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Zoom fatigue in review: A meta-analytical examination of videoconferencing fatigue's antecedents

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ABSTRACT

As videoconferencing increasingly integrates with modern life, becoming a regular part of work, education, and socialization, the adverse outcomes of increased usage have become a concern to researchers. Multiple scholars have examined Videoconference Fatigue (VF) to identify the causes of this new phenomenon. However, research has revealed conflicting findings regarding the causes of VF, highlighting the need for a meta-analysis. The present study uses quantitative meta-analysis techniques to examine 56 VF antecedents across 38 quantitative studies to examine the extent antecedent variables may affect VF. We collected quantitative studies on VF from Google Scholar, Web of Science, and PsychINFO. The present study organizes and examines the antecedents using two conceptualizations of VF (Bailenson, 2021; Li & Yee, 2022) and the Zoom Exhaustion and Fatigue (ZEF) scale (Fauv ille et al., 2021). We observed the largest effects on VF within the psychological factors category ($r = 0.24$, $k = 28$), with "feeling trapped" ($r = 0.33$, $k = 5$) being the largest predictor among uncategorized variables. The results for this study provide a map forward for research concerning negative facets of videoconferencing.

Videoconferencing platforms used to synchronously transmit pictures, voices, and data to supplant face-to-face (FtF) interactions (Lowden & Hostetter, 2012) are experiencing extensive growth, with the market size increasing by 20% in 2022 alone (33 Fascinating Video Conferencing Statistics, 2022 Data, 2022). Videoconferencing technology is increasingly integral to various aspects of modern life, extending beyond work to include socializing and education. Remote colleagues now use virtual meeting platforms to maintain social connections (Bleakley et al., 2022) and researchers have extensively evaluated the technology's adaptability and impact on e-learning (Correia et al., 2020). These studies highlight the multifaceted roles of virtual meetings, which, while beneficial, also pose challenges, warranting further scholarly investigation.

Given that videoconferencing applications are becoming an everyday tool in contemporary society, researchers are examining the outcomes of such increased usage. One chief concern is Videoconference Fatigue (VF), or Zoom Fatigue. Fatigue is an unpleasant exhaustion not relieved by standard strategies and can be physical, cognitive, and emotional (Aaronson et al., 1999). Videoconference-specific fatigue arises from extensive use and is comorbid with symptoms such as burnout or an increase in anxiety (Bailenson, 2021; Fauville et al., 2021; Li & Yee, 2022). While there is no evidence that VF has a greater or lesser negative effect on individuals than non-videoconference-based fatigue, increases in virtual meetings suggests the importance of understanding this relatively new phenomenon. VF has the potential to impact the health of frequent videoconference users (Li & Yee, 2022) and, therefore, requires a better understanding of its causes.

This study examines possible VF antecedents using quantitative meta-analysis techniques, a method where the results from a multitude of studies are systematically combined and analyzed to provide more precise estimates of effect sizes. These antecedents, which correlate with VF in the collected literature, may influence an individual's development of VF. As VF-related research is relatively new, there are too few experimental studies in the literature (see Table 2) to perform a meta-

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Table 1
Overview of conceptualizations of VF causes.

Study (Authors & Year)	Researchers Approach	Conceptualization	Possible Causes of VF
Bailenson (2021)	Theoretical Argument	4 Dimensions	Gaze Nonverbal Signals Hindered Movement Forever Mirror
Döring et al. (2022)	Conceptual Analysis	4-Dimensional Model	Personal Factors Individual Factors Social Factors Organizational Factors Temporal-Organizational Factors Context & Content Factors Technological Factors Presentation-Related Factors Communication-Related Factors Self-Related Factors Usability-Related Factors Environmental Factors Micro-Environmental Factors Macro-Environmental Factors
Li & Yee, 2022	Systematic review	5 Factors	Psychological Factors Social Factors Technical Factors Chronemic Factors Productivity Factors
Riedl (2022)	Systematic Literature Review and Media Naturalness Theory Framing	6 Root Causes	Asynchronicity of communication Lack of body language Lack of eye contact Self-Awarness Unnatural interaction with multiple faces Multitasking during videoconferences

analysis examining specific VF causal factors. Instead, the present study uses meta-analysis methods to identify factors and variables related to VF and map out a direction for future work. We identified a body of VF-related quantitative studies by examining academic publication outlets. We then selected those publications that reported quantitative results for inclusion. Statistics presented in these studies were used to calculate a standard effect size measure for two categories of VF antecedents conceptualized (Bailenson, 2021; Li & Yee, 2022) and for specific variables examined by a plurality of studies. Meta-analytic techniques, following generally established procedures (Rosenthal & DiMatteo, 2001), were used to identify categories and variables of interest for future research. Overall, our work examines two conceptualizations of VF antecedents, based on Bailenson's (2021) and Li and Yee's (2022) work, as well as the Zoom Exhaustion and Fatigue (ZEF) scale, a measure for VF (Fauville et al., 2021). Results suggest specific directions for future experimental research.

1. Bailenson (2021) Conceptualization

As a construct, fatigue is a type of exhaustion grounded in multiple physical and psychological causes (Potempa et al., 1986). It would be an oversimplification to say that spending too much time staring at a computer screen causes VF. Instead, VF likely occurs due to multiple interpersonal interactions within the digital environment (Bailenson, 2021; Nadler, 2020). Bailenson (2021) presents four dimensions of interpersonal interactions that differ within videoconferencing platforms: eye gaze, production and receiving of nonverbal signals, a mirror effect, and hindered movement. Bailenson (2021) proposed that these dimensions are antecedents for VF.

1.1. Eye gaze and interpersonal distance

Eye gaze and interpersonal distance are two forms of nonverbal communication that, alone and together, indicate intimate and non-intimate relationships. Prolonged eye contact and a closer physical distance convey high intimacy levels (Argyle & Dean, 1965; Burgoon et al., 1984). Additionally, if an individual with whom one is not intimate enters within an intimate distance (approximately 18 inches), distance violation, or crossing the threat threshold, can cause physical and psychological discomfort (Burgoon, 2015). Understanding distance and gaze carries over to digital environments, where evidence shows that individuals give more interpersonal distance to virtual humans that maintain a gaze (Bailenson et al., 2001).

Bailenson (2021) argues that these distance and gaze behaviors customarily reserved for intimate relationships are imposed on videoconferencing individuals. One is often in what would be considered an intimate distance from a computer screen, where the images of their communication partners are displayed. These images imitate constant eye gaze as individuals consistently look at each other. This way, coworkers and friends maintain a distance and gaze level generally reserved for intimate partners and close relationships. This distance violation, with non-intimate individuals being perceived as existing within an intimate distance, can create an increased level of arousal in the communicator (Burgoon, 1978).

While similar proximal violations do occur, usually in crowded public spaces such as an elevator or public transportation, videoconferencing applications do not allow for traditional avoidance mechanisms; when in uncomfortably close proximity to an individual in a public space, individuals can look down or avoid eye contact (Bailenson, 2021). Such techniques are not possible in a videoconference, where simulated eye gaze occurs through the computer monitor, with the only easy option being turning off video altogether. Additionally, this simulated gaze will occur throughout a meeting, which is uncommon in face-to-face (FtF) meetings, where, by contrast, individuals will spend a substantial portion of an interaction averting their gaze (Hanna & Brennan, 2007).

1.2. Production and receiving of nonverbal signals

Bailenson's (2021) second factor focuses on how the cognitive load of communication partners in videoconferences differs from FtF communication. This difference in cognitive load results from facets of nonverbal communication cues present in video environments. While nonverbal cues are complex in FtF meetings, individuals take on a higher

cognitive load when sending and receiving those cues in videoconferencing. This increase in cognitive load is likely due to needing to manage the technological aspects of the videoconference (Hinds, 1999). For example, in a videoconference, individuals need to monitor the camera position of their face, exaggerate head nods to signal agreement, and look into a camera to simulate eye contact (Bailenson, 2021). As a sender in a videoconference interaction, individuals must send extra cues, which take the form of monitoring nonverbal behavior and sending intentionally generated signals. Additionally, people tend to speak louder when participating in videoconferences (Croes et al., 2019). This extra monitoring and cue production increases the cognitive load of the sender in an interaction.

On the receiver side, individuals must allocate resources to correctly interpret nonverbal cues that have become non-intuitive within the digital environment. For example, people naturally draw meaning from eye and head movement in FtF communication, such as a speaker glancing at someone in a meeting to indicate turn-taking (Kleinke, 1986). While these nonverbal cues exist in videoconference environments, they are not tied to the associated meaning found in a FtF interaction. In a videoconference, if someone appears to glance at the individual in the "box" to their left, there is no accompanying meaning to the cue, as they are not glancing at the individual. Users constantly receive similar cues that do not carry the same information as those in an FtF context (Bailenson, 2021). The additional effort required to correctly interpret the meaning behind nonverbal cues creates an increased cognitive load for the receiver in an interaction.

1.3. The forever mirror

The effect of viewing oneself constantly within a virtual meeting, as if staring into a mirror, could also be an antecedent to VF. Videoconferencing software typically presents a live stream video of the user as a

Table 2
Overview of studies included in the present analysis.

Study (Authors & Year)	N	Measure	Bailenson Dimension included	Li & Yee Factor included	Research Method
Allen et al., (2022)	195	Meeting Recovery [b]	N/A	Psychological	Survey
Anh et al., (2023)	429	ZEF Scale	N/A	Technical	Survey
Bonanomi et al. (2021)	307	Online Fatigue [b]	N/A	Psychological, Social	Survey
Del Castillo-Arenillo et al. (2022)	111	ZEF Scale	N/A	Psychological	Survey
Delgado & Knox, n.d.	488	Meeting Fatigue Survey for Videoconferences (MFS-V)	N/A	Psychological, Technical	Survey
Ebardo et al., 2021	215	ZEF Scale	N/A	Psychological	Survey
Elbogen et al. (2022)	902	Zoom Fatigue [b]	N/A	Chronemic, Psychological, Social	Survey
Fauville et al. (2021b)	5506–10562 [a]	ZEF Scale	Gaze, Hinderd Movement, Mirror, Nonverbals,	Chronemic, Psychological, Social	Survey
Fauville et al., 2021b2	778	ZEF Scale	N/A	Social	Survey
Fauville et al. (2023)	7339–10448 [a]	ZEF Scale	Gaze, Hindered Movement, Mirror, Nonverbals	Chronemic, Psychological, Social	Survey
Fauville et al., 2023b	770	ZEF Scale	N/A	Social	Survey
Gijssel, 2022	77	4-Item Likert [b]	N/A	Social	Experimental
Harpool (2022)	163–290 [a]	ZEF Scale	N/A	Technical, Psychological, Social	Survey
Higgins et al. (2021)	14	1-Item Likert [b]	N/A	Psychological	Experimental
Jacquez et al. (2021)	515	ZEF Scale	N/A	Psychological	Survey
Johnson and Mabry (2022)	345	Maslach Burnout Scale	N/A	Chronemic, Psychological	Survey
Kantaş Yılmaz & Çapar (2022)	201	ZEF Scale	N/A	Chronemic	Survey
Kushlev and Epstein-Shuman (2022)	81	1-Item Likert [b]	N/A	Psychological	Survey
Lestari & Fayasari, 2022	376	ZEF Scale	N/A	Chronemic, Technical	Survey
Li (benjy), and Yee (2022)	1145	3-Item Likert [b]	N/A	Psychological, Social	Survey
Li, Lee, et al. (2022)	590	8-Item Likert [b]	N/A	Chronemic, Social	Survey
Manea, Macavei, and Pribeanu (2020a, 2020b)	177	1-Item Likert [b]	N/A	Psychological	Experimental
Mariappan and Nordin (2021)	230	ZEF Scale	N/A	Psychological	Survey
McCabe et al. (2023)	99	ZEF Scale	N/A	Chronemic	Survey
Montag et al. (2022)	311	ZEF Scale	N/A	Psychological, Social	Survey
Moralista et al. (2022)	109	ZEF Scale	Hindered Movement, Nonverbals	Psychological	Survey
Ngien & Hogan, 2023	210	ZEF Scale	N/A	Psychological	Survey
Oducado et al. (2021)	597	ZEF Scale	Mirror	Chronemic, Psychological	Survey
Oducado et al. (2022)	322	ZEF Scale	Hindered Movement, Mirror	Chronemic, Psychological, Social	Survey
Oducado (2021)	140	ZEF Scale	Gaze, Hindered Movement	Chronemic, Psychological, Social	Survey
Parkkonen and Loukola (2022)	194	ZEF Scale	N/A	Technical, Social	Survey
Phakey et al. (2023)	484	ZEF Scale	N/A	Psychological	Survey
Ratan et al. (2022)	609	ZEF Scale	N/A	Psychological, Social	Survey
Salim et al., 2022a	329	ZEF Scale	N/A	Chronemic, Psychological, Social	Survey
Sarangal and Nargotra (2022)	323	Student Digital Fatigue	N/A	Psychological	Survey
Shockley et al. (2021)	103	1-Item Likert [b]	N/A	Psychological	Experiment
Standaert et al. (2022)	814	1-Item Likert [b]	N/A	Chronemic	Survey
Zhang et al. (2023)	311	ZEF Scale	N/A	Social	Survey

[a] N varied based on variable examined.
[b] Scale developed for/unique to study in question.

default setting, viewable by both the receiver and sender in an interaction. While this live stream can be turned off, it may not always be socially acceptable or appropriate to do so, especially in work or education contexts where supervisors wish to monitor meeting participation and attention (Nguyen, 2022). This constant viewing of one's image in real-time can be detrimental; individuals are more likely to self-evaluate and self-focus when presented with a mirror image (Gonzales & Hancock, 2011), which can increase adverse effects, such as anxiety and depression (Mor & Winquist, 2002).

1.4. hindered movement

Lastly, an individual's movement is limited when participating in a videoconference. Primarily, the need to stay within the camera frame to be seen and within arm's reach of a keyboard dramatically restricts movement. This boxed-in area of participation is not conducive to those who may want to stand up, pace, stretch, and move as needed (Bailenson, 2021), and a lack of movement can hinder performance. For example, individuals produce more creative ideas when they can be locomotive (Oppezzo & Schwartz, 2014). This lack of movement could then reduce efficiency and increase stress within videoconferences.

Bailenson (2021) asserts that these dimensions—eye gaze, production and receiving of nonverbal signals, a mirror effect, and hindered movement—which differ in videoconferences from FtF communication, act as antecedents and, therefore, make VF more likely. The present study will examine the current VF literature within the framework outlined by Bailenson (2021) to identify the framework's possible explanatory power.

RQ1. What are the observed effect sizes of VF antecedents under Bailenson's (2021) four-dimension conceptualization?

2. Li and Yee (2022) Conceptualization

Li and Yee (2022) present a second conceptualization of the antecedents to VF. Their review of 14 related studies identified psychological, social, technical, chronemic, and productivity factors.

2.1. Psychological factors

Psychological factors relate to information overload and the increased cognitive effort required to focus on videoconference meetings. Research suggests that fatigue can result from increased information conveyed through videoconferencing tools (Amponsah et al., 2022). This overwhelming level of information can present in multiple ways. Li and Yee's (2022) conceptualization of the psychological factors affecting VF corresponds with Bailenson's (2021) dimensions. The interpretation of nonverbal cues, increased perceived gaze (i.e., hyper-gaze), hindered movement, and mirror anxiety are all psychological factors, according to Li and Yee's (2022) conceptualization. These items, as well as other antecedents, that may increase users' cognitive load (Amponsah et al., 2022; Fauville et al., 2021; Nesher Shoshan & Wehrt, 2022; Shahrvini et al., 2021; Wegge, 2006), makeup Li and Yee's (2022) psychological factors.

2.2. Social factors

Social factors that affect VF are related to the norms and expectations within videoconferences. They include disadvantaged social positions in the workplace (Pennington et al., 2022; Ratan et al., 2022; Shockley et al., 2021), pressure to be continuously available (Bennett et al., 2021), conflicting demands between work and private life (Vandenberg & Magnuson, 2021), and a mandate to have the computer's camera trained on users during virtual meetings (Nesher Shoshan & Wehrt, 2022). Social factors can also include the challenges of communicating virtually with others who have turned off their cameras and/or muted their microphones, eliminating some non-verbal cues that can carry semantic meaning (Li & Yee, 2022; McClave, 2000). This factor addresses the dynamic social pressures involved in workplace videoconferences, which may contribute to VF.

2.3. Technical Factors

VF's Technical factors relate to technological problems with communicating via videoconferencing devices that could result in anxiety, frustration, and fatigue. Examples of technical factors include internet disconnection issues (Bennett et al., 2021), unsatisfactory sound and video (Amponsah et al., 2022), and freezing issues (Nesher Shoshan & Wehrt, 2022).

2.4. Chronemic Factors

Chronemic factors in virtual meetings include meeting length, frequency of meetings, back-to-back meetings, and arranged meeting time (Amponsah et al., 2022; Bennett et al., 2021; Fauville et al., 2021). These chronemic factors can influence users' levels of sustained attention, leading to VF (Li & Yee, 2022).

2.5. Productivity Factors

Productivity factors pertain to workflow changes resulting from increased usage of videoconferencing. Such interruptions can include communication partners having technical issues, family interruptions, and loud background noises interrupting meetings (Amponsah et al., 2022; Shklarski et al., 2021). A state of constant disruption interfering with videoconference meetings may result in increased levels of fatigue (Li & Yee, 2022)

The present study will examine all the variables Li and Yee's (2022) perspective to understand where VF research stands when framed under this perspective. To this end, we will answer the following research question.

RQ2. What are the observed effect sizes of VF antecedents under Li and Yee's (2022) five-factor conceptualization?

3. Other VF conceptualization

While in the present study we examine VF antecedents using frameworks provided by Bailenson (2021) and Li and Yee (2022), other valuable and helpful conceptualizations of VF can aid in understanding possible causal relationships (See Table 1). Of note are the works of Riedl (2022) and Döring et al. (2022). Riedl (2022) presented six possible root causes of VF based on Media Naturalness Theory. While this framework provides interesting and valuable insights, we did not use Riedl's framework due to a need for experimental data to examine the presented 6 causes of VF that are not currently present in the literature. For example, Riedl (2022) conceptualizes videoconferences as a form of asynchronous communication, where communicators subconsciously perceive the asynchronicity of the virtual meeting within the range of milliseconds, resulting in increased cognitive effort and stress. To examine this possible cause would require specific experimental evidence that does not currently exist, to the knowledge of this paper's authors. Other causes presented by Riedl's work were not examined in the collected quantitative literature (e.g., Unnatural interaction with multiple faces and Multitasking during videoconferences) or were mirrored in the Bailenson (2021) conceptualization (e.g., Self-awareness was framed as the effect of viewing a mirrored version of oneself).

Döring et al. (2022) performed a conceptual analysis and developed a 4D model of VF. Their model consists of four dimensions, divided into ten sub-dimensions, which are then divided into twenty-one types of variables that may influence VF. While Döring et al.'s (2022) 4D-model provides valuable insight into possible VF causes, we did not address it

in our analysis due to a combination of sub-dimensions not being examined in the represented literature (e.g., Context and Content Factors) and those sub-dimensions that were examined overlapping with the work of Yi and Lee (2022) (e.g., Temporal-Organizational Factors with Chronemic Factors; Environmental Factors with Productivity Factors; and Technological Factors with Technical Factors).

4. Individual variables

While Bailenson (2021) and Li and Yee's (Li & Yee, 2022) conceptualizations of antecedents provide useful categorization frameworks for examining the sources of VF, a comparison of individual factors within the frameworks may also provide valuable insights. By its nature, any categorization will lose a level of precision held by the specificity of individual variables. Thus, to further elucidate Bailenson's (2021) and Li and Yee's (2022) conceptualizations and better understand the variables within these frameworks, we sought to compare effect sizes between the individual variables represented in the frameworks.

RQ3. What are individual antecedent variables' effect sizes on videoconference fatigue?

5. VF measures

Of equal interest in developing a theory-based classification of VF antecedents is examining how researchers measure VF. While researchers measure VF using various scales (see Table 2), Fauville et al. (2021) developed and validated the Zoom Exhaustion and Fatigue (ZEF) Scale, providing a possible standardization for measuring VF. As the ZEF scale has been disseminated and used in multiple studies, its utility as a standardized tool in VF research should be examined. We are fundamentally interested in how the ZEF scale compares to a compilation of other VF measures that have not been used in multiple studies and, thus, not adopted as a standardized measure for VF. As the ZEF scale has been substantiated for both validity and reliability, using it should provide more consistent measures of VF, allowing a more precise examination of the phenomenon.

H1. Studies that use the ZEF Scale will provide a more consistent measurement for VF than a compilation of those studies that do not use the ZEF Scale.

6. Methods

The present study organizes possible antecedents to VF into theoretical framings and then meta-analytically examines each category. We performed multiple separate meta-analyses to account for and categorize 56 possible antecedent variables to VF found across the connected studies. Additionally, VF is a new area of research with only four years of quantitative data to examine. While the collected studies lack the quantity of experimental research for a meta-analysis to identify causal effect sizes reliably, meta-analytical techniques are an appropriate method for identifying general trends in the literature (Hunter et al., 1982; Preiss & Allen, 1995; Rosenthal & DiMatteo, 2001).

6.1. Study selection and inclusion criteria

We started the study selection process by searching multiple academic databases (e.g., Google Scholar, Web of Science, and PsychINFO). We first searched for different terms related to VF (e.g., Zoom fatigue, videoconference fatigue, and CMC exhaustion). To examine our hypothesis, we also searched for "ZEF scale." We also employed a secondary search based on Yi and Lee's (2022) study. In this search, we cross-referenced our base search terms (e.g., digital, teleconference, and media) with terms found in Yi and Lee's (2022) review (e.g., overuse, burnout, anxiety). We chose these search strategies to minimize the likelihood of missing any relevant articles.

During the study selection process, we gathered articles that focused primarily on VF. Many studies refer to VF using different terminology, all of which were included in this process as they aim to describe the same phenomenon. We identified 105 studies that we could include in the final meta-analysis.

Next, we filtered out studies according to our inclusion criteria. We included only quantitative studies that examined possible antecedents to VF. While limiting our criteria to experimental studies would have allowed for causal arguments, the novelty of VF research required including observational, non-experimental studies to produce meaningful results. We eliminated Seventy-one studies because they did not include quantitative data on VF antecedents. Thus, we were left with 34 peer-reviewed articles, with four papers containing multiple studies, resulting in 38 studies to include in the analysis. We examined 56 possible Zoom Fatigue antecedents across all the collected studies.

For all studies in the set, we collected sample sizes and the reported test statistics (r, t values, F values, or β Values). Among the final sample of studies, the participant sample size ranged from 14 to 10,532, with a mean of 900.02. For studies that did not report an r value, we calculated an r value using reported t or F values, following a standard formula (Rosenthal & DiMatteo, 2001). In the case where regressions were reported, with only β values available, we used Peterson and Brown's (2005) formula for converting β to r. See Table 2 for a summary of the studies included.

To address our research questions, we recorded the antecedents examined in each study and organized them according to our framing categories. To address our hypothesis, we also recorded the scale used in each study (e.g., ZEF scale or other).

6.2. Analysis procedure

For each analysis, we followed generally established meta-analytic procedures (Rosenthal & DiMatteo, 2001). First, we calculated each study's weighted r values based on the sample size. As we were concerned with the effect size and not the direction of a given effect, we used the absolute values of our calculated r's for all analyses. We then used those values to calculate the average weighted r (*weighted* $r = (\Sigma(r^*N))/\Sigma N)$, 95% confidence intervals for r ($CI = \left(1/\left(\sqrt{(\Sigma N-1)}\right)^*1.96\right)$, variance ($\sigma^2 = \Sigma\left(N^*\sqrt{(r-\bar{r})}\right)/\Sigma N$), expected variance due to sampling error (*expected* $\sigma^2 = \left(1-\bar{r}^2\right)/(N-1)$), and unexplained variance. In the calculations for CI, 1.96 was used as there was a sufficiently large N (see Table 3) to assume a normal distribution.

7. Results

7.1. Bailenson's (2021) Four dimensions

First, we analyzed the studies that contained variables that fit into Bailenson's (2021) four dimensions (i.e., eye gaze, nonverbal signals, mirror effects, hindered movement) for RQ1. Each of these dimensions was analyzed separately, resulting in studies being analyzed in multiple categories if they examined more than one of the dimensions. For example, Fauville et al. (2021) examined VF using all four of Bailenson's (2021) suggested dimensions, thus appearing in each of our meta-analyses. We used the nonverbal cue interpretation variable for studies that reported the effect of nonverbal signal interpretation and production, which would fall under the nonverbal signals dimension. Based on Bailenson's suggested dimensions, these meta-analyses contain three to five studies (average $k = 3.75$) and an average $N = 15{,}505.5$. Hindered movement had the largest observed effect on VF, with an $r = 0.33$. See Table 3 for full results.

7.2. Li and Yee's five factors

We then analyzed the studies that contained variables that fit into Li

Table 3
Summary of meta-analyses results.

Study Subset	*K*	*N* (total)	*r* (weighted)	95% CI (±)	Variance	Expected Variance	Unexplained Variance	Correlation between *N* & *r*[a]
Bailenson Dimensions								
Forever Mirror	4	15647	0.20	0.016	0.002	0.0002	0.0015	−0.495
Hindered Movement[b]	5	15756	0.33	0.016	0.002	0.0003	0.0022	0.673
Nonverbal Signals	3	15294	0.11	0.016	0.001	0.0002	0.0005	−0.999
Gaze	3	15325	0.12	0.016	0.001	0.0002	0.0013	−0.885
Li & Yee Factors								
Social (Low)	17	22561	0.09	0.013	0.008	0.0007	0.0069	−0.281
Social (High)	17	20605	0.24	0.014	0.023	0.0007	0.0220	0.073
Chronological	13	24949	0.22	0.012	0.005	0.0005	0.0044	−0.140
Technology (Low)	5	1772	0.23	0.047	0.020	0.0025	0.0170	−0.134
Technology (High)	5	1772	0.27	0.047	0.027	0.0024	0.0242	0.065
Psychological (Low)	28	19399	0.24	0.014	0.067	0.0011	0.0658	−0.238
Psychological (High)	28	24221	0.39	0.013	0.022	0.0007	0.0214	−0.136
ZEF/Non-ZEF Scales								
ZEF Social (Low)	12	19540	0.09	0.014	0.004	0.0006	0.0038	−0.428
Non-ZEF Social (Low)	5	3021	0.11	0.036	0.021	0.0015	0.0199	−0.805
ZEF Social (High)	12	12528	0.25	0.018	0.016	0.0009	0.0147	0.422
Non-ZEF Social (High)	5	3021	0.35	0.036	0.085	0.0012	0.0840	−0.213
ZEF Chronological	8	22199	0.22	0.013	0.006	0.0003	0.0054	−0.245
Non-ZEF Chronological	5	2750	0.16	0.037	0.008	0.0017	0.0062	−0.753
ZEF Psychological (Low)	17	15319	0.19	0.016	0.053	0.0009	0.0524	−0.267
Non-ZEF Psychological (Low)	11	4080	0.48	0.031	0.020	0.0018	0.0185	0.347
ZEF Psychological (High)	17	20141	0.36	0.014	0.017	0.0006	0.0161	−0.133
Non-ZEF Psychological (High)	11	4080	0.53	0.031	0.021	0.0015	0.0193	0.200
Individual Variables								
Gender	10	19451	0.16	0.014	0.003	0.0005	0.0025	−0.072
Age	9	21811	0.15	0.013	0.004	0.0004	0.0037	0.509
Frequency	11	24141	0.16	0.012	0.010	0.0004	0.0096	−0.250
Duration	8	22583	0.21	0.013	0.001	0.0003	0.0005	0.130

[a] all correlations found significant at $p < .001$.
[b] The analysis of "Hindered Movement" & the individual variable of "Trapped" are identical, composed of the same study results. Thus "Trapped" is not shown.

and Yee's (2022) five factors to answer RQ2. We did not include the productivity factor because the studies in our sample did not examine such variables (i.e., familial interruptions while videoconferencing, difficulties with the software, etc.).

Some of the collected studies included multiple variables that could be included in a single factor. For example, Fauville et al. (2021) analyzed the feeling of being trapped, the production and interpretation of nonverbal cues, and hyper-gaze, all of which could be classified under psychological factors. To address this issue, we ran two analyses for each element. One analysis used the lowest available *r*-value, while the second used the highest available *r*-value. Of the $k = 13$ studies that addressed Chronological factors, each study only contained one variable that could be classified under Chronological aspects. For this reason, we only ran one analysis for Chronological factors. Our analysis found psychological factors to have the largest effect on VF, with a low calculated $r = 0.24$ and a high calculated $r = 0.39$. See Table 3 for full results.

7.3. Individual variables

For RQ3, we analyzed individual variables that occurred at least four times in the collected literature. This examination resulted in a separate meta-analysis for Gender ($k = 10$), Age ($k = 9$), Frequency ($k = 11$), Duration ($k = 8$), and Feeling Trapped ($k = 5$). The Feeling Trapped variable was the same analysis for the "Hindered Movement" dimension analyzed for RQ1. Our analysis found Feeling Trapped to be the largest possible predictor of VF, with an $r = 0.33$. See Table 3 for full results.

7.4. ZEF scale

Finally, to address our hypothesis, we ran the factors presented by Li and Yee (2022), subdividing each category by whether or not the ZEF scale was used. The Technology category was dropped from this analysis, as only one study in the collected literature did not use the ZEF scale. The researchers concluded that this limited number of non-ZEF scales would not provide a reliable comparison. In the analyses of the three remaining factors (Social, Chronological, and Psychological), using the ZEF scale resulted in lower r values with smaller confidence intervals (see Table 3), suggesting that the ZEF provided relatively more conservative and precise measurements of the VF construct. H1 was supported.

Additionally, usage of the ZEF scale resulted in less variance between studies and less unexplained variance (accounting for expected variance due to error) in all the categories examined except the low-score analysis of the psychological category.

7.5. Assessing publication bias

We calculated the correlation between sample size and weighted *r* to assess the potential for publication bias. The likelihood of publication bias is indicated by a negative correlation between the sample size and weighted *r*, as published studies with higher sample sizes increase the likelihood of significant findings with smaller *r* values (Levine et al., 2009). Study sample size and weighted *r* were negatively correlated for 17 out of the 25 meta-analyses run in the present study, indicating a possibility for publication bias (see Table 3). However, as the VF construct is relatively new, with the earliest collected research on VF published in 2020 (see Table 2), any publication bias indicators may be due to the necessary experimental research not yet being conducted rather than researchers not publishing studies with weaker statistical results (i.e., the file drawer effect). This is compounded by the fact that most identified studies were surveys ($k = 21$) with relatively large sample sizes (average $N = 995$). As more precise methods of identifying publication bias are statistically based on calculating a true effect size, if possible, missing studies were included (Alinaghi & Reed, 2017), and the current literature on VF lacks enough experimental research ($k = 4$) to calculate a causal effect size via meta-analyses, the researchers concluded that such publication bias tests would only misinform. Additionally, the present study is not meant to present reliable effect sizes of specific antecedents due to the scarcity of experimental research;

instead, we approached the studies meta-analytically to identify variables and categories for future VF research. Thus, we did not conduct more in-depth publication bias tests.

8. Discussion

The present study examined the current literature addressing VF antecedents. We organized quantitative data into two sets of categories, conceptualized by Bailenson (2021) and Li and Yee (2022), and meta-analyzed the resulting groupings. Additionally, we subdivided the Li and Yee (2022) categories by the type of measure used and confirmed our expectation that the ZEF provided more consistent results for examining VF antecedents.

Results from our analysis paint a picture of emerging issues surrounding VF. To reiterate, the studies around this phenomenon have been rapid, nascent, and based primarily on surveys, with many researchers calling for more diverse follow-ups, such as experiments and longitudinal studies, on their initial investigations. Despite this, we found the statistical tools used for meta-analysis helpful for understanding the current state of this emerging field and as a vital means to lay out a clear research path. Specifically, we identify how current findings point to psychological issues surrounding VF and methodological requirements that could be addressed in future research.

The most clear finding across all studies is how the feeling of being confined (i.e., stuck in a box) within the videoconferences seemed to affect a sense of fatigue. Both Bailenson's (2021) attribution of hindered movement ($r = 0.33$, $k = 5$) and Li and Yee's (2022) psychological factors ($r = 0.39$, $k = 28$), which include the "feeling of being trapped," suggest that hindered movement may play a significant role in fatigue. While Cohen (1992) suggests that such effect sizes should be interpreted as small to medium in size, he also stated that such guidelines should only be used when we lack estimates specific to the research area of interest. Such interpretations of effect sizes outside the specific research context are often considered too stringent and less useful (Funder & Ozer, 2019). Within the context of media effects, of which virtual meetings would fall, these results may be considered a relatively large effect size when compared to meta-analysis of other media effects, with effect sizes ranging from $r = 0.06$ to $r = 0.29$ (Beyea et al., 2022; Ferguson, 2015; Ratan et al., 2020). However, the present results are based primarily on large survey studies, which, in a full meta-analysis, might suggest publication bias. More research into VF is needed to confirm these observed effect sizes.

Such feelings of hindered movement could be attributed to the user interface and technology of most videoconferencing apps, which are set up to place communicators within a distinct physical location. Given how cameras and microphones are placed on most computers, users often remain close to and within the frame of the recording devices to fully participate in a meeting, which can hinder movement. And when cameras are expected to be on, people may feel pressure not to move from the frame. Indeed, many news articles have reported on employees concerned about having the correct behavior and appearance in virtual meetings (Gleason, 2021; Green, 2020; Pearson, 2023) and employers monitoring such behavior (Slabbekoorn, 2024; Tsipursky, 2024). Such concerns potentially reflect the struggle of adapting physical and social behavior to inherently limited technologies. Videoconferencing technology is primarily developed to support multiple users, allow for easy access to novice users, and provide lossless video. The technology designed around such parameters does not account for movement like pacing, stretching, and standing up (Bailenson, 2021). Thus, social and technical solutions to allow some of these physical activities would be beneficial. Such interventions could include attempts to change the norms around virtual meetings. Outside of taking breaks from the expected physical requirements of sitting close enough to the computer to access a keyboard, other possible antecedents for VF could be alleviated through changes in the social and workplace expectations of meetings. For example, meeting attendees could encourage each other to stand up and walk around a room during a videoconference. Changing such norms could be a preventative measure to VF, much as Vitamin C is used to avoid a cold. Barring changes to the norms involved in the individual meeting contexts, technical interventions that allow for physical movement without breaking behavioral expectations of a meeting would be desirable. encouraging attendees to take breaks from sitting at the computer to stand up and walk around during meetings (e.g., avatars which display the person as static even while they are moving.

Feeling stuck during in-person work meetings is hardly abnormal in work contexts, with low public sentiment about cubicles and long-standing experiments with open office plans and similar design strategies to combat the isolation. However, FtF meeting spaces can be divided up differently than VF applications. Users are, for instance, given mutual and common areas to interact, which can alleviate the feeling of being monitored and encourage movements different from those constituted in boardroom settings. The prevalence of feeling stuck in place illustrates shortcomings in how virtual meeting spaces are set up and how they may make users feel bound to the screen. It also suggests the need to experiment with different design strategies to verify these connections. Additionally, future research should examine the feeling of being trapped across different modalities. A comparison of both the levels of the feeling stuck in a box and the effect this feeling has on fatigue across FtF, videoconference, and virtual reality modalities would provide insight into the value of digital meeting spaces.

Our results also underscore the psychological impact of VF. Among Yi and Lee's factors, psychological issues were the highest ($r = 0.39$) and overlapped with factors found in Bailenson's work, such as lack of nonverbal cues and increased gaze. Furthermore, psychological factors were most heavily weighted among ZEF ($r = 0.36$), and non-ZEF scales ($r = 0.53$). The rank of psychological effects across studies suggests that the toll of using videoconferencing software persists outside of specific technical or social circumstances. While users may face challenges regarding issues like connectivity, video speed, or even accessibility features built into specific platforms, the feelings associated with fatigue seem to be more universal. Users may still have a sense of intensely staring at a mirror or, conversely, feel they are being stared at during the virtual meetings, which can affect the cognitive load they comfortably tolerate. Thus, it would be worthwhile for researchers to investigate both design strategies and organizational measures for reducing cognitive load in videoconferencing environments.

Also noteworthy is the disparity between low and high weighted r scores, specifically in social (low $r = 0.09$; high $r = 0.24$) and psychological (low $r = 0.24$; high $r = 0.39$) factors. In both cases, this large disparity may indicate the value of segmenting these components further, as they could represent multiple categorizations. Bailenson's (2021) dimensions provide valuable insight for such a segmentation for the psychological factor category, as all four suggested dimensions fit within the psychological factor.

More granular work also extends to individual variables themselves. Simply put, most publications did not consistently account for the same variables across studies. This may be expected considering the nascent level of explicitly VF-focused research. However, going forward, researchers should consider and replicate, when possible, the significant relationships found in the literature. At the same time, the prevalence of certain factors, such as feeling trapped, across different variables seems to be evident. It reinforces how impactful the feeling of being hindered in videoconferences is for many users, even while more work is required to understand how this impacts those of different ages, genders, cultures, and incomes, among other factors.

While our analysis demands more expansive work in studying VF, our findings suggest that the ZEF scale would be helpful in future research. Compared to non-ZEF measures, the scale allowed for more precise results, and, as was suggested, the scale's key components dovetailed with psychological factors outlined in Li and Yee's (2022) work. Thus, the scale can lay the foundation for future quantitative research, especially in experiments, which the field lacks presently.

However, while the existing ZEF scale serves as a helpful tool to assess exhaustion and stress resulting from videoconferencing, it may not be universally applicable across all quantitative empirical study contexts. As noted by Fauville et al. (2021), the ZEF scale captures general, visual, social, motivational, and emotional fatigue after videoconferencing meetings. Interestingly, our findings revealed that studies not employing the ZEF scale showed larger effect sizes. Developing a new scale encompassing social and psychological aspects of VF could contribute to a more holistic understanding of the phenomenon. Additionally, the ZEF scale could be helpful in developing new VF measures by providing a source for convergent validity. Virtual meetings serve different communication goals and entail distinct social dynamics depending on the context (e.g., educational, social, professional). A multidisciplinary approach integrating organizational psychology, interpersonal communication, and educational psychology is essential in grappling with VF.

Finally, Li & Yee's (2022) productivity factor did not appear in the quantitative studies we examined. These workflow interruptions based on videoconferencing, such as a communication partner having difficulty using the technology, are worth empirically examining further to identify their effect on VF.

8.1. Limitations

A primary limitation of the present work is that we draw from a small number of empirical studies to make our inferences. This is evident when examining for publication bias (see Table 3), where many negative correlations indicate that most of the present research relies on studies with large sample sizes and small effect sizes. Further, our ability to make causal claims was limited, given the dearth of experimental studies in the VF literature ($k = 4$). Given the field's nascency, these limitations were unavoidable, but as VF research continues to grow, future meta-analyses should be able to make stronger claims.

It is also necessary to note that the present study does not examine all possible frameworks for VF and its antecedents (See Table 1). While we examined VF antecedents based on a specific theoretical approach (i.e., Bailenson, 2021) and literature review (i.e., Li & Yee, 2022), we do not assume that these are the only approaches to examining the construct of VF. Riedl's (2022) and Döring et al.'s (2022) framework for possible VF causes can be valuable tools for understanding this phenomenon. However, the current literature does not provide the quantitative data needed to thoroughly examine these conceptualizations through meta-analytical methods. Riedl's (2022) and Döring et al.'s (2022) work should be further explored using observational and experimental methods.

9. Conclusion

Ultimately, our findings indicate a need for future work and some potential paths to explore. Future quantitative studies of videoconferencing and VF should consider alternate methodologies (e.g., experiments, interviews) that can further refine and/or develop measurements. This work should also examine social factors based on current research literature.

We are also witnessing the emergence of new types of virtual meetings mediated by extended reality (XR) technologies, including alternate forms of videoconferencing systems that use novel cameras (e.g., Owl Labs systems). We anticipate that educational institutions and organizations will incorporate these systems and applications for various virtual interactions, from classes to work meetings. While our findings suggest VF antecedents are primarily socio-psychological, we acknowledge that VF could manifest in different ways contingent on the technological context, including when utilizing XR. For example, more embodied and immersive interactions mediated by avatars may ameliorate mirror anxiety while facilitating the Proteus effect or perspective-taking in virtual meetings (Müsseler et al., 2022; Yee & Bailenson, 2007). On the one hand, this may alleviate VF induced by excessive self-viewing or negative self-focused attention. On the other hand, it may create other affective and communication challenges, such as depersonalization or derealization (Peckmann et al., 2022). Taken together, exploring the underlying mechanism of VF in the context of emerging technologies will enhance our understanding of future meetings, virtual or otherwise.

CRediT authorship contribution statement

David Beyea: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Chaeyun Lim:** Writing – review & editing, Writing – original draft, Data curation. **Alex Lover:** Writing – review & editing, Writing – original draft, Investigation, Data curation. **Maxwell Foxman:** Writing – review & editing, Writing – original draft, Funding acquisition. **Rabindra Ratan:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Alex Leith:** Writing – review & editing, Funding acquisition.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

As a meta-analysis, the Data is from publicly available articles, listed in the article.

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