THE EFFECT OF TAKING DIFFERENT TYPES OF BREAKS DURING ONLINE LECTURES ON STUDENT ATTENTION AND LEARNING

THE PURSUIT OF A BREAKTHROUGH FORMULA: INVESTIGATING HOW BREAKS CAN BE EFFECTIVELY DESIGNED TO PROMOTE STUDENT ATTENTION DURING ONLINE LECTURES AND ENHANCE LEARNING

By KITTY M.Q. GUO, B.Sc. (Hons.)

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree Master of Science

McMaster University MASTER OF SCIENCE (2023) Hamilton, Ontario (Psychology, Neuroscience & Behaviour)

TITLE: The Pursuit of a BREAKthrough Formula: Investigating How Breaks Can Be Effectively Designed to Promote Student Attention During Online Lectures and Enhance Learning

AUTHOR: Kitty M.Q. Guo, B.Sc. (Hons) (McMaster University)

SUPERVISORS: Dr. Joseph A. Kim & Dr. Faria Sana

NUMBER OF PAGES: xiii, 110

Lay Abstract

Maintaining attention during online lectures can be particularly challenging for students, which ultimately impacts their learning. Lecture breaks are often recommended as a tool to help improve attention and learning, but there is limited guidance on how they should be designed and implemented. In this study, I examined the effectiveness of different types of breaks in an online university lecture among university students. Surprisingly, frequent short open-ended breaks led to lower quiz scores compared to one longer open-ended break or no breaks. Interestingly, students who took at least one break engaged in more media multitasking and had reduced motivation to learn during the lecture. However, stretching during these breaks resulted in better quiz performance compared to using social media or taking no breaks. Therefore, while breaks can be poorly designed and unintentionally hinder learning, they can also be strategically integrated into online lectures by incorporating stretches to promote learning.

Abstract

Attention during lectures often declines due to high cognitive demands, challenging student learning. The increasing popularity of online education, especially since the COVID-19 pandemic, has added to the attention-sustaining difficulties students face during lectures. Online lecture breaks are a promising intervention to enhance attention and learning; however, there is limited research on how they should be designed. In the current study, I investigated the effects of break duration and frequency (Experiment 1) and break activity (Experiment 2) during an online lecture on student attention and learning. In both experiments, undergraduate students watched a 50-minute video-recorded online lecture and then completed an immediate comprehension quiz and a post-lecture survey that included questions about their lecture engagement and experiences. In Experiment 2, attention was measured through probes during the lecture, and a second comprehension quiz was administered one week later. Contrary to my predictions, findings from Experiment 1 revealed that taking three 2-minute open-ended lecture breaks led to significantly lower performance on the immediate quiz compared to taking one 6-minute open-ended lecture break or no breaks. Interestingly, participants in the combined break(s) conditions reported engaging in significantly more media multitasking behaviour and decreased levels of motivation during the lecture compared to the no breaks condition. Consistent with my predictions, Experiment 2 demonstrated that taking stretching breaks during an online lecture significantly improved immediate quiz performance compared to taking social media breaks or no breaks. These findings suggest that structuring online lectures with well-designed breaks can enhance learning outcomes,

with stretching breaks showing particular promise. However, further research is needed to explore other factors that influence the quality and effectiveness of lecture breaks, as poorly designed breaks may inadvertently hinder learning.

Acknowledgements

I would like to express my sincere gratitude to my amazing supervisors, Dr. Joseph A. Kim and Dr. Faria Sana, for providing me with this opportunity and for their continuous guidance and support throughout my time in the Education and Cognition Lab as a 3QQ3 student, undergraduate thesis student, lab manager, and now a Master's student. Over the past four years, you have both provided me with many enriching learning opportunities, imparted indispensable transferable skills, and fostered in me a growth mindset that cherishes learning from every mistake and perceived "failure". Thank you both for believing in my potential and for your invaluable mentorship.

I would also like to thank my graduate supervisory committee members, Dr. Joseph A. Kim, Dr. Faria Sana, and Dr. Bruce Milliken, for their expertise, support, and valuable feedback during my Master's program. Thank you for the fruitful discussions that have fostered my curiosity and excitement for research.

Additionally, I would like to extend my gratitude to Dr. Noah D. Forrin for being such an exceptional mentor, devoting many hours towards providing me with thoughtful feedback and valuable advice over the years. Noah, you are one of the kindest, most hard-working, and most supportive people I know. Thank you for your continued guidance and support even after transitioning to the next chapter of your life beyond the lab.

To my incredible family, friends, and partner, thank you for your unconditional love and unwavering support. I am beyond grateful to be surrounded by such kind, thoughtful, supportive, strong, and positive people in my life. Thank you for being a constant source of happiness and inspiration in my life. I love you all so much.

Table of Contents

List of Figures

List of Tables

Declaration of Academic Achievement

I, Kitty M.Q. Guo, declare that I am the sole author of this thesis. However, I would like to acknowledge the valuable contributions of those who have played a role in the design and execution of the current study.

Dr. Joseph A. Kim, Dr. Faria Sana, Dr. Noah D. Forrin, and Dr. Bruce Milliken contributed to the design of this study by providing valuable suggestions and feedback.

In Experiment 1, I worked closely with Dr. Noah D. Forrin and the undergraduate thesis student at the time, Ms. Abigail J. Fisher, to create and test the study materials, and to collect and analyze the data. Mr. Simrandeep Kalsi and Mr. Cameron Whalen assisted with the attention tracking data collection on WebEx.

In Experiment 2, I worked closely with the undergraduate thesis student at the time, Mr. Vraj Shah, to create and test the study materials, and to collect and analyze the data. Ms. Ginet Segui Lines from McMaster University's research computing support group provided immense support in programming the lecture videos and attention probes onto LimeSurvey. Members of the Education and Cognition Lab also assisted in piloting the study and providing feedback. Ms. Veronica Cui spent extra hours dedicated to piloting the study and helping to address some issues with LimeSurvey. Dr. Jeremy-Marty Dugas provided helpful suggestions to combat issues that arose during data collection. Finally, Dr. Faria Sana spent many hours helping to address some unexpected issues and limitations that occurred during data collection, as well as my many questions related to data analysis and the writing of my thesis paper. This research would not have been possible without the contributions and support of these individuals.

Introduction

In today's digital era, where the growth and popularity of online education have soared, the challenge of capturing and maintaining students' attention during lectures has become more critical than ever. The rapid expansion and development of online education, particularly accelerated by the COVID-19 pandemic, has not only introduced new challenges to instructional design and education but has also highlighted the urgency of addressing long-standing issues in education. Among these challenges, the difficulty for students to sustain their attention during lectures has been particularly pronounced. Undergraduate students who have pivoted to online learning by necessity due to the COVID-19 pandemic reported more difficulty sustaining their attention during online lectures (Peper et al., 2021).

Attentiveness plays a crucial role in the learning process by acting as a vital connection between information and learning (Keller et al., 2020). Thus, it is not surprising that inattentiveness has been found to predict poorer academic performance in both in-person (Lindquist & McLean, 2011) and online (Kane & Smeekens, 2017) lecture settings. Consequently, the growing popularity of online lectures necessitates evidence-based interventions that can effectively enhance student attention during online lectures, leading to improved learning outcomes. One promising intervention that has been proposed to address this challenge is the implementation of lecture breaks.

While some research suggests the potential benefits of incorporating breaks during online lectures (Fenesi et al., 2018; Paulus et al., 2021), there is limited research examining how these breaks should be designed to optimize student attention and

learning, particularly among older students. The present study aims to examine the impact of different types of breaks on attention during online lectures and learning among university students. By examining the impact of break duration and frequency (Experiment 1) as well as break activity (Experiment 2), this research aims to provide valuable insights that can help inform the design of effective break interventions that enhance student attention and learning. This research contributes to the growing body of literature on breaks in the context of online learning and provides practical implications for students, instructors, and policymakers.

Literature Review

1.1 The Cognitive Load Theory and the Role of Working Memory in Cognitive Processes

The Cognitive Load Theory (CLT) describes the role of working memory in the learning process (Sweller, 1988). According to the CLT, working memory has limited capacity, whereas long-term memory has virtually unlimited capacity (Sweller, 2020). During the learning process, information is temporarily held in working memory, where it undergoes active processing and comprehension to facilitate its transfer into long-term memory (Sweller, 2020). However, when too much information is presented simultaneously, working memory becomes overloaded, resulting in the loss of much of that information before it can be adequately processed (Lau, 2017; Sweller, 2020). Consequently, learning is impaired as information fails to be transferred into long-term memory (Lau, 2017).

Cognitive load refers to the total mental effort demanded on working memory at a given time (Lau, 2017). It consists of three types: intrinsic, extraneous, and germane, which collectively contribute to the cognitive load experienced and must remain within the limits of working memory capacity for learning to be effective (Hasler et al., 2007). Intrinsic cognitive load is associated with the intrinsic complexity and difficulty of the learning materials (Lau, 2017; Sweller, 1988). Conversely, extraneous cognitive load refers to the ineffective and unnecessary cognitive load imposed by poor design and presentation of the material (Lau, 2017; Paas et al., 2003). This type of cognitive load does not contribute to learning, but instead, diminishes the working memory capacity available for learning processes (Bannert, 2002; Sweller, 2008). On the other hand, germane cognitive load enhances learning by facilitating the effort exerted in information processing and the building and automation of schemas (Paas et al., 2003).

It has been theorized that these three types of cognitive loads are interconnected in a way that reducing one type of load frees up cognitive capacity and resources that can be allocated to the other types (Paas et al., 2003). Since instructional design can only manipulate extraneous and germane cognitive load, instructional designers should strive to decrease extraneous cognitive load to subsequently increase germane cognitive load, thereby allowing for a more effective allocation of cognitive resources to learning processes (Kirschner, 2002; Paas et al., 2003; Sweller, 2008).

Overall, the Cognitive Load Theory provides a valuable theoretical framework for understanding the different types of cognitive load and the role of working memory in the

learning process. By effectively managing cognitive load through instructional design, instructors may optimize students' learning outcomes during online lectures.

1.2 The Impact of Cognitive Resource Depletion on Cognitive Processes

The limited capacity of working memory has been attributed to the finite resources within the cognitive system (Oberauer, 2019). According to the attention-resource model, cognitive resources, such as attention, are finite and can only be sustained so long as they are available (Davies & Parasuraman, 1982, as cited in Harris et al., 2021). As cognitive resources deplete over time, individuals often experience time-on-task effects, including mental fatigue, frequent lapses in attention, and decreased performance (Lim et al., 2010; Lim & Kwok, 2016). Self-report studies have further shown a relationship between the difficulty in sustaining attention and higher levels of perceived task workload (Warm et al., 1996, as cited in Harris et al., 2021). Moreover, this perceived task workload has been linked to mental effort and the depletion of information-processing resources, supporting the notion that resource depletion is a factor of performance decrement (Warm et al., 1996, as cited in Szalma & Claypoole, 2019; Warm et al., 2008). Neuroimaging studies using various neuroimaging tools have further supported these findings by demonstrating that lapses in attention are associated with decreases in blood flow velocity, with the magnitude of decline directly related to task demands (see Warm et al., 2008).

Ultimately, when cognitive resources are exhausted, no resources remain available for allocation towards learning processes (Oberauer, 2019; Warm et al., 2008). Thus, the effort-recovery model emphasizes the need to replenish cognitive resources after

prolonged periods of attention, energy, and motivation (Hunter et al., 2016). Without adequate recovery, fatigue, negative affect, and other adverse outcomes may increase exponentially as a function of time (Thomsen, 2006, as cited in Hunter et al., 2016; Meijman et al., 1998, as cited in Hunter et al., 2016). By considering the limitations and consequences of resource depletion, researchers can potentially optimize learning outcomes by effectively managing cognitive resources during online lectures.

1.3 Cognitively Demanding Lectures Promote Off-Task Behaviours

Lectures often impose a significant extraneous load on students' working memory, demanding the coordination of multiple mental and physical tasks over a prolonged period (Hasler et al., 2007). These tasks include concentration, information selection, processing and connecting new and prior ideas, and note-taking (Cerbin, 2018). Consequently, mind wandering, characterized by the withdrawal of attention away from the primary task towards self-generated thoughts unrelated to the task (Lindquist & McLean, 2011; Ralph et al., 2017), and related lapses in attention are common occurrences that increase in frequency over time during both in-person (Bunce et al., 2010; Lindquist and McLean, 2011) and online (Risko et al., 2012) lectures. This tendency to engage in mind wandering has been negatively associated with available cognitive resources, where time-on-task facilitates the strength of that association (Randall et al., 2014).

Mind wandering during lectures has been consistently found to have significant costs on learning outcomes, such as poorer memory of lecture material, worse test performance, and decreased motivation to learn (Lindquist & McLean, 2011; Risko et al.,

2012; Wammes et al., 2016). Importantly, mind wandering has been shown to have both immediate and long-lasting impacts on test performance and learning outcomes (Wammes et al., 2016), as information presented during these attentional gaps cannot be processed or transferred into long-term memory, ultimately hindering learning (Hasler et al., 2007; Lau, 2017).

Another common off-task behaviour during lectures is media multitasking, which further increases the extraneous cognitive load and associated learning costs (Lau, 2017). Media multitasking refers to the simultaneous engagement in multiple media activities through multiple windows on a single platform or multiple media (Vega, 2003, as cited in Lee et al., 2012). Furthermore, media multitasking during a lecture refers to alternating between the academic task at hand and engaging with media for non-academic purposes (Guinness et al., 2017). This off-task behaviour is likely influenced by both the cognitively demanding nature of lectures (Hasler et al., 2007; Neiterman & Zara, 2019) and the ubiquity and distracting nature of technological devices (Loh et al., 2016; Rosen et al., 2013). While there is no consensus on how often students engage in media multitasking during lectures, previous studies have estimated this to be around 42% of the time (Kraushaar & Novak, 2010). Additionally, Leysens and colleagues (2016) surveyed 194 undergraduate students on their media multitasking behaviours and found that over 95% of those students reported engaging in instant messaging or social media at least once during lectures. Further, Coulter-Smith (2018) found that the most common reasons for media multitasking among students is that they felt like they could get more done, the

lecturers were reading off the slides, and they felt bored, suggesting that media multitasking may be promoted by poor lecture structure and design.

Based on the Cognitive Load Theory, media multitasking may impose additional extraneous cognitive load and reduce the working memory capacity available for learning processes (Bannert, 2002; Junco & Cotton, 2012). Consistent with this theory, prior studies have found that media multitasking during lectures or during studying may result in cognitive overload (Lee et al., 2012), difficulty retaining and processing lecture material (Risko et al., 2013), and decreases in students' academic performance (Fried, 2008; Rosen et al., 2013; Wood et al., 2012). Concerningly, while students who multitask often struggle to attend to information and switch tasks effectively, they may not be aware of the costs associated with their multitasking behaviour (Ophira et al., 2009, as cited by Hollis & Was, 2016).

While the tendency to mind wander and multitask is not unique to lectures, the associated costs of these off-task and inattentive states are substantial. As some lectures are cumulative in nature, brief instances of inattentiveness may result in the failure to encode information necessary for understanding upcoming or future lecture content. The cascade model of inattention (Smallwood, 2011) further suggests that momentary attentional lapses may disrupt the cognitive system's effective use of external information and internal representations to build a model or schema required for comprehension. Ultimately, the momentary costs of poor encoding can accumulate into more significant costs at a deeper level of analysis (Smallwood, 2011). Therefore, efforts to design and

structure lectures with effective strategies and interventions that help to hold students' attention is crucial for improving learning outcomes.

1.4 Challenges in Sustaining Attention During Online Lectures

The surging popularity of online learning, particularly in recent years, fueled by the expansion of Massive Open Online Courses (MOOCs) and necessitated by the ongoing COVID-19 pandemic, has brought attention to the amplified difficulties students face in sustaining attention during online lectures. Previous studies conducted over a decade ago revealed that students found it more challenging to maintain focus and exhibit reduced engagement during online lectures compared to traditional in-person lectures (Jensen, 2011). However, despite the exponential growth, popularity, and development of online education since, students still encounter considerable difficulties in sustaining attention and learning online (Hicks et al., 2021; Peper et al., 2021).

1.4.1 *Ubiquitous Technological Distractions and Media Multitasking*

It is likely that the ubiquitous and distracting nature of technology devices and environmental factors contribute to the heightened difficulty in maintaining attention during online lectures compared to in-person lectures among students.

Technology devices, particularly mobile phones, themselves can be sources of distraction (Harris et al., 2021). For example, devices are often equipped with visual, and sometimes even audible, notifications that frequently disrupt attention. Consequently, students who rely on these devices to watch online lectures may be more susceptible to distractions as they are prompted to interact with unrelated content or engage in multitasking, such as checking notifications and replying to messages. In addition, the

absence of a physical instructor and social norms against multitasking, among other factors, may also further facilitate media multitasking and other off-task behaviours. Indeed, media multitasking has been found to be significantly more prevalent in online courses than in in-person courses for undergraduate students (Aivaz & Teodorescu, 2022; Lepp et al., 2019). Consequently, this increased engagement in media multitasking during online lectures places additional demand on attentional resources and increases cognitive load (Harris et al., 2021), compromising learning outcomes (Risko et al., 2013).

1.4.2 *Distracting Learning Environments*

The influence of the learning environment on students' attention during online lectures is another important factor to consider. Although students often have limited control over the environments in which they watch lecture videos, it is important to consider this factor.

Students may choose or be restricted to watching online lecture videos in environments that are conducive to distractions (Hollis & Was, 2016; Szpunar et al., 2013). Importantly, these environments expose students to various attention-diverting materials and stimuli that may not be present or as prominent in a traditional physical classroom (Blasiman et al., 2018). Factors such as unstable internet connections, exposure to cues associated with entertainment or relaxation, and distractions arising from the presence of housemates or being in a public space can contribute to an influx of distractions that may be beyond the students' control in the online learning environment. These distractions ultimately pose additional challenges to sustaining attention during online lectures.

1.5 Lecture Breaks as an Intervention to Improve Attention and Learning

1.5.1 *Opportunities to Reduce Cognitive Load and Replenish Cognitive Resources*

Lecture breaks, which refer to intentional pauses or intervals within the lecture, may serve as valuable opportunities to reduce cognitive load and offer students moments to replenish cognitive resources, ultimately enhancing attention and learning outcomes. As previously discussed, the CLT posits that when working memory becomes overloaded with excessive information, it hinders learning because information cannot be adequately processed and transferred into long-term memory (Lau, 2017). By incorporating lecture breaks and splitting the lecture into smaller parts, the risk of cognitive overload may be mitigated. Presenting information in more manageable chunks during a lecture may reduce cognitive load and facilitate sustained attention (Harris et al., 2021).

Moreover, the implementation of lecture breaks has been proposed to benefit attention by allowing moments for cognitive resource replenishment (Tyler & Burns, 2008). The attention-resource model suggests that the cognitive resources required during a lecture can become depleted over time, leaving few resources available for learning processes (Davies & Parasuraman, 1982, as cited in Harris et al., 2021). Considering the negative outcomes associated with resource depletion, lecture breaks may offer a respite from the prolonged period of sustained attention and processing of information, providing opportunities to replenish cognitive resources.

1.5.2 *Maintaining Lecture-Related Goals: Preventing Goal Habituation and Vigilance Decrement*

Lecture breaks have the potential to maintain high activation levels of lecture-related goals, drawing insights from research on vigilance tasks. Vigilance tasks require prolonged periods of sustained and focused attention, often involving the detection of rare target stimuli amidst a continuous stream of non-target stimuli at an uncertain time (Davies and Parasuraman, 1982, as cited by Warm et al., 2008). However, performance on such attention-demanding tasks often declines as time-on-task increases, known as vigilance decrement (Davies and Parasuraman, 1982, as cited by Oken et al., 2006). The goal habituation hypothesis suggests that the cognitive control system faces difficulties in maintaining active goal representations, which are specific desirable behaviour objectives, of a vigilance task over extended periods of time (Ariga & Lleras, 2010).

The ability to maintain goal representations is crucial for cognitive control and successful performance on cognitive tasks, as goal representations influence information processing and guide the actions and behaviours necessary to achieve desired outcomes (Braver & Cohen, 2000). However, similar to other perceptual systems, the cognitive control system may experience habituation effects when maintaining the same goal representations for prolonged durations (Ariga & Lleras, 2010). This habituation may result in a decline and absence of sustained goal simulation, leading to poorer performance on vigilance tasks (Ariga & Lleras, 2010).

Drawing from the idea of habituation in perceptual systems, Ariga and Lleras (2010) proposed that interrupting the primary vigilance task with a secondary task that requires a momentary switch in task goals may dishabituate the primary vigilance task's goal. By briefly disengaging from the primary vigilance task, its goal representation may

deactivate, and upon returning to the task, the goal's activation level may be re-strengthened, preventing full goal habituation (Ariga & Lleras, 2010).

While attending a lecture does not involve monitoring a continuous stream of stimuli to detect infrequent target stimuli, it does require sustained concentration and information processing over an extended period of time. Although there are differences in task difficulty, goals, and stimuli between lectures and traditional vigilance tasks, the demands on attention and effort required to stay attentive throughout a lecture are comparable. Thus, it is reasonable to consider the relevance of the goal habituation hypothesis to lectures and their associated goal representations.

Similar to how task switching from a primary vigilance task to a secondary task has been found to ameliorate vigilance decrement and improve task performance (Ariga & Lleras, 2010), lecture breaks may provide students with opportunities to briefly disengage from the lecture and, upon returning, re-strengthen the lecture-related goals. Consequently, this would allow the cognitive control system to prevent goal habituation and maintain high activation levels of the primary goals throughout the lecture, thereby mitigating attentional declines.

1.5.3 *Providing Preferred Conditions for Memory Consolidation*

Memory consolidation is a critical process involved in encoding and refining new memory traces, ultimately reducing susceptibility to interference and forgetting (Bönstrup et al., 2019; Dewar et al., 2012; Simmons, 2011; Walker & Stickgold, 2004; Wamsley, 2019). While sleep has been extensively studied for its role in memory consolidation across various disciplines such as molecular, physiological, and behavioural studies

(Stickgold, 2005; Walker & Stickgold, 2004), recent research has begun to investigate the effects of non-sleep rests on memory consolidation (Dewer et al., 2012).

In a study conducted by Dewar et al. (2012), it was found that a brief period of wakeful rest, where participants closed their eyes and rested quietly after a learning session, significantly improved memory retention compared to engaging in a new task. Further, the magnitude of this memory enhancement was maintained over a 7-day period (Dewar et al., 2012) and was likely associated with automatic neural-level memory reactivation, a proposed mechanism of consolidation (Wamsely, 2019). In a different study that examined motor skill learning (Bönstrup et al., 2019), alternating short practice periods with wakeful rest periods resulted in no performance improvements during the practice periods, but significant improvements were observed following the periods of rest. Neural activity observed during these periods of rest indicated the reactivation of the task processes performed during practice (Bönstrup et al., 2019), potentially protecting against interference and forgetting of the learned material (Dewar et al., 2012).

Drawing parallels between wakeful rests and lecture breaks, it is reasonable to suspect that lecture breaks may offer favourable conditions for memory consolidation by reducing attentional and cognitive demands (Wamsley, 2019) and minimizing interference (Dewar et al., 2012). Lecture breaks may facilitate the automatic reactivation of recently encoded lecture information, promoting synaptic plasticity and enhancing the consolidation of the lecture content (Dewar et al., 2012; Wamsley, 2019).

1.6 The Benefits of Breaks: Insights from Other Contexts

Prior research on the effect of online lecture breaks on attention and learning, particularly in higher education, is limited. However, studies conducted in other contexts have demonstrated the benefits of breaks. In the industrial setting, frequent short breaks during prolonged task engagement have been found to improve task performance, productivity, and fatigue management and reduce the risk of errors and accidents (see Tucker et al., 2013 for a review). Additionally, taking moderate-intensity physical activity breaks, such as dancing, has been shown to enhance selective attention among office workers when compared to those who remained seated (Altenburg et al., 2016). Breaks have also been found to be beneficial in high-stress work environments. Surgeons who took intraoperative stretching (Park et al., 2017) and calisthenic exercising (Abdelall et al., 2018) microbreaks experienced enhanced performance and mental focus.

While prior studies on work breaks suggest that taking breaks enhances task performance and cognitive processes, research on the impact of lecture breaks, specifically, remains limited and inconclusive. Furthermore, there are several crucial factors that still need to be explored and examined to provide instructors with guidance on how to strategically design effective lecture breaks.

1.7 Considering the Effect of Lecture Break Activity on Attention and Learning

1.7.1 *Physical Activity Breaks*

Among various activities that can be incorporated during lecture breaks, short active breaks have garnered significant attention within the educational context (Infantes-Paniagua et al., 2021). The majority of studies that have investigated the effect of breaks

on cognitive and learning processes in academic settings have focused on active breaks, particularly exercise breaks during in-person classes among elementary school students. For instance, Ma et al. (2014) found that brief high-intensity whole-body exercise breaks may reduce off-task behaviour among primary school students. Similarly, Buchele Harris et al. (2018) found that taking coordinated-bilateral exercise breaks, involving bilateral movements while crossing the midline of the body, improved processing speed, focused attention, concentration, and attention span among school-aged children. However, while there is some support for the benefits of exercise breaks, two systematic reviews with meta-analysis suggested that the literature on the effect of exercise breaks on cognitive processes and academic performance among elementary school students is inconsistent (Infantes-Paniagua et al., 2021) and inconclusive (Daly-Smith et al., 2018). The limited number of studies available, the heterogeneity of break designs, and the variable quality of experimental designs and outcome measures across the studies warrant caution towards drawing conclusions regarding the effect of exercise breaks on cognitive processes and academic performance among younger students (Infantes-Paniagua et al., 2021).

Although very few prior studies have investigated the effect of online lecture breaks on attention and learning among older students, one study found that calisthenic exercise breaks, compared to no breaks and non-exercise breaks, promoted attention throughout a lecture and enhanced immediate and delayed test performance among university students (Fenesi et al., 2018). This study also found that exercise breaks significantly increased physiological arousal, which was measured using heart rate and found to be associated with on-task attention and learning. The authors suggested that,

based on the hypothalamic-pituitary-adrenal activation hypothesis, exercise may have increased physiological arousal and triggered the release of stress hormones that have been found to improve attention and memory.

While some support from prior research suggests that exercise breaks during online lectures are effective in improving students' attentiveness and learning, it is important to consider that exercises may not always be feasible or appealing to all students. Alternatively, stretching breaks, which require less physical space and are more inclusive, have been found to confer the cognitive benefits of exercise breaks in the workplace (Hutabarat et al., 2020; Park et al., 2017). However, to my knowledge, their impact on attention and learning in the academic context has yet to be investigated.

1.7.2 *Social Media Breaks*

Social media breaks have gained attention as an area of exploration during lecture breaks. Social media encompasses software, applications, or services that are accessed through technological devices that allow users to connect, create, share, and discuss information and content with others (Humphreys, 2013). When used as an extension of academic engagement between students and instructors, such as using social media platforms for academic discussions, social media use can be beneficial to student learning by increasing course engagement, satisfaction, performance, and overall semester grade point average (GreGory et al., 2014, as cited in Lau, 2017; Junco et al., 2011).

However, while technological devices can be used as valuable tools for learning, they are often more distracting than beneficial during lectures, as students frequently shift their attention between the lecture and social media use, impeding their learning process

(Ravizza et al., 2014; Rosen et al., 2013; Wammes et al., 2019; Wood et al., 2012). Neiterman and Zara (2019) argue the positive effects of technology use do not outweigh the associated costs to academic performance and educational satisfaction, as temptations to engage with social media encourage off-task behaviours such as multitasking. Hollis and Was (2016) further extended these concerns to online video lectures, finding that the majority of students' task-unrelated thoughts during online lectures were related to engaging with social media, even without tangibly using it during the lecture.

The implementation of technology breaks, during which students would briefly engage with technology for non-academic purposes has been suggested to benefit students by decreasing cognitive load and freeing up resources that would otherwise be spent on thinking about engaging with technology (Lawson & Henderson, 2015; Rosen et al., 2013). Similarly, one could suggest that implementing social media breaks during lectures may help reduce cognitive load and free up cognitive resources to enhance learning.

However, in contrast to Rosen et al.'s (2013) perspective, social media breaks may impose additional load on working memory, as well as auditory and visual channels, leading to potential learning costs (Lau, 2017). According to the cognitive theory of multimedia learning, the processing of verbal and pictorial information occurs through separate channels that can only process a limited number of elements at a given time (Mayer, 2010). These channels select, organize, and integrate relevant information with existing knowledge into long-term memory (Mayer, 2010). Consequently, engaging with social media, which often involves a continuous stream of information and visual inputs,

during lecture breaks may overload these limited auditory and visual channels, thus hindering the learning process (Mayer, 2010).

Although the interest in and potential implications of social media breaks during lectures are growing, particularly in today's digital era, to the best of my knowledge, no study has examined their impact on attention and learning specifically during online lectures. Further research is needed to understand the effects of social media breaks on students' learning outcomes during online lectures.

1.8 The Present Study

The research on lecture breaks, especially in the context of higher education, is still in its early stages. While some research suggests that lecture breaks are beneficial, there is currently a lack of general guidelines for their application and implementation during online lecture videos. Additional research is needed to understand how lecture breaks can be optimally designed, as various factors may influence its effectiveness.

In the present study, I examined the effect of break frequency (Experiment 1) and break activity (Experiment 2) on attention and learning among university students during an online lecture. In both experiments, participants were undergraduate Introductory Psychology students who completed the operation span task prior to attending an online lecture session. During the lecture session, participants rated their motivation to learn the lecture content before watching a 50-minute Introductory Psychology lecture video on the topic of form perception.

In Experiment 1, participants watched the lecture with either no breaks (control condition), one 6-minute open-ended break, or three 2-minute open-ended breaks. In

Experiment 2, participants watched the lecture with either no breaks (control and replication condition) or three 2-minute open-ended breaks (replication condition), stretching breaks, or social media breaks. After the lecture, participants were given a distraction task and then completed a 48-item multiple-choice quiz on the lecture content. After the quiz, participants completed a survey, which was included to test secondary predictions and for exploratory analyses. In Experiment 2, participants were asked to complete a second quiz on the lecture content one week later.

1.9 Implications

With the rise in popularity of online lectures, particularly accelerated by the COVID-19 pandemic, students have encountered additional difficulties in maintaining their attention throughout a lecture. Therefore, it is imperative for educators and policy makers to be well-informed about such critical issues in education and be equipped with evidence-based interventions to effectively address them. Hence, there is a growing sense of urgency for interventions that can be implemented in online lectures to enhance students' attention and learning.

The present study is both important and timely as it assesses how lecture breaks can be designed as an effective intervention during online lectures. To my knowledge, this is one of the first few studies to examine the effect of different types of breaks during an online lecture on attention and learning among university students. The results will contribute to the growing literature on lecture breaks, online learning, and instructional design and will help inform students, instructors, and policy makers about the types of breaks that are conducive to learning.

Experiment 1

In Experiment 1, I examined the effect of different lecture break durations and frequencies during an online university-level lecture on attention and learning. Participants completed the operation span (OSPAN) task by the night before their scheduled online lecture session. During each lecture session, participants rated their motivation to learn the lecture content (pre-lecture motivation) and then watched a 50-minute online lecture with either no breaks (control condition), one 6-minute break, or three 2-minute breaks. All lecture breaks were open-ended breaks, meaning that participants could do whatever they wanted to do during the break(s). Following the lecture, participants completed a short distraction task, followed by a comprehension quiz on the lecture content, and then finally, a post-lecture survey, which included questions for exploratory analyses. I hypothesized that lecture break(s) would improve attention during the lecture and enhance learning compared to no lecture breaks. I also hypothesized that frequent short lecture breaks would be more beneficial for attention and learning than one long lecture break.

Methods

Participants

Undergraduate students enrolled in an Introductory Psychology course at McMaster University were recruited online through the McMaster SONA system and were pre-screened to be at least 18 years old, fluent in English, and have normal-to-corrected vision and hearing. Participants randomly signed up for a time slot in our study and were instructed to complete the pre-lecture activity prior to attending their scheduled

lecture session. Only those who did so were provided with a link to attend the online lecture session.

A power analysis using the G*Power program (Faul et al., 2007) revealed that a total of 207 participants (69 participants per condition) would allow us to have a statistical power of .90 to detect a medium effect size (f = 0.25) between conditions. A total of 211 participants completed the pre-lecture activity. Of those participants, a total of 110 participants completed the lecture session, where participants of each session were assigned to the same condition: 35 participants in the no breaks condition, 43 participants in the 6-minute break condition, and 31 participants in the three 2-minute breaks condition. All participants provided informed consent (study approved by McMaster Research Ethics Board, #5612).

Participants who completed the pre-lecture activity and attended the lecture session received 2 SONA credits. Those who only completed the pre-lecture activity received 0.5 SONA credits. Participants who chose to withdraw from the study during or after their scheduled session or decline consent for us to use their data still received 2 SONA credits for participating. SONA credits count towards extra course credits as an incentive for participation in psychological research at McMaster University. 2 SONA participation credits are worth 2 bonus marks in the psychology course that the student is enrolled in.

Materials

Pre-Lecture Activity. Participants were provided with a link to the pre-lecture activity via the participant recruitment SONA ad and email reminders. The pre-lecture

activity took place on LimeSurvey and included the letter of information, the consent form, and a link to complete the operation span task.

Operation Span (OSPAN) Task. The OSPAN task is a valid, reliable, and non-verbal test of working memory capacity (Unsworth et al., 2005). The OSPAN task used in this experiment was run on the psychology testing software, Inquisit, provided by the company, Millisecond, and takes around 20 minutes to complete. In the SONA ad and email reminders, participants were informed that they would be prompted to install an Inquisit Player/plug-in, which they could uninstall after the activity, to complete the OSPAN task. During this task, participants were presented with sequences of three to seven unrelated letters. Each letter was followed by a simple math problem and a proposed solution to the math problem—participants had to indicate whether they thought the proposed answer was correct or not. Participants had to remember the letters while solving the math problems, and then recall the sequence of letters from a provided letter matrix after a series of problems had been presented. The participant's score on the OSPAN task was calculated using the traditional "absolute OSPAN" scoring method, which is the sum of all perfectly recalled sets. The highest achievable OSPAN score for the OSPAN task used in this experiment is 75. For full details on the OSPAN task used in this experiment, please see https://www.millisecond.com/download/library/v6/ospan/automatedospan/automatedospan.manual. Note that one minor change was made to the instructions provided during the OSPAN task. By default, the instructions during the task state, "For our purposes, we can only use data where participants were at least 85% accurate on the math. Therefore, in

order for you to be asked to come back for future experiments, you must perform at least 85% on the math problems WHILE doing your best to recall as many letters as possible". I removed these instructions that were not intended for our study, as they may give participants the wrong impression that if they do not meet a certain cut-off, they will not be allowed to participate in future SONA experiments (which would negatively impact their grades). Instead, I replaced them with the following instructions, "Please do your best to perform at least 85% on the math problems while doing your best to recall as many letters as possible." This encourages participants to do well on the OSPAN task, while removing the concerns and potential risks to participants that the previous instructions had.

Lecture Session. Participants who completed the pre-lecture activity by 11:59 pm EST the night before their scheduled time slot received an email with a WebEx meeting link the morning of their scheduled time slot.

***Study Instructions*.** The following instructions were shared on the screen with participants at the start of the lecture session: 1) A researcher will change your status to "Attendee" (which disables your video and microphone during this study), 2) Please only use a single monitor (no dual-monitor set-ups), 3) Prior to the start of this study, please do NOT change any settings in WebEx or shrink the size of the WebEx window, and 4) The study will begin promptly at [time slot + 1min] with a timed Pre-Lecture Survey. Please be ready to begin then.

***Pre-Lecture Instructions*.** Participants were provided with a link in the chat to the Pre-Lecture Survey, and the following instructions were shared on the screen with them:

1) A link to a "Pre-Lecture Survey" will be pasted in the chat now, 2) Please click the link now and complete the survey (2-min time limit), and 3) After you complete the Pre-Lecture Survey, please return to WebEx to watch the lecture video.

Pre-Lecture Survey. The Pre-Lecture Survey took place on LimeSurvey and participants were given two minutes to complete it. Participants were provided with an overview of the lecture session and were then asked to type their names if they consented to participating in our study (this was also for SONA credit granting purposes). Participants were then additionally informed that they will be watching a 50-minute PSYCH 1XX3 lecture video on Form Perception (from the Winter 2021 semester) in this study and asked, "How motivated are you to learn this content while watching the lecture video? (0 - *Not at all*, 10 - *Extremely*)".

Lecture Instructions. Before the lecture video started, the following instructions were shared on the screen with participants: 1) The lecture video will begin shortly, 2) Please learn the lecture content without writing/typing any notes, 3) Following the lecture there will be a quiz, and 4) Please do NOT adjust any settings in WebEx during the lecture.

Lecture Video with Break(s). Participants watched a 50-minute pre-recorded lecture video on the topic of form perception. The lecture video was made by editing two Introductory Psychology modules on form perception (from Winter 2021) together. The lecture video was presented to the participants through the share screen function on WebEx by the researcher host of the WebEx event. Thus, participants were not provided with the opportunity to control the video in any way, including pausing, stopping, and

rewinding the video, or to see a progress bar, making it similar to watching a live video lecture, even though the lecture video was pre-recorded. In the break(s) conditions, the lecture videos were edited to provide participants with lecture break(s) (see Appendix A for the time distribution of the breaks). In the one 6-minute break condition, one 6-minute break was inserted approximately halfway through the lecture. In the three 2-minute breaks condition, three 2-minute breaks were inserted into the lecture so that the lecture was split into four, roughly equal parts. The lecture breaks were open-ended, and participants were informed that they could do whatever they wished to do during the break(s). They were also informed that audio cues (ticking sounds) during the last five seconds of the break(s) would let them know when the lecture break was about to end. A timer was visible on the screen, counting down the remaining break time.

Attention Tracking. During the lecture, participants' attention was covertly tracked using WebEx's "attention tracking" feature: (Please see https://help.webex.com/en-us/yj9y4z/Track-Participant-Attention-in-Webex-Events-Classic). The live attention tracking monitor was recorded and indicated when a participant minimized the WebEx window or accessed another window on their computer by showing an exclamation point next to their name. The attention tracking feature also provided an attention tracking report that includes the name, email address, and the percentage of time that each participant had WebEx open as the main window on their computers during the study. No private data regarding websites participants visited, programs or apps they used, or other activities were seen or collected.

Post-Lecture

Post-Lecture Instructions. Immediately after the lecture, the following instructions were shared on the screen with participants: 1) Please return to the survey you were working on before the lecture, 2) Please enter the code word: RED, 3) Then click the "Next" button to continue. (If you closed the survey earlier, you can re-open it using the link in the chat.), and 4) When you are finished please come back to the Webex Call. Do not leave the call without being debriefed first.

Distraction Task. Participants were provided with a code word, "RED", which they were asked to input into the survey before proceeding to the comprehension quiz. This served a dual-purpose, as it was both a short distraction task and a way for us to ensure that participants did not start the quiz before they finished watching the lecture.

Comprehension Quiz. Participants were given 15 minutes to complete a 48-item, multiple-choice quiz (all factual; four response options) (see Appendix B) that tested lecture content that was either stated by the lecturer or presented on the slides. As the three 2-minute breaks condition divides the lecture into four parts, the quiz was designed such that four sets of 12 questions pertained to each of those parts of the lecture. Participants were instructed to try to answer all of the questions, even if they had to guess, and to not look up any answers.

Post-Lecture Survey. Please see Appendix C. Participants were asked questions related to their preferences and impressions of lecture breaks (in general and in this study) and demographics (gender and age). They were also asked to retrospectively rate their (in)attentiveness (which included three questions focused on their attentive, inattentive, and media multitasking behaviours) and motivation during the lecture. Lastly, they

answered questions related to the exclusion criteria (e.g., if they took any notes during the lecture, used a dual monitor, or experienced any issues during the study, such as technical issues and unexpected distractions in their home environment, that prevented them from watching or hearing the lecture video for more than five minutes). At the top of the survey page, participants were instructed to answer the questions honestly and accurately and that they would still receive their SONA credits regardless of their responses. Those in the break(s) conditions were additionally asked to indicate what they did during the break(s) by selecting from a list of activities, including an "Other" option.

Design and Procedure

Experiment 1 was a two-part online study that employed a between-subjects design. Before signing up for a lecture session time slot on the McMaster SONA system, participants could read a brief description about the study, including what they would be doing, the compensation they would receive, and the estimated completion time. Once participants signed up for a time slot, they were instructed to complete the Pre-Lecture Activity, which was hosted on LimeSurvey, in a single session and by 11:59 PM EST the night before their scheduled time slot. The link to the Pre-Lecture Activity was available on the SONA ad and included the letter of information, the consent form, and a link to complete the operation span (OSPAN) task. Participants were also sent two email reminders, 48 hours and 24 hours before their scheduled time slot, to complete the Pre-Lecture Activity. Participants who completed the OSPAN task by 11:59 PM EST the night before their scheduled time slot were emailed a link to attend their scheduled online lecture session, which was hosted on WebEx.

Participants were instructed to join their scheduled lecture session 5-10 minutes early, during which they were assigned as attendees, which disabled their microphones and videos and hid their names and displays from other attendees. However, while they could not see the names or displays of other participants, they could see the total number of participants in the session. The WebEx event was locked one minute after the scheduled start time to prevent any participants from joining late.

The researcher host of the WebEx event then verbally instructed participants to read the pre-lecture instructions, which were shared on the screen with them, and to use the chat if they had any questions. At the same time, a LimeSurvey link to the Pre-Lecture Survey was sent in the chat, and participants were given 2-minute to complete it. After reading an overview of the lecture session, participants were asked to type their names for consent and SONA credit granting purposes. Those who declined consent closed their browser and left the Webex session, while those who provided consent were asked to rate their motivation to learn the lecture content. Participants then moved on to the next page, which instructed them to leave the LimeSurvey browser window open and return to WebEx to watch the lecture. They were also informed that they would be given a code word after the lecture and would be asked to return to the browser window to enter it to proceed.

Upon returning back to WebEx, participants read the lecture instructions shared on the screen, which instructed them to learn the lecture content without taking any notes and not adjust any settings in Webex during the lecture. They were also informed that there would be a quiz following the lecture. Four minutes into the session, the researcher

host verbally let the participants know that the lecture would be starting shortly. The length and frequency of breaks (no breaks vs. one 6-minute break vs. three 2-minute breaks) during the lecture were manipulated between subjects. In the no breaks condition, participants watched the lecture while taking no breaks. In the one 6-minute break condition, participants took one 6-minute break approximately halfway through the lecture. In the three 2-minute breaks condition, participants watched the video lecture in four, roughly equal parts, with a 2-minute break between each part. Participants were instructed to do whatever they wished to do during each break and were also informed that during the last five seconds of the break(s), ticking sounds would be played, letting them know that the lecture break was about to end. These instructions, along with a timer counting down the remaining break time, were visible on the screen during each break.

During the lecture, participants' attention was covertly tracked using WebEx's attention tracking tool. This tool provided an attention tracking monitor in the attendance window during the lecture, where an exclamation mark appeared next to a participant's name whenever they minimized their WebEx window or accessed another window on their computer. In order to view all participants' names and attention tracking data at the same time, the research assistant had to join the WebEx session from multiple accounts (all named "Research Assistant #") to view multiple attendance windows, as one attendance window was not big enough to display all participants' names. The research assistant recorded all attendance windows along with a timer on one screen. The timer was started when the lecture began, which enabled us to see exactly when each participant directed their attention away from the lecture. While the use of the attention

tracking tool without prior participant consent was a deceptive aspect of the study, as discussed later on, we took steps to address this by informing participants about the use of this tool during the debriefing session and obtaining re-consent.

Following the lecture, the researcher host verbally instructed participants to read the post-lecture instructions that were shared with them on the screen. Along with the instructions, they were also given the code word, "RED". Participants returned to the survey on the LimeSurvey browser window to input the code word before proceeding to complete the comprehension quiz. If any participant did not enter the given code word, it indicated that they may have moved on to the quiz before the lecture had ended, and their data were excluded.

Participants had 15 minutes to complete the Comprehension Quiz before proceeding to the Post-Lecture Survey. If participants answered "Yes" to any of the exclusion criteria questions in the Post-Lecture Survey, their data were excluded from analyses. After completing the Post-Lecture Survey, participants were instructed to return to the WebEx session. The researcher host turned their camera and mic on to debrief participants about the study, including its purpose and hypotheses, and the use of the attention tracking tool during the lecture. Participants were asked to not disclose this information to their peers. They then returned to the survey page with the debriefing consent form and were asked to re-consent or decline consent. Additionally, they were asked whether they would like to receive a summary of the results. An email with the debriefing letter attached was sent to participants after the session. Participants were

informed that they could withdraw their data up to one week after their session by emailing the researchers of the study and that there were no consequences to doing so.

Participants who attended the lecture session, regardless of whether they withdrew from the study during or after the session, completed it, or declined consent after the debriefing session, were granted 2 SONA credits. Participants who only completed the Pre-Lecture Activity were granted 0.5 SONA credits.

Covariates

Pre-Lecture Motivation. As motivation is often associated with attentiveness and performance (Esterman et al., 2014), it may likely moderate the effect of lecture break(s) on attention and learning. I suspected that participants who were more motivated were also more attentive during the lecture and performed better on the quiz.

Working Memory Capacity. I also suspected that participants' working memory capacity is likely associated with the necessity of taking break(s), and therefore, may moderate the effect of lecture break(s) on attention and learning as well. For example, participants with a lower working memory capacity may experience more cognitive load throughout the lecture and benefit more from lecture breaks compared to those with a higher working memory capacity.

Results and Discussion

Demographics and Data Exclusion

A total of 110 participants completed the study, and after applying the exclusion criteria, a total of 14 participants were excluded from analyses: nine encountered issues during the study that prevented them from watching or hearing the lecture video for more

than five minutes, one used a dual monitor, one took notes, and two started the pre-lecture survey after the lecture had started. Further, one participant was excluded on more than one of the aforementioned exclusion criteria. Thus, the final sample consisted of 96 participants, with 31 participants in the no breaks condition, 39 participants in the one 6-minute break condition, and 26 participants in the three 2-minute breaks condition.[1] The mean age (with standard deviation) and gender distribution of participants in each condition can be found in Table 1.

Table 1

Demographic Statistics of Participants Across Each Condition

		No Breaks (n=31)	One 2-Minute Break (n=39)	Three 2-Minute Breaks (n=26)
Measure				
Age	*Mean* (*SD*)	18.71 (1.47)	18.51 (0.86)	18.35 (1.20)
Gender	Woman	74%	89.7%	76.9%
	Man	22.6%	10.3%	23.1%
	Non-binary	0%	0%	0%
	Prefer Not to Say	3.2%	0%	0%

[1] While the final sample size did not reach the target sample size, given the limited resources and interesting pattern of significant results (as discussed in the Results section), data collection of Experiment 1 was not extended, but instead, Experiment 2 was pursued.

Attention

Unfortunately, numerous technical issues were encountered with the WebEx attention tracking tool, which was my primary measure of attentiveness. As a result, I relied on the retrospective attentiveness ratings from the post-lecture survey to calculate an overall attentiveness rating. Three questions in the survey asked participants to rate their attentiveness during the lecture retrospectively. Two of the questions focused on participants' inattentive behaviours, while one focused on their attentive behaviours. To calculate the overall attentiveness rating for each participant, I first calculated the mean of the ratings of the two inattentive behaviours questions. I then converted this rating to an attentive rating by subtracting it from 10 (given the 11-point Likert scale). Finally, I obtained the overall attentiveness rating by calculating the mean of the converted attentiveness rating and the rating from the attentive behaviour question.[2] The overall attentiveness rating for each participant was then used to calculate the mean attentiveness rating for each condition (Table 2).

I conducted an ANCOVA with pre-lecture motivation as a covariate, which revealed a non-significant difference in attentiveness rating between the conditions, $F(2, 92) = 1.53$, $MSE = 2.87$, $p = .221$, $\eta_p^2 = .032$.[3] Pre-lecture motivation was significantly related to attentiveness, suggesting that participants' pre-lecture motivation significantly

[2] The method used to calculate the overall attentiveness rating for each participant differed from what was pre-registered because the pre-registered method was underrepresenting attention.
[3] Despite having planned to include working memory capacity as a covariate, it was removed from the analysis as it did not differ significantly between conditions, it was non-significantly related to attentiveness, and it did not impact the significance of the results. This reasoning was also applied to the analysis of quiz performance.

accounted for some of the variation in attentiveness, $F(1, 92) = 10.93$, $MSE = 2.87$, $p = .001$, $\eta_{p^2} = .106$.

Planned contrasts were conducted to test our predictions that, on average, 1) the combined break(s) conditions would report higher levels of attentiveness than the no breaks condition, and 2) the three 6-minute breaks condition would report higher levels of attentiveness than the three 2-minute breaks condition. There was a non-significant difference in attentiveness rating between the no breaks condition and combined break(s) conditions, $t(92) = -1.59$, $p = .116$, *Cohen's d* = 0.39. In addition, there was also a non-significant difference in mean attentiveness rating between the one 6-minute break and three 2-minute breaks conditions, $t(92) = 0.53$, $p = .596$, *Cohen's d* = 0.002. The p-values were not adjusted given that these were planned contrasts based on a priori predictions (this reasoning was applied for all planned contrasts conducted). Contrary to our predictions, attentiveness during the lecture did not differ between the no breaks condition and the combined break(s) conditions, nor between the one 6-minute break condition and the three 2-minute breaks condition.

Table 2

Mean Attentiveness Ratings (0 = Not at all; 10 = Extremely) and Mean Quiz Performance (%) with Standard Deviations (SD) for Each Condition and the Combined Break(s) Conditions

	No Breaks (n=31)	One 6-min Break (n=39)	Three 2-min Breaks (n=26)	Combined Break(s) (n=65)

	Mean (SD)	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
Attentiveness	5.90 (1.65)	5.22 (1.82)	5.22 (1.87)	5.22 (1.82)
Quiz Performance	63.71 (16.45)	59.08 (17.91)	49.52 (15.09)	55.26 (17.37)

Quiz Performance

Table 2 and Figure 1 depict the learning results. A 3 (Condition: no breaks vs. one 6-minute break, vs. three 2-minute breaks; between-subjects) x 4 (Quiz Quarter: 1 vs. 2 vs. 3 vs. 4; within-subjects) repeated-measures ANCOVA with pre-lecture motivation as a covariate revealed a significant main effect of Condition, $F(2, 92) = 4.57$, $MSE = 1111.12$, $p = .013$, $\eta_p^2 = .09$, and a significant main effect of Quiz Quarter $F(3, 276) = 6.75$, $MSE = 191.56$, $p < .001$, $\eta_p^2 = .068$.[4] However, there was a non-significant interaction between Quiz Quarter and Condition, $F(6, 276) = 1.73$, $MSE = 191.56$, $p = .115$, $\eta_p^2 = .036$, indicating that differences in quiz performance across Quiz Quarters were non-significantly different between Conditions. Pre-lecture motivation, $F(1, 92) = 1.55$, $MSE = 1111.12$, $p = .217$, $\eta_p^2 = .017$, was also non-significantly related to quiz performance.

[4] A post hoc power analysis for the main effect of Condition was conducted using the G*Power program (Faul et al., 2007), revealing an observed statistical power of .77.

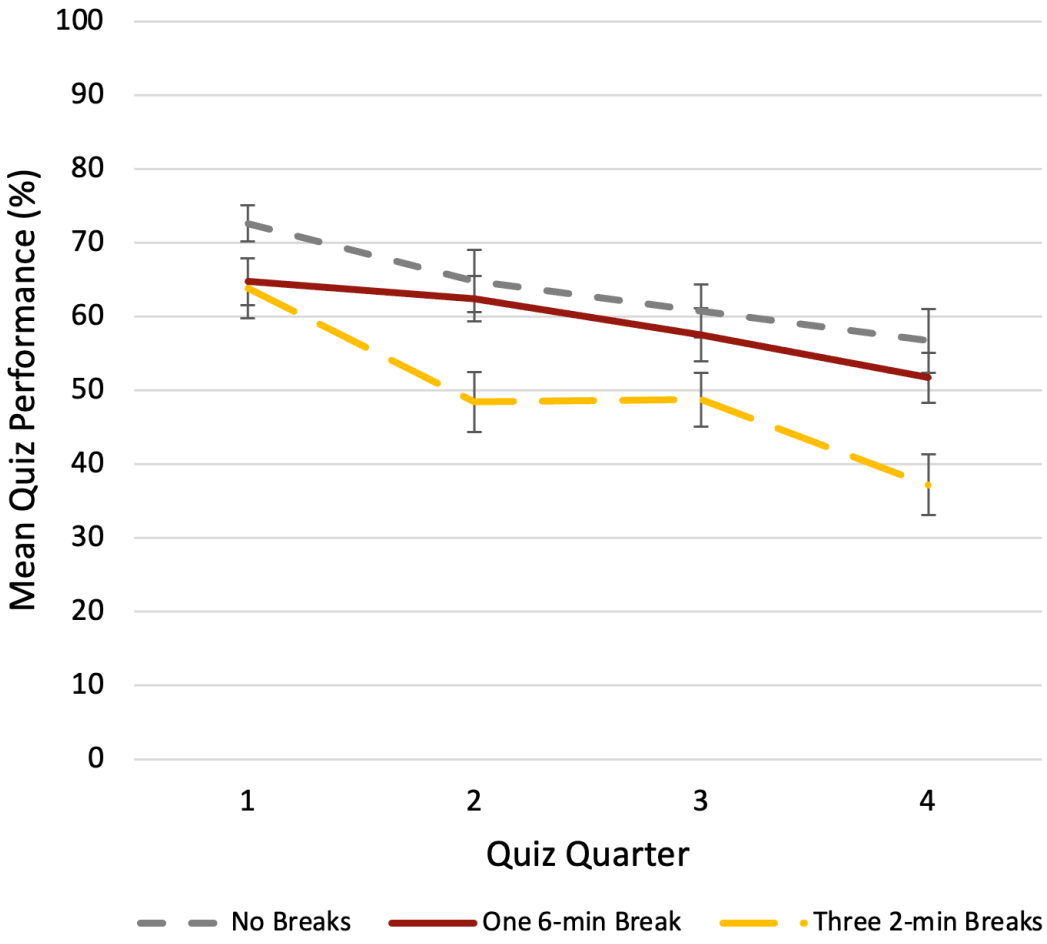


Figure 1

Mean Quiz Performance (%) with Standard Error Bars Across Quiz Quarters for Each Condition (No Break, One 6-Minute Break, and Three 2-Minute Breaks)

Quiz Performance Between Conditions. The significant difference in quiz performance between conditions suggests that some conditions may be more beneficial for learning than others. To further investigate the relationship between condition and quiz performance, planned contrasts were conducted. Contrary to our prediction that the combined break(s) conditions would, on average, perform better on the quiz than the no breaks condition, quiz performance in the combined break(s) conditions was significantly

worse, $t(92) = -2.47$, $p = .015$, *Cohen's d* = 0.50. In addition, contrary to our prediction that the three 2-minute breaks condition would, on average, perform better on the quiz than the one 6-minute break condition, the three 2-minute breaks condition performed significantly worse on the quiz, $t(92) = -2.03$, $p = .045$, *Cohen's d* = 0.58.

Post hoc comparisons (p-values adjusted using Bonferroni correction for comparing a family of 2) further revealed that while quiz performance did not differ significantly between the no breaks and one 6-minute break conditions, $t(68) = 1.18$, $p = .481$, *Cohen's d* = 0.23, participants in the no breaks condition performed significantly better on the quiz than those in the three 2-minute breaks condition, $t(55) = 3.00$, $p = .007$, *Cohen's d* = 0.65. This suggests that the significant difference between the no breaks and overall breaks conditions was driven by the lower quiz performance for multiple breaks compared to no breaks.

Not only did these findings fail to support my predictions, but I found the complete opposite pattern of results than what I had predicted. Taking no breaks during an online lecture was most beneficial to quiz performance, while taking three 2-minute open-ended breaks was most harmful to quiz performance.

Quiz Performance Across Quiz Quarters. Table 3 shows the post hoc comparisons for quiz performance across Quiz Quarters. Post hoc comparisons revealed that quiz performance in Quiz Quarter 1 was significantly greater than all other Quiz Quarters (2, 3, and 4). In addition, quiz performance in Quiz Quarters 2 and 3 were significantly higher than in Quiz Quarter 4. There was no significant difference in quiz performance between Quiz Quarters 2 and 3. As the quiz was designed such that the

questions in each quarter pertained to the content in each of those quarters of the lecture, these results suggest that learning may decrease at the beginning and at the end of online lectures but may be maintained during the middle.

Table 3

Post Hoc Comparisons for Quiz Performance Between Quiz Quarters (Q)

Comparison		*t*(95)	*Cohen's d*	p_{bonf}
Q1	Q2	4.20	0.42	< .001***
	Q3	5.57	0.55	< .001***
	Q4	9.11	0.90	< .001***
Q2	Q3	1.37	0.14	1.000
	Q4	4.91	0.49	< .001***
Q3	Q4	3.54	0.35	.003**

Note. P-value adjusted using Bonferroni correction for comparing a family of 6.

Note. Results are averaged over the levels of Condition.

* $p < .05$; ** $p < .01$; *** $p < .001$.

Correlations

A Pearson's bivariate correlation was completed for the following variables of interest: quiz performance, attentiveness, pre-lecture motivation, motivation during the

lecture (based on retrospective motivation ratings from the post-lecture survey), and working memory capacity.

Table 4 shows the correlation coefficient and p-values associated with each variable. There was a significant positive correlation between attentiveness and pre-lecture motivation and motivation during the lecture. Moreover, attentiveness and motivation during the lecture were significantly and positively correlated with quiz performance. Consistent with previous findings (Esterman et al., 2014), participants who reported being more motivated immediately before and, retrospectively, during the lecture, also retrospectively reported higher levels of attentiveness during the lecture. Furthermore, participants who retrospectively reported being more motivated and attentive during the lecture performed better on the quiz.

Contrary to previous findings (Hollis & Was, 2016), I did not find a significant correlation between working memory capacity and attentiveness or quiz performance. Specifically, higher working memory capacity was not associated with higher levels of attentiveness during the lecture or better quiz performance.

Table 4

Pearson's r Correlation Coefficients (r) and P-Values (p) for Each Measure of Interest

Measure		Quiz	Attentiveness	Pre Motiv	Motiv During Lecture	WMC
Attentiveness	*r*	.25	—			
	p	.015*	—			

Measure		Quiz	Attentiveness	Pre Motiv	Motiv During Lecture	WMC
Pre Motiv	*r*	.17	.47	—		
	p	.101	< .001***	—		
Motiv During Lecture	*r*	.29	.74	.71	—	
	p	.004**	< .001***	< .001***	—	
WMC	*r*	<.001	-.06	-.03	-.08	—
	p	1.00	.573	.746	.452	—
MM	*r*	-.29	-.48	-.17	-.28	.13
	p	.004**	<.001***	.107	.005**	.200

Note: Quiz Performance (Quiz), Attentiveness, Pre-Lecture Motivation (Pre Motiv), Motivation During Lecture (Motiv During Lecture), Working Memory Capacity (WMC), and Media Multitasking (MM).

*$p < .05$; **$p < .01$; ***$p < .001$.

Exploratory Analyses

Media Multitasking. Given the unexpected results that were contrary to what I had predicted, where taking no lecture breaks compared to taking lecture break(s) and taking one 6-minute lecture break compared to taking three 2-minute lecture breaks, led to better quiz performance, I explored whether participants' media multitasking ratings differed between the conditions. Participants' media multitasking ratings were of

particular interest as previous studies have demonstrated that media multitasking during a lecture, both in-person (Sana et al., 2013; Wood et al., 2012) and online (Junco, 2012), led to poorer academic performance.

In the post-lecture survey, participants were asked, "Overall, while the lecture video was playing, to what extent was your attention focused on things on another device, unrelated to the lecture? (0 - *Not at all*, 10 - *Extremely*)". Media multitasking was significantly and negatively correlated with quiz performance, attentiveness, and motivation during the lecture (Table 4). Participants who retrospectively reported more media multitasking during the lecture retrospectively reported less motivation and lower levels of attentiveness during the lecture and performed worse on the quiz.

Figure 2 depicts the media multitasking results. To investigate whether media multitasking ratings differed significantly between the no breaks and combined break(s) conditions, I conducted an ANCOVA with pre-lecture motivation as a covariate. Interestingly, participants in the no breaks condition ($M = 3.94$, $SD = 2.58$), on average, reported engaging in media multitasking significantly less than those in the break(s) conditions ($M = 5.25$, $SD = 2.62$), $F(1, 93) = 4.99$, $MSE = 6.71$, $p = .028$, $\eta_{p^2} = .051$. In other words, participants who took at least one open-ended break, compared to no breaks, during the online lecture reported more media multitasking, which was associated with worse quiz performance. Pre-lecture motivation was non-significantly associated with media multitasking ratings, $F(1, 93) = 2.38$, $MSE = 6.71$, $p = .126$, $\eta_{p^2} = .025$.

I also investigated whether media multitasking ratings differed significantly between the one 6-minute break and three 2-minute breaks conditions. An ANCOVA

with pre-lecture motivation as a covariate revealed that media multitasking ratings did not differ significantly between the one 6-minute break ($M = 5.44$, $SD = 2.46$) and three 2-minute breaks ($M = 4.96$, $SD = 2.88$) conditions. Pre-lecture motivation was non-significantly associated with media multitasking ratings, $F(1, 62) = 1.00$, $MSE = 6.79$, $p = .321$, $\eta_{p^2} = .016$.

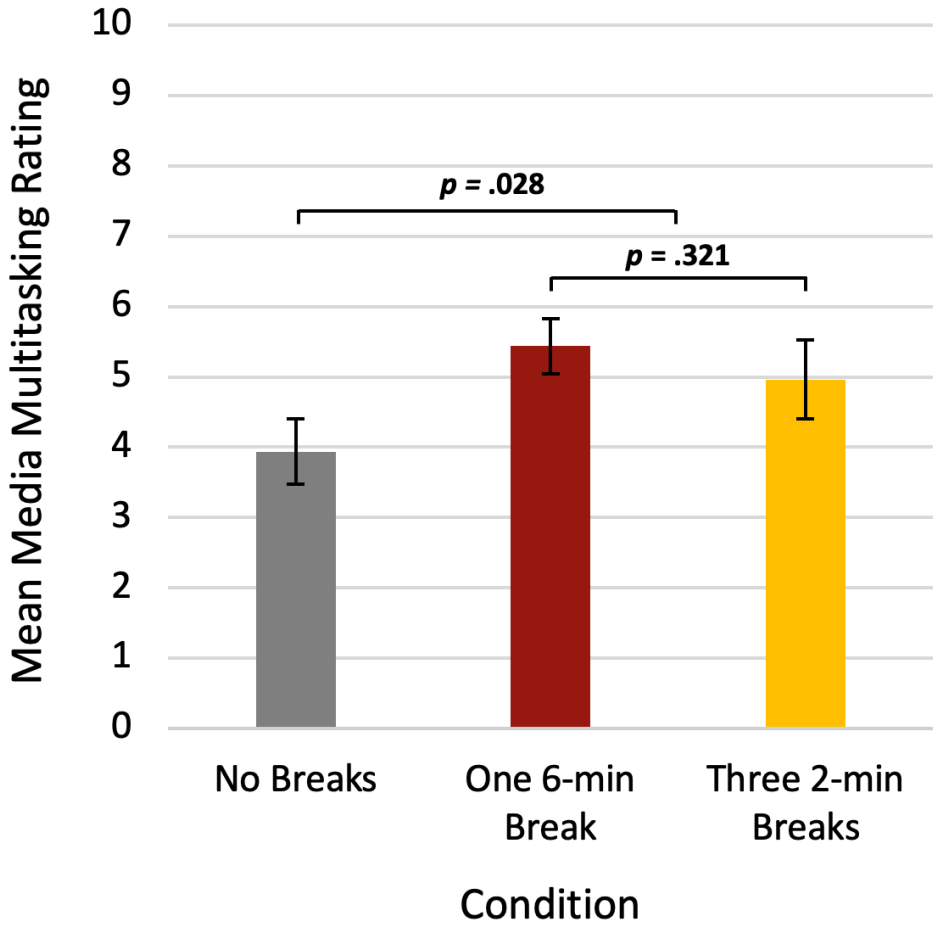


Figure 2

Mean Retrospective Media Multitasking Ratings (0 = Not at all; 10 = Extremely) with Standard Error Bars for Each Condition (No Break, One 6-Minute Break, Three 2-Minute Breaks)

Change in Lecture Motivation Levels. Wang and Tchernev (2012) suggested that media multitasking may be largely driven by resulting feelings of gratification, which may help to explain why students often engage in media multitasking while learning course material. As this suggests a motivational force for students to continue engaging in secondary tasks even after returning to the lecture, I wanted to explore whether participants' motivation to learn the lecture content during the lecture differed from their initial motivation levels, particularly among participants in the break(s) conditions.

Paired samples t-tests with pre-lecture motivation and motivation during the lecture were conducted for the no breaks condition and overall break(s) conditions. There was no significant difference between participants' pre-lecture motivation ($M = 6.23$, $SD = 2.11$) and their motivation during the lecture for the no breaks condition ($M = 6.03$, $SD = 2.20$), $t(30) = 0.78$, $p = .44$, *Cohen's d* $= 0.14$. However, participants in the break(s) conditions reported significantly lower levels of motivation during the lecture ($M = 5.20$, $SD = 2.30$) compared to their pre-lecture motivation levels ($M = 5.99$, $SD = 2.20$), $t(64) = 3.45$, $p < .001$, *Cohen's d* $= 0.43$.

Interestingly, taking a lecture break(s) was associated with a significant decrease in motivation during the lecture compared to pre-lecture motivation levels. It is important to acknowledge, however, that these results may have been impacted by how participants in the break(s) conditions were informed about the break(s) prior to rating their pre-lecture motivation.

Break Activities. Participants in the break(s) conditions were given a list of break activities, including an "Other" option, and asked to indicate all activities that they did during their break(s). Figure 3 shows the percentage of participants in the combined break(s) conditions who indicated having engaged in each break activity at any point during their break(s). Not surprisingly, the most popular break activities included sending/reading text messages (49% of break(s) participants), having thoughts unrelated to the lecture (48% of break(s) participants), using social media (46% of break(s) participants), and stretching (40% of break(s) participants).

Previous literature has shown that taking physically active breaks during an online lecture benefits learning (Fenesi et al., 2018). Thus, I wanted to explore if participants' quiz performance differed depending on whether or not they engaged in physical activity during their lecture break(s). I suspected that participants who engaged in physical activity during their breaks may perform better on the quiz than those who did not engage in any physical activity. If participants indicated that they engaged in at least one physical activity (exercised, walked around, or stretched) at any point during their break(s), they were grouped together as having engaged in physical activity. From this, I found that 52% of participants in the break(s) conditions engaged in at least one physical activity during their break(s). An independent samples t-test revealed a non-significant difference in quiz performance between participants who engaged in at least one physical activity during their break(s) ($M = 55.02$, $SD = 15.40$) and participants who did not engage in any physical activity during their break(s) ($M = 55.51$, $SD = 19.56$), $t(63) = 0.11$, $p = .911$, *Cohen's d* = 0.03.

Given the prevalent use of technology and social media during class for reasons unrelated to the lecture (Ragan et al., 2014), it is reasonable to suspect that many students would choose to engage in screen time activities during lecture breaks. Despite this, to my knowledge, no previous study has examined the effect of engaging in screen time activities during lecture break(s) on online learning. Thus, I also wanted to explore if participants' quiz performance differed depending on whether or not they engaged in screen time activities during their lecture break(s). If participants indicated that they engaged in at least one screen time activity (sent/checked email, read/replied to a text message, used social media, viewed another website (not including social media), or watched a video) at any point during their break(s), they were grouped together as having engaged in screen time activity. From this, I found that 75% of participants in the break(s) conditions engaged in at least one screen-time activity during their break(s). An independent samples t-test revealed a non-significant difference in quiz performance between participants who engaged in at least one screen time activity during their break(s) ($M = 56.67$, $SD = 17.90$) and participants who did not engage in any screen time activities during their break(s) ($M = 50.91$, $SD = 15.33$), $t(63) = -1.16$, $p = .252$, *Cohen's* $d = -0.33$.

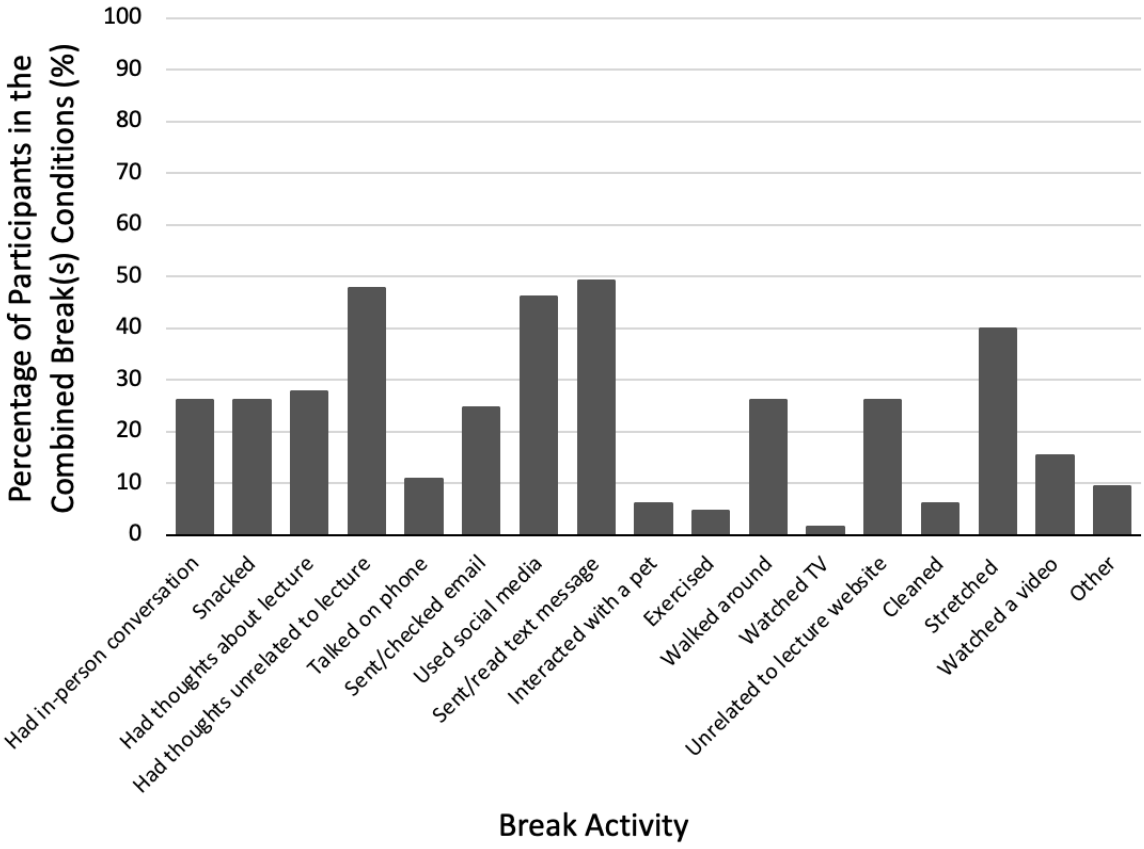


Figure 3

Percentage (%) of Participants in the Combined Break(s) Conditions (One 6-Minute Break and Three 2-Minute Breaks) Who Indicated Having Engaged in Each Activity at Any Point During Their Break(s)

Experiment 2

Experiment 1 revealed a counterintuitive and intriguing finding: Taking frequent short open-ended breaks during an online university-level lecture may have a detrimental effect on learning. Thus, Experiment 2 had two goals: 1) to replicate this finding from Experiment 1, and 2) to investigate the effect of different types of lecture break activities, specifically stretching and social media breaks, on attention during an online university-level lecture and learning of the lecture material.

Breaks can be designed in various ways, and it is plausible that other factors contributed to the negative effect of breaks observed in Experiment 1. Therefore, it is crucial not to generalize the findings from Experiment 1 and conclude that all lecture breaks are harmful to learning and should be avoided, without understanding the different factors that may influence their effectiveness. Perhaps the lecture breaks implemented in Experiment 1 were poorly designed, and thus it is important to explore and identify the potential factors that constitute a well-designed break. Given that the breaks in Experiment 1 were open-ended, lecture break activity (what students do during their breaks) may be an important factor to consider. By making these comparisons, it can help us to evaluate break activity as a potential factor that impacts the effectiveness of taking breaks during an online lecture.

In Experiment 2, I was particularly interested in examining the effect of stretching breaks, as they may be a more accessible, feasible, and appealing alternative for students while potentially providing similar cognitive benefits to exercise breaks. Additionally, I was also interested in investigating the impact of social media breaks, considering their

popularity among students, despite the limited understanding of their effect on learning. I hypothesized that stretching breaks would be beneficial for attention and learning because they may help replenish cognitive resources and avoid cognitive overload. Conversely, I hypothesized that social media breaks would have a detrimental effect on attention and learning due to their potential to activate secondary goals, unrelated to the lecture content, that promote media multitasking and compete for cognitive resources.

Method

As discussed in more detail below, the study design, materials, and procedure were the same as those of Experiment 1, except for the following key changes, which were made to address some of the limitations identified in Experiment 1. Firstly, due to the technical issues encountered with WebEx's attention tracking tool in Experiment 1, it was removed from Experiment 2. Instead, attention probes were used during the lecture to assess participants' attention levels. Consequently, there was no need to host the lecture session on WebEx, and instead, participants completed the entire lecture session on LimeSurvey. Furthermore, the placement of the lecture breaks was adjusted to align with more "natural" break points within the lecture by considering the lecture content (e.g., a break between two subtopics), in contrast to only considering the lecture time (e.g., a break at the halfway mark), as in Experiment 1. Additionally, to ensure that participants had the full allocated break time, an extra 10 seconds were also added to each break timer. This adjustment accounted for the approximate time that it would take participants to read the break instructions and return from their breaks. Lastly, several exploratory

questions were added, including ones focused on participants' judgement of learning and mental fatigue, as well as a delayed test.

Participants

Similar to Experiment 1, undergraduate students enrolled in an Introductory Psychology course at McMaster University were recruited online through the McMaster SONA system and were pre-screened to be at least 18 years old and have normal-to-corrected vision and hearing.[5] Participants randomly signed up for a timeslot in our study and were instructed to complete Part 1 of the study, the pre-lecture activity. A link to complete Part 2, the lecture session, was made accessible 12 hours after completing Part 1 and was available for 24 hours. One week later, a link to complete Part 3, which included the delayed comprehension quiz and debriefing letter, was made accessible to participants and was available for 24 hours.

A power analysis using the G*Power program (Faul et al., 2007) revealed that a total of 232 participants (58 participants per condition) would allow us to have a statistical power of .90 to detect a medium effect size ($f = 0.25$) between conditions. A total of 92 participants completed Part 1, 60 participants completed Part 2 (no breaks: 10 participants, open-ended breaks: 11 participants, stretching breaks: 17 participants, and social media breaks: 19 participants), and 40 participants completed Part 3 (no breaks: 5 participants, open-ended breaks: 5 participants, stretching breaks: 16 participants, and

[5] In Experiment 2, the option to pre-screen participants to be fluent in English was not available on the SONA system. However, given that the participants were current university students enrolled in a psychology course and have been previously exposed to university-level lectures, it can be assumed that they possess sufficient English proficiency to understand and participate in the experiment. The use of an authentic university-level psychology module from a past course further provides reassurance for this assumption.

social media breaks: 14 participants). All participants provided informed consent (study approved by McMaster Research Ethics Board, #5612).

Participants who completed all three parts of the study received 2.5 SONA credits. Those who only completed Part 1 received 0.5 SONA credits. Participants who completed Part 2 or chose to withdraw from the study during or after their scheduled session received an additional 1.5 SONA credits for participating. Participants who completed Part 3 or chose to withdraw from the study during or after their scheduled session received an additional 0.5 SONA credits for participating. Thus, a maximum of 2.5 SONA participation credits (worth 2.5 bonus marks in the psychology course that the student is enrolled in) were awarded to participants in our study.

Materials

The materials were the same as those in Experiment 1, except for the following changes.

Pre-Lecture Survey. Participants were asked to use a browser other than Safari to participate in Part 2 of the study. This was necessary because Safari would reveal the intentionally hidden video control buttons. Additionally, information about the attention probes and lecture breaks (if applicable) was provided to participants after they rated their pre-lecture motivation.

Online Video Lecture. Unlike in Experiment 1 where participants had to join a WebEx event to watch the pre-recorded video lecture, which was shared on the screen with them, in Experiment 2, the video lecture was programmed onto LimeSurvey, along with the rest of the lecture session. Thus, all participants watched the lecture on their own

time from any location that provided an internet connection. Similar to their experience on WebEx, participants were not able to control the video in any way, including pausing, stopping, and rewinding the video, or seeing a progress bar on LimeSurvey.

Attention Probes. In all conditions, one attention probe randomly appeared between two to eight minutes into each lecture quarter (see Appendix A) as a pop-up window on the screen that asked participants, "Immediately before this screen appeared, how attentive were you to the lecture? (0 - *Not at all*, 10 - *Extremely*)". The pop-up window would disappear when the participant responded to the question or after a one-minute timeout.

Lecture Breaks. Similar to Experiment 1, in the breaks conditions, the lecture videos were edited to incorporate lecture breaks, during which the break instructions and a timer counting down the remaining break time were visible on the screen. In Experiment 2, the placement of the lecture breaks was adjusted to align with more "natural" break points, where they occurred between two subtopics (see Appendix A). Additionally, each break timer was extended by an extra 10 seconds to account for participants reading the instructions and the audio cue signalling the last five seconds of the break. In the open-ended breaks condition, participants were instructed to do whatever they wished during the break. In the stretching breaks condition, participants were instructed to follow a stretching video and to refrain from engaging in any other activities during the break.[6] Each stretching break featured a different series of four 30-second

[6] Permission was granted by Jules of the YouTube channel "Improved Health" to use their stretching video (https://youtu.be/LdW4i3KXXIk) to create the stretching videos in my study.

seated stretches, and participants were not able to control the stretching videos in any way, including pausing, stopping, or rewinding the videos. In the social media breaks condition, participants were instructed to remain seated and engage with social media during the break.

Measure of Judgement of Learning. Participants were asked two judgement of learning questions: (1) how much of the information from the lecture video do you think you will be able to recall right now; and (2) how much of the information from the lecture video do you think you will be able to recall one week from now, both on a scale from 0 % (*none of it*) to 100 % (*all of it*) in 20% intervals.

Comprehension Quizzes. Since a delayed quiz was added to Experiment 2, two quiz versions were created and counterbalanced between the immediate and delayed quizzes, resulting in a total of eight sub-conditions (two sub-conditions for each of the four conditions). The quiz versions consisted of 48 factual multiple-choice questions with four response options and were matched for content and difficulty (Appendix C). Participants were given 15 minutes to complete each quiz.

Post-Lecture Survey. Participants were given the same Post-Lecture Survey as in Experiment 1 (Appendix B), apart from a few changes. Firstly, the questions related to break duration and frequency preferences were removed. In addition, two questions were added to assess participants' mental fatigue: (1) In a 50-min live online university lecture, taking a lecture break(s) would help my mind feel fully refreshed upon returning back to the lecture; and (2) The lecture breaks helped/would have helped my mind feel fully refreshed upon returning back to the lecture (0 - *Strongly Disagree*, 5 - *Strongly Agree*).

A question regarding participants' media multitasking behaviour was also added and asked participants, "Overall, while the lecture video was playing, to what extent was your attention focused on things on another computer tab or window, unrelated to the lecture? (0 - *Not at all*, 10 - *Extremely*)" Lastly, questions were also added to assess compliance with lecture break instructions and engagement with break activities (Appendix D). For exploratory analyses, participants who indicated having engaged with social media during the breaks were also asked what social media platform(s) they engaged with, what they used social media for, and what activities they did on social media (Appendix D).

Measure of Prior Knowledge. During data collection, I learned that the topic of the video lecture used in this experiment was being taught in the Introductory Psychology course and was taught in the equivalent online course that took place the semester before. Thus, questions were added to the end of the Post-Lecture Survey and after the delayed quiz to ask if participants had prior exposure to the lecture material through the Introductory Psychology courses (Appendix E). Participants who had completed the study before these questions were added received them via email.

Design and Procedure

Experiment 2 was a three-part online study that employed a 4 (Condition: no breaks vs. open-ended breaks vs. stretching breaks vs. social media breaks; between-subjects) x 2 (Time of Test: immediate vs. delayed; within-subjects) mixed factorial design. In Part 1, participants completed the OSPAN task.[7] 12 hours later, they were

[7] To address the high attrition rate and increase the sample size of Experiment 2, particularly Part 2, the data collection period was extended by three weeks, during which Part 1 of the experiment was removed.

given access to a link to Part 2 for 24 hours. In Part 2, participants rated their pre-lecture motivation and then watched the 50-minute Introductory Psychology lecture, during which an attention probe appeared in each lecture quarter. Depending on the condition that participants randomly signed up for, they either watched the lecture with no breaks (control and replication of Experiment 1), open-ended breaks (replication of Experiment 1), stretching breaks, or social media breaks. Following the lecture, they were given a short distraction task, where they entered the provided code word and answered two judgement of learning questions, before completing an immediate comprehension quiz and a post-lecture survey. One week later, all participants were given access to Part 3, which included the delayed comprehension quiz and debriefing letter, for 24 hours.

Results and Discussion

Demographics and Data Exclusion

A total of 60 participants completed Part 2 of the experiment, and after applying the exclusion criteria, 25 participants were excluded from the analyses. Among the excluded participants, eight encountered issues during the study that prevented them from watching or hearing the lecture video for more than five minutes, three took notes during the lecture, eight reported not engaging in the instructed break activity, and two watched the lecture video more than once (exited and revisited the link immediately after)[8]. Additionally, four participants were excluded on more than one of the aforementioned exclusion criteria. Thus, the final sample for Part 2 consisted of 35 participants (no

[8] Although this was not a preregistered exclusion criterion, it was added in response to its occurrence, as repeated exposure to the lecture material and video could potentially impact the results of the experiment.

breaks: nine participants, open-ended breaks: eight participants, stretching breaks: eight participants, and social media breaks: 10 participants).

Of those who completed Part 2 of the experiment, a total of 40 participants completed Part 3. Among them, 14 were already excluded from analyses from Part 2 and an additional two were excluded from analyses: one participant completed Part 3 one month later and another participant answered fewer than half of the multiple-choice questions. Thus, the final sample for Part 3 consisted of 24 participants (no breaks: five participants, open-ended breaks: four participants, stretching breaks: six participants, and social media breaks: nine participants).

The mean age (with standard deviation) and gender distribution of participants in each condition for Parts 2 and 3 of Experiment 2 are presented in Table 5. Participants who did not respond to the exclusion criteria questions or performed worse than chance (< 25%) were included in the analyses but later excluded for secondary analyses (see Secondary Analyses).

Table 5

Mean Age, with Standard Deviation (SD), and Gender Distribution of Participants in the Four Conditions (No Breaks, Open-Ended Breaks, Stretching Breaks, and Social Media Breaks) For Part 2 (Table 5A) and Part 3 (Table 5B) of Experiment 2

A

	No Breaks (n=9)	Open-Ended Breaks (n=8)	Stretching Breaks (n=8)	Social Media Breaks (n=10)
Measure				

Age	*Mean* (*SD*)	18.33 (1.00)	18.63 (0.74)	18.63 (1.41)	18.50 (1.27)
Gender	Woman	77.8%	87.5%	75%	50%
	Man	22.2%	12.5%	25%	30%
	Non-binary	0%	0%	0%	20%
	Prefer Not to Say	0%	0%	0%	0%

B

		No Breaks (n=5)	Open-Ended Breaks (n=4)	Stretching Breaks (n=6)	Social Media Breaks (n=9)
Measure					
Age	*Mean* (*SD*)	18.00 (0.00)	18.25 (0.5)	18.67 (1.79)	18.56 (1.33)
Gender	Woman	80%	75%	66.67%	44.44%
	Man	20%	25%	33.33%	33.33%
	Non-binary	0%	0%	0%	22.22%
	Prefer Not to Say	0%	0%	0%	0%

Prior Knowledge

Participants who reported having prior knowledge on the topic of form perception had watched the module(s) and/or lecture on the topic in an Introductory Psychology course prior to completing Part 2 and/or Part 3 of the experiment.[9]

Among the 21 participants that responded, 13 indicated having prior knowledge on form perception before completing Part 2 of the study (no breaks: three participants, open-ended breaks: four participants, stretching breaks: three participants, and social media breaks: three participants). There were no significant differences in attention probe rating, $t(19) = 0.30$, $p = .766$, *Cohen's d* = 0.14, or immediate quiz score, $t(19) = -0.88$, $p = .390$, *Cohen's d* = -0.40, between those who indicated no prior knowledge before Part 2 (attention probe rating: $M = 5.18$, $SD = 1.90$; immediate quiz score: $M = 53.46$, $SD = 13.53$) and those who indicated having this prior knowledge (attention probe rating: $M = 4.89$, $SD = 2.23$; immediate quiz score: $M = 60.23$, $SD = 18.94$).

Of the 18 participants that responded, 12 indicated having prior knowledge on form perception before completing Part 3 of the study (no breaks: three participants, open-ended breaks: two participants, stretching breaks: three participants, and social media breaks: four participants). There was a non-significant difference in delayed quiz score, $t(16) = -2.01$, $p = .062$, *Cohen's d* = -1.00, between those who indicated no prior knowledge before Part 3 ($M = 47.29$, $SD = 17.93$) and those who indicated having this prior knowledge ($M = 66.73$, $SD = 19.98$).

[9] Participants in the final sample who reported having prior knowledge on the topic all indicated having had exposure to it through the PSYCH 1XX3 course, which was taught during data collection.

The non-significant differences in attention probe rating and quiz performance between those with and without prior knowledge may be attributed to the lack of power. Alternatively, it is also possible that those who reported having watched the module(s) and/or lecture on form perception in the Introductory Psychology course prior to this study were exposed to the content but did not actively engage with the module and/or lecture to learn the material.

Attention

Attention Probe Ratings. Tables 6, 7, and 8 depict the attention results based on the attention probe ratings. An ANCOVA, with pre-lecture motivation as a covariate[10], revealed that attention probe ratings did not differ significantly between conditions, $F(3, 28) = 0.40$, $MSE = 2.47$, $p = .753$, $\eta_{p^2} = .041$.[11] However, pre-lecture motivation was found to be significantly related to attention probe ratings, $F(1, 28) = 12.96$, $MSE = 2.47$, $p = .001$, $\eta_{p^2} = .316$. Planned contrasts were conducted, and contrary to my predictions, attention probe ratings did not differ between the no breaks condition and the open-ended, stretching, or social media breaks conditions. Attention probe ratings were also non-significantly different between the stretching breaks and social media breaks conditions.[12]

[10] JASP 0.17.2.1, the statistical software program used for analyses in this study, automatically excluded a participant from the open-ended breaks condition in the analyses of attention, as they did not have a pre-lecture motivation rating. This exclusion was also applied to the quiz performance analyses.
[11] Working memory capacity was removed as a covariate in the analysis for the same reasons as in Experiment 1. This reasoning was also applied to the analyses of quiz performance.
[12] Due to the automatic exclusion of participants who had at least one missing attention probe response by JASP 0.17.2.1, which led to a much smaller sample size, an ANCOVA was run instead of a 4 (Condition: no breaks vs. open-ended breaks vs. stretching breaks vs. social media breaks; between-subjects) x 4 (Attention Probe: 1 vs. 2 vs. 3 vs. 4; within-subjects) repeated-measures ANCOVA. However, the descriptive statistics are presented in Table 7.

Table 6

Mean Attention Probe Ratings (0 = Not at all; 10 = Extremely), Media Multitasking Ratings (0 = Not at all; 10 = Extremely), and Quiz Performance (%) with Standard Deviations (SD) and Sample Sizes (n) for Each Condition (No Breaks, Open-Ended Breaks, Stretching Breaks, and Social Media Breaks)

		n	*Mean* (*SD*)
Attention Probe Rating	No Breaks	8	5.51 (2.08)
	Open-Ended Breaks	8	5.75 (1.02)
	Stretching Breaks	8	4.81 (2.36)
	Social Media Breaks	10	4.71 (1.74)
Media Multitasking Rating	No Breaks	8	3.56 (2.56)
	Open-Ended Breaks	8	4.56 (1.88)
	Stretching Breaks	8	5.00 (3.30)
	Social Media Breaks	10	4.30 (2.14)
Immediate Quiz Performance	No Breaks	9	52.25 (18.85)
	Open-Ended Breaks	8	51.33 (20.36)
	Stretching Breaks	8	73.94 (13.68)

	Social Media Breaks	10	55.32 (19.58)
Delayed Quiz Performance	No Breaks	5	56.49 (18.14)
	Open-Ended Breaks	4	60.51(18.12)
	Stretching Breaks	6	72.49 (17.23)
	Social Media Breaks	9	51.11 (21.95)

Table 7

Mean Attention Probe Ratings (0 = Not at all; 10 = Extremely) With Standard Deviations (SD) During Lecture Quarters 1, 2, 3, and 4 Across the Four Conditions (No Breaks, Open-Ended Breaks, Stretching Breaks, and Social Media Breaks)

	Lecture Quarter			
	1	2	3	4
No Breaks	5.33 (1.53)	6.00 (1.00)	7.00 (2.65)	6.67 (2.52)
Open-Ended Breaks	6.00 (0.00)	6.50 (0.71)	6.00 (1.41)	5.50 (0.71)
Stretching Breaks	5.33 (2.94)	5.67 (2.94)	4.17 (2.40)	4.67 (3.20)
Social Media Breaks	5.00 (1.55)	4.83 (2.14)	4.33 (1.37)	4.00 (2.10)

Note. Numbers outside the parentheses denote mean, while numbers inside the parentheses denote standard deviation.

Table 8

Planned Contrasts for Attention Probe Ratings Between Conditions (No Breaks vs. Open-Ended Breaks, Stretching Breaks, and Social Media Breaks and Stretching Breaks vs. Social Media Breaks)

Comparison		*t*(28)	*p*	*Cohen's d*
No Breaks	Open-Ended Breaks	-0.33	.743	0.02
	Stretching Breaks	-1.07	.294	0.31
	Social Media Breaks	-0.59	.560	0.42
Stretching Breaks	Social Media Breaks	0.52	.605	0.05

Media Multitasking

Table 6 depicts the media multitasking results. To test my hypothesis that engaging with social media during lecture breaks may promote media multitasking during the lecture, planned contrasts were conducted using an ANCOVA model (with pre-lecture motivation as covariate). Contrary to what I had predicted, participants in the social media breaks condition did not report having engaged in media multitasking significantly more than those in the no breaks condition, $t(28) = 0.54$, $p = .597$, *Cohen's d* = 0.31, or stretching breaks condition, $t(28) = -0.72$, $p = .480$, *Cohen's d* = 0.25. However, consistent with Experiment 1, media multitasking was significantly and negatively correlated with attention probe ratings and motivation during the lecture (Table 12). Participants who

retrospectively reported more media multitasking during the lecture reported lower levels of attentiveness and, in retrospect, motivation during the lecture.

Quiz Performance

Immediate Quiz. Table 6 and Figure 4 depict the immediate learning results. A 4 (Condition: no breaks vs. open-ended breaks vs. stretching breaks vs. social media breaks; between-subjects) x 4 (Quiz Quarter: 1 vs. 2 vs. 3 vs. 4; within-subjects) repeated-measures ANCOVA with pre-lecture motivation as a covariate revealed a significant main effect of Condition, $F(3, 29) = 3.18$, $MSE = 1337.86$, $p = .039$, $\eta_p^2 = .248$, and a non-significant main effect of Quiz Quarter $F(3, 87) = 2.28$, $MSE = 263.61$, $p = .085$, $\eta_p^2 = .073$.[13] Further, there was a non-significant interaction between Quiz Quarter and Condition, $F(9, 87) = 1.21$, $MSE = 263.61$, $p = .300$, $\eta_p^2 = .111$, indicating that differences in quiz scores across Quiz Quarters were non-significantly different between Conditions. Pre-lecture motivation was non-significantly related to quiz performance, $F(1, 29) = 0.06$, $MSE = 1337.86$, $p = .803$, $\eta_p^2 = .002$.

[13] A post hoc power analysis was conducted for the main effect of Condition using the G*Power program (Faul et al., 2007), revealing an observed statistical power of .70.

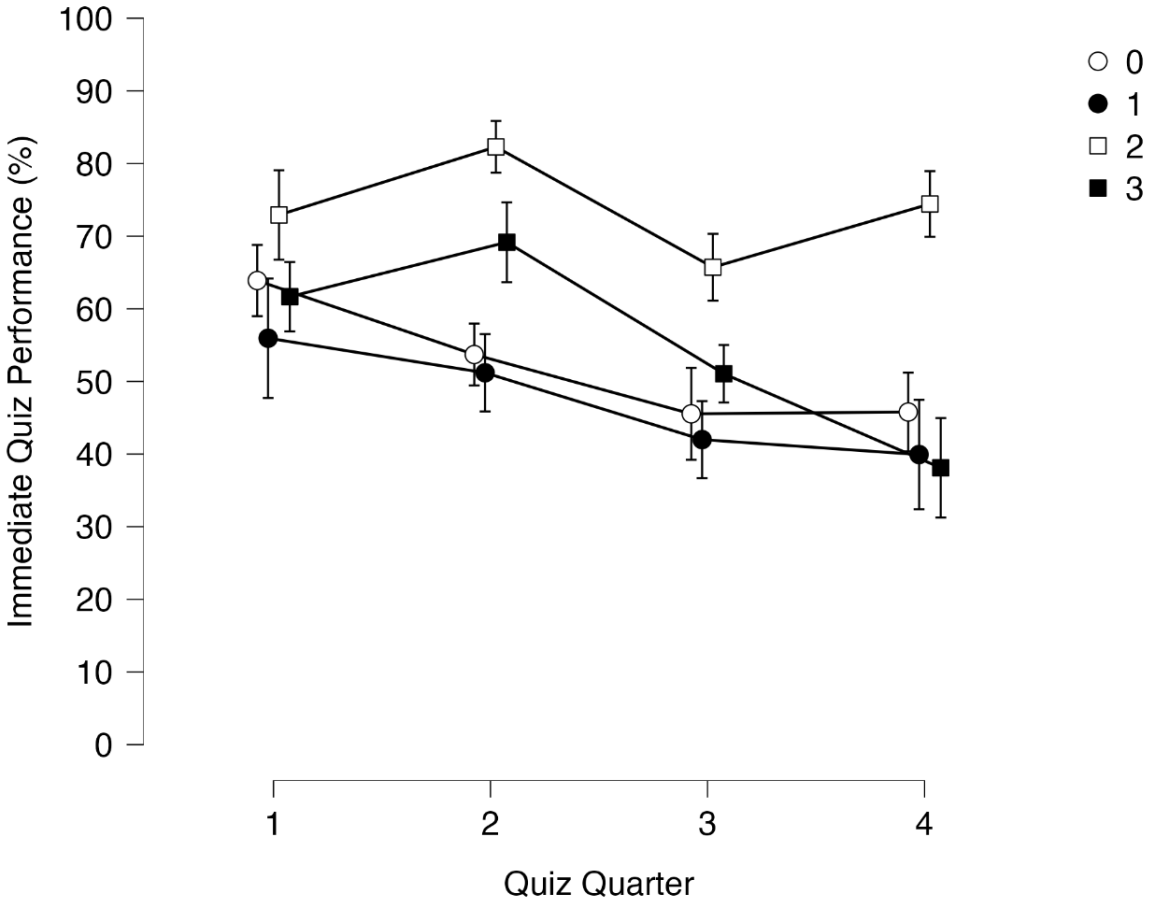


Figure 4

Immediate Quiz Performance (%) with Standard Error Bars Across Quiz Quarters for Each Condition (0 - No Break, 1 - Open-Ended Breaks, 2 - Stretching Breaks, and 3 - Social Media Breaks)

Difference in Quiz Performance Between Conditions. Table 9 depicts the planned contrasts conducted between Conditions for quiz performance. Consistent with our predictions, planned contrasts revealed that participants in the stretching breaks condition performed significantly better on the quiz than both the no breaks and social media breaks conditions. However, contrary to our prediction that participants in the

social media breaks condition would perform worse on the quiz than the no breaks condition, quiz performance did not differ significantly between these two conditions. In addition, the finding from Experiment 1, where participants in the no breaks condition performed significantly better on the quiz than those in the frequent short open-ended breaks condition, was not replicated here, which may have been due to the lack of power. There was a non-significant difference in quiz performance between the no breaks and open-ended breaks conditions.

Table 9

Planned Contrasts for Immediate Quiz Performance Between Conditions (No Breaks vs. Open-Ended Breaks, Stretching Breaks, and Social Media breaks and Stretching Breaks vs. Social Media Breaks)

Comparison		*t*(29)	*Cohen's d*	*p*
No Breaks	Open-Ended Breaks	-0.49	0.26	.626
	Stretching Breaks	2.45	1.32	.021*
	Social Media Breaks	0.31	0.15	.758
Stretching Breaks	Social Media Breaks	-2.18	1.10	.037*

Note. Results are averaged over the levels of Quiz Quarter.
*$p < .05$.

Difference in Quiz Performance Across Quiz Quarters. Table 10 shows the post hoc comparisons for quiz performance across Quiz Quarters. Post hoc comparisons

revealed that while there was no significant difference in quiz performance between Quiz Quarters 1 and 2 nor between Quiz Quarters 3 and 4, both Quiz Quarters 1 and 2 did differ significantly from both Quiz Quarters 3 and 4. This is consistent with previous studies that have found a decline in a decline in performance as time on task increases (Risko et al., 2021). Additionally, these findings suggest that learning of the lecture material may decline during the middle of an online lecture.

Table 10

Post Hoc Comparisons for Immediate Quiz Performance Between Quiz Quarters (Q)

Comparison		*t*(34)	*Cohen's d*	p_{bonf}
Q1	Q2	-0.10	-0.02	1.000
	Q3	3.19	0.55	.012*
	Q4	3.57	0.62	.004**
Q2	Q3	3.29	0.57	.009**
	Q4	3.67	0.63	.003**
Q3	Q4	0.377	0.07	1.000

Note. P-value adjusted using Bonferroni correction for comparing a family of 6.

Note. Results are averaged over the levels of Condition.

* $p < .05$; ** $p < .01$.

Delayed Quiz. Table 6 and Figure 5 depict the delayed learning results. A 4 (Condition: no breaks vs. open-ended breaks vs. stretching breaks vs. social media

breaks; between-subjects) x 4 (Quiz Quarter: 1 vs. 2 vs. 3 vs. 4; within-subjects) repeated-measures ANCOVA with pre-lecture motivation as a covariate revealed a non-significant main effect of Condition, $F(3, 18) = 1.29$, $MSE = 1622.90$ $p = .308$, $\eta_{p^2} = .177$, and a non-significant main effect of Quiz Quarter $F(3, 54) = 1.01$, $MSE = 192.76$, $p = .389$, $\eta_{p^2} = .053$.[14] Further, there was a non-significant interaction between Quiz Quarter and Condition, $F(9, 54) = 0.90$, $MSE = 192.76$, $p = .536$, $\eta_{p^2} = .130$, indicating that differences in quiz scores across Quiz Quarters were non-significantly different between Conditions. Pre-lecture motivation, $F(1, 18) = 0.02$, $MSE = 1622.90$, $p = .895$, $\eta_{p^2} = .001$, was non-significantly related to quiz performance.

Table 11 depicts the planned contrasts conducted between Conditions for quiz performance. Contrary to my predictions that quiz performance would be higher in the stretching breaks condition and lower in the social media breaks condition than the no breaks condition, quiz performance did not differ significantly between those in the no breaks condition and those in the stretching condition and social media breaks condition. Additionally, quiz performance did not differ significantly between those in the stretching breaks condition and those in the social media breaks condition, as well as between those in the no breaks condition and those in the open-ended breaks condition.

[14] A post hoc power analysis was conducted for the main effect of Condition using the G*Power program (Faul et al., 2007), revealing an observed statistical power of .25.

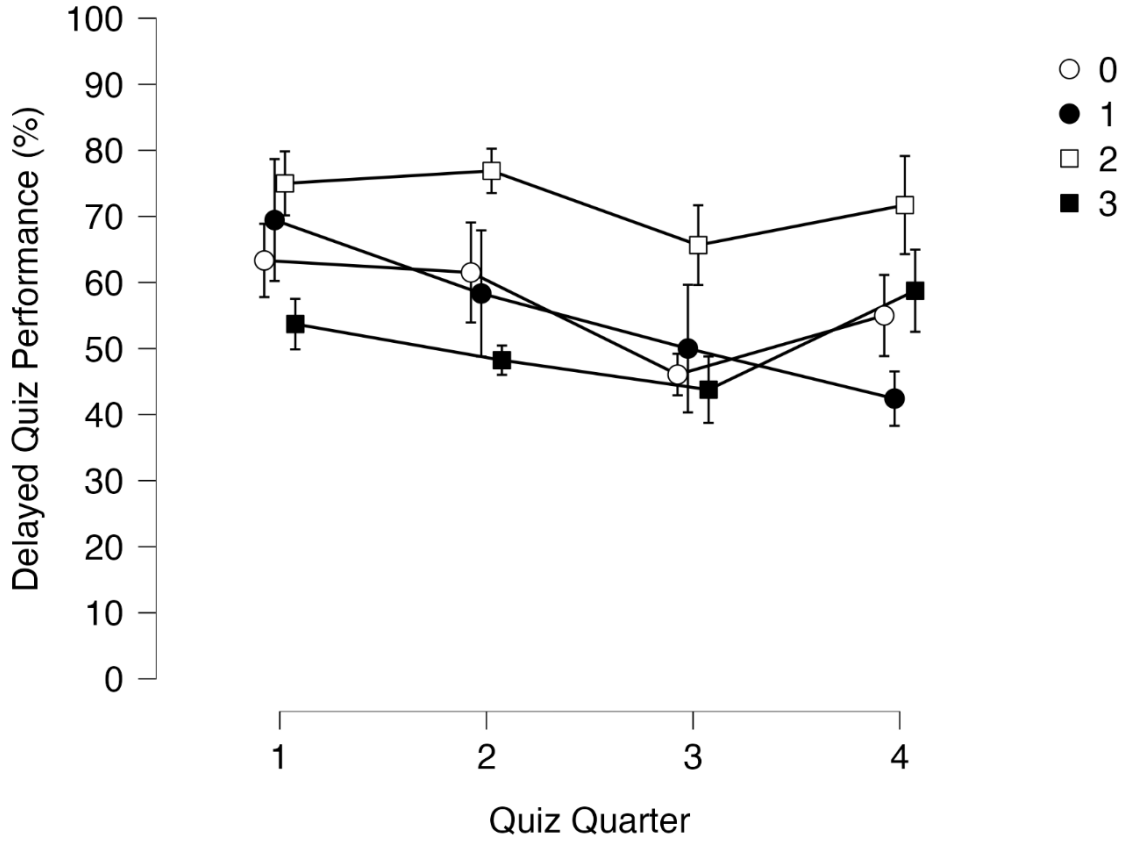


Figure 5

Delayed Quiz Performance (%) with Standard Error Bars Across Quiz Quarters for Each Condition (0 - No Break, 1 - Open-Ended Breaks, 2 - Stretching Breaks, and 3 - Social Media Breaks)

Table 11

Planned Contrasts for Delayed Quiz Performance Between Conditions (No Breaks vs. Open-Ended Breaks, Stretching Breaks, and Social Media breaks and Stretching Breaks vs. Social Media Breaks)

Comparison	*t*(18)	*Cohen's d*	*p*

No Breaks	Open-Ended Breaks	-0.07	0.22	.949
	Stretching Breaks	1.31	0.90	.208
	Social Media Breaks	-0.39	0.27	.699
Stretching Breaks	Social Media Breaks	-1.89	1.08	.075

Note. Results are averaged over the levels of Quiz Quarter.
*$p < .05$.

Correlations

A Pearson's bivariate correlation was completed for the following variables of interest: immediate quiz score, attention probe rating, pre-lecture motivation, motivation during the lecture (based on retrospective motivation rating from the post-lecture survey), judgement of immediate learning, and working memory capacity.

Table 12 shows the correlation coefficient and p-values associated with each variable. Attention probe rating, pre-lecture motivation, motivation during the lecture, and judgement of immediate learning were all significantly and positively correlated with one another. Consistent with previous findings (Esterman et al., 2014), participants who reported being more motivated immediately before and, retrospectively, during the lecture, also retrospectively reported higher levels of attentiveness during the lecture.

Working memory capacity was non-significantly correlated with quiz performance (immediate and delayed). However, contrary to previous findings (Hollis & Was, 2016), working memory capacity was significantly and negatively correlated with attention probe rating. Participants with higher working memory capacity were likely able

to store and process more information simultaneously, including those unrelated to the lecture content. Consequently, they may have experienced more mind wandering, and thus lower levels of attentiveness during the lecture.

Further, quiz performance was positively correlated with judgement of learning for both the immediate and delayed quizzes, suggesting that participants had a good metacognitive awareness of their learning.

Table 12

Pearson's r Correlation Coefficients (r) and P-Values (p) for Each Measure of Interest

		IQuiz	DQuiz	Atten Probe	Pre Motiv	Motiv During	WM	MM	iJOL
DQuiz	*r*	0.83	—						
	p	< .001***	—						
Atten Probe	*r*	0.04	-0.07	—					
	p	.808	.747	—					
Pre Motiv	*r*	-0.02	0.12	0.57	—				
	p	.901	.600	< .001***	—				
Motiv During	*r*	0.33	0.21	0.62	0.45	—			
	p	.054	.337	< .001***	.008**	—			
WM	*r*	-0.02	0.18	-0.44	-0.11	-0.16	—		
	p	.902	.438	.018*	.584	.413	—		
MM	*r*	0.01	0.26	-0.63	-0.12	-0.49	0.21	—	

	p	.968	.227	< .001***	.493	.004	.277	—	
	r	0.56	0.49	0.39	0.39	0.43	-0.06	-0.11	—
iJOL	*p*	< .001***	.014*	.024	.022*	.010*	.750	.556	—
	r	0.32	0.47	0.38	0.38	0.52	-0.12	-0.09	0.69
dJOL	*p*	.061	.019*	.029*	.029*	.002**	.545	.623	< .001***

Note. The variables of interest, along with the abbreviations used, are as followed: Immediate Quiz Performance (iQuiz), Delayed Quiz Performance (dQuiz) Attention Probe Ratings (Atten Probe), Pre-Lecture Motivation (Pre Motiv), Motivation During Lecture (Motiv During), Working Memory Capacity (WMC), Media Multitasking (MM), Judgement of Immediate Learning (iJOL), and Judgement of Delayed Learning (dJOL).

*$p < .05$; **$p < .01$; ***$p < .001$.

Secondary Analyses

Secondary Exclusions. Two participants did not reply to the exclusionary questions and were excluded for secondary analyses: one did not indicate if they experienced issues during the lecture and the other did not indicate whether they engaged with their instructed break activity (both from the social media breaks condition). In addition, as pre-registered, for a secondary analysis of quiz performance, participants who had worse than chance performance on the quizzes (< 25%) were removed. Out of those who were not already excluded, two participants (one from the open-ended breaks condition and one from the social media breaks condition) were excluded for secondary analysis of immediate quiz performance. The statistical significance of the attention probe rating and quiz performance results was not impacted.

Practice Effect on Delayed Quiz Performance. After data collection had already started, it was discovered that some participants received the same quiz version for both the immediate and delayed tests. Specifically, of the 24 participants who completed the delayed quiz, eight (no breaks: two participants, open-ended breaks: one participant, stretching breaks: three participants, and social media breaks: two participants) were given and completed the same quiz version for both the immediate and delayed tests.

As some participants received the same test version twice, they may have experienced practice effects that may have led to better performance on the delayed quiz. Thus, I investigated the potential impact of practice effects on delayed quiz performance. An independent samples t-test revealed that there was no significant difference in delayed quiz performance between those who received the same quiz version as their immediate quiz ($M = 68.09$, $SD = 19.30$) and those who received a different quiz version ($M = 54.67$, $SD = 19.60$), $t(22) = 1.59$, $p = .127$, *Cohen's* $d = 0.69$.[15]

Quiz Performance Between Quiz Versions 1 and 2. While the two quiz versions used in this experiment were matched for content and difficulty to the best of our abilities, I ran paired samples t-tests to check whether quiz performance differed between the two test versions for each condition (participants who did not complete the delayed test or completed the same quiz version twice were excluded from the analyses).

[15] The independent samples t-test was run across all conditions, rather than for each condition due to the extremely low sample size of those who did not receive the counterbalanced quizzes (one to three participants in each condition). However, given that this issue affected a similar number of participants in each condition, it can be assumed that any practice effects due to the issue with counterbalancing affected all groups similarly.

Table 13 depicts the quiz performance between the quiz versions results. Quiz performance did not differ significantly between quiz versions 1 and 2 in all conditions, except for the social media breaks condition. Participants in the social media breaks condition performed significantly better on quiz version 1 than on quiz version 2. However, this significant difference is likely due to the unbalanced design of the experiment that resulted in six out of the seven participants in the social media breaks condition completing quiz version 1 as the immediate quiz and quiz version 2 as the delayed quiz. For each of the other three conditions, the number of participants who completed quiz version 1 versus quiz version 2 was similar for both the immediate and delayed quizzes. Thus, the significant difference in quiz performance between the two quiz versions in the social media breaks condition may be attributed to the natural declines in memory retention across time.

Table 13

Results of Paired Samples T-Tests Comparing Quiz Performance (%) On Quiz Version 1 (V1) Versus Quiz Version 2 (V2) For Each Condition

		n	*Mean* (*SD*)	*df*	*t*	*Cohen's d*	*p*
No Breaks	V1	5	61.70 (21.38)	2	0.92	0.53	.456
	V2	3	64.37 (15.49)				

Open-Ended Breaks	V1	5	62.55 (20.33)	2	0.60	0.35	.608
	V2	4	54.66 (16.84)				
Stretching Breaks	V1	5	73.19 (15.82)	2	3.59	2.07	.070
	V2	3	57.74 (14.39)				
Social Media Breaks	V1	8	52.39 (14.43)	6	3.20	1.21	.019*
	V2	7	39.88 (17.48)				

*$p < .05$

Change in Lecture Motivation Levels. I wanted to explore whether participants' motivation to learn the lecture content during the lecture differed from their initial motivation levels for each condition, given that in Experiment 1, participants in the break(s) conditions reported a significant decrease in motivation during the lecture.

Table 14 presents the change in lecture motivation levels results. Paired samples t-tests with pre-lecture motivation and motivation during the lecture were conducted for each condition. Participants' pre-lecture motivation did not differ significantly from their motivation during the lecture for all conditions.

Table 14

Results of Paired Samples T-Tests Comparing Pre-Lecture Motivation (Pre Motiv) and Motivation During the Lecture (Motiv During) For Each Condition

		n	*Mean* (*SD*)	*df*	*t*	*Cohen's d*	*p*
No Breaks	Pre Motiv	9	5.33 (2.35)	8	0.47	0.16	.650
	Motiv During	9	5.00 (1.73)				
Open-Ended Breaks	Pre Motiv	7	6.14 (1.07)	6	0.81	0.31	.450
	Motiv During	8	5.75 (1.04)				
Stretching Breaks	Pre Motiv	8	5.88 (0.84)	7	1.35	0.48	.219
	Motiv During	8	4.75 (2.05)				
Social Media Breaks	Pre Motiv	10	5.00 (2.31)	9	0.46	0.15	.656
	Motiv During	10	4.70 (2.50)				

General Discussion

In the present two-part study, I aimed to uncover how lecture breaks can be effectively designed to promote attention during online lectures and enhance learning among university students. I investigated the effect of lecture break duration and frequency (Experiment 1) and the effect of lecture break activity (Experiment 2) on attention and online learning.

Effect of Lecture Break Duration and Frequency

The results in Experiment 1 did not support my hypotheses, which proposed that taking break(s) during an online lecture would enhance attention and learning compared to taking no breaks, and that frequent breaks would be more beneficial than infrequent breaks. The findings revealed that taking open-ended lecture breaks, compared to taking no breaks, did not significantly improve attention; instead, it resulted in significant costs to learning, as measured through immediate quiz performance. In addition, taking three 2-minute open-ended lecture breaks, compared to taking one 6-minute lecture break, also did not significantly impact attention, but led to significantly worse learning. Lastly, consistent with previous studies, pre-lecture motivation was significantly associated with attentiveness, suggesting that participants' level of motivation accounted for some of the variance in attentiveness.

The unexpected results on learning were intriguing, as they completely contradicted the predicted pattern of results. Interestingly, participants in the combined break(s) conditions reported significantly higher engagement in media multitasking than those in the no breaks condition and reported a significant decrease in motivation during

the lecture. This suggests that open-ended breaks may promote media multitasking during online lectures, lower motivation levels, and hinder learning; however, it is important not to infer causal relationships between these associations.

The detrimental effect of taking lecture breaks in this experiment may be largely explained by the open-ended nature of the breaks, where participants in the break(s) conditions had the freedom to engage in any activity they preferred. It is possible that participants did not choose break activities with effectiveness in mind, but rather focused on productivity or enjoyment. Consequently, participants may have engaged in other cognitive tasks during the breaks (e.g., working on an assignment, reading an email, etc.), depleting the same cognitive resources used during the lecture and hindering the replenishment of these resources.

Further, the negative effect of taking lecture break(s) could also be attributed to the difficulty of task-switching effectively, as switching between two tasks, particularly cognitive tasks, can further deplete attention and impede task performance (Rogers & Monsell, 1995). When individuals switch between uncompleted tasks, primary task performance often decreases as additional cognitive load may be imposed by the lingering thoughts of the unfinished secondary task and cause the individual to be distracted and lose focus (Leroy, 2009). Thus, if participants in the break(s) conditions started a task during their break but were not able to complete it before resuming the lecture, especially for those who took short breaks, it may have served as a source of distraction. Additionally, task-switching may have had a more detrimental effect on learning for

participants who engaged in multiple tasks during their break(s) or took more frequent breaks.

Relatedly, if participants engaged in an activity(s) or task(s) that they found to be productive or enjoyable during the breaks, they may have felt more motivated by them, resulting in high activation of secondary goals and increased difficulty to task-switch effectively (Hofer, 2007). For example, as found in the current experiment, a popular break activity among participants was engaging with screen-time activity, particularly media. As media usage has been linked to satisfying emotional needs and feelings of gratification (Wang & Tchernev, 2012), it is possible that break activities were chosen by participants to satisfy their needs at the time and were consequently more motivating. As a result, the high activation levels of secondary goals during breaks may have persisted upon returning to the lecture, resulting in a motivational conflict between on-task and off-task goals and an inclination towards continuing off-task activities (Hofer et al., 2007). This may explain the higher media multitasking ratings reported by participants who took a break(s) compared to those who did not take any breaks. Additionally, given the limited time, attention, and effort resources, this would mean that pursuing off-task goals consumed resources that could have been allocated towards on-task goals. Further, high motivation towards secondary goals may have also reduced motivation towards lecture-related goals and necessitated additional time to reactivate those goals (Rosen et al. 2013).

Exploratory analyses in Experiment 1 revealed a significant decrease in motivation during the lecture for participants who took a break(s) compared to their pre-

lecture motivation. This decrease in motivation was not observed in participants who took no break(s). Thus, lecture breaks may have hindered learning if participants were more motivated to engage in the break activity(s) than the lecture itself. Overall, these results suggest that contrary to the goal habituation hypothesis, brief disengagement(s) from the primary task through engagement in a secondary task might not effectively strengthen the activation level of the primary task upon return. On the contrary, it could inadvertently weaken its activation level depending on the nature of the secondary task.

Effect of Lecture Break Activity

The results in Experiment 2 partially supported my hypotheses that stretching breaks would be beneficial for attention and learning, while social media breaks would be detrimental. Taking stretching lecture breaks led to significantly better learning when measured through immediate quiz performance, than taking no lecture breaks and social media breaks. However, contrary to what I had hypothesized, taking social media breaks did not result in significantly worse learning compared to no breaks. In addition, there were no significant differences in learning between the conditions when measured through delayed quiz performance. Attention, media multitasking, and changes in motivation during the lecture also did not differ significantly between the conditions.

Stretching Breaks

While prior research (Fenesi et al., 2018) has shown that exercise breaks during online lectures improve learning among university students, the current results suggest that the benefits of active lecture breaks extend beyond high-intensity exercises; specifically, stretching breaks were found to confer the same benefits as exercise breaks.

As stretching involves simple physical movements without complex cognitive processing, it is likely a non-cognitively demanding activity. Thus, taking stretching breaks during a lecture may have helped to reduce cognitive load and facilitated the replenishment of cognitive resources. Additionally, similar to the hypothesized physiological mechanisms underlying the benefits of exercise breaks on cognition (Fenesi et al., 2018), stretching may have also increased physiological arousal levels and facilitated the release of hormones that are associated with attention and learning processes. Although the effect of stretching breaks on cognitive function, specifically attention and memory, has, to my knowledge, not been studied in the classroom setting before, research on walking breaks suggests that the physiological mechanisms underlying the benefit of exercise breaks may apply to lower-intensity exercises as well. For example, office workers who took periodic short walking breaks during work, compared to interrupted sitting, reported improved mood and energy levels, reduced fatigue, and maintained attention levels (Bergouignan et al., 2016). In addition, they also had an increased heart rate, suggesting that walking increased blood flow, thereby increasing mood, maintenance of energy levels, and alertness (Bergouignan et al., 2016).

Taken together, these findings suggest that stretching breaks during online lectures may provide cognitive benefits similar to exercise breaks. The non-cognitively demanding nature of stretching, along with its potential to promote increases in blood flow and physiological arousal, may contribute to its positive impact on learning.

Social Media Breaks

While previous research has associated non-academic social media use during lectures with poorer learning outcomes (Ravizza et al., 2014), the current results suggest that using social media during lecture breaks may not have a detrimental impact on learning. However, it is important to acknowledge that the non-significant effect of social media breaks on learning could be attributed to the low statistical power in the experiment.

Another potential explanation for the results of social media breaks could be related to the timing of data collection in Experiment 2. Data collection occurred during the same semester as the Introductory Psychology course, which covered the same topic of form perception in one of its units as the online video lecture in this experiment. Consequently, this overlap may have resulted in higher levels of intrinsic motivation and goal activation levels related to the primary task. Given that intrinsic motivation has been associated with vigilance and task engagement (Neigel et al., 2017), this could have mitigated any potential negative effects of social media breaks and facilitated a more effective and faster reactivation of primary task goals upon returning to the lecture. Furthermore, the non-significant difference in media multitasking between the social media breaks and no breaks conditions suggests that engaging with social media during the breaks may not have increased motivation or goal activation beyond that of the primary task to have encouraged continued social media engagement. Consequently, this may have reduced the likelihood of experiencing motivational conflicts between on- and off-task goals and engaging in media multitasking during the lecture (Hofer et al., 2007). As there were no significant changes in motivation levels during the lecture for the social

media breaks conditions, it further supports the idea that engaging with social media during the breaks may not have led to motivational conflicts between task goals that impacted participants' motivation to learn.

It is also possible that social media breaks have learning benefits that offset any potential detrimental effects. If participants had thoughts or urges to engage with social media, providing social media breaks may have allowed them to fulfill some of those off-task goals, thereby freeing up cognitive load and resources. This potential benefit could have offset any additional cognitive load or resource depletion caused by engaging with social media during the break(s).

Additionally, the types of social media activities that participants engaged in during the breaks may have influenced the effect of social media breaks on learning outcomes. According to the Uses and Gratifications theory, social media is used to satisfy social, hedonic, and cognitive needs (Ali-Hassan et al., 2015). Social needs involve maintaining social connections, while hedonic needs pertain to relaxation and entertainment, and cognitive needs revolve around creating, seeking, and sharing experiences and information (Cheng & Cho, 2021). Cheng and Cho (2021) found that only hedonic and cognitive social media break activities were positively associated with work recovery experiences in frontline hospitality employees. However, in the context of lectures, which place high demands on limited working memory, I suspect that using social media for cognitive activities may not contribute to improved recovery or learning experiences. While many participants reported using social media for hedonic activities during the lecture breaks (see Appendix F), some engaged in social activities, cognitive

activities, or a combination of these. This mixed variety of social media activities with potentially contrasting impacts on learning may have contributed to the overall non-significant effect of social media breaks.

Overall, these findings indicate that incorporating social media breaks during online lectures does not appear to have a significant impact on learning outcomes. However, considering that many students commonly engage with social media during breaks, allowing them to do so might contribute to a more positive learning experience. Further research with a larger sample size and more controlled conditions is needed to provide a more comprehensive understanding of the effects of social media breaks on learning in online lecture settings. Additionally, exploring the influence of different types of social media activities on learning may provide valuable insights.

Limitations

The current study has several limitations that should be acknowledged. Firstly, a convenience sample was used. The sample used in this study consisted of undergraduate students enrolled in an Introductory Psychology course, which may limit the generalizability of the results to online lectures of different course subjects, such as statistics, biology, engineering, computer science, and others. Thus, future studies should include a random sample that takes into account various course subjects.

Secondly, most of the measures employed in this study were introspective measures based on participants' self-report, except for quiz performance. Future studies should consider using more objective measures of attentiveness, media multitasking, etc. Furthermore, as mind-wandering is a common inattentive behaviour during lectures, it

would also be informative to include a measure of mind-wandering for a more comprehensive measure of attentiveness.

Another notable limitation of this study, specifically of Experiment 2, was the discrepancy between the intended timing and the actual timing at which Parts 2 and 3 were made accessible to participants. This discrepancy stemmed from the interpretation of completion time by the McMaster SONA system, which relied on when the SONA credits were granted for each part, rather than participants' actual completion times. Despite our efforts to approximate the correct timings through frequent manual checks, the system's preset timings for accessing subsequent parts (e.g., Part 3 becoming available one week after completing Part 2) were not based on the participants' actual completion times. As a result, the accessibility of Parts 2 and 3 did not precisely align with the intended timing. Although the difference in time between participants' completion of each part and the granting of SONA credits was relatively small given the delay period, this difference was not consistent across participants, which may have introduced some noise into the data.

Lastly, it is also important to acknowledge that the online lecture format used in the current study differed slightly from real online synchronous lectures and pre-recorded asynchronous lectures. Although it shared similarities with online synchronous lectures in terms of the lack of control over the lecture (e.g., pausing, rewinding, and lecture speed), it lacked opportunities for engagement with the lecturer and fellow students, such as options for raising hands, asking lecture-related questions, and turning on cameras. Conversely, while the online lecture format used in the current study resembled pre-

recorded asynchronous lectures in terms of being a pre-recorded instructional video with no opportunities to interact with the lecturer and fellow students during the lecture, it lacked the options for controlling the video playback. Future studies would benefit from conducting similar studies in authentic online lecture settings to increase the ecological validity and generalizability of the findings.

Future Directions

Future research should explore the impact of breaks during longer lectures (e.g., 2-hour and 3-hour lectures). As the duration of a lecture increases, students are likely to face greater challenges in maintaining focus on the lecture and experience more lapses in attention, multitasking, and other time-on-task effects. Thus, the effect of lecture breaks on attention and learning may be influenced by lecture duration, where students may need, and consequently benefit more from breaks during longer lectures. Further, it is also critical to determine how breaks dosage (e.g., duration and frequency of breaks) may interact with lecture duration to optimize the effectiveness of lecture breaks, by finding balance between restoring students' cognitive resources and avoiding causing any unnecessary disruptions. Collectively, these findings will help to inform instructors of how breaks can be optimally structured into lectures and instructional videos of different lengths.

Finally, future research should also investigate the optimal placement of lecture breaks by considering factors such as content difficulty. For example, placing a break immediately before or after parts of a lecture that are particularly more difficult or more cognitively demanding may enhance students' attention and retention of the material. By

understanding the different factors that impact the effectiveness of online lecture breaks, it can help to create general guidelines for educators and policy makers on how to design and implement breaks that work best for their lecture and students.

Conclusions

As the popularity and development of online education will only continue to grow, research on interventions that can help improve online learning outcomes is crucial. The current study is one of the first few to investigate the effects of break duration and frequency, as well as break activity, specifically stretching and social media, during an online lecture on attention and learning among university students. Notably, it is, to my knowledge, the first study to demonstrate the benefit of stretching breaks on learning in an online lecture setting among university students. Thus, strategically structuring online lectures with well-designed breaks can enhance learning outcomes, with stretching breaks showing particular promise. However, further research is needed to uncover other factors that influence the quality and effectiveness of lecture breaks, as poorly designed breaks may inadvertently hinder learning. The findings of this study contribute to the ongoing research on how to effectively design lecture breaks to promote student attention during online lectures and enhance learning, bringing us closer to developing the *BREAKthrough formula* for effective break design.

References

Abdelall, E. S., Lowndes, B. R., Abdelrahman, A. M., Hawthorne, H. J., & Hallbeck, M. S. (2018). Mini breaks, many benefits: development and pilot testing of an intraoperative microbreak stretch web-application for surgeons. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *62*(1), 1042-1046. https://doi.org/10.1177/1541931218621240

Aivaz, K. A., & Teodorescu, D. (2022). College students' distractions from learning caused by multitasking in online vs. face-to-face classes: A case study at a public university in Romania. *International Journal of Environmental Research and Public Health*, *19*(18), 11188. https://doi.org/10.3390/ijerph191811188

Ali-Hassan, H., Nevo, D., & Wade, M. (2015). Linking dimensions of social media use to job performance: The role of social capital. *The Journal of Strategic Information Systems*, *24*(2), 65-89. https://doi.org/10.1016/j.jsis.2015.03.001

Altenburg, T. M., Chinapaw, M. J., & Singh, A. S. (2016). Effects of one versus two bouts of moderate intensity physical activity on selective attention during a school morning in Dutch primary schoolchildren: A randomized controlled trial. *Journal of Science and Medicine in Sport*, *19*(10), 820-824.

Ariga, A., & Lleras, A. (2011). Brief and rare mental "breaks" keep you focused: deactivation and reactivation of task goals preempt vigilance decrements. *Cognition, 118*(3), 439-43. https://doi.org/10.1016/j.cognition.2010.12.007

Bannert, M. (2002). Managing cognitive load—recent trends in cognitive load theory. *Learning and Instruction*, *12*(1), 139-146. https://doi.org/10.1016/S0959-4752(01)00021-4

Bergouignan, A., Legget, K. T., De Jong, N., Kealey, E., Nikolovski, J., Groppel, J. L., Jordan, C., O'Day, R., Hill, J.O., & Bessesen, D. H. (2016). Effect of frequent interruptions of prolonged sitting on self-perceived levels of energy, mood, food cravings and cognitive function. *International Journal of Behavioral Nutrition and Physical Activity*, *13*(1), 1-12. http://doi.org/10.1186/s12966-016-0437-z

Blasiman, R. N., Larabee, D., & Fabry, D. (2018). Distracted students: A comparison of multiple types of distractions on learning in online lectures. *Scholarship of Teaching and Learning in Psychology*, *4*(4), 222. https://doi.org/10.1037/stl0000122

Bönstrup, M., Iturrate, I., Thompson, R., Cruciani, G., Censor, N., & Cohen, L.G. (2019). A rapid form of offline consolidation in skill learning. *Current Biology, 29*(8), 1346-1351. https://doi.org/10.1016/j.cub.2019.02.049

Braver, T. S., & Cohen, J. D. (2000). On the control of control: The role of dopamine in regulating prefrontal function and working memory. *Control of Cognitive Processes: Attention and performance XVIII*, 713-737.

Buchele Harris, H., Cortina, K. S., Templin, T., Colabianchi, N., & Chen, W. (2018). Impact of coordinated-bilateral physical activities on attention and concentration in school-aged children. *BioMed Research International*, *2018*. https://doi.org/10.1155/2018/2539748

Bunce, D. M., Flens, E. A., & Neiles, K. Y. (2010). How long can students pay attention in class? A study of student attention decline using clickers. *Journal of Chemical Education, 87*(12), 1438-1443. https://doi.org/10.1021/ed100409p

Cerbin, W. (2018). Improving student learning from lectures. *Scholarship of Teaching and Learning in Psychology, 4*(3), 151-163. https://doi.org/10.1037/stl0000113

Cheng, Y. S., & Cho, S. (2021). Are social media bad for your employees? Effects of at-work break activities on recovery experiences. *International Journal of Hospitality Management*, *96*, 102957. https://doi.org/10.1016/j.ijhm.2021.102957

Coulter-Smith, L. (2018). Changing minds: Multitasking during lectures. *Higher Education Computer Science: A Manual of Practical Approaches*, 3-16. https://doi.org/10.1007/978-3-319-98590-9_1

Daly-Smith, A. J., Zwolinsky, S., McKenna, J., Tomporowski, P. D., Defeyter, M. A., & Manley, A. (2018). Systematic review of acute physically active learning and classroom movement breaks on children's physical activity, cognition, academic performance and classroom behaviour: understanding critical design features. *BMJ Open Sport & Exercise Medicine*, *4*(1), e000341. http://dx.doi.org/10.1136/bmjsem-2018-000341

Dewar, M., Alber, J., Butler, C., Cowan, N., & Sala, S. D. (2012). Brief wakeful resting boosts new memories over the long term. *Psychological Science, 23*(9), 955-960. https://doi.org/10.1177/0956797612441220

Esterman, M., Reagan, A., Liu, G., Turner, C., & DeGutis, J. (2014). Reward reveals dissociable aspects of sustained attention. *Journal of Experimental Psychology: General*, *143*(6), 2287. https://doi.org/10.1037/xge0000019

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175-191. https://doi-org.libaccess.lib.mcmaster.ca/10.3758/BF03193146

Fenesi, B., Lucibello, K., Kim, J. A., & Heisz, J. J. (2018). Sweat so you don't forget: Exercise breaks during a university lecture increase on-task attention and learning. *Journal of Applied Research in Memory and Cognition*, *7*(2), 261-269. https://doi.org/10.1016/j.jarmac.2018.01.012

Fried, C. B. (2008). In-class laptop use and its effects on student learning. *Computers & Education*, *50*(3), 906-914. https://doi.org/10.1016/j.compedu.2006.09.006

Guinness, K. E., Beaulieu, L., & MacDonald, J. M. (2018). Effects of technology breaks on media multitasking with college students. *Behavioral Interventions*, *33*(4), 427-439. https://doi.org/10.1002/bin.1529

Halser, B. S., Kersten, B., & Sweller, J. (2007). Learner control, cognitive load and instructional animation. *Applied Cognitive Psychology, 21*, 713-729. https://doi.org/10.1002/acp.1345

Harris, A., Buglass, S., & Gous, G. (2021). The impact of lecture chunking format on university student vigilance: Implications for classroom pedagogy. *Journal of*

Pedagogical Sociology and Psychology, *3*(2), 90-102. https://doi.org/10.33902/JPSP.2021272429

Hicks, L. J., Caron, E. E., & Smilek, D. (2021). SARS-CoV-2 and learning: The impact of a global pandemic on undergraduate learning experiences. *Scholarship of Teaching and Learning in Psychology*. https://psycnet.apa.org/doi/10.1037/stl0000250

Hofer, M. (2007). Goal conflicts and self-regulation: A new look at pupils' off-task behaviour in the classroom. *Educational Research Review*, *2*(1), 28-38. https://doi.org/10.1016/j.edurev.2007.02.002

Hollis, R. B., & Was, C. A. (2016). Mind wandering, control failures, and social media distractions in online learning. *Learning and Instruction*, *42*, 104-112. https://doi.org/10.1016/j.learninstruc.2016.01.007

Humphreys, L. (2013). Mobile social media: Future challenges and opportunities. *Mobile Media & Communication*, *1*(1), 20-25. https://doi.org/10.1177/2050157912459499

Hunter, E. M., & Wu, C. (2016). Give me a better break: Choosing workday break activities to maximize resource recovery. *Journal of Applied Psychology, 101*(2), 302–311. https://doi.org/10.1037/apl0000045

Hutabarat, J. (2020). Stretching interventions and their effect on mental the workload. *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, *9*(7), 268-295. http://doi.org/10.35940/ijitee.G4982.059720

Infantes-Paniagua, Á., Silva, A. F., Ramirez-Campillo, R., Sarmento, H., González-Fernández, F. T., González-Víllora, S., & Clemente, F. M. (2021). Active school breaks and students' attention: A systematic review with meta-analysis. *Brain Sciences*, *11*(6), 675. https://doi.org/10.3390/brainsci11060675

Jensen, S. A. (2011). In-class versus online video lectures: Similar learning outcomes, but a preference for in-class. *Teaching of Psychology*, *38*(4), 298-302. https://doi.org/10.1177/0098628311421336

Junco, R., & Cotten, S. R. (2012). No A 4 U: The relationship between multitasking and academic performance. *Computers & Education*, *59*(2), 505-514. https://doi.org/10.1016/j.compedu.2011.12.023

Junco, R., Heiberger, G., & Loken, E. (2011). The effect of Twitter on college student engagement and grades. *Journal of Computer Assisted Learning, 27*(2), 119-132. https://doi.org/10.1111/j.1365-2729.2010.00387.x

Kane, M. J., Smeekens, B. A., von Bastian, C. C., Lurquin, J. H., Carruth, N. P., & Miyake, A. (2017). A combined experimental and individual-differences investigation into mind wandering during a video lecture. *Journal of Experimental Psychology: General, 146*(11), 1649–1674. https://doi.org/10.1037/xge0000362

Keller, A. S., Davidesco, I., & Tanner, K. D. (2020). Attention matters: How orchestrating attention may relate to classroom learning. *CBE—Life Sciences Education*, *19*(3), fe5. https://doi.org/10.1187/cbe.20-05-0106

Kirschner, P. A. (2002). Cognitive load theory: Implications of cognitive load theory on the design of learning. *Learning and Instruction, 12*(1), 1-10. https://doi.org/10.1016/S0959-4752(01)00014-7

Kraushaar, J. M., & Novak, D. C. (2010). Examining the affects of student multitasking with laptops during the lecture. *Journal of Information Systems Education*, *21*(2), 241-252.

Lau, W. W. F. (2017). Effects of social media usage and social media multitasking on the academic performance of university students. *Computers in Human Behavior, 68*, 286-291. https://doi.org/10.1016/j.chb.2016.11.043

Lawson, D., & Henderson, B. B. (2015). The costs of texting in the classroom. *College Teaching*, *63*(3), 119-124. https://doi.org/10.1080/87567555.2015.1019826

Lee, J., Lin, L., & Robertson, T. (2012). The impact of media multitasking on learning. *Learning, Media and Technology*, *37*(1), 94-104. https://doi.org/10.1080/17439884.2010.537664

Lepp, A., Barkley, J. E., Karpinski, A. C., & Singh, S. (2019). College students' multitasking behavior in online versus face-to-face courses. *Sage Open*, *9*(1), 2158244018824505. https://doi.org/10.1177/2158244018824505

Leroy, S. (2009). Why is it so hard to do my work? The challenge of attention residue when switching between work tasks. *Organizational Behavior and Human Decision Processes*, *109*(2), 168-181. https://doi.org/10.1016/j.obhdp.2009.04.002

Leysens, J. L., le Roux, D. B., & Parry, D. A. (2016). Can I have your attention, please?: An empirical investigation of media multitasking during university lectures. *Proceedings of the Annual Conference of the South African Institute of Computer Scientists and Information Technologists*, 1-10. http://dx.doi.org/10.1145/2987491.2987498

Lim, J., & Kwok, K. (2015). The effects of varying break length on attention and time on task. *Human Factors, 58*(3), 472-481. https://doi.org/10.1177/0018720815617395

Lim, J., Wu, W., Wang, J., Detre, J. A., Dinges, D. F., & Rao, H. (2010). Imaging brain fatigue from sustained mental workload: An ASL perfusion study of the time-on-task effect. *NeuroImage, 49*(4), 3426-3435. https://doi.org/10.1016/j.neuroimage.2009.11.020

Lindquist, S. I. & McLean, J. P. (2011). Daydreaming and its correlates in an educational environment. *Learning and Individual Differences, 21*(2), 158-167. https://doi.org/10.1016/j.lindif.2010.12.006

Loh, K. K., Tan, B. Z. H., & Lim, S. W. H. (2016). Media multitasking predicts video-recorded lecture learning performance through mind wandering tendencies. *Computers in Human Behavior*, *63*, 943-947. https://doi.org/10.1016/j.chb.2016.06.030

Ma, J. K., Mare, L. L., & Gurd, B. J. (2014). Classroom-based high-intensity interval activity improves off-task behaviour in primary school students. *Applied Physiology, Nutrition, and Metabolism*, *39*(12), 1332-1337. http://dx.doi.org/10.1139/apnm-2014-0125

Mayer, R. E. (2010). Applying the science of learning to medical education. *Medical Education, 44*(6), 543-549. https://doi.org/10.1111/j.1365-2923.2010.03624.x

Neigel, A. R., Claypoole, V. L., Waldorf, K. M., Dever, D. A., & Szalma, J. L. (2017). Motivational correlates of vigilance task engagement. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *61*(1), 1524-1528. https://doi.org/10.1177/1541931213601865

Neiterman, E., & Zaza, C. (2019). A mixed blessing? Students' and instructors' perspectives about off-task technology use in the academic classroom. *Canadian Journal for the Scholarship of Teaching and Learning*, *10*(1), n1. https://doi.org/10.5206/cjsotl-rcacea.2019.1.8002

Oberauer, K. (2019). Working memory and attention—A conceptual analysis and review. *Journal of Cognition*, *2*(1), 36. https://doi.org/10.5334/joc.58

Oken, B. S., Salinsky, M. C., & Elsas, S. (2006). Vigilance, alertness, or sustained attention: physiological basis and measurement. *Clinical Neurophysiology*, *117*(9), 1885-1901. https://doi.org/10.1016/j.clinph.2006.01.017

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychologist*, *38*(1), 63-71. https://doi.org/10.1207/S15326985EP3801_8

Park, A. E., Zahiri, H. R., Hallbeck, M. S., Augenstein, V., Sutton, E., Yu, D., Lowndes B.R., & Bingener, J. (2017). Intraoperative "micro breaks" with targeted stretching enhance surgeon physical function and mental focus. *Annals of Surgery*, *265*(2), 340-346. https://doi.org/10.1097/SLA.0000000000001665

Paulus, M., Kunkel, J., Schmidt, S. C., Bachert, P., Wäsche, H., Neumann, R., & Woll, A. (2021). Standing breaks in lectures improve university students' self-perceived physical, mental, and cognitive condition. *International Journal of Environmental Research and Public Health*, *18*(8), 4204. https://doi.org/10.3390/ijerph18084204

Peper, E., Wilson, V., Martin, M., Rosegard, E., & Harvey, R. (2021). Avoid Zoom fatigue, be present and learn. *NeuroRegulation*, *8*(1), 47–56. https://doi.org/10.15540/nr.8.1.47

Ragan, E. D., Jennings, S. R., Massey, J. D., & Doolittle, P. E. (2014). Unregulated use of laptops over time in large lecture classes. *Computers & Education*, *78*, 78-86. https://doi.org/10.1016/j.compedu.2014.05.002

Ralph, B. C. W., Wammes, J. D., Barr, N., & Smilek, D. (2017). Wandering minds and wavering goals: Examining the relation between mind wandering and grit in everyday life and the classroom. *Canadian Journal of Experimental Psychology, 71*(2), 120–132. https://doi.org/10.1037/cep0000116

Randall, J. G., Oswald, F. L., & Beier, M. E. (2014). Mind-wandering, cognition, and performance: a theory-driven meta-analysis of attention regulation. *Psychological Bulletin*, *140*(6), 1411. https://doi.org/10.1037/a0037428

Ravizza, S. M., Hambrick, D. Z., & Fenn, K. M. (2014). Non-academic internet use in the classroom is negatively related to classroom learning regardless of intellectual ability. *Computers & Education*, *78*, 109-114. https://doi.org/10.1016/j.compedu.2014.05.007

Risko, E. F., Anderson, N., Sarwal, A., Engelhardt, M., & Kingstone, A. (2012). Everyday attention: Variation in mind wandering and memory in a lecture. *Applied Cognitive Psychology*, *26*(2), 234-242. https://doi.org/10.1002/acp.1814

Risko, E. F., Buchanan, D., Medimorec, S., & Kingstone, A. (2013). Everyday attention: Mind wandering and computer use during lectures. *Computers & Education*, *68*, 275-283. https://doi.org/10.3389/fpsyg.2013.00619

Rogers, R. D., & Monsell, S. (1995). Costs of a predictible switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124*(2), 207–231. https://doi.org/10.1037/0096-3445.124.2.207

Rosen, L. D., Carrier, L. M., & Cheever, N. A. (2013). Facebook and texting made me do it: Media-induced task-switching while studying. *Computers in Human Behavior, 29*(3), 948- 958. https://doi.org/10.1016/j.chb.2012.12.001

Sana, F., Weston, T., & Cepeda, N. J. (2013). Laptop multitasking hinders classroom learning for both users and nearby peers. *Computers & Education*, *62*, 24-31. https://doi.org/10.1016/j.compedu.2012.10.003

Simmons, A. L. (2012). Distributed practice and procedural memory consolidation in musicians' skill learning. *Journal of Research in Music Education, 59*(4), 357-368. https://doi.org/10.1177/0022429411424798

Smallwood, J., Fishman, D. J., & Schooler, J. W. (2007). Counting the cost of an absent mind: Mind wandering as an underrecognized influence on educational performance. *Psychonomic Bulletin & Review*, *14*, 230-236. https://doi.org/10.3758/BF03194057

Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature, 437*(27), 1272-1278. https://doi.org/10.1038/nature04286

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. Cognitive science, *12*(2), 257-285. https://doi.org/10.1016/0364-0213(88)90023-7

Sweller, J. (2008). Human cognitive architecture. In *Handbook of research on educational communications and technology* (3rd ed., pp. 369-381). Routledge.

Sweller, J. (2020). Cognitive load theory and educational technology. *Educational Technology Research and Development*, *68*(1), 1-16. https://doi.org/10.1007/s11423-019-09701-3

Szalma, J. L., & Claypoole, V. L. (2019). Vigilance and workload in automated systems: Patterns of association, dissociation, and insensitivity. In *Human performance in automated and autonomous systems* (pp. 85-102). CRC Press. https://doi.org/10.1201/9780429458330-5

Szpunar, K. K., Moulton, S. T., & Schacter, D. L. (2013). Mind wandering and education: From the classroom to online learning. *Frontiers in Psychology*, *4*, 495. https://doi.org/10.3389/fpsyg.2013.00495

Tucker, P. (2003). The impact of rest breaks upon accident risk, fatigue and performance: a review. *Work & Stress*, *17*(2), 123-137. https://doi.org/10.1080/0267837031000155949

Tyler, J. M., & Burns, K. C. (2008). After depletion: The replenishment of the self's regulatory resources. *Self and Identity*, *7*(3), 305-321. https://doi.org/10.1080/15298860701799997

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods*, *37*(3), 498-505. https://doi-org.libaccess.lib.mcmaster.ca/10.3758/BF03192720

Walker, M. P., & Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. *Neuron, 44*(1), 121-133. https://doi.org/10.1016/j.neuron.2004.08.031

Wammes, J. D., Seli, P., Cheyne, J. A., Boucher, P. O., & Smilek, D. (2016). Mind wandering during lectures II: Relation to academic performance. *Scholarship of Teaching and Learning in Psychology, 2*(1), 33-48. https://doi.org/10.1037/stl0000055

Wamsley E. J. (2019). Memory consolidation during waking rest. *Trends in Cognitive Sciences, 23*(3), 171–173. https://doi.org/10.1016/j.tics.2018.12.007

Wang, Z., & Tchernev, J. M. (2012). The "myth" of media multitasking: Reciprocal dynamics of media multitasking, personal needs, and gratifications. *Journal of Communication*, *62*(3), 493-513. https://doi.org/10.1111/j.1460-2466.2012.01641.x

Warm, J. S., Parasuraman, R., & Matthews, G. (2008). Vigilance requires hard mental work and is stressful. *Human Factors*, *50*(3), 433-441. https://doi.org/10.1518/001872008X312152

Wood, E., Zivcakova, L., Gentile, P., Archer, K., De Pasquale, D., & Nosko, A. (2012). Examining the impact of off-task multi-tasking with technology on real-time

classroom learning. *Computers & Education*, *58*(1), 365-374.

https://doi.org/10.1016/j.compedu.2011.08.029

Appendices

Appendix A

Lecture Quarters Divided by Breaks (Experiment 1)

	Start Time	End Time	Total Duration
Lecture Quarter 1	0:00	11:26	11 minutes 26 seconds
Lecture Quarter 2	11:26	24:40	13 minutes 14 seconds
Lecture Quarter 3	24:40	37:23	12 minutes 43 seconds
Lecture Quarter 4	37:23	50:21	12 minutes 58 seconds

Note. Total lecture time was 50 minutes and 21 seconds.

Note. A 6-minute break occurred between Lecture Parts 2 and 3 in the one 6-minute break condition. A 2-minute break occurred between Lecture Parts 1 and 2, Parts 2 and 3, and Parts 3 and 4 in the three 2-minute breaks condition.

Lecture Quarters Divided by Breaks (Experiment 2)

	Start Time	End Time	Total Duration
Lecture Quarter 1	0:00	13:26	13 minutes 26 seconds
Lecture Quarter 2	13:26	26:39	13 minutes 12 seconds
Lecture Quarter 3	26:39	39:30	12 minutes 51 seconds
Lecture Quarter 4	39:30	50:21	10 minutes 50 seconds

Note. Total lecture time was 50 minutes and 21 seconds.

Note. A 2-minute break occurred between Lecture Parts 1 and 2, Parts 2 and 3, and Parts 3 and 4 in the three breaks conditions (open-ended breaks, stretching breaks, and social media breaks).

Appendix B

Preferences and Impressions of Lecture Breaks

General questions

1. Please rate the extent that you agree/disagree with the following statements (0 - *Strongly Disagree*, 5 - *Strongly Agree*):
    a. I find it difficult to sustain my attention throughout a 50-min live online university lecture.
    b. In a 50-min live online university lecture, taking lecture breaks would help me to stay focused throughout the lecture.
    c. In a 50-min live online university lecture, taking lecture break(s) would help me to increase my engagement with the lecture.
    d. In a 50-min live online university lecture, taking lecture break(s) would make it more difficult for me to follow along with the lecture.
    e. In a 50-min live online university lecture, taking lecture break(s) would make it difficult for me to remember the lecture content
    f. In a 50-min live online university lecture, taking lecture break(s) would be a waste of time.
2. In a 50-min live online university lecture, do you prefer to have no breaks, a single break, or multiple breaks?
        a. [If selected single break option]
            i. How long would you prefer the single lecture break to be?
                1. Less than 5 mins
                2. 5-10 mins
                3. 10+ mins
            ii. When would you prefer to have a single lecture break?
                1. Near the beginning of the lecture
                2. Near the middle of the lecture
                3. Near the end of the lecture
        b. [If selected multiple breaks option]
            i. How long would you prefer each lecture break to be?
                1. Less than 5 mins
                2. 5-10 mins
                3. 10+ mins
            ii. How many lecture breaks would you prefer to have?
                1. [Participants can enter a number]
            iii. How would you prefer the breaks to be distributed?
                1. Near the beginning of the lecture

2. Near the middle of the lecture
3. Evenly spread throughout the lecture
4. Near the end of the lecture
5. Other:

Specific-to-lecture questions

1. Please rate the extent that you agree/disagree with the following statements (0 - *Strongly Disagree*, 5 - *Strongly Agree*): (for the no breaks condition, change the wording to "would have")
    a. The lecture break(s) helped me to sustain my attention during this lecture.
    b. The lecture break(s) helped me to increase my engagement with this lecture.
    c. The lecture break(s) made it more difficult for me to follow along with this lecture.
    d. The lecture break(s) made it difficult for me to remember the lecture content.
    e. The lecture break(s) was/were a waste of time.
2. You were in the [condition] condition. In this 50-min lecture, would you have preferred no breaks, a single break, or multiple breaks?
    a. [If selected single break option]
        i. How long would you have preferred the single lecture break to be?
            1. Less than 5 mins
            2. 5-10 mins
            3. 10+ mins
        ii. When would you have preferred to have a single lecture break?
            1. Near the beginning of this lecture
            2. Near the middle of this lecture
            3. Near the end of this lecture
    b. [If selected multiple breaks option]
        i. How long would you have preferred each lecture break to be?
            1. Less than 5 mins
            2. 5-10 mins
            3. 10+ mins
        ii. How many lecture breaks would you have preferred to have?
            1. [Participants can enter a number]
        iii. How would you have preferred the breaks to be distributed?
            1. Near the beginning of this lecture
            2. Near the middle of the lecture

3. Evenly spread throughout this lecture
4. Near the end of this lecture
5. Other:

Demographic Questionnaire

1. Your age (in years): _____

2. Your gender: Woman ___ Man ___ Non-binary ___ Prefer not to say ___

Post-lecture Survey

Please answer all of the following questions honestly and accurately. You will still receive your SONA credits regardless of your responses.

1. Overall, how attentive to the lecture were you?

0 1 2 3 4 5 6 7 8 9 10

Not at all attentive Extremely attentive

2. While watching the lecture video, how motivated were you to learn the content?

0 1 2 3 4 5 6 7 8 9 10

Not at all motivated Extremely motivated

3. Overall, while the lecture video was playing, to what extent was your attention focused on things on another device, unrelated to the lecture?

0 1 2 3 4 5 6 7 8 9 10

Not at all Extremely

4. Overall, while the lecture video was playing, to what extent was your attention focused on things going on around you (not including electronic devices)?

0 1 2 3 4 5 6 7 8 9 10

Not at all Extremely

5. Did you take any notes during the lecture?

☐ Yes ☐ No

6. During this study, did you use a dual-monitor setup (i.e., two computer monitors simultaneously)? ☐ Yes ☐ No

7. Did you experience any issues during the study (e.g., technical issues, unexpected distractions in your home environment) that prevented you from watching or hearing the lecture video for **more than five minutes?**

☐ Yes ☐ No

Break Activity(s)

What activities listed below best reflect(s) what you did during your break(s)? (Select all that apply)

__ Had a snack

__ Walked around (indoors or outside)

__ Thought about something unrelated to the lecture

__ Had an in-person conversation with someone

__ Cleaned or tidied

__ Talked on the phone

__ Interacted with your pet (if you have one)

__ Exercised

__ Thought about the lecture

__ Viewed another website (not including social media)

__ Sent or checked email

__ Stretched

__ Read or replied to a text message

__ Used social media

__ Watched a video

__ Watched television

__ Other:

Appendix C

Lecture Quiz Version 1 (First Five Questions)

You have 15 minutes to answer the 48 questions below. Please try to answer *all* of the questions (even if you have to guess). Also, please don't look up any answers (doing so would invalidate our results). Thank you.

Q1. Which approach dominated the field prior to the Gestalt philosophy?
A. Functionalist approach
B. Structuralist approach
C. Psychodynamic approach
D. Humanistic approach

Q2. Which is the most fundamental Gestalt principle?
A. Figure-ground
B. Proximity
C. Common fate
D. Similarity

Q3. Cues guide our ability to segregate figures from the background. However, this automated process is influenced by which of the following?
A. Prior assumptions, opinions, and perceptions
B. Prior experiences and biases of the people around us
C. Prior experiences, biases, and heuristics
D. Prior assumptions and perceptions of the people around us

Q4. What is the Gestalt Principle of Proximity?
A. Elements that are close together in space tend to be grouped together
B. Elements that are far apart in space tend to be grouped together
C. Elements that are close together in space tend to be separated
D. Elements that are far apart in space tend to be separated

Q5. Based on the Gestalt Principle of Closure, if there are gaps in the contours of shape, what do we tend to do?
A. We tend to notice the gaps immediately because they direct our attention
B. We tend to analyze each contour because we find them interesting
C. We tend to perceive the contours as several simple lines, rather than a combination of awkward forms
D. We tend to fill in the gaps to perceive a whole object

Lecture Quiz Version 2 (First Five Questions)

You have 15 minutes to answer the 48 questions below. Please try to answer *all* of the questions (even if you have to guess). Also, please don't look up any answers (doing so would invalidate our results). Thank you.

Q1. What approach revolted against the structuralist approach?
a) Functionalist approach
b) Humanistic approach
c) Psychodynamic approach
d) Gestalt approach

Q2. Which is the most fundamental Gestalt principle?
a) Common fate
b) Figure-ground
c) Continuity
d) Closure

Q3. Our ability to segregate figures from the background is an automated process that is guided by cues and influenced by which of the following?
a) Prior assumptions, opinions, and perceptions
b) Prior assumptions, biases, and perceptions
c) Prior experiences, biases, and heuristics
d) Prior experiences, impartiality, and perceptions

Q4. What is the Gestalt Principle of Proximity?
a) The tendency to group elements that are close together in space
b) The tendency to group elements that are far apart in space
c) The tendency to separate elements that are close together in space
d) The tendency to separate elements that are far apart in space

Q5. What Gestalt principle allows you to fill in the gaps to perceive a single object?
a) Proximity
b) Closure
c) Continuity
d) Similarity

Appendix D

Stretching Breaks Condition

1. Did you follow the stretching video during the breaks?

☐ Yes
☐ No, I did my own stretches during the breaks
☐ No, I did not stretch during the breaks

Social Media Breaks Condition

1. Did you engage in social media during the breaks?

☐ Yes
☐ Yes, but I engaged in other activities too
☐ No

[IF YES]

2. Which of the following social media platform(s) did you use? (Select all that apply)

- Facebook
- Youtube
- Twitter
- Instagram
- Snapchat
- TikTok
- Pinterest
- WhatsApp
- LinkedIn
- Reddit
- Tumblr
- Other:

3. During the breaks, what did you use social media for? (Select all that apply)

- For meeting new people and/or keeping in touch with family, friends, and peers (e.g., adding or following someone, making new friends, viewing someone's posts/updates, messaging someone, etc.)
- For relaxation and entertainment (e.g., watching videos, listening to music, playing games, etc.)
- For creating, seeking, and/or sharing information (e.g., searching for information, participating in a discussion, sharing others' posts, creating content, etc.)
- Other:

4. What activities listed below best reflect(s) what you did on social media during your breaks? (Select all that apply)

- Looked at my notifications
- Read a message(s) that was sent to me
- Sent a message(s) to someone
- Looked at a photo-based post(s)
- Read a text-based post(s)
- Watched a video-based post(s)
- Liked someone's post(s)
- Commented or replied to a comment on a post(s)
- Shared someone's post(s)
- Saved someone's post(s)
- Added/Followed someone I know or just met
- Followed someone/a page that I found entertaining
- Followed someone/a page that I found informative
- Looked at someone's profile/post(s)
- Looked at my own profile/post(s)
- Drafted or published my own post(s)
- Listened to music
- Played games
- Other:

Appendix E

8. Have you watched the **module(s)** on form perception in **PSYCH 1XX3** prior to completing this part of the study?

- ☐ Yes, I have watched one of the form perception modules in PSYCH 1XX3.
- ☐ Yes, I have watched both of the form perception modules in PSYCH 1XX3.
- ☐ No, I have not watched the form perception modules in PSYCH 1XX3.
- ☐ I have not taken/am not currently taking the PSYCH 1XX3 course.

9. Have you attended the **PSYCH 1XX3 live lecture** on form perception (or watched the recording of the lecture) prior to completing this part of the study?

- ☐ Yes, I have attended or watched the PSYCH 1XX3 lecture on form perception.
- ☐ No, I have not attended or watched the PSYCH 1XX3 lecture on form perception.
- ☐ I have not taken/am not currently taking PSYCH 1XX3 course.

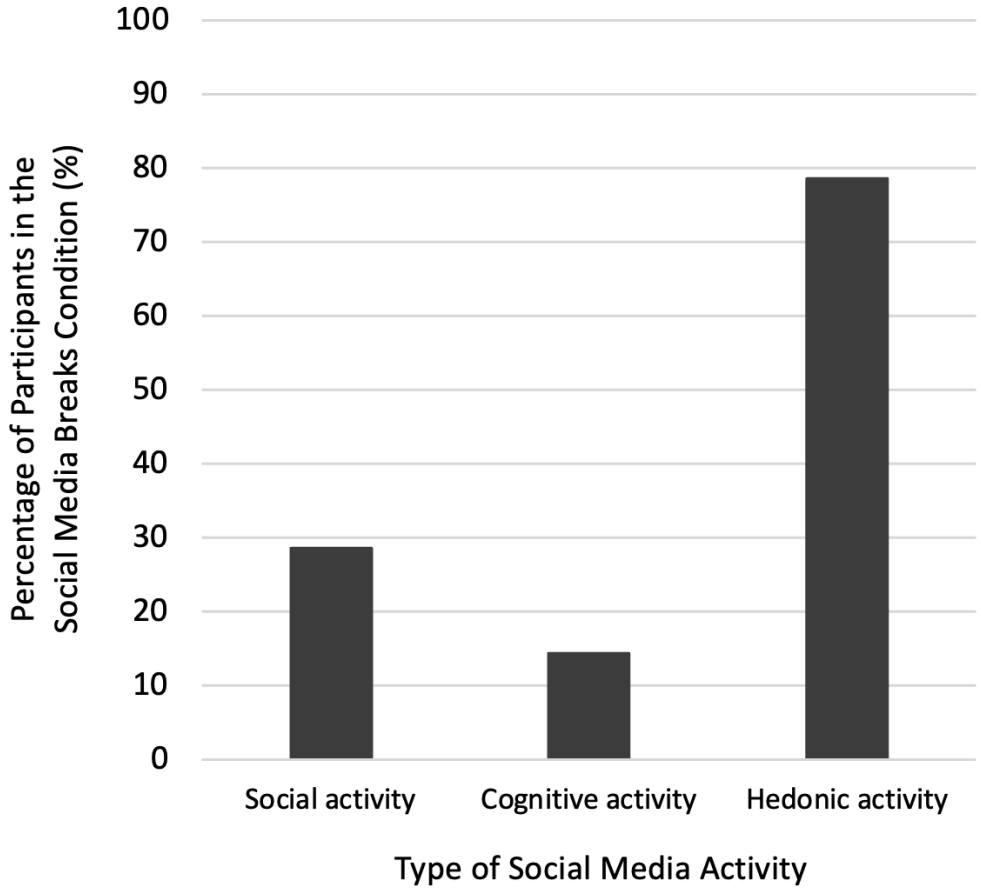
10. Have you watched the **module(s)** on form perception in **PSYCH 1FF3** prior to completing this part of the study?

- ☐ Yes, I have watched at least one of the form perception modules in PSYCH 1FF3.
- ☐ No, I have not watched the form perception modules in PSYCH 1FF3.
- ☐ I don't remember.
- ☐ I have not taken the PSYCH 1FF3 course before.

11. Have you watched the **PSYCH 1FF3 lecture** on form perception prior to completing this part of the study?

- ☐ Yes, I have watched the PSYCH 1FF3 lecture on form perception.
- ☐ No, I have not watched the PSYCH 1FF3 lecture on form perception.
- ☐ I don't remember.
- ☐ I have not taken the PSYCH 1FF3 course before.

Appendix F


100
90
80
70
60
50
40
30
20
10
0
Percentage of Participants in the Social Media Breaks Condition (%)
Social activity
Cognitive activity
Hedonic activity
Type of Social Media Activity