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Jiaqi Li
Leiden University, jiaqi.li7@outlook.com

Maarten H. Lamers
Leiden University, m.h.lamers@liacs.leidenuniv.nl

René Riedl
University of Applied Sciences Upper Austria, rene.riedl@fh-steyr.at

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Short Paper

Jiaqi Li
Leiden Institute of Advanced Computer Science, Leiden University
Leiden, Netherlands
j.li.21@umail.leidenuniv.nl

Maarten H Lamers
Leiden Institute of Advanced Computer Science, Leiden University
Leiden, Netherlands
m.h.lamers@liacs.leidenuniv.nl

René Riedl
University of Applied Sciences Upper Austria & Johannes Kepler University Linz
Steyr/Linz, Austria
rene.riedl@jku.at

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. Researchers have proposed multiple problems in the online interaction with human faces that may contribute to videoconference fatigue (VCF). To contribute to this upcoming new research domain, this study investigates whether VCF can be reduced if we change the unnatural interaction with multiple enlarged faces on videoconferencing tools. We compare Zoom's "speaker view" with "gallery view", and based on theoretical insights from the information processing and brain research domains, we argue that Zoom "gallery view" leads to higher fatigue and stress levels than "speaker view". Moreover, we investigate whether the face manipulation ("gallery view" vs. "speaker view") affects learning outcome and learning satisfaction, as well as the role of fatigue and stress as mediators in this relationship.

Keywords: Videoconference fatigue, Zoom fatigue, distance education, online learning, 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 and Pradhan 2020). 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 (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). 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).

However, according to Peper et al. (2021), a majority of students reported distance learning on Zoom as difficult compared to 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 videoconference 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 that developed a definition based on twelve conceptualizations of the phenomenon, we define videoconference 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 2022, p. 157). In fact, recent survey research found a positive relationship between VCF, depression, and burnout (Montag et al. 2022).

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 videoconferencing tools.

Therefore, in this study, we investigate whether students' fatigue level in distance learning can be reduced if they can interact with human images in an optimized way on videoconferencing tools. To be more precise, in order to target the potential problems underlying the VCF phenomenon, we should modify the display of student images in a way such that a student will not view others' images as many 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 and 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 and Merisotis 1999), during which 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). 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, already before the COVID-19 pandemic (Allen et al. 2004). According to 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 and 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 chance 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 and Magnuson 2021), researchers found only 25% of 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 experiencing psychological barriers such as stress and anxiety during the distance learning.

Zoom Fatigue

Overview of Theoretical Causes

Because of the massive use of videoconferencing tools for synchronous distance communication in the last two years globally, 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. 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 (2022), 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 (2022) presented theoretical insights on *possible* causes of VCF (see Table 1 for an overview) and made calls for corresponding empirical examinations.

	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 2022).	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 2022).	Viewing the self-image could lead to negative effects (Fejfar and 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 2022).	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 2022).	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,	Inter-individual neural synchronization evidence has been found for shared intention during mutual eye contact in social interaction situations (Saito et al.

	reduce coordination efficiency, and thus increase cognitive effort (Riedl 2022).	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 2022).	Internet multitasking was related to stress and had effects on burnout and anxiety (Reinecke et al. 2017).
Reduced Mobility	People must 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

As shown in Table 1, theoretically, all these factors can be possible causes of VCF. In this study, we chose to focus on the unnatural interaction with multiple faces (and their eye gaze) at close distances, not only because both Bailenson's (2021) and Riedl's (2022) theoretical frameworks explicitly indicate that the interaction with several faces in videoconferencing constitutes a major possible root cause of VCF, but also because of the special role faces play in information processing. Humans are regarded as "face experts", with highly developed visual skills and neural networks for face perception (Haxby et al. 2000). Our visual system automatically processes information from faces, such as facial expressions, and our brain is highly sensitive to this facial information (Balas et al. 2007). In electroencephalogram (EEG) research, altered EEG signals were found when multiple individuals' faces were shown and participants had to process different face identities rather than only one face or multiple inverted face stimuli (Rossion and Boremanse 2011). This sensitivity to different individual faces even emerged as early as 160 ms after the face stimulus onset (Caharel et al. 2009). The abilities to individualize and analyze faces and to process changeable facial information such as eye gaze and expression is crucial for social communication with other individuals and for the establishment and maintenance of inter-individual relationship, and hence is considered as one of the key social cognition skills in shaping human society (Parr 2011).

When using videoconferencing tools, individual faces are usually the main visual information during online communication. However, faces of videoconferencing participants are usually shown as equal-size enlarged stimuli displayed simultaneously in a grid pattern (like the default "gallery view" layout on Zoom). 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 physical rooms large groups of people are spaced in different locations, making perceived facial stimuli typically appear smaller). In face-to-face communication, we can turn around and move, selectively seeing more or fewer faces, depending on our preferences. In contrast, on videoconferencing tools like Zoom all the people's faces are shown on the medium (often displayed in a grid on the same screen, and requiring specific action from the viewer to change this visualization mode), which forces our visual system to perceive and process multiple enlarged faces during the videoconferencing session. Considering our brain's sensitivity and continuous information processing of faces with different identities and looks, this enlarged and increased amount of information potentially leads to an increased level of workload and exhaustion (Bailenson 2021).

Furthermore, the hyper eye gaze that takes place in the face interaction on videoconferencing tools can also enhance VCF. When people are communicating with others via conferencing tools, they often keep staring at a grid of others' faces for a long time (e.g., for hours) to keep the communication going and to avoid missing nonverbal signals (Bailenson 2021). 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). The negative effects of hyper eye gaze during videoconferencing might become even more severe by the enlarging of faces. 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 and Dean 1965). However, on videoconferencing tools, the distance is close while 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 2022). 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.

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 (2022). 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 a grid. 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 enlarged 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 2022) 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 enlarged faces shown on the screen simultaneously. To enable this change, one solution is to adjust the way people view the faces during videoconferencing. For example, we can enable them to control their view as if turning around in real life to selectively see different faces. However, applying this solution might introduce many confounding factors such as the navigation function and the level of flexibility. Therefore, to avoid bringing more factors than the face difference, we would like to make participants in this study still see the faces shown simultaneously on the screen, but with a focus on one face rather than having all the enlarged faces displayed with equal size. This approach is supported by a video layout feature on Zoom called "speaker view", which allows users to view the active speaker as a bigger video window and the others as smaller video windows. This is also more natural and similar to the face-to-face communication, where we gaze at a major target rather than having all the other individuals' faces perceived in equal sizes simultaneously. According to previous research, people seem 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 and 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 we adopt group meetings as the context of distance communication. Recent research revealed that people who had used the speaker view on Zoom preferred to use this view rather than the gallery view (Sample layout of these two views can be found in Figure 1) for larger meetings like online lectures (Balogova and Brumby 2022), but whether this view can effectively reduce VCF and improve learning experience has not been investigated.

Therefore, in this study, we will conduct an experiment in which a group of students will have a lecture either in the gallery view or in the speaker view on Zoom. The speaker view will limit the number of enlarged face stimuli shown on the screen and guide users' eye gaze and attention to one face (the active speaker) rather than many equal-size faces. We hypothesize that students using the speaker view, where other individuals' facial information can be limited and hence a clear focus is established (rather than seeing a large number of equal-size windows listed in a grid format), would perceive less fatigue as well as less stress than those who use Zoom's gallery view, and thus will have a better learning experience.

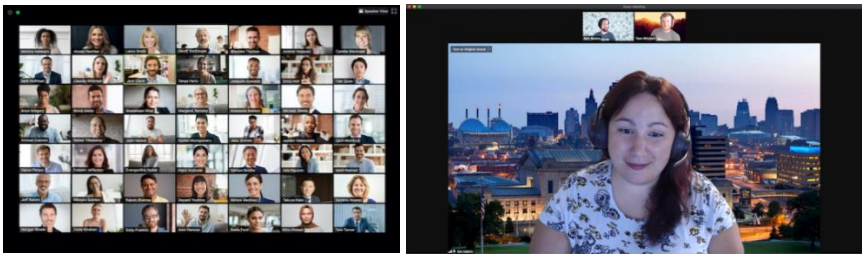

Figure 1. Zoom Gallery View (Left) and Speaker View (Right) Layout

Notes: **Both pictures are taken from https://support.zoom.us/.**

Methodology

Participants and Task

The participants in this study are students at an applied sciences university in The Netherlands that volunteered for the experiment. The experiment will take place in a non-curricular guest lecture that is given live (in real-time) in the videoconferencing format. Students and the teacher are all located at different places. Considering that in this experiment students need to all be in one virtual space, turning on their camera and being able to see the teacher and other students' images, we cannot separate the same class into two groups and make them have a distance class simultaneously on two different tools. As an alternative, this study adopts a within-subject design. The lecture will be split into two parts (part 1 and part 2) that are given in sequence, with students experiencing both parts in different experimental conditions (gallery view and speaker view). To consider possible order effects, we will recruit two groups of students. The first group of students will have the first half of their lecture on gallery view (20 minutes), have a 5 minutes break, and then participate the second half via speaker view (additional 20 minutes). The other group of students will have the first half of their lecture via speaker view, have a 5 minutes break, and then participate the second half via gallery view. Based on this procedure, possible carry-over effects can 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.

Measurement and Hypothesis

Before the experiment, participants will fill in a short demographic survey asking for their age, gender, and videoconferencing experience. To examine whether participants have felt VCF during the lecture, we will measure their fatigue level after each half of the lecture. Considering the close relation between stress and fatigue illustrated in Bailenson (2021) and Riedl (2022)'s VCF theories and supported by previous research (see Massner 2021; Vandenberg and Magnuson 2021), we also include stress as a measured variable. As shown in our proposed theoretical model in Figure 2, the unnatural interaction with human faces on videoconferencing tools is modelled as the cause of increased fatigue and stress, and the latter two variables are hypothesized to lead to the harmed learning experience, shown as reduced learning outcome (a performance measure) and satisfaction. To check whether our facial information manipulation is successful by using the speaker view, we will ask participants to evaluate the amount of facial information that they perceived during each half of the lecture (on 7-point scale ranging from very low to very high).

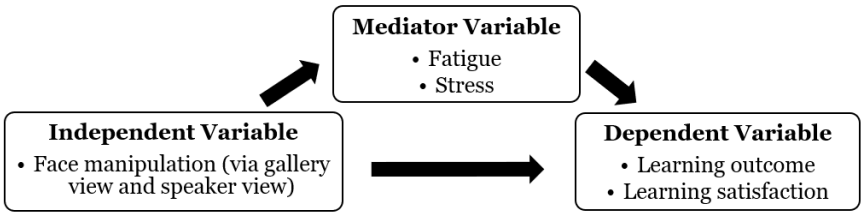

Figure 2. Theoretical Model of the Unnatural Interaction with Faces, VCF and Stress, and Learning Outcome and Satisfaction

For fatigue measurement, we administer Fauville et al.'s (2021b) Zoom Exhaustion & Fatigue Scale (ZEF Scale) to the participants after each half of the lecture. This 5-point Likert-scale comprises 15 items and constitutes a validated instrument to measure VCF (Fauville et al. 2021a; Oducado et al. 2021; Ratan et al. 2021). For stress measurement, students will fill in a five-item self-reported stress survey, being a validated instrument from Tams et al. (2014), with some adjustments to consider our novel context (7-point scale ranging from strongly disagree to strongly agree). Besides fatigue and stress levels, we would also measure students' learning outcome and satisfaction to examine if a difference between Zoom's gallery view and speaker view exists. We use a quiz examining the students' understanding about the lecture contents as the objective learning outcome. The quiz was designed by the authors based on the lecture contents and includes 5 questions. Moreover, we measure satisfaction based on a two-item satisfaction survey which we adapted from Bray et al.'s (2008) Distance Learning Questionnaire (DLQ). They developed these two items to measure students' satisfaction level in a Likert 5-point scale (ranging from 1-strongly disagree to 5-strongly agree).

Because of the speaker view's potential advantage in reducing the amount of face information that students process during the lecture, we hypothesize that after having the online lecture in the speaker view, students will have less fatigue, less stress, more satisfaction, and higher quiz performance if compared to having the lecture in gallery view. As shown in Figure 2, we expect both (i) direct effects from the independent to the dependent variables and (ii) also a mediation effect via fatigue and stress.

Current Progress and Future Direction

Currently, we are recruiting participants and plan to conduct the experiment by the end of 2022. The participants in this study are students at an applied sciences university in The Netherlands, with age ranging from 18 to 35 years. Their gender options will include female, male and other, and we expect to have a similar proportion of female and male participants. They are also expected to have moderate to high videoconferencing familiarity as a result of the heavily used distance learning tools during the COVID-19-induced lockdowns. After the experiment, we will conduct statistical analysis including paired sample *T*-Tests and mediator analysis to examine whether and to what extent our hypotheses hold true.

In our experimental design, we chose Zoom's speaker view as a facial information manipulation in comparison to Zoom's default gallery view, because we want to use an existing tool for its potential ecological validity advantage. However, we 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 Zoom) are used in the experiment. Yet, assuming that our empirical findings will support our theoretical model (Figure 2), future studies with a focus on experimental isolation should follow in the present study domain to complement the current investigation. Moreover, if the face interaction's effect on VCF can be confirmed, more natural ways of selectively viewing faces can also be explored in the videoconferencing context. Altogether, it is hoped that the present study, based on the presented theory and evidence (once collected and analyzed), 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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