. Thus, the poor functionality and usability of FRAME might be the cause of the increased stress level and decreased learning satisfaction that we observed in the experiment.

One of the limitations in this study is that FRAME is different from Zoom in many aspects and thus the effect of natural human face interaction on VCF and stress was not examined on two tools that have similar functionality but only differ from the face manipulation. In this research, FRAME was chosen because it provided an innovative function for users to move around and thus can provide a more natural face interaction. Although different functions were included in the comparison, this research still used FRAME, instead of using two tools with the same functionality as what Avouris et al. (2001) did in their research on system usability. The reason was that the author wanted to use real tools that might potentially have a

higher ecological validity (Kihlstrom, 2021). However, the FRAME-specific functions turned out to have caused poor functionality and usability for users who wanted to concentrate on the lecture contents, and therefore differed from Zoom in more ways than what the author wanted to manipulate in this study (i.e., face interactions) and possibly affected the results. Screenshots of Zoom and FRAME interface during the lecture are shown in Figure 6.

The use of FRAME also introduced novelty as an uncontrolled factor in this study. Demographics results revealed that participants generally had more experience with Zoom compared to FRAME. The novelty of FRAME might affect participants' feelings of fatigue. In the correlation results, lower general fatigue was found correlated with higher frequency of playing video games in the daily life for FRAME-mediated learning, not Zoom-mediated learning. This might be caused by the similarity of the virtual environment and navigation system in FRAME and video games. People with less video game playing experience may have stronger general fatigue feelings from trying to get used to the FRAME virtual environment during the online lecture, while when learning the lecture on Zoom, participants were already familiar and didn't have to learn how to use it. In future study, it would be helpful to examine the effect of human face interaction on VCF with a more complete experimental isolation, such as comparing Zoom with a modified version of it, and reduce the number of uncontrolled factors in the experiment.

Figure 6. Screenshots of the Online Lecture on Zoom (Left) and on FRAME (Right) in This Study

Notes: **The screenshots were processed by adding an image filter to anonymize the faces and thus protect participants' privacy.**

In the mediation model of tool (independent variable), stress (mediator) and learning satisfaction (dependent variable), the indirect effect of stress was statically significant when data from the two parts of the lecture were combined, while the effect was no longer significant when the mediation analysis was conducted on only the first-half lecture or the second-half lecture. A possible reason might be that when analyzing data from one half of the lecture, the sample size was too small, or the lecture time was not long enough to observe the mediation effect. The stress and fatigue level found in this study were generally on a mild to moderate level, which might also be due to the lecture length (i.e., 20 minutes for each half of the lecture), since most people have videoconferencing-mediated communication for around 45 minutes (Fauville et al., 2021a; Oducado et al., 2021). In future study, more participants and longer lecture time could be used for a better observation of VCF.

Additionally, an effect of time was found on the general fatigue level in this study. Participants' general fatigue level after the first half of the lecture turned out to be stronger than that after the second half of the lecture. This time effect might be caused by the lecture contents. During the first-half lecture, there were mainly theories being taught to the participants, while the second-half lecture included lots of fun examples and thus possibly helped reduce participants' general fatigue feelings. Another possible reason is that the first half of the lecture included more tasks than the second half. During the first-half lecture, besides the lecture itself, participants were given an introduction of the experiment and related instructions, and had to fill in a consent form and demographic survey before starting the first lecture and complete a questionnaire after it; while during the second half of the lecture, participants only had one questionnaire to complete. Therefore, there might be a lower general fatigue level among participants in the second half of the lecture. It is suggested for future research that when two parts of the lecture are compared, it is

important to consider the division of lecture contents and task workload, as well as the potential influence of them on participants' experience.

As a summary, in this study, a significant difference was found between Zoom and FRAME in participants' stress and learning satisfaction. When learning on FRAME, where attendees' faces can be seen flexibly (by controlling the virtual avatars to move and turn around) rather than be displayed in one grid on the screen, participants experienced significantly higher stress levels and lower learning satisfaction than learning on Zoom. The tool effect was believed to be caused by the functionality and usability issues in FRAME as a distance learning tool, as well as FRAME's novelty. In future research, using a real videoconferencing tool to pursue a higher ecological validity is good, but when choosing the tools, their functionality, usability, and novelty are important factors that should be taken into account. When trying to adopt game-like or virtual environments for distance education, it is also important to consider target learners' background and whether the environment will introduce new fatigue/stress-related factors into the distance learning experience. It is hoped that the present study, based on the presented theory and evidence, will instigate future research and policy making in practice as many consequences of the huge shift from more traditional learning settings to learning based on videoconferencing are hardly understood today.

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Appendices

Appendix A: Measurement Items of Fatigue

The following questions will ask about your exhaustion and fatigue feelings after the first half of the online lecture taken place in the video conferencing form. Please choose from below (1 = "Not at all", 2 = "Slightly", 3 = "Moderately", 4 = "Very", 5 = "Extremely").

- How much do you dread having to do things after video conferencing?
- How much do you want to be alone after video conferencing?
- How mentally drained do you feel after video conferencing?
- How much do you feel too tired to do other things after video conferencing?
- How emotionally drained do you feel after video conferencing?
- How irritable do you feel after video conferencing?
- How much do you tend to avoid social situations after video conferencing?
- How much do your eyes hurt after video conferencing?
- How tired do you feel after video conferencing?
- How much do you feel like doing nothing after video conferencing?
- How moody do you feel after video conferencing?
- How blurred does your vision get after video conferencing?

- How exhausted do you feel after video conferencing?
- How irritated do your eyes feel after video conferencing?
- How much do you need time by yourself after video conferencing?

Note: The words "first half" would be "second half" for the questionnaire that participants filled out after the second half of the online lecture.

Appendix B: Measurement Items of Stress

The following questions will ask about your stress after the first half of the online lecture taken place in the video conferencing form. Please choose from the points 1-7 (1 = "strongly disagree", 7 = "strongly agree").

- During the first half of the video conferencing lecture just now, I felt strain due to the video conferencing.
- During the first half of the video conferencing lecture just now, I felt nervous and "stressed".
- During the first half of the video conferencing lecture just now, I found that I could not cope with all the things that I had to do.
- During the first half of the video conferencing lecture just now, I felt that I was on top of things.
- During the first half of the video conferencing lecture just now, I felt difficulties were piling up so high that I could not overcome them.

Note: The words "first half" would be "second half" for the questionnaire that participants filled out after the second half of the online lecture; score of the fourth item was reversed in data analysis.

Appendix C: Measurement Items of Learning Satisfaction

The following questions will ask about your learning experience after the first half of the online lecture taken place in the video conferencing form. Please choose from the points 1-7 (1 = "strongly disagree", 7 = "strongly agree").

- All in all, I am satisfied with my learning in the first half of the video conferencing lecture.
- All in all, based on my own experience, I would not recommend the first half of the video conferencing lecture to my friends.

Note: The words "first half" would be "second half" for the questionnaire that participants filled out after the second half of the online lecture; score of the second item was reversed in data analysis.

Appendix D: Measurement Items of Learning Outcome

According to the lecture contents, what do you think about the statements below? (The statement is true / false / you are not sure)
Quiz items after the first half of the lecture:

- Better understanding human creativity is a goal of artificial creativity research.
- Alan Turing believed that machines could not learn.
- Douglas Hofstadter thinks that intelligent machines are not necessarily creative.

Quiz items after the second half of the lecture:

- According to Margaret Boden there are four ways of achieving creativity.
- Picasso's change in painting style is an example of "transformational creativity".
- Google's "Deep Dream" is a form of algorithmic schizophrenia.

Appendix E: Open Questions for Participants' Feedback

- Did you experience any significant issues while having the second half of the lecture on the video conferencing tool just now?

- Are there any thoughts you would like to share regarding the video conferencing lecture experience just now?