EFFECTS OF PAUSING AND TASK RELEVANCE ON ONLINE LEARNING, A MEDIA MULTITASKING STUDY

DOES PAUSING AND TASK-RELEVANCE ATTENUATE LEARNING DEFICITS WHILE MEDIA MULTITASKING? INVESTIGATING THE EFFECTS OF PAUSING AND TASK RELEVANCE ON LEARNING DURING AN ASYNCHRONOUS LECTURE VIDEO, A MEDIA MULTITASKING STUDY

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TITLE: Does pausing and task-relevance attenuate learning deficits while media multitasking? Investigating the effects of pausing and task relevance on learning during an asynchronous lecture video, a media multitasking study.

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Lay Abstract

In context of students engaging in media multitasking behaviours during an online video lecture environment, it is unclear the extent to which pausing behaviours and task-relevance influences learning. To our surprise, findings demonstrate that engaging in distractive secondary media tasks simultaneously with the video lecture did not impair learning. On the other hand, a learning boost was found when the secondary media task is relevant to the lecture and tended to while the video lecture is paused. This suggests that multitasking, regardless of whether its unrelated to the lecture or done simultaneously to online lectures, does not impair learning. However, analysis reveals that these results may be skewed by participants engaging in non-study-related media multitasking.

Abstract

The shift to online learning amidst the COVID-19 pandemic created a host of new challenges. One of which involves students' rising media multitasking (MMT) habits while engaging online academic content. Few studies have investigated the learning implications of newer forms asynchronous video lecture consumption in context of concurrent and sequential MMT behaviours, such as social media scrolling. The current study investigates the impact of media-based secondary tasks under conditions of pausing (pause and no-pause) and task-relevance (relevant and non-relevant) on academic performance during a pre-recorded psychology lecture video. In addition, two separate Media Multitasking Indexes (MMI) assessing students' general MMT and online lecture MMT habits were compared to each other, and to academic performance. To our surprise no-pause conditions did not demonstrate an academic performance cost when compared to both the control and pause conditions, and the relevant pause condition demonstrated an academic enhancement effect. However, academic performance costs were found for no-pause groups when academic performance was narrowed to content that overlapped with the six MMT distractors. Moderate positive correlations were revealed between both MMI's. Both indexes demonstrated similar correlations to academic performance across all conditions. However, further speculation reveals the control scores may be deflated as a result of "non-compliant" participants paradoxically engaging in a higher volume of non-study-related MMT behaviours during the uninterrupted lecture than participants in the experimental conditions. Future online MMT studies need to enforce novel methods to prevent or control for non-study-related MMT during the study.

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Declaration of Academic Achievement

The current thesis is the product of an ongoing battle of ADHD-type shifts in study interests. After fumbling through a series of unfinished prospective studies over the last two years, I, Mehdi Hussain, am the sole author of this thesis and successfully brought to completion. Dr. Jeremy-Marty Dugas, Dr. Joe Kim, Dr. Faria Sana, Dr. Noah Forrin all played roles in the constructive criticisms and guidance to the design of the current thesis.

Introduction

While media and online engagement is central to the lives of many students, the universal shift to online learning amid the COVID-19 pandemic created a new terrain of academic challenges. Particularly concerning are the variety of popular social media platforms, and rising social media dependence among students. According to a largescale meta-analysis spanning thirty-two countries, social media addiction is estimated to be as high as 25% (Cheng et al., 2021). Primarily designed to ceaselessly solicit attentional resources from their consumers, social medias now share and compete for the same digital real estate as educational content. To manage the conflict, students often engage in media multitasking (MMT), the purposeful execution of more than one media-based task, each encompassing uniquely distinct goals (Salvucci & Taatgen, 2015).

While there is a growing body of research exposing the negative effects of trait-level and state-level media use on learning and academic performance (Al-Menayes, 2015; Bellur et al., 2015; Burak, 2012; Carrier et al., 2015; Duncan et al., 2012; Fried, 2008; Gaudreau et al., 2014; Junco & Cotton, 2012; Kraushaar J, 2010; Kuznekoff & Titsworth, 2013; Larry D. et al., 2011; Lau, 2017; McDonald, 2013; Sana et al., 2013; Van Der Schuur et al., 2015; Walsh et al., 2013; Wei et al., 2014), recent investigations have found an exacerbation effect where students are projected to be approximately 25% more likely to engage off-task media distractions during online courses than in-person courses (Kohler et al., 2021; Zhang et al., 2022). While this poses an obvious pedagogical problem, unfortunately, there are surprisingly few experimental studies investigating the learning consequences of MMT in context of online video lectures.

With respect to lecture consumption, it appears learning patterns have changed in two fundamental ways. First, while students' media use during in-person lectures are constrained by social norms and instructor monitoring, students engaging online lectures at home are typically faced with a wider range of media distractions and with little to no inhibitory forces to moderate the frequency and volume of their media consumption. Secondly, asynchronous video lectures have control features (pause/play, skip/replay, lecture speed) that present new norms of engagement radically different from an in-person lecture. Crucially, these two fundamental shifts are interconnected. Unlike in a classroom setting, students may pause their video lecture to tend to a distraction (e.g., a social media notification) or explore content related to the lecture (e.g., search up a key term). No experimental studies to date have investigated the learning effects of both *pausing* and *task-relevance* manipulations.

In light of the few MMT studies in online lecture contexts, the general aim of the current study is three-fold: First, to determine how academic performance is affected across pausing and task relevance manipulations during an online pre-recorded lecture environment; Second, to determine how academic performance is affected across pausing and task relevance manipulations during media multitasking segments; Third, to investigate the relationship between two trait-level MMT indexes, general versus online, and their connection to academic performance (discussed in more detail later; see section *1.3 MMT and Cognitive Functioning*).

Literature Review

The literature review is subdivided into five parts, (1) A general and chronological overview of multitasking research, (2) the current state of MMT studies and associated theoretical models, (3) Cognition and MMT measures, (4) students' MMT habits and behaviours, and (5) MMT and academic performance.

1.1 Multitasking

Within the literature, multitasking is either defined in terms of computer-based processors or human-based behaviours (Foehr, 2006) and dates decades before the advent of modern technological distraction (Meyer & Kieras, 1997). Over the years there has been numerous ways of defining and conceptualizing *multitasking* as a pattern of behaviour. Interruption, distraction, dual-task completion, divided attention, and task switching are terms often synonymously used with multitasking. The most universally accepted definition is a broad one. Namely, multitasking refers to a purposeful execution of more than one task, each encompassing uniquely distinct goals (Salvucci & Taatgen, 2015). From this broader definition are delineations of adjacent and context-specific descriptions. One common understanding of the behaviour would refer to the act of carrying out multiple tasks at a given moment (Burak, 2012), and typically occurs as a result of either engaging external interruptions or a volitional switch in the task performed (Benbunan-Fich et al., 2011). In contrast, the competing conceptualization is predicated on the idea that only one specific task can be consciously tended to at a time

(Bannister & Remenyi, 2008), evoking several academics to suggest multitasking is the sequential execution of multiple tasks in rapid succession (Burak, 2012).

Delving deeper, many scholars subscribe to idea that humans are incapable of parallel processing due to cognitive limitations. Consequently, there exists a push towards representing multitasking as a "myth" and replacing it with other terminologies, such as "distraction" (Aagard 2019) or "task-switching" (Kirschner 2017). While multitasking as a term can be misleading, ambiguous, and unproductive in some segments of the literature, retiring the term wholesale overlooks the dexterity it can provide in framing experimental studies within an academic context. For example, Kraushaar and Novac (2010) pose a useful way of conceptualizing multitasking by task efficiency whereby *productive multitasking* involves tasks relevant to the primary activity (e.g. searching up a key term on google during a lecture) and *distractive multitasking* involves tasks irrelevant to learning (e.g. scrolling through social media feed during a lecture).

1.2 Media Multitasking

Slightly distinct from multitasking, media multitasking has its own separate descriptions of motivations and behaviours (Leysens et al., 2016). The term is often defined in terms of engaging multiple media simultaneously (e.g., talking on cell phone and watching television, watching a video lecture and playing chess on the same device) or a broader and more traditional view that includes engaging media along with other media and/or non-media activities simultaneously (Jeong & Hwang, 2012; Ophir et al., 2009; Wallis, 2010). For example, driving and cellphone use qualifies as a MMT behaviour, and has been found to impair driving ability (Caird et al., 2018; Drews et al., 2008; Horrey et al., 2008).

To make sense of these performance deficits, there are several theories that provide underlying cognitive processing accounts of media multitasking and multitasking behaviours more broadly. Contingent on our brains limited capacity to exhaustively analyze all the incoming sensory information (Tsotsos et al., 1995), *Broadbent's Filter Model of Attention* (D. E. Broadbent, 1958) was introduced to postulate that the brains sequential pattern of stimuli sorting creates bottlenecks in information processing that creates inherent limitations in our cognitive architecture, ultimately preventing absolute engagement of multiple tasks at once (Marois & Ivanoff, 2005; Tombu et al., 2011). On the other hand the *Capacity Model of Attention,* although integrating the same logic of limited cognitive capacity in Broadbent's model (Egeth & Kahneman, 1975), asserts it is in fact possible to concurrently tend to multiple tasks in so far as the available cognitive resources meet the processing demands from each task.

While the *Filter Model's* and *Capacity Model's* prime focus is on task volume and task difficulty, the *Multiple Resource Theory* emphasizes the demands and qualitative features of each task. It asserts there are cognitive modalities specific to particular sensory stimuli, and that they compete for resources. Implying that performance hinges on the pattern of competition between the particular cognitive streams of processing engaged while multitasking (Wickens, 2002). For example, in context of MMT, a student that scrolls through twitter while watching a lecture would invoke visual processing costs that lead to memory performance deficits. Building on this idea are the *Motivated*

Cognition Theories which broadly asserts attention allocation works as a function of affect towards a particular stimulus.

In another model, the *Domain-free Unified Theory of Multitasking*, the emphasis is on the pattern of tasks tended to across time and divides multitasking behaviours into two categories: sequential or concurrent (Salvucci et al., 2009). The former involving quick switching between tasks (e.g. driving and talking to a passenger) and the latter involving switches that occur over longer periods of time (e.g. watching a television show and writing an email). This theory follows logic proposed from the *Adaptive Control of Thought-Rational (ACT-R) model* (Anderson et al., 2008) that suggests our cognition can be understood in terms of interacting modules. These modules can run a task, called a *thread*. Although these threads can exist and be processed simultaneously, only a single task can ultimately be executed at a given moment. Building off the *Threaded Cognition Theory* (Salvucci & Taatgen, 2008) and *Memory for Goals Theory* (Altmann & Trafton, 2002), Salvucci et al. (2009) argues that a goal that has been solidified over time can decay as a function of interruption length, and that this performance deficit can be attenuated by rehearsing the interrupted task in an active thread. The aforementioned models and theories are meant to be widely applicable to many contexts.

To accommodate multimedia scenarios specifically, the *Multimedia learning theory* was developed. Based on Paivo's (2008) *Dual-coding theory*, it asserts that learning is processed through two sensory channels, learning potential is optimal when presented via audio and video, and cognitive over load may occur if the dual-coding threshold is superseded by multiple media components (Mayer & Anderson, 1991; R. Moreno &

Mayer, 2000). For example, if a student is watching a video lecture while also responding to tweets on their twitter account, the information systems are overflowed with four streams of processing: video visuals, video audio, twitter visuals, and twitter texting. Three of these components require the visual system which offsets resources away from note-taking or auditory processing. As a results, cognitive load is amplified since the model purports dual-coding threshold increases as a function of topic-relatedness between media components (R. Moreno & Mayer, 1999). The learning effects from the type and pattern of weights these media components have in a variety of online educational contexts are largely unknown. To fine-tune and add clarity to the variety of theoretical models and perspectives on multitasking there remains a need for further investigations in novel and real-world MMT scenarios (Wallis, 2010).

1.3 Cognition and MMT Measures

The majority of studies evaluating the impact of media multitasking on cognition examine properties of cognitive control, working memory, and long-term memory (Uncapher & Wagner, 2018). Cognitive control encompasses a range of top-down processes that include attention, distraction filtering, task-switching, inhibitory control, and planning. While long-term memory refers to robust consolidation of concepts and facts into memory (Rosenbaum et al., 2016; Tulving, 1972), working memory is the brains immediate conscious perceptual processing that is limited in capacity and engages active manipulation and maintenance of information (Baddeley, 2003). The inception of cognitive research is largely aligned with the notion that attentional resources are finite and competition between cognitive tasks impairs performance (Deutsch & Deutsch, 1963; Treisman, 1960). This introduced a demand for measures that precisely account for multitasking behaviours and habits.

To gauge students' general media use and trait-level MMT habits across various dimensions of cognition, The Media Use Questionnaire or Media Multitasking Index (MMI) (Ophir et al., 2009) is often used to differentiate participants into two groups: low media multitaskers (LMMs) and high media multitaskers (HMMs). Findings have been mixed, however the literature tends to generally indicate that HMMs are subject to more performance impairments than LMMs on measures of working memory (Cardoso-Leite et al., 2015; Cohen et al., 1994; May & Elder, 2018; Sanbonmatsu et al., 2013; Uncapher & Wagner, 2018; Unsworth et al., 2005; Vogel et al., 2005), cognitive control (Cain & Mitroff, 2011; Seli et al., 2013; Wiradhany & Nieuwenstein, 2017) and long-term memory (Frein et al., 2013; Uncapher et al., 2016). However, some studies fail to find significant differences between the two groups (Cardoso-Leite et al., 2015; Gorman & Green, 2016; Minear et al., 2013; Murphy et al., 2017; Ophir et al., 2009; Ralph & Smilek, 2017; Wiradhany & Nieuwenstein, 2017; Wu et al., 2018) or find a greater cost for LMMs compared to HMMs (Alzahabi & Becker, 2013). Therefore, while HMMs appear to incur most of the cognitive impairment, there is no clear consensus.

Moreover, it is unclear whether high MMT leads to cognitive performance impairments or if the cognitively impaired are prone to MMT behaviours (Ophir et al., 2009; Uncapher et al., 2016). To provide further insights, it would be useful to investigate MMT in real-world scenarios that engage several dimensions of cognition. Relevant to the current thesis, To engage elements of cognitive control, working memory, and long-term memory, one avenue of investigation is to evaluate academic performance as a function of MMI in context of an applied academic setting.

However, it is important to note that since the MMI predominantly used in unidimensional cognition studies evaluate MMT on non-academic related media tasks (i.e. television, music, video games, social media, text messaging, emailing etc.) and most experimental academic performance studies focus on measuring trait-level MMT via a single distractor variable (i.e. texting) in a particular academic context (i.e. while studying), it is unclear whether general trait-level MMT behaviours will translate onto MMT behaviours in academic environments. One recent study found that cyberloafing – engaging in non-work or school-related internet use – during class was negatively associated with academic performance while general media use (outside of academic settings) had a positive association to academic performance (Wu et al., 2018). This suggests that non-academic MMT habits may not be predictive of academic MMT habits. Therefore, to assess whether the popularly used *general* MMI scores predicts academic performance and MMT behaviours in academic settings, the *general* MMI will be compared to a modified *specific* MMI, MMI_{onl}, that captures MMT habits specific to online video lecture engagement. In addition to being compared to each other in isolation and to academic performance, they will be compared to state-level MMT levels. By serving as an exclusionary criterion for data analysis, post-experiment *compliance checks* assessing whether participants engaged in non-study-related media during the study (e.g, texting, social media, television etc.) may also serve as a rudimentary state-level MMT measure.

1.4 MMT among students

Generational differences in media multitasking behaviors have increased rapidly as a function of time (Carrier et al., 2009; Downs et al., 2015) resulting in younger cohorts of students being referred to as "the multitasking generation" (Demirbilek & Talan, 2018). Students tend to favour the use of technology in the classroom (Downs et al., 2011) and often exhibit signs of frustration when not permitted to use it (Young, 2006). This dynamic is in part tied to students' lack of metacognitive awareness in their abilities to effectively multitask (Downs et al., 2015; P. A. Kirschner et al., 2006; Sweller et al., 2007). Learning problems are further deepened by perceptions of multitasking ability being a highly desirable trait (Wang & Tchernev, 2012), and students' tendency to underestimate their non-class related media use during lectures (Bolkan & Griffin, 2017).

These biases were spawned and spread by techno-optimist literature popularizing the misleading idea that the younger generations, often referred to as the "net generation" (le Roux & Parry, 2017) or "digital natives" (Prensky, 2001), developed the incredible ability to media multitask productively (Aagaard, 2019). Predicated on the notion that growing up with technology fundamentally reshapes one's cognitive abilities and ways of thinking, these ideas gained traction and began to permeate educational policy. Subsequent empirical refutations marked the onset of MMT research within the literature.

Since the inception of media multitasking studies in academic contexts, the most common in-class distractors by far have been texting and social media browsing (Harrison & Risler, 2015). Leysens et al. (2016) found that over 95% of students reported instant messaging and over 57% reported engaging social media at least once during a lecture. Over the course of a single lecture, students on average opened more than 26 browser tabs, 62% of which irrelevant to lecture content. Similarly, in-class laptop use significantly increased non-academic related engagement 22% of the time during an unstructured lecture –81% used media to check email and 68% for instant messages (Fried, 2008).

Junco et al (Junco, 2012a) surveyed over 1800 university students and divided their media multitasking patterns into three levels of frequency: texting was found to be high-frequency, social networks and email were medium-frequency, and instant messaging and phone calls were low-frequency. Interestingly, of these distractors, only the social technologies – text messaging and social network sites – were found to impair academic performance measures. Other large scale studies involving digital tracking (Moreno et al., 2012) and eye-tracking (Calderwood et al., 2014) find that students share a tendency to multitask frequently during learning activities. Among the most common distractive activities include social networking, texting, listening to music, emailing, gaming, and eating (Burak, 2012; Fried, 2008).

Since the shift to online learning, when comparing pre-pandemic and post-pandemic prevalence, recent surveys raise concerns about significant increases in digital addictive behaviours—particularly social media (Paschke et al., 2021). Kolhar and colleagues

(2021) in a study of 300 participants aged between 17 and 29 reported that 97% of students used social media applications, 1% of whom used them for academic purposes. This suggests the importance of evaluating the relationship these medias have to academic performance outcomes among students in online environments.

1.5 MMT and Academic Performance

1.5.1 Correlational Research

There have been a growing number of correlational studies evaluating the relationship between MMT and academic performance. After conducting the broadest review on the subject, Van der Schuur et al. (2015) assessed 43 studies that evaluate the consequences of MMT on academic performance (includes the following measures: school grades, lecture outcomes, homework outcomes, study attitudes, and perceived academic learning) and found a small to moderate negative relationship. Some studies found no significant relationship and it was concluded the causality of this relationship is still lacking.

The vast majority of these correlational studies utilize questionnaires or observations to assess trait-level media use, and data bases or questionnaires to obtain descriptive measures of academic outcomes—often using either course grades or overall GPA (Junco & Cotton, 2012). More specifically, Van der Schuur et al. (2015) in a review of 11 studies found that eight studies produced small to moderate negative correlations ($r = -.03$ to $-.30$) between self-reported media use and GPA (Burak, 2012; Duncan et al., 2012; Fetler, 1984; Gaudreau et al., 2014; Junco, 2012b; Junco & Cotton, 2012; Larry D. et al., 2011; Ravizza et al., 2014), and three studies found no relationship (Clayson & Haley, 2013; Flora Wei et al., 2012; Karpinski et al., 2013). The review is not exhaustive, however, as there are other correlational studies demonstrating a negative relationship between GPA and MMT behaviours (Al-Menayes, 2015; Bellur et al., 2015b; Fried, 2008; Kraushaar J, 2010; Lau, 2017; Leysens et al., 2016; McDonald, 2013; Walsh et al., 2013). Interestingly, in one of these studies, McDonald (2013) found classroom media use accounted for 22% of a final grade even when standardized testing scores and GPA were controlled for (McDonald, 2013). While tempting to conclude that MMT habits causally influence bad academic outcomes, these studies only used correlational methods.

1.5.2 Experimental Research

Experimental studies are often divided into *class lectures* or *studying* scenarios. The former involves either live in-person lectures (Carrier et al., 2015; Elder, 2013; Ellis & Jauregui, 2010; Junco, 2012b; Kuznekoff & Titsworth, 2013; Larry D. et al., 2011; Lawson, 2013; Leysens et al., 2016; Wood et al., 2012) or in-person video lectures (Brooks, 2015; Dindar & Akbulut, 2016; Kuznekoff et al., 2015; Larry D. et al., 2011; Pashler et al., 2013; Risko et al., 2013; Wei et al., 2014). However, it is worth bearing in mind that many of these studies lack the kind of ecological validity that is relevant to the current pandemic. Unlike most students currently engaging video lectures at home in the privacy of their own room, these video lecture studies typically require students to come into a lab or classroom setting where they are often in the presence of researchers and/or other students.

Correlational studies alike, the majority of experimental studies investigate the impact of distractive phone use—particularly texting during lectures. Findings generally indicate that learning is impaired as a function of texting use (Brooks, 2015; Carrier et al., 2015; Dindar & Akbulut, 2016; Kuznekoff et al., 2015; Kuznekoff & Titsworth, 2013; Larry D. et al., 2011; Pashler et al., 2013; Risko et al., 2013; Wei et al., 2014), however, there are also instances where learning decreased irrespective of the amount of texting (Ellis & Jauregui, 2010), learning was unaffected as a function of texting (Elder, 2013; Lawson, 2013) or unaffected by other MMT behaviours (Lee et al., 2012).

One study found that concurrent AOL instant messenger interruptions during an assigned SAT/GRE reading passage, although increasing overall reading duration, posed no significant impairment in learning performance (Fox et al., 2009). The terminology here sheds light on a common operationalization problem within the literature. Unlike a multitasking scenario where an interruption doesn't require total disengagement from the primary task, the instant message interruption here necessitates a clear switching of task goals and behaviours (from reading the passage to reading and addressing the AOL message), yet the findings were discussed in context of media multitasking in general. However, when more aptly and precisely reframed as an instance of sequential MMT, the findings become less interesting—highlighting the importance of presenting both concurrent and sequential forms of MMT in experimental studies.

Interestingly, Kuznekoff and colleagues (2015) found that students in a low-distractor multitasking group who sent text messages related to the lecture content performed approximately 70% better than students in a high-distraction group (who sent unrelated text messages). Suggesting that task-relevance of the secondary task may be a central mediating factor in determining academic performance. Much like the evolution in "mind wandering" literature where more recent studies integrate probes to distinguish between relevant and non-relevant mind wandering, it would be useful for experimental MMT research to consider an adjacent approach. Namely, to investigate the learning effects of task-relevant and non-relevant MMT in online academic settings across both sequential and concurrent conditions. In context of online academic lectures, the present study aims to address this as no experimental studies to knowledge have investigated these relationships.

With respect to sequential and concurrent online MMT studies, there are few studies and the findings reveal a somewhat unclear relationship. Dindar & Akbulut (2016) investigated the impact sequential and concurrent MMT had on academic performance (content retention) and topic interest in a multimedia learning context. The MMT task involved either switching between two instructional videos or responding to online chat questions while engaging one of the videos. Findings revealed sequential multitasking did not interfere with content retention while concurrent multitasking interfered with retention and topic interest. Furthermore, no relationship was found between general daily multitasking habits and content retention. However, there was a negative relationship between daily media exposure and academic performance when students switched between the two videos. More studies are required to determine whether these effects are the result of the MMT itself, the distractor variable, and/or the type of instructional content.

Pashler et. al (2013) conducted a related MMT study, however, it involved audio and written passages with instant messaging distractors. Compared to the previous study, similar findings emerged with respect to concurrent and sequential conditions, and associated learning performance costs. Although negligible impairments in the sequential multitasking conditions were found, Pashler and colleagues point out the implausibility of the "true costs being actually zero". In fact, content close to the interruption points were not included in the academic performance test, therefore the study design does not permit the detection of possible interruption-based performance costs. In other words, it may be that the total academic performance measure fails to capture learning impairments during the MMT distractor task—highlighting the need of an experimental design that individually assesses instances of learning performance during the MMT interruptions. Discussed in more detail later, the current study aims to address this by adding another academic performance measure, targeted academic performance (AP_{MMT}), that tests content specific to fixed MMT interruptions during the lecture.

In the lecture-based experimental MMT literature, Wood and colleagues (2012) study is among the few implementing a multi-faceted design testing the impact of numerous media distractors on lecture test scores. The results show that e-mailing, instant messaging, and text messaging had no effect on test scores, while Facebook use demonstrated notable test performance losses. This suggests that social media may pose a greater learning liability than texting, yet most MMT studies focus on texting and instant messaging (May et al., 2018; Van der Schuur et al., 2015).

The rise of online learning and escalating social media obsession presents an apparent and urgent demand for experimental studies investigating the impact of real-time social media use on academic performance. Particularly pertinent to the current study are social media scrolling behaviours – the act of browsing up and down a media feed – where entranced users are often bombarded with a constant stream of ideas, images, videos, advertisements, notifications and sounds. In fact, a recent study found 43% of students engaged in browsing (social media scrolling) to pass time, while 35% used the platforms to instant message (Kohler et al., 2021). Despite the most common means of consumption across the most popular social media platforms (e.g., TikTok, Twitter, Instagram, and Facebook), no MMT study design to knowledge has invigated its consequences.

1.6 The Present Study

The current study involves an online video lecture in a between-subjects design (see Figure 1). The dependent variables are spanned across four experimental groups that consist of combining each variation of relevance (relevant or non-relevant) and pausing (sequential or concurrent) manipulations: relevant sequential, relevant concurrent, non-relevant sequential, and non-relevant concurrent. While attending to the lecture content (primary task) participants are directed to engage in six secondary MMT tasks over the duration of the lecture video. In the relevant conditions participants are directed to answer a trivia-type question related to the video lecture topic on a new browser tab, while in the non-relevant conditions' participants were directed to scroll through a twitter feed to find a particular tweet on a new browser tab. These MMT tasks are done either while the video lecture continues (concurrent conditions) or is paused until an answer is submitted (concurrent conditions). After completing the questionnaires (demographics, MMI_{gen}, MMI_{onl}) and engaging the video lecture, participants complete twenty multiple-choice questions, which serves as the independent variable—academic performance (AP). Seven of these questions tested material during the six MMT segments of the video lecture serving as the targeted AP measure (AP_{MMT}).

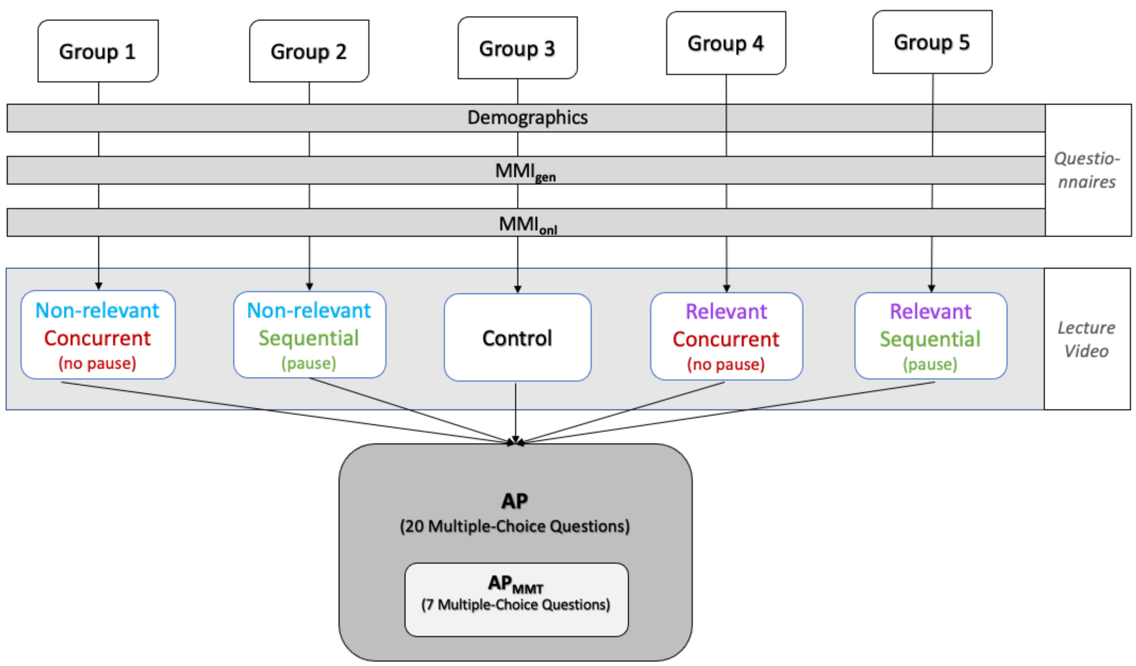

Figure 1

Study Flow

To summarize, in light of the sudden global precedent for online learning, social media dependence on the rise, and the online experimental MMT literature's lack of sequential (pause) and concurrent (no-pause) manipulations, task-relevance manipulations, social media distractor and scrolling conditions, and targeted AP measures during MMT segments, the current study design's primary aims and hypotheses are as follows:

(1) Determine how academic performance is affected across pausing and task relevance manipulations during an online MMT lecture environment.

(H1a) With exception to the relevant pause condition (predict to be equal to control), all other group conditions (relevant non-pause, non-relevant pause, non-relevant non-pause) will incur significant academic performance costs.

(H1b) Combined no-pause conditions will incur significantly higher academic performance costs.

(H1c) Combined relevant conditions will demonstrate significantly higher academic performance scores than combined non-relevant conditions.

(2) Determine how AP_{MMT} is affected across pausing and task-relevance manipulations during an online MMT lecture environment.

(H2a) The relevant pause condition and non-relevant pause condition will bear no AP_{MMT} costs (equal to control), while the relevant no pause condition and the non-relevant no pause condition will incur significant AP_{MMT} costs.

(H2b) The combined no pause condition will incur significantly higher academic performance costs.

(H2c) The combined relevant condition will perform equally to the combined non-relevant condition.

(3) Determine if online lecture MMT habits align with general MMT habits, and if they equally predict AP scores and state-level MMT.

(H3a) MMI_{gen} scores will not strongly correlate positively with MMI_{onl}.

(H3b) Both indexes (MMI_{gen} and MMI_{onl}) will correlate negatively with AP.

(H3c) MMI_{onl} scores will demonstrate stronger correlations to AP than MMI_{gen} scores.

(H3d) MMI_{onl} scores will be more predictive of non-compliance during the study than MMI_{gen} scores.

Methods

Participants

Participants were recruited via McMasters Undergraduate pool of participants on SONA voluntarily and were rewarded 1.0 SONA credit for their participation. Participants were screened for fluency in English as well as access to a quiet environment with their computer for at least a 45-minute window to ensure uninterrupted engagement with the lecture content and multiple-choice test portions of the study. A post-study compliance check was added to ask participants whether they engaged in non-study-related media over the duration of the experiment. Participants that failed to follow instructions were originally planned to be excluded from the final analysis, however, due to the large proportion of non-responders (37% left the question blank) and non-compliance (53% answered yes), they were not discounted from the final analysis. More details regarding non-compliance are reviewed in the discussion section. Participant were also removed for incomplete data (over 50% of responses left blank). A G*Power calculation was determined prior to the study to ensure an appropriate sample size. A total of 523 participants are necessary to reach a moderate effect size (*i.e., partial eta squared = 0.6)* with a 0.05 alpha value and 0.95 power value. A total of 885 participants consented to the study. After removing participants, the current sample of 603 (aged 17-36 years, M = 18.65, SD = 1.96; 465 female, 127 male, 9 non-binary or preferred not to answer) is rendered sufficiently powered. See Table 1 below for more detailed demographic statistics across each group condition.

Table 1

Participant Demographic Statistics across each Experimental Condition

Data Type	Participants	Age		Sex	
	N	*M*	*SD*	*Male*	*Female*
Total Participants	603	18.65	1.96	465	127
Relevant Pause	111	18.55	0.97	92	14
Relevant No-Pause	105	18.83	2.24	88	15
Non-Relevant Pause	158	18.48	1.82	114	41
Non-Relevant No-Pause	105	19.10	3.1	85	20
Control	124	18.41	0.98	86	37

Note. *N* = sample size, *M* = mean, *SD* = standard deviation.

Procedure

The study was conducted entirely online using LimeSurvey and a personal third-party website (www.todaywelearn.ca/login.php) used to host the online lecture experiment. Participants were randomly assigned to one of five condition groups: relevant sequential, relevant concurrent, non-relevant sequential, and non-relevant concurrent and a no-interruption control—“non-relevant” referring to non-lecture related social media pop-up questions, “relevant” referring to lecture-related pop-up questions, and “concurrent” and “sequential” are no-pause and pause conditions, respectively. The control condition contains no pop-up questions or interruptions. After electronically consenting to participate in the study, participants completed a demographic questionnaire (see Appendix A) to acquire information pertaining to employment, living accommodations, academic degree, sleep, and exercise. Participants were then instructed to complete a standard First Media Use Questionnaire (MMI-1). Before providing a password and a link to the website hosting the lecture video, to ensure anonymity, participants were asked to create a non-self-identifying dummy username. They were instructed to “choose a random non-self-identifying noun followed by a random 3-digit number i.e. *cupcake921*”. The username and password were used to login and access the appropriate lecture video condition and ensure data collected to be matched with lime survey data while preserving participant anonymity.

Once logged on, the video will appear with a “start lecture” button above the video with a disclaimer noting that the participant cannot pause, skip, or rewind the video and must be able to watch uninterrupted in a quiet environment for approximately 20 minutes. With exception to the control group, the distractor questions arise at 6 specific times during the video lecture (2:58, 4:27, 6:05, 10:56, 12:05, 14:18) for all experimental conditions. These particular times were purposely selected prior to the introduction of a key concept from which one or two designated multiple-choice questions are associated. For the relevant group conditions (relevant pause and relevant no-pause), the questions asked were related to the topic discussed prior to the interruption (e.g. "We just learned what binocular disparity is. Open a new google search tab in your browser to discover what 'binocular summation' means. Copy and paste the answer here: ___"). For non-relevant group conditions, the distractor questions were variations of the following "What was Justin Trudeau's last tweet of day on December 21, 2021?". While the structure remains the same, the name and date would change for each question. To ensure familiarity, accessibility, and consistency (via scrolling for approximately 15-20 seconds), old tweets were selected from famous but relatively inactive (low frequency of tweets) profiles.

The participants were instructed to open a new browser tab, scroll through the appropriate twitter profile feed before copying and pasting the answer. The answers were recorded to ensure participants carried out the secondary task appropriately. Participants were instructed to try and answer the question within 45 seconds and time stamps were recorded to measure how long participants took to answer each question prompt. If participants took too long on one particular question in the concurrent condition, the next pop-up question would override the previous one. The purpose here is to simulate a common distractor approximating social media scrolling. After the video is completed a pop-up window appears providing a code that participants are then instructed to copy and paste into LimeSurvey to ensure the video was watched in its entirety (particularly for the control condition). Lastly, participants completed *compliance checks* (see Materials section), and twenty multiple-choice questions (see Appendix F) testing the content of the lecture video—seven of which test content taught during the multitasking phases of the lecture video. After the debriefing form a SONA accreditation link was provided. The entire study took approximately one hour for participants to complete.

Materials

General Media Multitasking Index (MMI$_{gen}$): based on the original Media Multitasking Index (MMI-1) (Ophir et al., 2009), we used an updated version that better aligns with current media consumption patterns (Madore et al., 2020) (see Appendix ___). The index is divided into two sections. The first part asked how many hours per week (on average) participants spend on 11 different types of media (television, computer-based video, music, non-music audio, games, voice calls, social media, text/instant messaging, email, web surfing, other computer-based applications (e.g. word). Next participants indicated the extent to which they would simultaneously media multitask with every other media option on the list. Using a four-point scale (0-never; 3-most of the time) a weighted MMI score for each participant was determined by summing these responses, dividing by 3, then multiplying them by the total number of hours engaged in all media (determined from the first section). In addition to being used as a continuous measure, participants may be categorized into low media multitasker (LMM) or high media multitasker (HMM) groups based on their score.

$$\text{MMI} = \sum_{i=1}^{9} \frac{m_i \times h_i}{h_{total}}$$

Figure 2

Media Multitasking Index Score Formula

Note. Equation used to calculate general media multitasking index (MMI) score. m_i = total number of medias used at the same time as the primary media, h_i = total hours engaging the primary medium per week, h_{total} = sum of the number of hours per week with all primary media

Online Media Multitasking Index (MMI_{onl}): Similar in structure to MMI_{gen} except captures only one primary media, online lectures. To capture MMT behaviours common to online learning settings, a slightly modified list of secondary medias was included (Homework/studying, social sites, texting/instant messaging, non-social text-oriented sites, calls/video chats, music, video/shows/movies, video/computer games). Scores were calculated using the same formula as MMI_{gen}.

Compliance Checks: Participants were asked if they responded randomly at any point during the survey and if they were multitasking during the study (see Appendix D). Also served as a rudimentary state-level MMT measure.

Total Academic Performance (AP): Lecture content retention was tested across 20 multiple choice questions (See Appendix F). The order of the multiple-choice questions remained consistent for all participants. Used as a continuous dependent variable, final scores were established by dividing totalled correct answers by 20.

Targeted Academic Performance (AP_{MMT}): This includes seven of the original twenty multiple choice questions. These questions test content during the six multitasking phases of the lecture. Used as a continuous dependent variable, final scores were established by dividing totalled correct answers by seven.

Results

Impact of Relevancy and Pausing on Academic Performance

To determine how academic performance is affected across pausing and task-relevance manipulations, a between-groups one-way ANOVA (type III) was performed to compare the effect of pausing and relevancy on post-lecture multiple choice test scores. A one-way ANOVA revealed a statistically significant difference between the group conditions at the p<.05 level, $F(4, 608) = 8.217$, $p < 0.001$. Tukey HSD test comparisons only found significant differences between the relevant pause condition to every other condition (see Table 2).

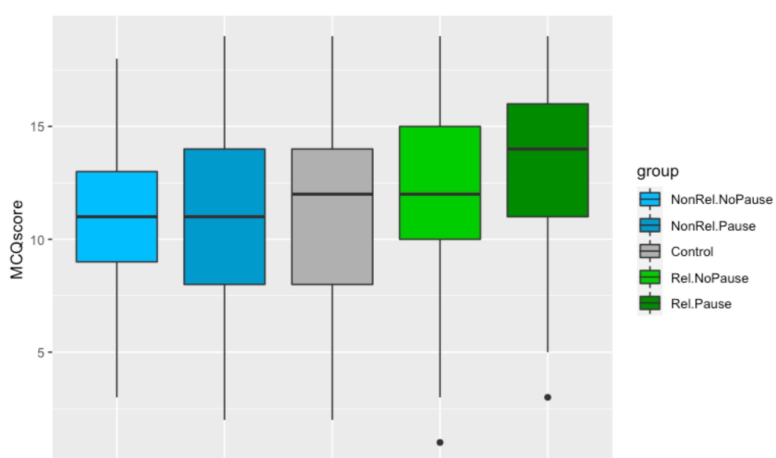

Figure 3

Academic Performance across each Group Condition

Table 2

Tukey HSD Comparisons (AP)

Comparison			95% C.I.		
Condition	Condition	Mean Difference	Lower	Upper	P_{tukey}
Relevant pause	Relevant no-pause	1.333	0.01	2.66	.048*
Relevant pause	Non-relevant pause	2.174	0.97	3.38	p<.001**
Relevant pause	Non-relevant no-pause	2.085	0.75	3.42	p<.001**
Relevant no-pause	Non-relevant pause	0.840	-0.38	2.06	.324
Relevant no-pause	Non-relevant no-pause	0.752	-0.59	2.10	.543
Non-relevant no-pause	Non-relevant pause	-0.089	-1.31	1.36	.999
Control	Relevant-pause	2.223	0.96	3.50	p<.001**
Control	Relevant no-pause	0.090	0.38	2.18	.308
Control	Non-relevant pause	-0.148	-1.44	1.14	.998
Control	Non-relevant no-pause	-.060	-1.22	1.10	.999

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

To investigate whether pausing had an influence on memory performance, I used a planned contrast to compare combined pause groups to combined no-pause groups. Non-relevant and relevant pause conditions were equally weighted against non-relevant and relevant no-pause conditions. The combined pause condition (M = 12.39, SD = 3.5) was not found to have significantly higher test scores than the combined no-pause condition (M = 11.74, SD = 3.2), $t(608) = -1.9$, $p = 0.06$. Thus, in contrast to my predictions, pausing during the lecture does not appear to have a beneficial effect on memory performance.

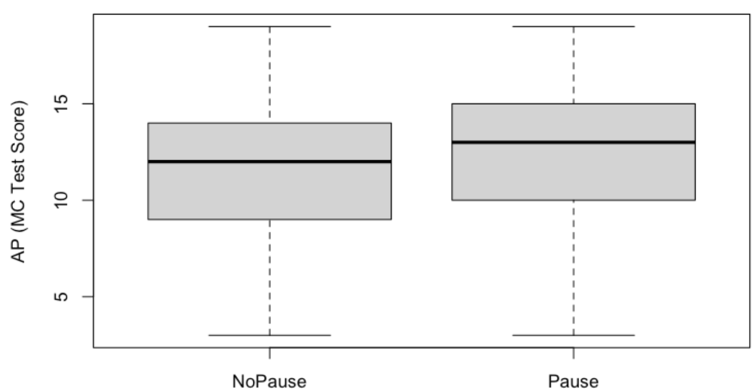

Figure 4

Combined Pause and No Pause Conditions vs. Academic Performance (AP)

To analyze whether relevance had an influence on memory performance, I used planned contrasts to compare combined relevant groups to combined non-relevant groups. Pause and no-pause relevant conditions were equally weighted against pause and no-pause irrelevant conditions. In alignment with our prediction, combined relevant conditions (*M* = 12.78, *SD* = 3.3) scored significantly higher scores than non-relevant conditions (*M* = 11.35, *SD* = 3.3), $t(608) = -4.4$, $p < .001$.

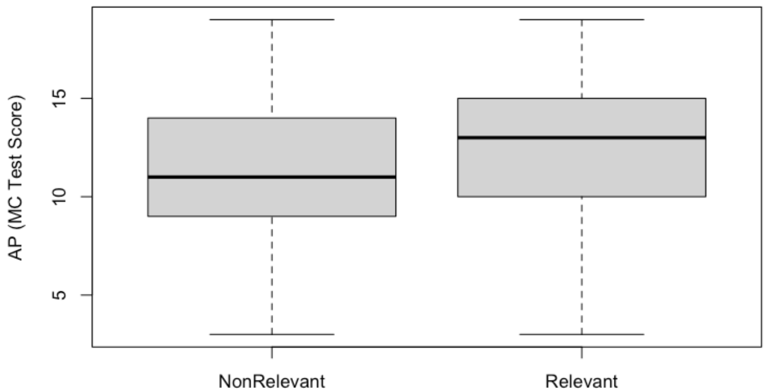

Figure 5

Combined Relevant and Non-Relevant Conditions vs. Academic Performance

To investigate how combined relevance conditions and combined pause conditions perform in relation to a baseline measure, planned contrasts were conducted between the control group to combined pause, no-pause, relevant, and non-relevant conditions. The combined relevant (*M* = 12.78, *SD* = 3.3) condition demonstrated significantly higher test scores than the control group (*M* = 11.27, *SD* = 3.7) ($t(608) = 3.9$, $p < .001$), while the combined non-relevant condition (*M* = 11.35, *SD* = 3.3), was found to have no significant difference to control (*M* = 11.27, *SD* = 3.7), $t(608) = 0.2$, $p = 0.789$. The combined pause condition demonstrated significantly higher test scores than control ($t(608) = 2.9$, $p = 0.003$), while the combined no-pause condition was found to have no significant difference to control ($t(608) = 1.3$, $p = 0.192$).

Targeted MMTAcademic Performance (AP_{MMT}) Effects of Relevancy and Pausing

Analysis used to evaluate targeted AP_{MMT} scores mirror that of the previous section. To determine how AP_{MMT} is affected across pausing and task-relevance manipulations, a between-groups one-way ANOVA (type III) was performed to compare the effect of pausing and relevancy on targeted post-lecture multiple choice test scores. A one-way ANOVA revealed a statistically significant difference between the group conditions at the p<.05 level, $F(4, 598) = 10.62$, $p < 0.001$.

Tukey HSD test found that the mean value of test scores was significantly different between the relevant-pause ($M = 5.11$, $SD = 1.4$) and control ($M = 4.08$, $SD = 1.6$), non-relevant pause ($M = 4.21$, $SD = 1.6$), and non-relevant no-pause ($M = 3.96$, $SD = 1.4$). Also demonstrating significant differences are the relevant no-pause ($M = 4.60$, $SD = 1.5$) and non-relevant no-pause conditions ($M = 2.96$, $SD = 1.4$) (p=.020, 95% C.I. = 0.06, 1.21). See Table 3 below for all the comparisons.

Table 3

Tukey HSD Comparisons (AP_{MMT})

Comparison			95% C.I.		
Condition	Condition	Mean Difference	Lower	Upper	P_{tukey}
Relevant pause	Relevant no-pause	0.508	-0.06	1.07	.102
Relevant pause	Non-relevant pause	0.899	0.38	1.41	p<.001**
Relevant pause	Non-relevant no-pause	1.462	0.58	1.71	p<.001**
Relevant no-pause	Non-relevant pause	0.391	-0.13	0.91	.245
Relevant no-pause	Non-relevant no-pause	0.638	0.06	1.21	.020*
Non-relevant no-pause	Non-relevant pause	0.247	-0.28	0.77	.696
Control	Relevant-pause	1.027	0.48	1.57	p<.001**
Control	Relevant no-pause	0.519	-0.03	1.07	.075
Control	Non-relevant pause	-0.128	-0.06	0.37	.956
Control	Non-relevant no-pause	0.119	-0.43	0.67	.977

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

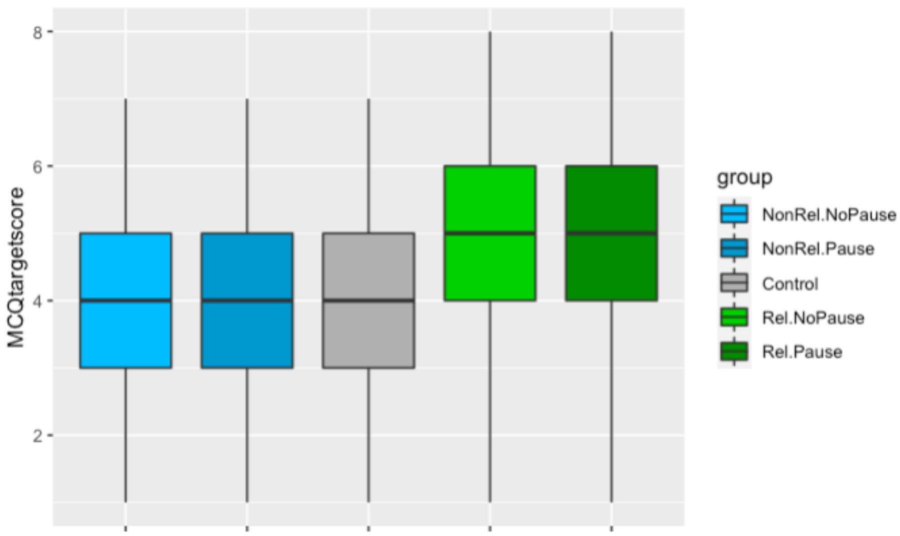

Figure 6

AP_{MMT} across each Group Condition

To investigate whether pausing had an influence on academic performance, I used a planned contrast to compare combined pause groups to combined no-pause group. Non-relevant and relevant pause conditions were equally weighted against non-relevant and relevant no-pause conditions. Congruent with our predictions and in contrast to the total AP results, the combined pause condition (M = 4.66, SD = 1.5) was not found to have significantly higher AP_{MMT} test scores than the combined no-pause condition (M = 4.28, SD = 1.4), $t(598) = -2.7$, $p = 0.0075$.

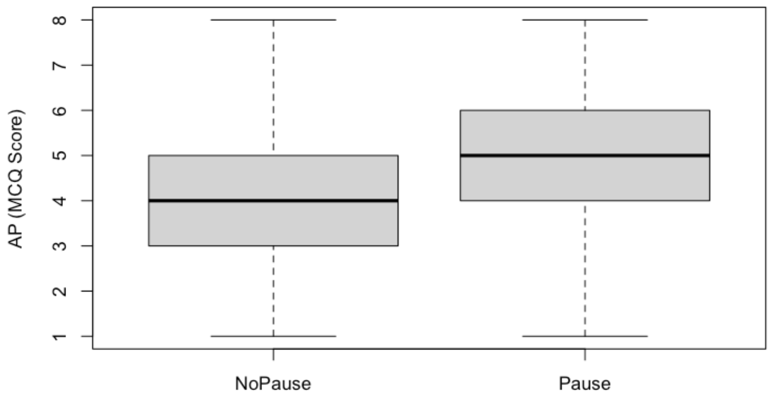

Figure 7

Combined Pause and No Pause Conditions vs. AP_{MMT}

To investigate whether relevance had an influence on memory performance, I used planned contrasts to compare and combined relevant groups to combined non-relevant groups. Pause and no-pause relevant conditions were equally weighted against pause and no-pause irrelevant conditions. Confirming our predictions, combined relevant conditions ($M = 4.85$, $SD = 1.4$) scored significantly higher scores than non-relevant conditions ($M = 4.09$, $SD = 1.5$), $t(608) = -4.4$, $p < .001$.

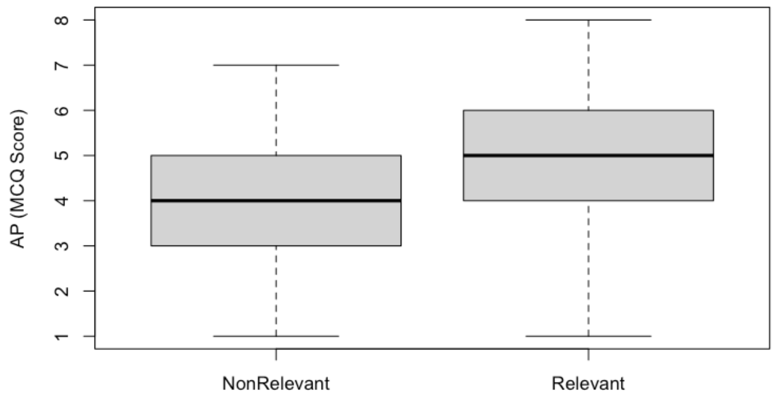

Figure 8

Combined Relevant and Non-Relevant Conditions vs. AP_{MMT}

To investigate how combined task-relevance conditions and combined pause conditions perform on AP_{MMT} scores in relation to a baseline measure, planned contrasts were conducted between the control group to combined pause, no-pause, relevant, and non-relevant conditions. The combined relevant ($M = 12.78$, $SD = 3.3$) condition demonstrated significantly higher test scores than the control group ($M = 11.27$, $SD = 3.7$) ($t(608) = 3.9$, $p < .001$), while the combined non-relevant condition ($M = 11.35$, $SD = 3.3$), was found to have no significant difference to control ($M = 11.27$, $SD = 3.7$), $t(608) = 0.2$, $p = 0.789$. The combined pause condition demonstrated significantly higher test scores than control ($t(608) = 2.9$, $p = 0.003$), while the combined no-pause condition was found to have no significant difference to control ($t(608) = 1.3$, $p = 0.192$).

To assess how combined relevance conditions and combined pause conditions perform (on AP_{MMT}) in relation to a baseline measure, planned contrasts were conducted between the control group to combined pause, no-pause, relevant, and non-relevant conditions. These relationships were found to be analogous to total AP scores. The combined relevant condition (M = 4.85, SD = 1.4) demonstrated significantly higher test scores than the control group (M = 4.08, SD = 1.6) ($t(598)$ = 4.5, p < .001), while the combined non-relevant condition (M = 4.09, SD = 1.5) was found to have no significant difference to control (M = 4.08, SD = 1.6) ($t(598)$ = 0.03, p = 0.977). The combined pause condition (M = 4.66, SD = 1.5) demonstrated significantly higher test scores than control (M = 4.08, SD = 1.65) ($t(598)$ = 3.5, p < .001), while the combined no-pause condition (M = 4.28, SD = 1.5) was found to have no significant difference to control (M = 4.08, SD = 1.6) ($t(598)$ = 1.2, p = 0.245).

Comparing general and online Media Multitasking Indexes MMI_{gen} vs. MMI_{onl}

Outliers were first removed based on impossible self-reports that indicate more time engaged in a particular activity than there is time available during the week or day. Likely attributed to misunderstanding the question and reporting weekly hours when asked to report daily hours or possibly overestimating how much time they are spending. To avoid mean or standard deviation dependency, the Interquartile Range (IQR) method was used in a second round of screening out outliers by removing above the 75^{th} or below the 25^{th} percentile by a factor of 1.5 times the IQR.

To investigate the relationship between the two MMI indexes a Pearson correlation coefficient was computed between MMI_{gen} and MMI_{onl}. There was a medium-sized positive correlation between the two index scores, r(538)=.28, p<0.001.

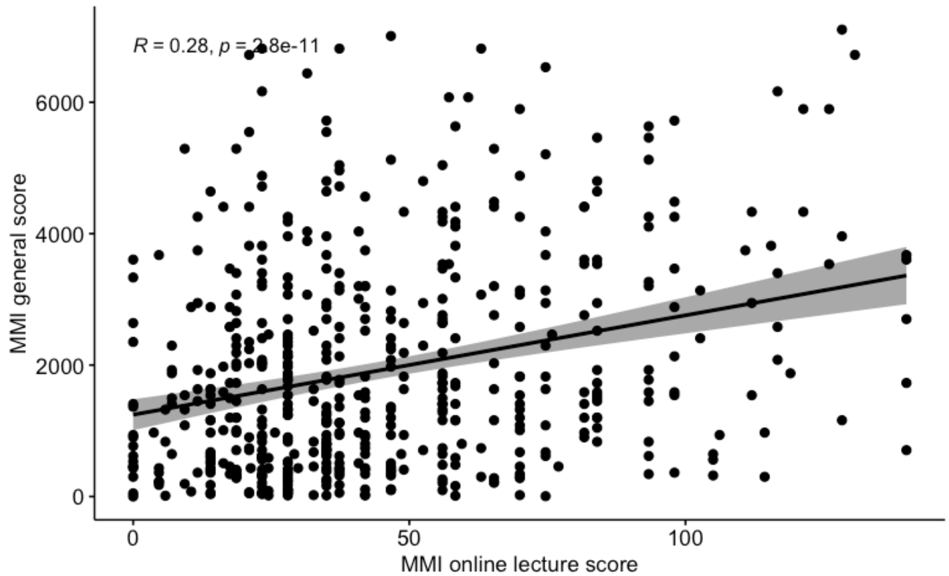

Figure 9

Relationship between MMIgen vs. MMIonl scores

To investigate the relationship between self-reported media multitasking habits and AP, Pearson correlations were conducted between the two self-reported media multitasking indexes and their relationship to AP test scores across all conditions. Total scores across all conditions reveal a weak negative relationship to MMIonl (r(538 = -.13, p=.002), and no significant relationship to MMI_{gen} (r(538 = -.083, p=.054). When both MMIs were compared to each group condition individually, only the relevant pause condition demonstrated a significant relationship to MMI_{gen} (r(95) = -.20, p= .041) and MMI_{onl} (r(101) = -.30, p= .002)—both medium-sized negative correlations. No significant relationship was found between the control groups academic performance test scores for both MMI_{gen} ($r(105) = -.05$, $p=.58$) and MMI_{onl} ($r(104) = -.12$, $p=.227$.

Table 4

Pearson Correlations of MMI versus AP across each Group Condition

Group Condition	MMI_{gen} vs. AP	MMI_{onl} vs. AP
Non-Relevant No-Pause	.024	.01
Non-Relevant Pause	-.10	-.131
Control	-.053	-.118
Relevant No-Pause	-.060	-.068
Relevant Pause	-.202*	-.304**
Total	-.083	-.13*

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

To investigate context-dependent relationships between media multitasking and memory performance, MMI indexes were compared across the following combined conditions: pause, no-pause, relevant, and non-relevant. The pause group combines data sets from relevant pause and non-relevant pause conditions, while the no-pause group combines relevant no-pause and non-relevant no-pause conditions. The same logic was applied to the relevant and non-relevant combined conditions.

Pearson correlations revealed small to negligible effect sizes, however, a few significant results emerged. MMI_{gen} and the combined pause condition ($r(242) = -.15$, $p = .015$), as well as MMI_{gen} and the combined non-relevant condition ($r(233) = -.06$, $p = .03$) were both found to be weakly negatively correlated. Similarly, $MMIo_{nl}$ and the combined pause condition ($r(242) = -.19$, $p = .002$), as well as MMI_{onl} and the combined non-relevant condition ($r(198) = -.18$, $p = .001$) were both found to be weakly negatively correlated.

Table 5

Pearson Correlations of both MMI versus AP across combined relevance and pause conditions

Combined Condition	MMI_{gen} vs. AP	MMI_{onl} vs. AP
Pause	-.155*	-.19**
No-Pause	-.006	-.04
Relevant	-.061	-.083
Non-Relevant	-.196**	-.182**

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

To investigate whether MMI_{gen} serves as a good proxy for MMI_{onl} scores across various conditions, Hittner, May, and Silver's (2003) modification of Dunn and Clark's z

(1969) using a back transformed average Fisher's (1921) Z procedure was used to compare if correlations between MMI_{gen} and MMI_{onl} were significantly different. Results demonstrate that they were not significantly different to each other across all individual and combined conditions.

Finally, to assess the extent to which both MMI_{onl} and MMI_{gen} (trait-level MMT measures) predict study compliance (state-level MMT), Pearson correlations were conducted. From the 63% of participants that responded, results demonstrate compliance rates across all group conditions did not correlate with MMI_{onl} ($r(312) = .03$, $p = .562$), and weakly correlated with MMI_{gen} ($r(312) = .19$, $p<.001$).

Discussion

The main purpose of this paper was to build on the literature surrounding media multitasking in online academic settings. We investigated (1) how total academic performance is affected across measures of pausing and task relevance during an online pre-recorded lecture environment, (2) how targeted academic performance is affected across measures of pausing and task relevance, (3) how MMI_{onl} and MMI_{gen} are related, and relate to AP and compliance rates.

Impact of Pausing and Task Relevance on Academic Performance (AP)

Results partially supported our first set of hypotheses. Specifically, with exception to the relevant pause condition that was predicted to demonstrate no significant difference to the control group, the first hypothesis (H1a) predicted all group conditions (with exception to relevant pause) will incur significant academic performance costs. Results, however, indicated not only that the relevant pause condition demonstrated significantly higher academic performance than control, but also that every other group condition did not incur significant academic performance costs (compared to control). The second hypothesis (H1b) predicted that combined no-pause conditions will incur higher academic performance costs than the combined pause conditions. To our surprise results revealed no significant difference between the two. The third hypothesis (H1c) predicted that the combined non-relevant conditions will incur higher academic performance costs than the combined relevant conditions. Results supported this prediction.

Three key findings stand out as unexpected. First, no academic performance costs were observed across all group conditions. This result contradicts relatively robust multitasking literature in alignment with cognitive load theory, which states frequent task-switching requires a change of cognitive work (via increased cognitive load) that results in performance costs (Demirbilek & Talan, 2018; Junco & Cotten, 2011; Paivio, 2008; Vedrana Jez, 2011), and is inconsistent with previous lecture-based multitasking studies that found decreased productivity or performance (Burak, 2012; Esteban-Millat et al., 2014; Gaudreau et al., 2014; Judd & Kennedy, 2011; Kraushaar J, 2010; Van Der Schuur et al., 2015).

Particularly surprising was that the non-relevant concurrent (no pause) condition demonstrated no academic performance cost and performed equally to the non-relevant sequential (pause) condition. The theoretical implication of this finding aligns most with the *Capacity Model of Attention*, which posits that multiple tasks can be concurrently tended to insofar as the available cognitive resources meet the processing demands from each task (Egeth & Kahneman, 1975). However, when this same comparison is made in the relevant condition, predictions were met as the relevant no-pause group performed worse than the relevant pause group. The theoretical implication here is more in support of the *Selective Filter Theory*, which suggests bottlenecks in information processing can only enable a sequential pattern of task execution when multiple tasks are at play (Tsotsos et al., 1995). Paradoxically, these results suggest that social media scrolling MMT behaviours during an online lecture evoke no academic performance costs. Possible alternative explanations for these results are explored.

One contributing factor may be driven by students in the control group who did not follow instructions and were media multitasking during the study (e.g., texting on their phone). This is evidenced by our compliance checks revealing that 53% of participants admitted to engaging in non-study-related media during the experiment—a rate much higher than anticipated. Although strangely, AP is similar even after removing non-compliant participants, it is likely the current proportion of self-reported non-compliance, as a consequence of social desirability and participant biases, is an underrepresentation. This is further supported by the fact that a higher proportion of participants in the control group left the compliance check blank.

In retrospect it would have been useful to further probe the extent to which students were engaging in unsolicited MMT during the study. Of the non-compliant students in the control lecture condition, it remains possible that they were more likely to engage a higher volume of MMT than the experimental conditions. This may be due to the fact that the experimental lectures force a certain level of engagement and vigilance via the six intermittent pop-up questions that would limit non-study-related MMT. It has been demonstrated that students spend a large proportion of their time mind wandering over the course of a lecture (Lindquist & McLean, 2011). In fact, in experimental conditions without a secondary task, participants have been found to spend approximately 40% of the time mind wandering (Risko et al., 2012). It is possible that students in the control condition, although not partaking in distractive secondary tasks by design, may be engaging in higher proportions of mind wandering than students in the experimental conditions. Thus, the control group AP scores are subdued as a result.

Alternatively, it may be that the non-relevant pause and no-pause groups did not pose a salient enough distractor from the lecture material or perhaps some students were finding tweets much faster than others. However, we found that most students took between 20-50 seconds to find the tweet, and reported (via compliance check question) following the instructions by engaging in scrolling behaviours as a means to arrive at the tweet as opposed to other potentially quicker methods (e.g., *control* + *F*).

The second unexpected finding was that the relevant pause group exhibited an academic performance enhancement. Although AP performance was expected to not be statistically significantly different, we expected minor AP costs for the relevant pause condition since they consumed more information. It is worth noting, for both relevant group conditions, to ensure AP scores are the result of context cues and not artificially inflated, the relevant content learned during the six MMT segments were strategically chosen to be related to the lecture topic but were not tested for in the post-lecture multiple choice assessment. Moreover, while participants expect a post-lecture multiple choice test, they would be oblivious to whether information during the MMT segments would be tested or not. Nevertheless, it appears that under particular circumstances the relevance of the MMT task may hold more weight in influencing AP scores. We see an unanticipated performance enhancement effect when MMT tasks are relevant *and* sequentially tended to. One possible mechanism may be related to active versus passive engagement. Students passively listen to the lecture in the control group, while the relevant experimental condition engages a form of hands-on learning as they are tasked to actively find lecture-related answers. The literature suggests that this form of inquiry-based learning, discovery learning, and hand-on learning can offer salient learning advantages (J. Broadbent & Poon, 2015; P. Kirschner et al., 2004) and have been particularly useful in emergency remote pedagogy (Zhang et al., 2022).

The third unexpected finding was that the combined no-pause conditions performed equally to combined pause conditions. Since this relationship is the product of a planned contrast that omits the control condition and compliance rates remain relatively consistent across the experimental conditions, it may be possible that participants in the pause conditions engaged in a higher volume of non-study-related MMT. However, unlike the control condition discussed previously, this result remains largely unexplained.

Impact of Pausing and Task Relevance on Targeted Academic Performance (AP_{MMT})

In terms of the second research question, with a few exceptions, targeted AP_{MMT} results generally did not align with our predictions. Our first hypothesis (H2a) predicted that the pause conditions (relevant pause and non-relevant pause) will demonstrate no AP costs or enhancements while the no-pause conditions (relevant no pause and non-relevant no-pause) will incur AP_{MMT} costs. The non-relevant no pause group's equal score to control were consistent with our prediction, while the relevant pause group's significantly higher scores to control, the non-relevant no pause group's significantly higher scores than control, and the non-relevant pause groups equal score to control were in contrast to our predictions. Our second hypothesis (H2b) predicted that the combined no-pause condition will perform significantly worse than the combined pause condition and control. Confirming our predictions, results demonstrate the combined no-pause condition performed significantly worse than the combined pause condition, however, it did not perform worse than the control. Our third hypothesis (H2c) predicted the combined relevant condition will perform equally to the combined non-relevant condition and control. However, results indicated the combined relevant condition significantly outperformed the combined non-relevant condition and control.

Motivated by the fact that previous designs often aggregated their scores and did not include or isolate for testing content during the MMT manipulation portions of the experimental study, the targeted AP_{MMT} measure was developed to give insight on how well students learn during the multitasking portions of the video lecture. Pashler and colleagues (2013) found no academic costs for sequential (pause) conditions, however, speculated that this cost may be revealed after testing for content proximal to the MMT manipulation (Pashler et al., 2013). While these costs may exist, our predictions for the current study were that this decline would not be large enough to obtain statistically different results from the control. The results corroborated this prediction for the non-relevant pause condition, however, similar to the total AP scores the relevant pause group condition unexpectedly performed significantly higher than control (and the non-relevant pause condition). Though, the idea that multitasking may pose a learning improvement is not a novel one. Bjork & Schmidt (1992) suggest that frequent interruptions while reducing performance during learning may actually enhance learning as assessed with later tests. Since we see no apparent performance benefit from the non-relevant pause condition, it is plausible to primarily attribute this academic boost to the relevance manipulation. Alternatively, a form of synergism may be at play only when relevant media multitasking is tended to sequentially. To tease this apart a subsequent study could attempt a MMT control condition whereby participants perform a counting-task, which tends to neither relevant or non-relevant media information consumption.

Similar to AP scores, the AP_{MMT} scores reveal no apparent academic costs across all conditions, and may be due to subdued control group scores from non-compliant participants. Since the AP_{MMT} questions were dispersed unevenly at six different points during the lecture and the control participants were unaware of these points, it would not be unreasonable to infer participants in the control group were engaging in a high volume of distractive behaviours (i.e. MMT and/or mind wandering) consistently throughout the lecture so as to be able to attenuate the target AP_{MMT} scores to the same level as the concurrent conditions.

Comparing MMIgen to MMIonl

The first hypothesis (H3a) predicts against strong correlations between the two media multitasking indexes. This is predicated on the presumption that a considerable proportion high achieving students who offer their undivided attention in academic settings also partake in a high degree of general media multitasking outside of the classroom. These students were predicted to offset a strong positive correlation. The results were supported insofar as MMI_{gen} scores did not correlate strongly with MMI_{onl} scores. A medium-sized positive linear correlation was revealed between the two indexes. If general media multitasking habits are only moderately predictive of media multitasking habits during an online lecture, this puts into question whether general media multitasking indexes would be applicable to academic performance contexts.

Since general MMI scores are often used as a metric to categorize participants into low media multitaskers or high media multitaskers. Some participants were found to qualify as HMM according to the MMI_{gen} while also ranking LMM in the MMI_{onl}, representing students who often media multitask during leisurely activities, but are focused when it comes to their academics. While MMI_{onl} is specific to online lectures, a general academic MMT index would be useful for future studies to assess MMT habits during various academic environments (lectures, tutorials, readings, studying, homework etc.). It may also be useful to include multiple medias for each academic activity as students at home have unrestricted access to engage multiple forms of medias at any given moment while engaging online video lectures (i.e. television, music, social media scrolling, text messaging, checking email etc.).

With respect to how both media multitasking indexes relate to academic performance, the results were somewhat in support of my predictions. The general basis for my prediction is that MMI_{onl} scores are precisely congruent with the study context (lecture video) whereby participants who scored high on MMI_{onl} are anticipated to perform worse by virtue of context-dependent cues, greater levels of engaging non-study-related MMT behaviours, or internally produced factors (i.e. motivation, attitude, mood etc...). Our prediction (H3b) that total AP scores (across all conditions) will correlate negatively with media multitasking habits was supported by MMI_{onl} but not MMI_{gen} scores. However, it is worth noting that the effect sizes were similar and total academic performance scores here were heavily influenced by the relevant pause condition which was the only group condition that demonstrated significant relationships to either MMI index by demonstrating medium-sized negative correlations (see Table 2).

The third hypothesis (H3c) predicts academic performance scores across each individual group condition to demonstrate stronger correlations for MMI_{onl} compared to MMI_{gen}. In agreement with our predictions, each MMI_{onl} group condition demonstrated larger effect sizes, however, the null hypothesis was not rejected as the differences in effect sizes were relatively small (ranging from 0.008 to 0.121) and the correlations were not significantly different from each other. Similarly, academic performance scores across all combined group conditions to demonstrate stronger correlations for MMI_{onl} compared to MMI_{gen}, combined conditions (Pause, No-pause, Relevant) with exception to the combined non-relevant group demonstrated larger effect sizes for MMI_{onl}, however in contrast to our hypothesis, the differences were small and the correlations were not significantly different from each other. These results indicate that the differences between the two indexes are evident in relation to total AP scores across all conditions, however, not large enough to show up on individual group conditions. Taken together, these results demonstrate that MMI_{onl} is a weak predictor of AP, and MMI_{gen} is an even weaker predictor of AP in an online lecture environment.

Finally, the last hypothesis (H3d) predicts MMI_{onl} will be a stronger predictor of non-study-related MMT (via compliance checks) than MMI_{gen}. However, results indicate the opposite. MMIgen significantly correlated negatively with compliance rates, while no significant correlation was found to MMI_{onl}. This suggests three things. First, Non-study-related MMT appears to have played an insignificant role in mediating the relationship between both MMI indexes and AP. Specifically, there must be alternative factors at play beyond non-study-related MMT influencing the aforementioned correlational relationship between MMI_{onl} and AP. Second, MMIgen so often used in experimental cognition studies may also be applicable to experimental academic performance studies. Third, context-specific MMT indexes, online lectures in this case, do not appear to be reliably predictive of state-level MMT behaviours during online lectures. However, future studies would have to explore whether this relationship applies to other online academic contexts (i.e. synchronous lectures).

Taken together these results demonstrate the complexities and prevalence of trait-level media multitasking and its connection to state-level MMT and academic performance. The high levels of non-compliance further highlight the importance of addressing rising media and social media dependency amongst students in online academic settings. It is important instructors, researchers, and administrators are made aware of these patterns so that various strategies are implemented and experimented with to mitigate non-relevant media use. One study found that creating course policies that rule out media use in classroom settings had little to no effect (McDonald, 2013). As it is much more difficult to monitor students, this outcome will likely seamlessly translate to online settings. However, there are other potential strategies that instructors can encourage. While there is evidence that students seldom change as a result of learning about the negative learning implications of particular behaviours (Terry et al., 2016), some students may benefit from the meta-awareness acquired by learning about the consequences of media multitasking and social media addiction, and the extent to which they impair learning and academic achievement. Another avenue may be for instructors to teach better media hygiene by encouraging the use of productivity tracker apps and social media blocking programs.

Limitations

Compared to much of the experimental MMT studies that occur in controlled lab conditions and under supervision, conducting an academic experimental study remotely presents its own unique set of challenges to address. One category of limitations involve participant monitoring and study instruction non-compliance. The main limitation being the large proportion of non-compliant participants. Slightly more participants were recruited for the study than what is typical of an in-person study to account for this, however, the 63% response rate and 53% non-compliance rate were unanticipated. Moreover, since there's no way to verify the non-responders or whether students reported their compliance checks honestly, the non-compliance is likely much higher.

Another monitoring related limitation involves potential cheating during the post lecture academic test. Although a link to the video was not provided or accessible on the website (via right click option), cheating was unaccounted for since participants could use a search engine from any one of the multiple devices they have available to them to find the correct answer without my knowledge. It is also worth noting that data collection coincided with the last few weeks leading up to student SONA credit deadlines.

Therefore, it is possible the participants that enrolled "last minute" may not accurately represent the entire cohort of available students.

Other limitations involve aspects of the design itself. Discussing and accounting for pause, no-pause, relevant, non-relevant as separate and individual manipulations is not as clear-cut since each group condition contains both manipulations, and the data analysis does not code them as separate variables. Another limitation was that some students may have prior knowledge of the tested material. A visual processing lecture was strategically selected to draw more participants from a pool of students who were going to learn this material later on in the course. However, since we did not include pre-tests or directly ask participants about their familiarity on the subject, it is quite possible some participants with pre-existing knowledge performed better. Also, taking away from the ecological validity, unlike in a real video lecture context, participants did not have the volition to media multitask. Although this was somewhat captured by the state-level MMT measure, non-study-related MMT was not accounted with respect to pattern, frequency, and type of media used. Lastly, it is worth noting that the self-reporting nature of both MMI questionnaires may invoke underreported scores as a consequence of participant biases and social desirability biases.

Future Directions

It is unclear whether the findings from this investigation apply to other academic contexts. It would be useful to carry out a study in a live lecture setting and explore a variety of subjects and lecture topics and lengths. Relatedly, the MMI_{onl} does not distinguish between synchronous and asynchronous video lectures. Each type may engage their own unique patterns of MMT behaviours from students. Future studies should investigate and account for this distinction.

With respect to study compliance rates, future studies should inquire more thoroughly the frequency, type, and volume of non-study-related MMT participants engaged in. Intermittent probes and reminders may also be useful to increase compliance rates. However, it would be ideal to enforce some form of participant monitoring to ensure students are not engaging in non-study-related MMT. Although there are obvious ethical implications, webcam monitoring may be necessitous. Fortunately, a variety of online proctoring services have become more prevalent and may be useful to integrate. This can also open up other avenues of investigation. In context of live lectures, it would be interesting to compare MMT behaviours when webcams are on versus off. Also, eye-tracking technologies would be accessible and useful to capture the attentional patterns of participants throughout the study. In regard to achieving more precise trait-level measures of MMT, future observational studies should explore students' patterns of behaviours while engaging in online academic content in a variety of environments (i.e. at home, at the library, alone in a controlled lab setting, among other students in a controlled lab setting etc.). Much like the existing observational research that found particular patterns of instant messaging during in-person live lectures, future investigations should take advantage of increasingly prevalent media tracking software to account for the type, frequency, and volume of medias being engaged over the duration of both synchronous and asynchronous video lectures.

Conclusions

The current online media multitasking experimental study provided a host of unexpected results. When the lecture was paused for participants to tend to a relevant secondary media task, a learning boost was found. When the secondary media task was tended to concurrently with the lecture video, whether relevant or non-relevant, no learning costs were observed. Contrary to contemporary theoretical frameworks, this suggests that social media scrolling behaviours and concurrent multitasking poses no learning impairments. With respect to both trait-level media multitasking indexes, general and online lecture specific indices, they appear to associate equably between each other and to academic performance across all group conditions. Though, the general index was more predictive of non-compliance rates. In consideration of the fact that some of these unexpected findings may be explained by the high non-compliance rates, future studies are encouraged to enforce more rigorous compliance checks and monitoring procedures.

With few experimental studies examining media multitasking in online learning settings, this is the first to evaluate social media scrolling behaviours, and combine task-relevance and pausing manipulations. With growing media and social media dependence, and a new precedent for online learning set by the COVID-19 pandemic, competition for students' attentional resources is stronger than ever. By investigating the online learning implications of social media and media multitasking under particular online academic scenarios, instructors and administrators will be better equipped to encourage more productive technological learning practises to students and ultimately design more effective online-based pedagogical strategies in the future.

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Appendix A

Demographic Questionnaire

1. What is your program?
2. Under which faculty are you studying?
    - ___ Business
    - ___ Engineering
    - ___ Health Sciences
    - ___ Humanities
    - ___ Science
    - ___ Social Sciences
    - ___ Arts & Science Program
    - ___ Other (e.g. Interdisciplinary program)
    - ___ Continuing Education
3. What is your degree
    a. Bsc
    b. BA
    c. Other
4. Please indicate your age [<19, 19-20, 21-22, 23-24, >24]
5. What is your gender? [MC: male, female, prefer not to answer, prefer to self-describe ____]
6. Are you a full-time student? [Y/N]
7. Are you an international student? [Y/N]
8. How many hours per week are you currently spending on your coursework? [MC: 1-5h, 5-10h, 10-15h, <15]
9. If you are employed, how many hours per week do you currently work? [MC: 1-5h, 5-10h, 10-15h, <15]
10. How would you rate your overall online learning experience this last academic year? [scale 1-5; very poor – excellent]
11. On average how many hours do you sleep at night? [MC: <4, 4-5, 5-6, 6-7, 7-8, 8-9, 9-10, >10]
12. What are your current living accommodations? [MC: detached house, semi-detached, apartment/condominium, one room rental in shared accommodation, Other-please describe ___]
13. Please indicate with whom you are sharing your living accommodations [MC+: Parent(s), sibling(s), friend(s), partner, child(ren), I am living alone, Other ___]
14. How would you rate the reliability of your internet connection during the school year? [scale 1-5; very poor – excellent]
15. Generally, how many hours a week did you engage in physical activity during the school year? [MC: 0hrs, 0-1, 1-2, 2-3, 4-5, 5+]

Appendix B

General Media Multitasking Index (MMI_{gen})

Part 1. On average, how many hours per week do you spend using each of the following media? (Please enter a single number for each; remember there is a maximum of 168 hours in a week)

- Television: _____
- Computer-based video (e.g., YouTube): _____
- Music: _____
- Non-music audio (i.e. Podcasts, Audiobooks): _____
- Video/Computer Games: _____
- Social Media _____
- Telephone/Cell phone voice calls: _____
- Instant/Text-messaging (SMS): _____
- Email: _____
- Web Surfing: _____
- Other computer-based Application (e.g., Word): _____

Part 2. For each type of media, please indicate how often you simultaneously engage in each of the other types of media.

How often do you concurrently use **Computer-based video (e.g., YouTube)** with each of these other mediums?

	0 - Never	1 - A little of the time	2 - Some of the time	3 - Most of the time
Television	○	○	○	○
Music	○	○	○	○
Non-music audio (e.g. Podcasts)	○	○	○	○
Video/Computer Games	○	○	○	○
Video and Audio Calls	○	○	○	○
Social Media	○	○	○	○
Instant/Text Messaging	○	○	○	○
Web Surfing	○	○	○	○
Other Computer-based applications (e.g., Word)	○	○	○	○

How often do you concurrently use **Music** with each of these other mediums?

	0 - Never	1 - A little of the time	2 - Some of the time	3 - Most of the time
Television	○	○	○	○
Computer-based video (e.g., Youtube)	○	○	○	○
Non-music audio (e.g. Podcasts)	○	○	○	○
Video/Computer Games	○	○	○	○
Video and Audio Calls	○	○	○	○
Social Media	○	○	○	○
Instant/Text Messaging	○	○	○	○
Web Surfing	○	○	○	○
Other Computer-based applications (e.g., Word)	○	○	○	○

This is repeated for the other seven medias (Television, non-music audio, social media, cell phone voice calls, instant/text messaging, email, web surfing, and other computer-based applications)

Appendix C

Online Lecture Media Multitasking Index (MMI_{onl})

Q2.1 On an average week, how many hours do you spend watching lecture videos? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0. ____

Q2.2 While you are watching lecture videos, indicate how often you simultaneously engage in each of the following types of activities:

	0 - Never	1 - A little of the time	2 - Some of the time	3 - Most of the time	No answer
Texting, instant messaging, or emailing	○	○	○	○	●
Using social sites (e.g., Facebook, Twitter)	○	○	○	○	●
Using non-social text-oriented sites (e.g., online news, blogs, eBooks)	○	○	○	○	●
Talking on the telephone or video chatting (e.g., Skype, iPhone video chat)	○	○	○	○	●
Listening to music	○	○	○	○	●
Watching Videos/Movies/Shows (e.g., Netflix, Youtube)	○	○	○	○	●
Playing video games or online games	○	○	○	○	●
Doing homework/studing/writing papers	○	○	○	○	●
Talking face-to-face with a second person	○	○	○	○	●

Appendix D

Compliance Checks:

Did you respond randomly at any point during the first survey of media use?
Please answer honestly. You will receive your HIT regardless of your response.

- Yes
- No

Did you respond randomly at any point during this second survey of media use?
Please answer honestly. You will receive your HIT regardless of your response.

- Yes
- No

To find the tweet to the pop-up questions during the lecture I:

A. scrolled down their twitter home feed until I found it
B. Googled the name and date
C. Used the *control* + *F* function
D. Other ____

Lastly, given that this study is about media use and multitasking, we are also interested in whether you were multitasking with media while you completed this study.
Please answer honestly. You will receive your HIT regardless of your response.

- I was multitasking during this study
- I was not multitasking during this study

Appendix E

Secondary MMT Video Lecture Task Questions, Answers, and Timing

<u>Non-Relevant</u> group conditions (non-relevant pause & non-relevant no pause)		
Time	**Question**	**Answer**
2:58	Open a new browser tab, locate the following individuals twitter page and scroll to find the requested tweet: What was Ryan Reynold's only tweet on September 1, 2021?	"Mint Mobile Ida Update: Any data add-ons for customers in Louisiana or Mississippi between 8/29-9/12 will be refunded. Must have an area code or zip in those states. Refunds will take us 3-4 days. Be Safe. *@Mintmobile"*
4:27	Open a new browser tab, locate the following individuals twitter page and scroll to find the requested tweet: What was Tom Hank's only tweet on February, 20, 2020?	"You in High School? Want to Vote in Novemeber? Register! Check out how! Hanx *#WhenWeAllVote #PromChallenge"*
6:05	Open a new browser tab, locate the following individuals twitter page and scroll to find the requested tweet: What was Chris Rock's first tweet of this year, 2021?	"TOTAL BLACK OUT: The Tamborine Extended Cut is coming to Netflix on January 12th. *@NetflixIsAJoke"*
10:56	Open a new browser tab, locate the following individuals twitter page and scroll to find the requested tweet: What was Jerry Seinfeld's last tweet of the year in 2020?	"Maybe just this once, just for this Festivus 2020, we take pass on the "Airing of Grievances"..
12:05	Open a new browser tab, locate the following individuals twitter page and scroll to find the requested tweet: What was Jim Carrey's only tweet on July 16, 2021?	"At it's finest, life is a toothless grin. If you're wearing one in the end, you win. Goodness, JC"

14:18	Open a new browser tab, locate the following individuals twitter page and scroll to find the requested tweet: What was Bill Nye's only tweet of the day on June 20, 2021?	"Happy First Day of Northern Hemisphere Summer— the ol' Earth is tilted."

<u>Relevant</u> group conditions (relevant pause & relevant no pause)		
Time	**Question**	**Approximate Answer**
2:58	We just learned what binocular disparity is. Open a new google search tab in your browser to discover what "binocular summation" means. Copy and paste the answer here:	Binocular summation refers to the improved visual performance of binocular vision compared to that of monocular vision.
4:27	Open a new google search tab in your browser and discover how "tapetum lucidum" enables high resolultion night vision in some non-human species. Copy and paste the answer here:	Many animals such as cats possess high-resolution night vision, allowing them to discriminate objects with high frequencies in low illumination settings. The *tapetum lucidum* is a reflective structure that is responsible for this superior night vision as it mirrors light back through the retina exposing the photoreceptor cells to an increased amount of light
6:05	Open a new google search tab and discover in what shape cones are arranged in the fovea? Copy and paste the answer here:	The central fovea consists of very compact cones, thinner and more rod-like in appearance than cones elsewhere. These cones are very densely packed (in a hexagonal pattern).
10:56	Open a new google search tab in your browser and discover what "averted vision" is in context of rods and cones. Copy and paste the answer here:	Since the fovea does not have rods, it is not sensitive to dim lighting. Hence, in order to observe dim stars, astronomers use averted vision, looking out of the side of their eyes where the density of rods is greater, and hence dim objects are more easily visible.
12:05	Open a new google search tab in your browser. Discover what "positive afterimages" are. Copy and paste the answer here:	Positive afterimages appear the same color as the original image. They are often very brief, lasting less than half a second. A stimulus which elicits a positive image will usually trigger a negative afterimage quickly via the adaptation process

14:18	Open a new google search tab in your browser and discover what "Koniocellular cells" are and where they are located in relation to Parvocellular and Magnocellular cells. Copy and paste the answer here:	A koniocellular cell is a neuron with a small cell body that is located in the koniocellular layer of the lateral geniculate nucleus (LGN) in primates, including humans. Koniocellular layers are located ventral to each parvocellular and magnocellular layer of the LGN.

Appendix F

Post Lecture Multiple-Choice Questions

1. We have evolved to see what range on the electromagnetic spectrum?
    A. 200-400nm
    B. 400-700nm*
    C. 400-800nm
    D. None of the above
2. Light is:
    A. A photon
    B. A wave
    C. A particle
    D. All of the above*
3. The disruption in the receptor layer that this bundle of axons creates is what results in ____
    A. Rods and cones to become activated
    B. A blind spot in our vision*
    C. The fovea
    D. Amacrine cells
4. **Which of the following about Binocular Disparity is FALSE:**
    A. It is the difference between the image's position on the two retinas
    B. Greater disparity means the object is farther
    C. The difference in distance between the left and right eye to the object in view*
    D. A and B
5. Cones are:
    A. Photoreceptors*
    B. Bipolar cells
    C. Horizontal cells
    D. Retinal ganglion cells
6. **Cones have:**
    a. Photopic vision; when there is plenty of light*
    b. Photopic vision; when the light source is dim
    c. Scotopic vision; when the there is plenty of light
    d. Scotopic vision; when the light source is dim
7. The pupil changes size to adjust to the intensity of the light source via:
    A. Blinking
    B. Constriction
    C. Dilation
    D. B and C*
8. **The fovea:**
    A. Contains rods and cones
    B. Contains mostly cones and some rods *
    C. Only cones and no rods
    D. Only rods and no cones

9. Rods can amplify a dim light source because of:
    A. The wavelength range it absorbs
    B. The convergence of multiple rods onto a single ganglion*
    C. Its location on the retina
    D. Its peculiar shape
10. **Rods have ____ pigment molecule(s) and cones have _____ pigment molecule(s)**
    A. 3, 3
    B. 1, 3*
    C. 1, 1
    D. 5, 1
11. Which of the following is not part of the eye
    A. Iris
    B. Cornea
    C. Lens
    D. None of the above*
12. Cones have:
    A. High sensitivity & high acuity
    B. Low sensitivity & low acuity
    C. Low sensitivity & high acuity *
    D. High sensitivity & low acuity
13. **There are ___ layers that respond to colour, fine details, and still objects. There are also ____ layers that respond to objects in motion**
    A. P, M*
    B. C, P
    C. A, M
    D. C, R
14. **Inputs from the left visual field travel to the _____**
    A. Left primary visual cortex
    B. Right primary visual cortex *
    C. Right cornea
    D. Left iris
15. The negative afterimage effect occurs because:
    A. Of the rod to cone ratio
    B. Cones become fatigued*
    C. Rods become fatigued
    D. Of the Purkinje effect
16. Yellow and red are brightest in high-light conditions, while green and blue are brightest in low-light conditions is an example of:
    A. The Purkinje Effect*
    B. Fatigued cones
    C. Colour adaptation
    D. Trichromatic theory
17. **The two streams of visual processing that occur in the brain are the:**
    A. Dorsal stream and lateral stream
    B. Ventral stream and dorsal stream*
    C. Medial stream and ventral stream

D. None of the above

18. Rod density is highest ____ degrees (angle) from the fovea
    - A. 10
    - B. 20*
    - C. 30
    - D. 40
19. The secondary visual cortex receives information from the:
    - A. Primary visual cortex*
    - B. Optic nerve
    - C. Rods and cones
    - D. Ganglion cells
20. The lecturers name in the video is:
    - A. Professor Rick
    - B. Professor Larry
    - C. Professor Dave*
    - D. Professor Patel

Note: Questions in **bold** are the 7 questions used to measure AP_{MMT}

Multiple Choice Answers

1. B
2. D
3. B
4. C
5. A
6. A
7. A
8. B
9. B
10. B
11. D
12. C
13. A
14. B
15. B
16. A
17. B
18. B
19. A
20. C