Media multitasking and performance on attentionally demanding tasks

by

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Examining Committee Membership

The following served on the Examining Committee for this thesis. The decision of the Examining Committee is by majority vote.

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

A version of Chapter 2 is available in Ralph, B. C. W., & Smilek, D. (2017). Individual differences in media multitasking and performance on the n-back. *Attention, Perception, & Psychophysics*, *79*(2), 582-592. Doi: 10.3758/s13414-016-1260-y. For the purposes of the present dissertation, in Chapter 2 I report a subset of analyses found in Ralph and Smilek (2017), removing sections of the result pertaining to lure versus non-lure sequences.

Abstract

This dissertation examined the behaviour of media multitasking, with a specific focus on three broad goals. The first goal, explored in Chapter 2, was to examine whether individual differences in the propensity to media multitask are associated with performance on attentionally demanding tasks. One particular attentionally demanding task – the n-back – was selected as it yielded mixed findings in prior work. It was found that higher trait-levels of media multitasking were associated with poorer performance on the n-back in terms of higher false alarm rates, but also with a greater propensity to omit trials, a performance metric that often goes unreported. The second goal, examined in Chapter 3, was to assess whether the presence of a concurrent, non-required media stream (video) influences performance on an attentionally demanding task, and whether the presence or absence of such a media stream influences subjective judgments of performance. The general findings were that the presence of the non-required video negatively affects performance on the attentionally demanding task (n-back), and that participants judged their performance to be worse when the video was present than when it was absent. Lastly, the third goal, explored in Chapter 4, was to examine whether participants will modulate their exposure to a non-required media stream in response to the demands of a primary task. In addition to replicating findings from Chapter 3, in Chapter 4, when given direct control over the presence or absence of the media stimuli, participants performing a high-demanding task (2-back) were more likely to turn off the video than participants performing a low-demanding task (0-back). It also appears that having a concurrently available media may be beneficial, particularly in situations of low demand, as it might increase perceived demand of the task to reach a more optimal zone of engagement, as well as lead to reduced boredom. In Chapter 5, the findings are discussed in the context of alternative

theoretical perspectives and the utility of a laboratory-based paradigm for studying media multitasking.

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Dedication

I dedicate this thesis to my loving wife, Shelly, and my little man, Joseph. You are the inspiration for all that I do, and none of this would have been accomplished without you.

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Chapter 1: General Introduction

Consider for a moment the case of a particular doctoral student, let's call him BR, writing his dissertation. As BR works on his dissertation, he often listens to music, uses secondary-screens to acquire information, and sometimes even has a YouTube video playing on the side. When BR goes home after a long day's work, he commonly plays video games with his wife as they watch various television programs in the background. To BR's amazement, his wife will sometimes even engage in cellphone conversations while they hunt virtual monsters and watch the latest dramas, juggling the demands of the various tasks to which she is involved. These activities of BR, and indeed his wife, are characteristic of a behaviour known as *media multitasking* – simultaneously engaging with multiple media-based sources of information – that is becoming increasingly popular, especially amongst youths (Carrier, Cheever, Rosen, Benitez, & Chang, 2009; Rideout, Foehr, & Roberts, 2010).

While multitasking has been a widely studied phenomenon in cognitive psychology for decades, *media multitasking* may operate quite differently in everyday life. One core feature of media multitasking in everyday life that seems to separate it from how we typically think about and study multitasking is that engagement with many (but not all) additional media is often *non-required,* and therefore *voluntary*. Typically, laboratory-based paradigms of multitasking *require* participants to attend to and complete multiple tasks simultaneously, and performance is compared to when the tasks are performed individually (e.g., Baddeley & Hitch, 1974; Baddeley, Lewis, Eldridge, & Thomson, 1984; Bourke, Duncan, & Nommi-Smith, 1996; Cauwenberge, Schaap, & van Roy, 2014; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Drews, Pasupathi, & Strayer, 2008; Fox, Rosen, & Crawford, 2009; Hancock, Lesch, & Simmons, 2003; Horrey, Lesch, & Garabet, 2008; Jacoby, Woloshyn, & Kelley, 1989; Lesch & Hancock, 2004; Medeiros-Ward, Cooper, & Strayer, 2014; Risko, Buchanan, Medimorec, & Kingstone, 2013; Sana, Weston, &

Cepeda, 2013; Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001; Wood, Zivcakova, Gentile, Archer, De Pasquale, & Nosko, 2012; to name but a few). In these situations, it makes sense to collect important performance metrics on both primary and secondary tasks to measure how successful participants were at completing both of the experimentally-required tasks. However, if we consider how individuals such as BR, or his wife, engage with multiple media in real-world contexts, it is clear that these requirements to perform do not apply, and collection of success metrics make less sense. For example, BR is not required to listen to music or watch YouTube videos while he works on his dissertation. Similarly, students are not required to send text-messages or browse social-networking sites as they complete their homework, and drivers do not have to listen to a radio broadcast or talk on a cellphone. Rather, they do so by their own volition. Given the non-required and volitional nature of media multitasking in many real-world contexts, it stands to reason that performance metrics of 'success' on these additional media activities are not collected and would be difficult to index in any meaningful way. That is not to say we cannot test content-knowledge, for example, of musical lyrics, cellphone conversations, or browsed social sites – it is just that 'performance' on such activities are irrelevant when considered in the context of a primary task, such as doing work or driving.

A second core feature of media multitasking in real-world contexts is that additional media-based activities can be *flexibly engaged*. For instance, it may be possible for BR to strategically change how his attention is allocated to his dissertation, the music he may be listening to, and / or videos he may be watching. Sometimes, more attention may be devoted towards writing his dissertation. Other times, his attention may be split more evenly between writing his dissertation and attending to other media-inputs (such as music or video). Further still, sometimes he may even disengage from writing his dissertation to devote more attention to a song or video segment.

However, the contextual demands of much previous multitasking research requires participants to attend to and complete all tasks equally.

Recently, there has been a surge of interest in studying various aspects of media multitasking and how it relates to different personality traits (e.g., Becker, Alzahabi, & Hopwood, 2013; Chang, 2016; Duff, Yoon, Wang, & Anghelcev, 2015; Malivoire, Mazachowsky, & Arnell, *Under Review* ; Pea et al., 2012; Ralph, Thomson, Cheyne, & Smilek, 2014; Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013; Schutten, Stokes, & Arnell, 2017; Shih, 2013; Wilmer & Chein, 2016) and cognitive ability (Alzahabi & Becker, 2013; Cain, Leonard, Gabrieli, & Finn, 2016; Cain & Mitroff, 2011; Cardoso-Leite, Kludt, Vignola, Ma, Green, & Bavelier, 2016; Lui & Wong, 2012; Minear, Brasher, McCurdy, Lewis, & Younggren, 2013; Ophir, Nass, & Wagner, 2009; Ralph, Thomson, Seli, Carriere, & Smilek, 2015; Sanbonmatsu et al., 2013; Uncapher, Thieu, & Wagner, 2016). Building on this growing body of work, this dissertation will address several broad yet interrelated issues. The first issue, addressed in Chapter 2, is whether individual differences in media multitasking are related to performance metrics on attentionally demanding tasks. The second issue, examined in Chapter 3, is the extent to which a non-required simultaneous media stream (here, a video) interferes with performance on an attentionally demanding task, and whether individuals report performing more poorly when such a media stream is present versus absent. Lastly, the third goal, addressed in Chapter 4, is whether individuals will actively modulate their exposure to a non-required simultaneous media stream (video) based on the attentional-demands of a primary task (i.e., low demand versus high demand).

Individual Differences in Media Multitasking

There are several reasons as to why we might expect media multitasking to be associated with performance on attentionally demanding tasks. For one, there is now a growing body of research suggesting that *individual differences* in media multitasking are associated with differences in socio-affective and cognitive profiles. Throughout much of this work, individual differences in media multitasking have commonly been captured by using a fairly exhaustive self-report inventory known as the Media Multitasking Index (MMI; Ophir et al., 2009). In this inventory, participants report upon their daily or weekly media usage across a number of different media platforms, as well as how often they multitask using each combination of listed media. In the socio-affective domain, higher trait-levels of media multitasking have been associated with poorer social well-being (Pea et al., 2012; but see Shih, 2013), greater negative affect and neuroticism (Malivoire et al., *Under Review*), greater sensation seeking (Chang, 2016; Sanbonmatsu et al., 2013) and impulsivity (Sanbonmatsu et al., 2013; Schutten et al., 2017), greater depression (Becker et al., 2013), more mindlessness (Ralph et al., 2014), and higher levels of anxiety (Becker et al., 2013; Malivoire et al., *Under Review*). Heavier media multitaskers have also been shown to have reductions in the propensity to delay-gratification (Schutten et al., 2017; Wilmer & Chein, 2016), and endorse intuitive yet incorrect decisions when problem solving (Schutten et al., 2017).

Most relevant are studies looking directly at how individual differences in media multitasking are tied to performance on various cognitive tasks. For instance, researchers have examined how heavy media multitaskers compare to their lighter media multitasking counterparts on measures of dual-tasking (Alzahabi & Becker, 2013; Sanbonmatsu et al., 2013), task-switching (Alzahabi & Becker, 2013; Minear et al., 2013; Ophir et al., 2009), the ability to ignore singleton distractors (Cain & Mitroff, 2011), multisensory integration (Lui & Wang, 2012), measures of fluid-intelligence (Minear et al., 2013), sustained attention (Ralph, Thomson, Seli, Carriere, & Smilek, 2015), and working memory (Cain et al., 2016; Cardoso-Leite et al., 2016; Minear et al., 2013 Ophir et al., 2009; Uncapher et al., 2016). Whatever the nuances in the putative mechanisms these tasks index, it is fair to say that many of these cognitive tasks are reasonably attentionally demanding. When the foregoing studies are considered together, then, one might expect that we could make some statement about how heavy and light media multitaskers compare on attentionally demanding tasks.

Unfortunately, much of the work linking individual differences in media multitasking to performance on attentionally demanding cognitive tasks has produced mixed results, both when using different paradigms to measure the same underlying construct, and when using the same paradigm. For example, while Sanbonmatsu et al. (2013) found heavier media multitaskers to be poorer at dual-tasking, Alzahabi and Becker (2013) found no differences in dual-tasking ability using a different dual-task paradigm. When using the exact same task-switching paradigm, Ophir et al. (2009) found heavier media multitaskers to be poorer at task-switching, while Minear et al. (2013) found no such differences, and Alzahabi and Becker (2013) actually found heavier media multitaskers to be *better* at task-switching.

Similar inconsistencies have been reported when researchers have explored the association between media multitasking and performance metrics on an assortment of working memory paradigms. The attention-demanding working memory tasks examined in this line of work include the n-back (Cain et al., 2016; Cardoso-Leite et al., 2016; Ophir et al., 2009), Vogel, McCollough, and Machizawa's (2005) filtering task (Cardoso-Leite et al., 2016; Ophir et al., 2009; Uncapher et al., 2016; see Cain et al., 2016 for a similar version), the AX-continuous performance task (AX-CPT; Cardoso-Leite et al., 2016; Ophir et al., 2009), a probed item-recognition task (Minear et al., 2013), as well as the Operation Span Task (OSPAN; Sanbonmatsu et al., 2013) and Reading Span Task (RSPAN; Minear et al., 2013). In terms of inconsistencies in conclusions drawn from studies using different working memory tasks, performance on some tasks suggest that higher levels of media multitasking are associated with poorer working memory, whereas performance on other tasks suggests no such relation between media multitasking and working memory. For instance, Ophir et al. (2009) initially found that heavier media multitaskers (as identified by the MMI) generally performed more poorly on the n-back, a filtering task, and the AX-CPT than did lighter multitaskers. In contrast, Minear et al. (2013) found no such differences when indexing working memory via the RSPAN or with a probe item-recognition task.

Like the discrepant task-switching findings that utilized the same paradigm, there are also inconsistencies in conclusions drawn from studies using the *same* ostensible working memory tasks. In three different studies (Cardoso-Leite et al., 2016; Cain et al., 2016; Ophir et al., 2009), individual differences in media multitasking were measured using the MMI (Ophir et al., 2009), and in each study, n-back performance was assessed via hits and false alarms across various cognitive loads. Yet, in each of the three different studies, the researchers arrived at a different conclusion based on a different set of results. Whereas Ophir et al. (2009) found that heavier multitaskers produced more *false alarms* than did light multitaskers, Cain et al. (2016) and Cardoso-Leite et al. (2016) found no such differences. At the same time, whereas Cain et al. (2016) found that heavier multitaskers produced *fewer hits* than did light multitaskers, this result was not observed in Ophir et al. (2009) and Cardoso-Leite et al. (2016). Lastly, although (as noted above) both Cain et al. (2016) and Ophir et al. (2009) showed differences in rates of hits *or* false alarms across heavy and light media multitaskers, Cardoso-Leite et al. (2016) found no differences whatsoever in either of these measures.

It is therefore unclear exactly how individual differences in media multitasking relate to performance on attentionally demanding tasks. Despite a number of studies exploring this very relation, one perhaps obvious question to be raised is – why might these studies have found such variable results, especially when using the *same* cognitive task? Many investigations of media multitasking suffer from two important shortcomings: (1) the use of an extreme-groups approach, and (2) the use of small sample sizes that likely overestimate effect sizes and capitalize on chance findings. In Chapter 2, these shortcomings are addressed with respect to performance on one such attentionally demanding task – the n-back – by adopting a correlational approach and using a large sample to more conclusively address how individual differences in media multitasking are related to performance metrics on the n-back.

Media Multitasking in-the-Moment

Beyond an individual differences approach, there is also good reason to suspect that moments of media multitasking might produce the same consequences on primary-task performance as standard multitasking paradigms. A commonly held notion in cognitive psychology is that cognitive resources are limited to some degree (e.g., Baddeley & Hitch, 1974; Kahneman, 1973; Lang, 2000; Lavie, Hirst, de Fockert, & Vidings, 2004; Wickens, 2002). According to Limited Capacity (e.g., Kahneman, 1973) and Multiple Resource models (e.g., Wickens, 2002), when some proportion of these resources are co-opted by one activity, fewer resources are left over to devote towards other activities. In the context of typical multitasking paradigms, this co-opting of cognitive resources is one proposed mechanism for dual-task interference. Indeed, the extent to which two or more concurrently performed tasks will interfere with one another is likely to depend on: (a) the type of cognitive resource being utilized, including domain-general resources (e.g., central executive) used when completing any task and domain-specific resources (e.g., visuospatial and verbal) used when completing specific types of tasks (Baddeley & Hitch, 1974; Wickens, 2002); and (b) the rate at which these resources are being consumed. In the context of media multitasking, concurrently engaged media activities may interfere with performance on a primary task if there are sufficient demands placed on domain-general resources (e.g., executive control) and / or both activities utilize the same domain-specific cognitive resource (e.g., visuospatial). Indeed, several studies have now demonstrated that multitasking with a cellphone impairs driving ability (e.g., Drews et al., 2008; Hancock et al., 2003; Horrey et al., 2008; Lesch & Hancock, 2004; Strayer & Drews, 2007; Strayer, Drews, & Crouch, 2006; Strayer et al., 2003; Strayer & Johnston, 2001; Tractinsky, Ram, & Shinar, 2013), and multitasking with a cellphone and / or laptop during real or simulated lectures impairs learning (e.g., Barak, Lipson, & Lerman, 2006; Hembrooke & Gay, 2003; Ravizza, Hambrick, & Fenn, 2014; Risko et al., 2013; Sana et al., 2013; Wood et al., 2012). Others have demonstrated that listening to music sometimes hinders performance on mental tasks (e.g., Cassidy & Macdonald, 2007; Furnham & Bradley, 1997; Furnham & Strbac, 2002; Kirkpatrick, 1943), as does looking up information on the internet (Cauwenerge et al., 2014), holding instant-messaging conversations (Fox et al., 2009), and having a video playing in the background (e.g., Armstrong & Chung, 2000; Furnham, Gunter, & Peterson, 1994; Pool, Koolstra, & van der Voot, 2003).

On the other hand, given that media multitasking in real-world contexts involves more volitional engagement with often *non-required* and *task-irrelevant* media (such watching Netflix while you work), it is also possible that individuals may be able to simply *ignore* simultaneous media streams in order to avoid performance costs to the primary task, particularly during moments when the primary task is demanding. For instance, research on inattention blindness has demonstrated that people are quite good at not even realizing task-irrelevant stimuli are present in a visual scene when shown unexpectedly (Mack & Rock, 1998; Neisser & Becklen, 1975; Simons & Chabris, 1999), particularly under conditions of high cognitive load (Fougnie & Marois, 2007).

As Neisser and Becklen (1975) write, “The ordinary perceptual skills of following visually-given events, which develop in the first year of life … are simply applied to the attended episode and not to the other.” (pg. 491 & 492). Indeed, when visual stimuli are irrelevant to one’s goal and are not the focus of attention, such unattended stimuli can go unprocessed and without cost to performance (e.g., Gronau & Izoutcheev, 2017). In more real-world scenarios, although engaging in researcher-motivated cellphone conversations negatively impacts driving performance, listening to a radio broadcast does not (Strayer & Johnston, 2000). In fact, during low-demanding / predictable road conditions, adding a secondary cognitive task (auditory n-back) has actually been found to *improve* driver performance (Medeiros-Ward et al., 2014). Similarly, while some studies have found music to interfere with performance on a primary task, many studies have also demonstrated that music can be played without hindering performance on complex tasks at all (e.g., reading comprehension, mental arithmetic tasks; Cool et al., 1994; Furnham & Strbac, 2002; Furnham, Trews, & Sneade, 1999; McGehee & Gardner, 1949; Newman, Hunt, & Rhodes, 1966; Pool, et al., 2003), and in the case of low-demanding primary tasks, concurrently listening to music may even *benefit* performance (Fox & Embrey, 1972; Konz, 1962; Lesiuk, 2005; Oldham, Cummings, Mischel, Schmidtke, & Zhou, 1995). Lastly, while some researchers have found background videos to interfere with performance on a primary task (e.g., Armstrong & Chung, 2000; Furnham et al., 1994; Pool et al., 2003), others have found no negative impact of background videos on primary-task performance (Cool, Yarbrough, Patton, Runde, & Keith, 1994; Lin, Robertson, & Lee, 2009; Pool, van der Voot, Beentjes, & Koolstra, 2000).

Of course, a fundamental aspect of media multitasking is that individuals have some *choice* in their media multitasking behaviour. This aspect of media multitasking is potentially important given previous findings that providing participants with a choice, even if illusory, can be motivational and confer benefits to performance. For example, providing workers with actual choice over musical selection (if any) has been found to improve productivity, satisfaction, and mood (Oldham et al., 1995). In the vigilance literature, even providing participants with the *illusion* of choice as to which task to perform has been found to reduce the commonly observed vigilance decrement (Dember, Galinsky, & Warm; 1992; Szalma & Hancock, 2006). In light of these findings it is conceivable that the choice involved in media multitasking might increase motivation and perhaps even improve primary task performance. It is worth noting that in contrast to media multitasking, in many investigations of dual-task interference, participants have no such choice over task engagement or completion.

If media multitasking does influence performance on an attentionally demanding task, another interesting issue that arises is whether people evaluate their performance to be better or worse during moments of media multitasking. Awareness and metacognitive evaluation of one's performance seems to be predicated on the notion that (a) there are sufficient information-processing resources to devote to such monitoring behaviour, and (b) information-processing resources are coupled with the task-at-hand so as to allow errors to enter consciousness. But, what if the cognitive demand of the primary task is sufficient as to render a paucity of mental resources leftover for metacognitive processes? Alternatively, what if those processing resources become de-coupled from the primary task and consumed by other activities; for instance, by engaging in an auditory musical or visual video stream? It seems reasonable to assume that if either or both of the foregoing conditions were met, awareness of any potential impact of media multitasking on performance should decline. Consistent with this possibility, previous work has shown that simply increasing cognitive load compromises participants' ability to monitor the passage of time (Chinchanachokchai, Duff, & Sar, 2015). In situations where information-processing may be de-coupled from the primary task by media-based activities, such as using a cellphone while driving, Horrey et al. (2008) argue that although participants subjectively report performing worse when multitasking while driving, compared to not multitasking while driving, they are not well-calibrated to the magnitude of such distraction effects. Of course, the mere fact that individuals report their driving performance to be poorer while using a cellphone versus driving without using a cellphone might suggest that, when people are engaged in media multitasking, their attention is not fully absorbed. Individuals may therefore have some awareness of their performance while media multitasking, even if not wholly accurate.

In Chapter 3, the lack of clarity as to whether a *non-required* and *task-irrelevant* media stream might impact performance on a primary, attentionally demanding task is addressed, as well as how participants evaluate their performance to be on the primary task when such a media stream is present versus absent. To do so, a paradigm similar to that of Lleras, Buetti, and Mordkoff (2014) was developed, wherein participants are instructed to complete a demanding visual primary task while a non-required, task-irrelevant media (here, a video) is embedded in a portion of the visual display. At key points throughout the task subjective estimates of certain performance variables are also collected to assess perceptions of performance, and determine how sensitive participants are to interference effects, if any.

Modulating Media Multitasking Behaviour

If media multitasking does interfere with performance on some primary task, and people subjectively report performing more poorly during episodes of media multitasking (e.g., Horrey et al., 2008), another issue is whether individuals will modulate their media multitasking behaviour in response to the demands of their primary task. Load Theory, for instance, provides evidence that people will modulate the deployment of their cognitive resources in response to task demands

(Lavie et al., 2004). According to Load Theory (Lavie et al., 2004), there are both perceptual and cognitive-control selection mechanisms that act upon the processing of task-relevant and irrelevant information. Importantly, in both cases, perceptual and cognitive resources are limited to some degree. At the early stage of perceptual processing, when the analysis of task-relevant information places a high demand on perceptual resources, thereby taxing an individual's perceptual capacity, the analysis of task-irrelevant information is restricted. Placing high demand on cognitive-control, however, leads to very different predictions as to the processing of task-irrelevant information. At later stages of information processing, the cognitive-control selection mechanism is thought to play a role in keeping task-processing priorities orderly. In contrast to manipulations of perceptual demand, events that increase load of this cognitive-control system will disrupt its ability to maintain task-processing priority, thereby causing greater interference from task-irrelevant information (Lavie et al., 2004).

Recent work by Lleras et al. (2014; see also Buetti & Lleras, 2016) also provides evidence that people may reflexively modulate their eye movements to task-irrelevant information in response to primary-task demands. Lleras et al. (2014) had participants perform auditory versions of either a 1-back, 2-back, or an ongoing arithmetic task, while looking at a blank (white) computer display. Critically, between trials, Lleras et al. presented participants with task-irrelevant (albeit expected) pictures, and measured the extent to which participants looked at the pictures versus other regions of the display. Interestingly, they found that participants were much more likely to look at the task-irrelevant picture when the demands of the primary task was low (i.e., during the 1-back), and were therefore much less likely to look at the task-irrelevant picture when the demands of the primary task was high (i.e., during the 2-back).

There is also some evidence that people can modulate their attention to task-irrelevant information much more strategically. In the mind wandering literature, for instance, there is considerable evidence that people regulate their levels of mind wandering based on the difficulty of the primary task (see Smallwood & Schooler, 2006, for a review). In terms of overall mind wandering rates, Thomson, Besner, and Smilek (2013) found in one experiment that mind wandering rates varied as a function of the lexical status of words (word versus non-word), such that participants mind wandered less for non-words (which are presumably more difficult to read) than true-words (which are presumably less difficult to read). In a second experiment, Thomson et al. (2013) also found that during a Stroop Task, participants mind wandered more while reading congruent (less difficult) words and less while reading incongruent (more difficult) words. Other researchers have found that imposing a secondary mental task, in the form of a prospective memory task (i.e., a 'monitoring' task), while completing a primary task (e.g., lexical decision-making) reduces mind wandering compared to when a primary task is performed alone (Rummel, Smeekens, & Kane, 2016), presumably because the prospective memory task occupies cognitive resources that would otherwise be used for mind wandering (or the primary-task at hand; Smallwood & Schooler, 2006). Critically, Seli, Risko, and Smilek (2016) have provided a more fine-grained analysis of mind wandering in response to task demand by further separating *unintentional* and *intentional* (volitional) bouts of mind wandering during an easy, predictable sustained attention task versus a more difficult, unpredictable sustained attention task. Seli et al. (2016) observed that *unintentional* mind wandering was more common in the difficult compared to easy task, and *intentional* mind wandering was more common in the easy compared to difficult task. Seli et al.'s findings suggest that participants are sensitive to task demands and actively refrained from deliberately allocating cognitive resources to mind wandering when the task became more difficult.

Considering the foregoing findings together, one hypothesis is that if the demands of a primary task are low and information-processing resources are available, individuals may allocate these resources to task-irrelevant simultaneous streams of media-based information, much like they do towards mind wandering. If, however, the demands of a primary task are high and sufficient processing resources are not available, it stands to reason that individuals should be less likely to engage in media multitasking because such engagement may interfere with primary-task performance. Relating back to Lavie et al.'s (2004) Load Theory, this should be true for both high perceptual load where individuals simply do not have the visual resources required, and for high loads on cognitive-control, insofar as individuals can recognize the media as a potential source of distraction that should be avoided (as evidenced for by Buetti & Lleras, 2016; Lleras et al., 2014; Horrey et al., 2008; Seli et al., 2016).

Building on previous work, in Chapter 4 it was tested whether participants would modulate their media multitasking by utilizing a similar paradigm to that of Chapter 3. However, the paradigm used in Chapter 4 contained two important changes. First, the attentional demands of the primary task were manipulated by giving participants either a low-demanding, easy task (0-back), or a relatively high-demanding, difficult task (2-back). Second, control of the non-required video was given to the participants, such that participants could toggle the video on and off, at their leisure, throughout the experiment. Thus, in Chapter 4, a particular focus is on whether participants would media multitask less in the high-demanding condition, compared to the low-demanding condition, by acting to physically turn off the non-required video stream, in addition to addressing similar issues to those in Chapter 3.

Overview of Chapters

In Chapter 2, findings from Ralph and Smilek (2017) are presented, exploring how individual differences in media multitasking are associated with performance on one attentionally demanding cognitive task – the n-back – that has thus far yielded mixed results. To address shortcomings in previous work, a correlational approach was adopted, thereby using the full spectrum of media multitasking tendencies, and data was collected from a sufficiently large sample to protect against chance-findings and overestimates of effect sizes. Higher levels of habitual media multitasking were found to be associated with increased false alarms, but not with changes in hits, consistent with observations by Ophir et al. (2009), but not with those of Cain et al. (2016) or Cardoso-Leite et al. (2016). It was also found that heavier habitual media multitasking was associated with greater omissions (trials for which no response was provided) and an increased likelihood to media multitask during the actual experiment.

In Chapter 3, data from four studies are presented, examining; (a) whether having irrelevant, non-required media (video) influences performance on an attentionally demanding primary task, and (b) whether participants can accurately pick-up on and subjectively report these influences. To do so, a media multitasking paradigm was developed, similar to the distraction paradigm used by Lleras et al. (2014; see also Buetti & Lleras, 2016). In this media multitasking paradigm, participants completed a required primary task (here, the n-back) either alone or with an irrelevant, non-required video embedded in a portion of the visual display screen. In Study 3.1, the presence of the irrelevant, non-required video was manipulated between-groups such that one group of participants performed the n-back with no video playing, and another group of participants performed the n-back with the irrelevant, non-required video playing. Studies 3.2, 3.3, and 3.4 adopted a within-subjects approach, whereby all participants completed two phases of the required primary task (n-back) – one phase where the primary task was performed alone, and another phase where the primary task was performed with the irrelevant, non-required video embedded in the display. Critically, at certain points throughout the task, participants were asked to provide subjective estimates of their performance. In general, findings from the studies presented in Chapter 3 suggest that (1) the opportunity to engage with an irrelevant, non-required media does indeed negatively impact performance on an attentionally demanding primary task, (2) participants subjectively report performing more poorly when additional media is present compared to when performing the primary task alone, (3) participants are sensitive to the magnitude of the impact of the additional media on performance (i.e., relative changes in performance from video-absent to video-present task-segments), and (4) participants attribute declines in performance to the presence of the video.

Lastly, in Chapter 4, I examine whether participants will media multitask less when performing a high attentionally demanding primary task, and more when performing a low attentionally demanding primary task. Chapter 4 relied upon a similar methodology as Chapter 3 (Studies 3.2 and 3.3), except that control of the media stimuli was given to participants. Control over when and how to engage with available media is something fundamental to how people media multitask in everyday life. In Chapter 4, this element was brought into the laboratory by giving participants the ability to *toggle* the non-required, task-irrelevant media on and off at their leisure, throughout the experiment. Critically, the demands of the primary task were manipulated (between-groups), such that participants performed either an easy, low-demanding task (0-back), or a relatively more difficult, high-demanding task (2-back). This allowed for the comparison of how participants modulated their media multitasking behaviour based on the demands of a primary task in a controlled laboratory environment. In addition to replicating results from Study 3.2, 3.3, and 3.4, in Chapter 4, participants were more likely to physically act to *turn-off* and eliminate the media (video) when the primary task was demanding, but readily left the media on, without costs to performance, when the primary task was low in demand. Lastly, to more fully capture the subjective experience during moments of media multitasking, participants also provided self-reports of task demand, boredom, and motivation, alongside the subjective estimates of performance. It seems that, when the primary task is low in demand, media multitasking (i.e., leaving the video on while performing the primary task) serves to simultaneously increase perceived demand of the primary task and reduce boredom.

In Chapter 5, I conclude with a general discussion of the findings and possible theoretical perspectives on media multitasking. In particular is the consideration of whether habitual media multitasking is associated with differences in the ability to perform on cognitive tasks, or more simply a particular way of approaching certain situations. In addition, the limitations of the current work are discussed, as are future directions for improving upon and expanding the media multitasking paradigm employed in Chapters 3 and 4.

Chapter 2: Individual differences in media multitasking and performance on the n-back

Chapter Introduction

The goal of Chapter 2 is to examine how individual differences in media multitasking, assessed via the Media Multitasking Index (MMI; Ophir et al., 2009), relate to performance metrics on one attentionally demanding cognitive task – the n-back. Recently, many researchers have begun to explore media multitasking from an individual differences perspective. In particular, many studies have focused on exploring how the tendency to media multitask in everyday life relate to performance on a variety of cognitive tasks that tend to capture some aspect of the behaviour, such as the ability to dual-task (Alzahabi & Becker, 2013; Sanbonmatsu et al., 2013), task-switch (Alzahabi & Becker, 2013; Minear et al., 2013; Ophir et al., 2009), sustain attention (Ralph et al., 2014), and utilize working memory (Cain et al., 2016; Cardoso-Leite et al., 2016; Ophir et al., 2009; Uncapher et al., 2016). However, as noted in Chapter 1, there is considerable variability in the extant literature as to the relation between media multitasking and performance on various attentionally demanding cognitive tasks, both when using *different* cognitive paradigms to tap the same underlying construct and when using the exact *same* cognitive paradigm. And while variable findings with regard to associations between media multitasking and different paradigms designed to tap the same underlying construct may not be all that surprising – as each paradigm is unique in some way, relying at least to some extent on a different subset of cognitive processes – variable findings when the *same* paradigm is used are substantially more problematic.

Here I have chosen to focus on one particular task that has led to such variability – the *n-back*, a putative measure of working memory (Cain et al., 2016; Cardoso-Leite et al., 2016; Ophir et al., 2009). In the n-back, participants are presented with a series of items, one at a time, and are required to indicate when the current item matches the item presented *n* items back. Recall that in three different studies (Cardoso-Leite et al., 2016; Cain et al., 2016; Ophir et al., 2009), the researchers measured individual differences in media multitasking using the same inventory (the MMI; Ophir et al., 2009) and performance on the n-back was measured via hits and false alarms across different cognitive loads (e.g., 2-back, 3-back). Yet, each arrived at a different conclusion based on a different pattern of results. Ophir et al. (2009) found that heavier media multitaskers produced more *false alarms* than did light multitaskers, but Cain et al. (2016) and Cardoso-Leite et al. (2016) found no such differences in false alarms. Similarly, although Cain et al. (2016) found that heavier media multitaskers produced *fewer hits* than did light multitaskers, Ophir et al. (2009) and Cardoso-Leite et al. (2016) found no differences in hits. Lastly, despite both Cain et al. (2016) and Ophir et al. (2009) finding differences in at least one performance metric (hits or false alarms), Cardoso-Leite et al. (2016) found no differences whatsoever between heavy and light media multitaskers and either of these performance metrics.

Why might these studies have found such variable results, especially when using the same measures of media multitasking (the MMI) *and* cognitive paradigm (e.g., the n-back)? Such inconsistent results are certainly not unique to the media-multitasking literature, and in fact, it appears that the media-multitasking literature is facing a similar problem to that recently experienced by the video-gaming literature (see Unsworth, Redick, McMillan, Hambrick, Kane, & Engle, 2015). In particular, many investigations of media multitasking suffer from two important shortcomings: (1) the use of an extreme-groups approach, and (2) the use of small sample sizes that likely overestimate effect sizes and capitalize on chance findings.

With respect to the first shortcoming (i.e., the use of an extreme-groups approach), it is interesting to note that in each investigation of media multitasking, researchers have consistently found that there is no bimodal distribution of “heavy media multitaskers” and “light media multitaskers.” Despite this observation, many researchers in the media-multitasking literature have adopted an extreme-groups approach (as in the video-game literature), which has involved comparing ‘heavy’ and ‘light’ media multitaskers (HMMs vs. LMMS) – participants whose MMI scores fall one standard deviation above or below the mean (Cardoso-Leite et al., 2016; Ophir et al., 2009; Uncapher et al., 2016), or in the upper and lower quartile of the MMI distribution (Alzahabi & Becker, 2013; Cain & Mitroff, 2011; Minear et al., 2013). Importantly, however, one problem with this extreme-groups approach is that participants within each extreme group (i.e., HMMs vs. LMMs) are all treated as being equal, when it seems likely to be the case that they are not. Indeed, the range in MMI scores between the upper bound of the light media-multitasking group (LMM) and the lower bound of the heavy media-multitasking group (HMM) have been reported to be smaller than the possible range within a particular extreme group (e.g., Cain & Mitroff, 2011; Cardoso-Leite et al., 2016; Minear et al., 2013; Ophir et al., 2009). A second problem with the extreme-groups approach is that a large amount of information is lost from the middle portion of the distribution. To reiterate, given that MMI scores are unanimously found to be relatively normally distributed, there is no clear reason why one ought to discard data from individuals whose scores fall in the middle portion of the distribution when one could examine the entire distribution.

The second, perhaps more troubling and pervasive shortcoming of many media-multitasking studies is that they often rely on small sample sizes. For example, in the n-back studies discussed earlier, Ophir et al. (2009) compared 15 HMMs to 15 LMMs, Cardoso-Leite et al. (2016) compared 20 LMMs to 12 HMMs, and Cain et al. (2016) conducted a correlational analysis on a sample of 58. Extending to media-multitasking papers using other paradigms, Minear et al. (2013) compared 36 LMMs to 33 HMMs on the RSPAN, and in another experiment, compared 27 HMMs to 26 LMMs on a recent probes item recognition task. In their singleton-distractor study, Cain and

Mitroff (2011) also compared 21 HMMs to 21 LMMs. The core issue with using such small sample sizes is that they can lead to gross overestimates of effect sizes, increasing the likelihood of finding spurious significant effects and thus decreasing the reproducibility of results (Button et al., 2013).

In the present study we attempted to resolve the conflicting findings with regard to the relation between media multitasking and performance on at least one attentionally demanding cognitive task: the n-back. We focused on the n-back because the n-back has (a) been shown to have considerable variability in its relation to media multitasking (as we have noted above) and (b) been explored solely using small samples and an extreme-group approach. Given the aforementioned limitations of the prior media multitasking studies using the n-back, we were mindful to: (1) collect a large sample (over 300 participants) and (2) treat media multitasking behaviour as a continuous variable, using a correlational approach to analyze performance variables of interest (hits and false alarms). Lastly, we also utilized *two different*, albeit highly similar, indices of media multitasking through two alternate versions of Ophir et al.'s (2009) MMI – one that has been used in most media multitasking studies (e.g., Cain et al., 2016; Cardoso-Leite et al., 2016; Minear et al., 2013; Ophir et al., 2009), and another that has been used less frequently (Ralph et al., 2015).

Method

Participants

Three hundred and seventeen participants (163 male 154 Female) with an age range of 19 to 64 years old (M = 32.86, SD = 9.11) signed up for the study via Amazon Mechanical Turk and received $3.00 as compensation for their time.

Stimuli and Procedure

When participants signed up for the study, they first completed a demographics questionnaire as well as the MMI. Afterwards, participants performed a 2-back, followed by a 3-back in fixed order. Following the n-back, participants were asked to complete a second, alternate version of the MMI, as well as a few questions designed as compliance checks at the conclusion of the study.

Demographic Information. The first part of the experiment involved participants responding to a few basic demographic questions, indicating their biological gender, age, highest level of education, combined annual household income, and whether or not they were currently employed (full time or part time) outside of Mechanical Turk. These questions are provided as a supplementary material in Appendix A.

First Media Use Questionnaire (MMI-1). Participants then completed the original Media Multitasking Index (Here referred to as MMI-1) as per Ophir et al. (2009). This survey (provided as a supplementary material in Appendix B) is divided into two parts. In the first part of the survey, participants are asked to indicate, on average, how many hours per week they spend using any of 12 different forms of media. These 12 forms of media include: (1) Print media, (2) Television, (3) Computer-based video (e.g., YouTube), (4) Music, (5) Non-music audio, (6) Video/Computer Games, (7) Telephone/Cell phone voice calls, (8) Instant messaging, (9) Text-messaging (SMS), (10) Email, (11) Web Surfing, and (12) Other computer-based applications (e.g., Word). In the second part of the survey, participants complete a ‘multitasking matrix’ whereby they indicate, for each of the 12 media, how often they simultaneously use each of the other 11 media. Participants were told to enter 0 for “Never”, 1 for “A little of the time”, 2 for “Some of the time” and 3 for “Most of the time.” For each of the 12 media activities, these responses are summed and divided by three (so that each value is either 0, .33, .66, or 1), and then multiplied by the total number of hours spent with a given media as indicated in part one. These 12 weighted multitasking scores are then divided by the total number of hours spent engaging in all media (i.e., the sum of the hours indicated in part one of the survey) to produce the MMI score.

N-Back. After completing the MMI-1, participants completed four blocks of 48 trials of both a 2-back and 3-back (192 trials each), with a small break in-between each block. Cognitive Load (2-back, 3-back) was thus manipulated within-subjects. The stimulus set was obtained from Kane, Conway, Miura, and Colflesh (2007). Each trial began with the presentation of one of eight phonologically distinct letters – B, F, K, H, M, Q, R, and X – for 500 ms, followed by a fixation cross for 2000 ms (Figure 1). On each trial, participants were instructed to indicate whether the current letter matched the letter presented *n* items back by pressing one of two response keys (L for 'match' or A for 'non-match'). A reminder of these keys ("Press A for NON-MATCH" and "Press L for MATCH") was displayed in the lower portion of the screen on each trial. Targets were when the current letter matched the letter presented *n* items back (i.e., two items back in the 2-back, and three items back for the 3-back), and non-targets were when the current letter did not match the letter presented *n* items back. Within each block of 48 trials, there were eight targets (16.67%) and 40 non-targets, with each letter appearing six times (once as a target).

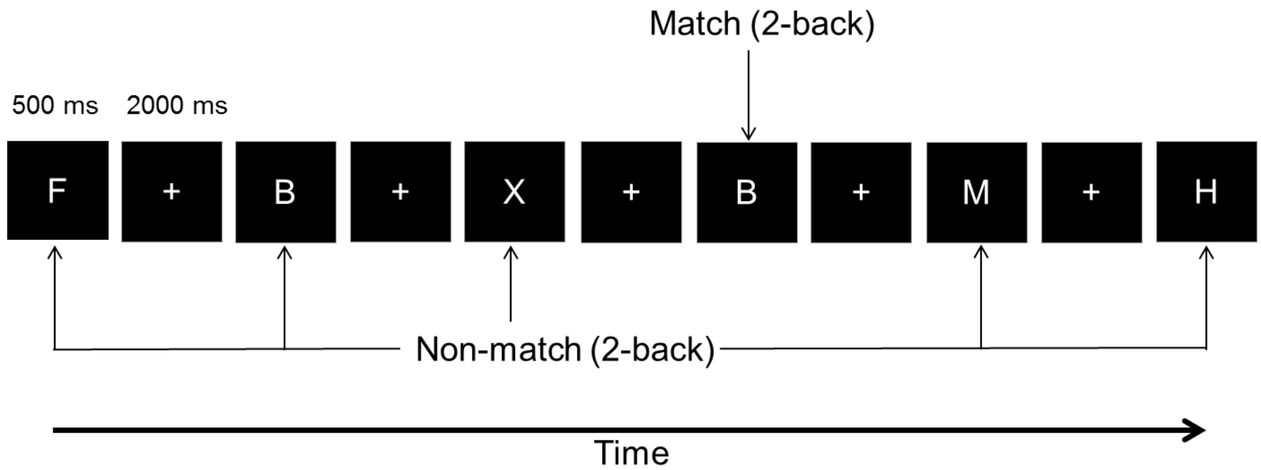

Figure 1. Example trial sequence from the 2-back.

Second Media Use Questionnaire (MMI-2). After completing the n-back, participants responded to a *second* version of the Media Multitasking Index (referred to as MMI-2). This version of the MMI has been used by our research team in previous papers (e.g., Ralph et al., 2015) and was obtained through Clifford Nass' research website at Stanford University in December of 2012 shortly before his passing in 2013. When we originally accessed this version of the MMI, it was linked to the original paper, so we made the assumption that this was the measure used by Ophir et al. (2009). As we have become more familiar with the tools that others are using, we are still not sure how widely this version is used, and in fact we have not seen this version of the MMI used elsewhere beyond our own research. However, it includes slightly different items and alternative groups of items than the original MMI, which may be useful in comparing predictability of various forms of multitasking. A copy of this MMI-2 is provided as a supplementary material in Appendix C. The MMI-2 addresses 10 groupings of activities (nine media-based), including: (1) face-to-face communication, (2) using print media (including print books, print newspapers, etc.), (3) texting, instant messaging, or emailing, (4) using social sites (e.g., Facebook, Twitter, etc., except games), (5) using non-social text-oriented sites (e.g., online news, blogs, eBooks), (6) talking on the telephone or video chatting (e.g., Skype, iPhone video chat), (7) listening to music, (8) watching TV and Movies (online and off-line) or YouTube, (9) playing video games or online games, and (10) doing homework/studying/writing papers. For each medium, participants first indicate (a) on an average *day* (not week, as per MMI-1), how many hours they spend engaging in the given medium, followed by (b) indicating the extent to which they simultaneously engage in each of the remaining nine activities (e.g., using a social site and listening to music) and the extent to which they perform a second activity of the same type (e.g., using a social site and using a second social site). Responses to the (b) component are indicated using the same scale as the original MMI, and resulting MMI scores are produced in the same fashion, exception only across 10 activities instead of 12.

Compliance Checks. At the end of the study, participants responded to four final questions asking about their compliance with study instructions. These included (1) "Did you respond randomly at any point during the first survey of media use?", (2) "Did you respond randomly at any point during the second survey of media use?", (3) "Did you respond randomly at any point during the attention task (i.e., the n-back)?" and (4) participants were asked to indicate whether or not they were in fact multitasking while they perform our study on multitasking ("I was multitasking during this study" versus "I was not multitasking during this study"). These questions are provided in full in Appendix D.

Results

Before analyzing the data, we decided to remove data from participants who reported that they had responded randomly to either of the MMI surveys. This led to the removal of 52 participants. However, we included data from those who indicated they responded randomly at some point during the n-back because the implication of this response is less clear: it may be a sign of non-compliance, or it may be that participants were compliant with task instructions, yet admitted to responding randomly following errors, while they re-constructed their working-memory stream. Thus, we report the following analyses on a dataset of 265 participants (128 male, 137 female).

Here the primarily goal was to assess whether media multitasking is correlated with performance on the n-back (2-back and 3-back) using the full dataset of participants (265 total). Performance on the n-back was assessed in terms of hits (the proportion of target trials that were correctly identified as targets), false alarms (the proportion of non-target trials that were incorrectly identified as targets), correct rejections (the proportion of non-target trials that were correctly identified as non-targets) and omissions (the proportion of trials for which no response was provided). Furthermore, media multitasking was indexed by two related but slightly different versions of the MMI (referred to as MMI-1 and MMI-2). In Table 1, we present descriptive statistics for the MMI-1 (the original MMI discussed in Ophir et al., 2009), the MMI-2 (an alternative version of the MMI downloaded from Clifford Nass' website), as well as overall hits, false alarms, and omissions for both the 2-back and 3-back. Both indices of media multitasking (MMI-1 and MMI-2) demonstrated good skew and kurtoses with values within an acceptable range of < 2 and < 4, respectively (Kline, 1998). The MMIs were also reasonably well correlated with one another (see Table 3), although not as high as one might expect given that the two indices are supposedly tapping the same underlying construct. Nevertheless, we present the following data as a function of each of the two indices of media multitasking.

Table 1. Descriptive statistics for scores on the MMI-1, MMI-2, and overall proportion of hits, false alarms, and omissions on both the 2-back and 3-back, $N = 265$.

	Mean (SD)	Skew[a]	Kurtosis[b]
MMI-1	3.00 (1.97)	0.71	-0.15
MMI-2	2.57 (1.67)	1.19	2.18
2-back			
hits	0.64 (0.27)	-0.72	-0.56
false alarms	0.11 (0.12)	1.72	3.10
omissions	0.21 (0.26)	-0.05	-0.68
3-back			
hits	0.46 (0.24)	0.99	0.66
false alarms	0.16 (0.14)	1.49	0.83
omissions	0.21 (0.30)	1.46	0.57

[a]*SE* = 0.14, [b]*SE* = 0.27

Performance on the n-back. Before examining the relation between the MMIs and performance on the n-back, we first report on the general performance of participants on the n-back. To reiterate, the n-back included a within-subject manipulation of Cognitive Load (2-back, 3-back). As such, we conducted four repeated-measures analyses of variance (ANOVAs) with Cognitive Load (2-back, 3-back) entered as the within-subjects variable and either proportion hits, false alarms, or omissions entered as the dependent variable. There was a main effect of Cognitive Load on hits, $F(1,264) = 184.88$, $p < .001$, $\eta^2_p = .41$, and false alarms, $F(1,264) = 51.69$, $p < .001$, $\eta^2_p = .16$, such that participants had fewer hits and more false alarms in the 3-back compared to the 2-back. There was no effect of Cognitive Load on omissions, $F < 1$ (see Table 1).

MMIs and n-back Performance. Pearson product-moment correlations between both indices of media multitasking (MMI-1 and MMI-2) and performance measures on the n-back (overall hits, false alarms, and omissions) are depicted in Table 2. Given that age was found to correlate with both indices of media multitasking (both *r'*s = -.20, *p'*s = .001), and age is known to be related to working memory performance (to which the n-back is an ostensible measure; e.g., Mattay et al., 2006; Oberauer, 2005), we also reported partial correlations below the diagonal controlling for age effects.

Table 2. Correlations among media multitasking indices (MMI-1 and MMI-2), hits, false alarms (FA), and omissions on the 2-back and 3-back. Partial correlations controlling for the association with age are presented below the diagonal, *N* = 265.

	MMI-1	MMI-2	2-back hits	2-back FA	2-back omissions	3-back hits	3-back FA	3-back omissions
MMI-1	--	.62***	-.15*	.12	.18**	-.13*	0.08	.21**
MMI-2	.61***	--	-.23***	.31***	.17**	-.14*	.22***	.19**
2-back hits	-.12*	-.21***	--	-.14*	-.73***	.67***	.12	-.66***
2-back FA	.11	.30***	-.14*	--	-.10	-.05	.67***	-.04
2-back omission	.18**	.18**	-.74***	-.09	--	-.56***	-.30***	.88***
3-back hits	-.09	-.11	.66***	-.04	-.57***	--	.21***	-.63***
3-back FA	.08	.23***	.12	.68***	-.30***	.21***	--	-.37***
3-back omission	.21***	.20***	-.66***	-.04	.88***	-.64***	-.37***	--

$*p \leq .05$, $**p \leq .01$, $***p \leq .001$

Overall hits and false alarms. At first glance, it appears that heavier media multitasking generally predicts poorer performance on both the 2-back and 3-back. When age is not taken into account (Table 2, above the diagonal; see also Figure 2), higher scores on the MMI-1 and MMI-2 predict fewer hits in both the 2-back and 3-back. Meanwhile, higher scores on the MMI-2 (but not the MMI-1) were found to predict higher false alarms, again, in both the 2-back and 3-back. Given that the relations between the MMI-2 and performance measures on the n-back were nominally stronger than those of the MMI-1, we visualize a subset of these relations in Figure 2. When controlling for the association of age with media multitasking and working memory (Table 2, below the diagonal), which is likely the more appropriate set of relations to focus on, the pattern of results changes slightly. While the aforementioned association of the MMI-2 and false alarms (in both the 2-and 3-back) remains the same, the association of both the MMI's with hits is restricted to the 2-back only.

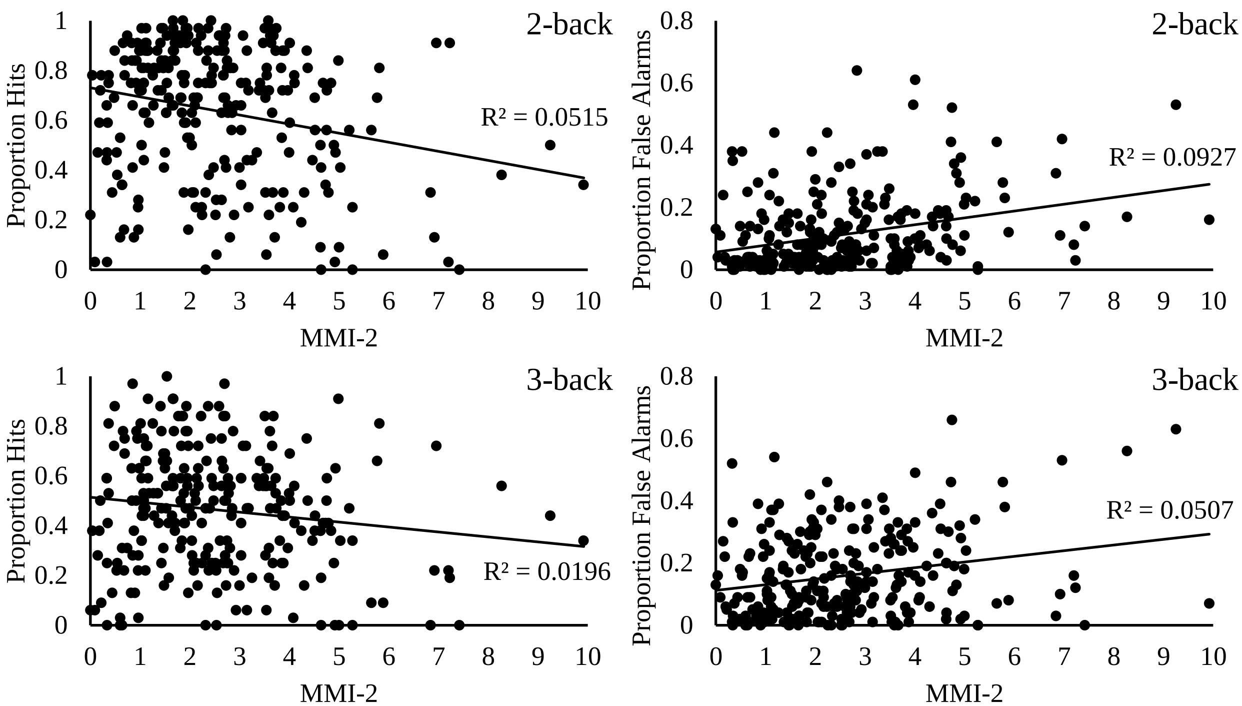

Figure 2. Scatterplots depicting the relation of the MMI-2 with proportion hits (left panels) and false alarms (right panels) for the 2-back (upper panels) and 3-back (lower panels).

Omissions. Our third performance metric obtained from the n-back was omissions (the proportion of trials to which participants did not make a response). In both the 2-back and 3-back, regardless of whether age was controlled, scores on both media multitasking indices (MMI-1 and MMI-2) were positively correlated with omissions. On the one hand, an analysis of overall hits and false alarms seem in-line with the general claim that heavier media multitaskers have poorer working memory than their light multitasking counterparts – with some clear nuances as to the specific relations with hits versus false alarms. However, these data also highlight a dispositional perspective – heavier media multitaskers may also be less likely or less willing to comply with task instructions. In addition to the foregoing findings, we also found that heavier multitaskers were more likely to be *multitasking while completing the study* (indicated via our Compliance Check question # 4 ["*I was multitasking during this study*" vs. """*I was not multitasking during this* *study*""]), r_s = .22 and .21, *ps* ≤ .001 (for the MMI-1 and MMI-2, respectively)[1]. Furthermore, perhaps owing to such multitasking, there is also a marginal trend whereby heavier media multitaskers admitted to responding slightly more randomly during the n-back, r_s = -.114, *p* = .065.

Another important observation shown in Table 3 is that omissions and hits were highly and inversely correlated. Intuitively, this makes good sense as the less a participant responds, the poorer their performance measures that are contingent on a response. A lack of a response (omission) has the effect of lowering hits while simultaneously lowering false alarms. Given that media multitasking indices (MMI-1 and MMI-2) were both found to positively predict omissions, and omissions were strongly tied to other performance metrics on the n-back, we re-analyzed our data while controlling for differences in omissions (see Table 3).

[1] Thirty-four of our 265 participants (12.8%) indicated that they were multitasking during the experiment.

Table 3. Partial correlations among media multitasking indices (MMI-1 and MMI-2), hits, and false alarms (FA) when controlling for omissions (above the diagonal), and when controlling for omissions together with age (below the diagonal), $N = 265$.

	MMI-1	MMI-2	2-back hits	2-back FA	3-back hits	3-back FA
MMI-1	--	.61***	-.01	.13*	-.004	.16*
MMI-2	.59***	--	.14*	.32***	0.03	.31***
2-back hits	.04	-.10	--	-.27***	.42***	-.20***
2-back FA	.13*	.32***	-.27***	--	-.11	.70***
3-back hits	.05	.02	.39***	-.10	--	-.01
3-back FA	.16**	.32***	-.20***	.70***	-.01	--

$^*p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$

Hits and false alarms when controlling for omissions. When controlling for the influence of omissions and age (shown below the diagonal in Table 3; see also Figure 3) we find that heavier media multitasking is associated with a higher false alarm rate in both the 2-back and 3-back. Importantly, however, we no longer find any evidence that media multitasking is associated with a change in hits (although we do note a modest correlation between the MMI-2 and hits in the 2-back, when not controlling for differences in age). Figure 3 depicts the relations between MMI-2 (given that it was nominally more strongly tied to performance metrics) and n-back hits and false alarms after removing variance associated with age and overall omissions by using unstandardized residuals. A similar pattern of results was also observed when individuals who responded with "*I was multitasking during this study*" to Compliance Check #4 were removed (see Appendix E), although, it seems counter-productive to truncate the sample in this way (i.e., removing participants who are the focus of the current investigation).

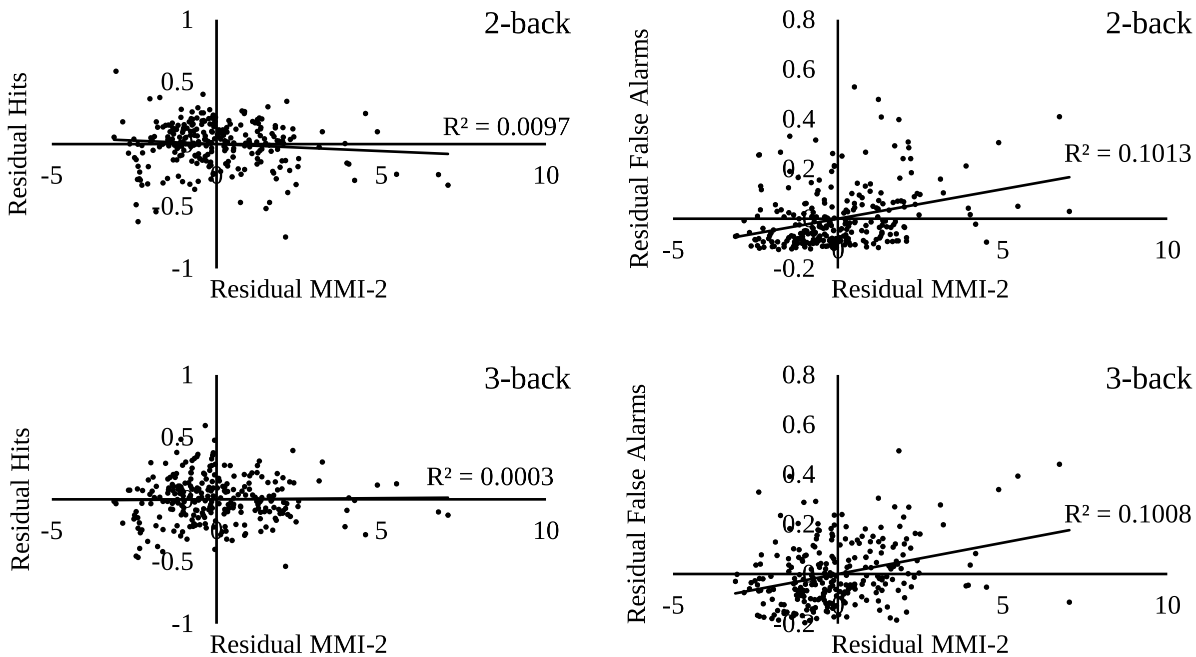

Figure 3. Scatterplots of the relation between unstandardized residuals of the MMI-2 with hits (left panels) and false alarms (right panels) for the 2-back (top panels) and 3-back (bottom panels) after controlling for age and omissions.

Sensitivity vs. bias. We end with an examination of the relation between scores on the media multitasking indices with calculated sensitivity (d_L) and response bias (C_L) measures; computing these signal detection metrics is common practice in both the working memory literature, as well as the literature linking media multitasking and working memory performance. These measures of sensitivity (d_L) and response bias (C_L) were calculated as was done by Kane et al. (2007, pg. 617), as they followed a recommendation put forth by Snodgrass and Corwin (1988). Interestingly, in both the 2-back and 3-back, higher scores on each of the media multitasking indices (MMI-1 and MMI-2) were significantly associated with decreases in sensitivity (d_L) but not with a change in response bias (C_L; see Table 4). As also shown in Table 4, consistent with the general pattern of results discussed thus far, the relation between media multitasking and sensitivity was nominally stronger for the MMI-2 than the MMI-1. Lastly, it is worth noting that most of these associations remain statistically significant after controlling for the shared association with age. Only the relation between the MMI-1 and sensitivity on the 3-back becomes non-significant when controlling for the shared association with age.

Table 4. Correlations between scores on the MMIs (MMI-1 and MMI-2) and measures of sensitivity (d_L) and response bias (C_L) for the 2-back and 3-back. Partial correlations controlling for the association with age are presented in parentheses, $N = 265$.

	2-back		3-back	
	Sensitivity (d_L)	Bias (C_L)	Sensitivity (d_L)	Bias (C_L)
MMI-1	-.18** (-.16**)	.03 (-.01)	-.13* (-.10)	.04 (.01)
MMI-2	-.35*** (-.33***)	-.02 (-.04)	-.27*** (-.24***)	-.01 (-.03)

$*p \leq .05$, $**p \leq .01$, $***p \leq .001$

Chapter Discussion

The purpose of the current investigation was to reach a firm conclusion as to how individual differences in media multitasking relate to performance on the n-back. We sought to reach a firm conclusion by (1) treating media multitasking as a continuous variable, using the entire media multitasking spectrum (rather than extreme-groups) and (2) collecting a large sample of participants. One important observation we made was that individuals who scored higher on the MMIs also omitted a greater proportion of trials in the n-back – a behavioural measure that has not been reported in previous media multitasking studies using the n-back. Given that participants were instructed to provide a response on each trial of the n-back (i.e., to indicate whether the current letter matched the letter presented *n* items ago by pressing one of two response keys (match vs. non-match), omissions appear to be reflective of a disengagement from the task. One obvious implication is that heavier media multitaskers might be less engaged while completing the n-back. Whether this is due to explicit non-compliance or implicit differences in attentional mechanisms remains an open question. However, it is clear that such omissions have an impact on other performance measures such as hits and false alarms. For instance, the less a participant responds, the fewer false alarms they will commit, but also the fewer hits they will achieve. Indeed, we noted a substantial relation between omissions and hits (more omissions were linked with fewer hits) as well as false alarms (more omissions were linked with fewer false alarms). It therefore seems most reasonable to assess the relation between media multitasking and performance on the n-back when controlling for the proportion of omitted trials.

When controlling for omissions (and age effects), we found a robust relation between media multitasking and false alarms on both the 2-back and 3-back wherein higher levels of media multitasking were associated with an increase in false alarms. Furthermore, no strong evidence was found for a link between media multitasking and hits (contrary to Cain et al., 2016). Independent of cognitive load (2-back, 3-back) heavier media multitaskers are thus more likely to endorse non-targets as targets, but are not different from lighter media multitaskers in terms of the ability to correctly identify targets as targets. This finding is relatively consistent with those initially reported by Ophir et al. (2009; albeit cognitive load influenced the outcome in their work but not in ours). Lastly, we note that when calculating measures of sensitivity and response bias, scores on the MMIs were associated with changes in sensitivity (on both the 2-back and 3-back) but not response bias, wherein higher levels of media multitasking were associated with poorer sensitivity.

When omissions are not taken into consideration, significant associations between media multitasking and hits (as found by Cain et al., 2016) begin to emerge. A likely possibility is that these emergent relations between media multitasking and hits are due to the shared association with omissions. This divergence of results depending on the treatment of omissions also highlights the importance of taking into account omitted trials (see Cheyne, Solman, Carriere, & Smilek, 2009), and points towards one possible source of previous, discrepant findings (e.g., Cain et al., 2016; Ophir et al., 2009).

Another interesting implication of the current results is that individual differences in media multitasking might be linked with individual differences in the propensity to overtly disengage from ongoing tasks. In addition to heavier media multitaskers omitting a greater proportion of trials, we also found that heavier multitaskers reported being more likely to media multitask *during* the n-back, and were marginally more likely to report that they responded randomly at some point during the n-back. Taken together, these findings suggest that in addition to potential differences in cognitive control observed in previous work (e.g., Cain & Mitroff, 2011; Ophir et al., 2009), media multitasking may be associated with differences in how individuals approach or engage with tasks. However, as alluded to earlier, it remains unclear whether such a tendency towards disengagement/inattention reflects a deficit in the *ability* to remain attentive or alternatively, insufficient interest and/or motivation to remain attentive.

Thus far, several studies have been conducted to determine whether media multitasking is associated with differences in various aspects of cognitive control. It is worthwhile to take a step back and consider *why* this is a topic of such interest. One clear concern is that habitually attending to multiple streams of information might have the unfortunate consequence of eroding executive control systems (see Cain & Mitroff, 2011) – we refer to this as an *ability hypothesis of media* *multitasking*. For example, heavier media multitaskers in Ophir et al.'s (2009) and Cain and Mitroff's (2011) experiments may be fundamentally *less able* to ignore distracting information as a result of their media use tendencies – a possibility that is quite troubling. An alternative formulation of the ability hypothesis of media multitasking is of course that individuals find themselves in media multitasking scenarios due to fundamental differences in cognitive control (i.e., those that are less able to ignore distracting information on the aforementioned laboratory tasks are also less likely to ignore multiple media streams available in the environment).

We suggest that it is important to consider yet another possibility – a *strategic hypothesis of media multitasking* – wherein individual differences in media multitasking may reflect how individuals *choose* to engage with their environment, without involving particular underlying differences in ability (discussed in Ralph et al., 2015). That is, it is not that heavier media multitaskers cannot ignore distracting information, it is that they choose not to; a scenario that is clearly much less concerning. But what might drive such strategic differences in task engagement? One factor might be individual differences in thresholds of engagement, whereby heavier media multitaskers may need more stimulation to be motivated to engage with a task. In prior work, higher levels of media multitasking have been linked with greater reports of impulsivity and sensation seeking (Sanbonmatsu et al., 2013; Wilmer & Chein, 2016), a greater discounting of delayed rewards (Wilmer & Chein, 2016), the endorsement of intuitive yet incorrect decisions on the cognitive reflection task (CRT; Shutten, Stokes, & Arnell, 2017), as well as a speeding of responses at the expense of accuracy on difficult Raven's Matrices problems (Minear et al., 2013). In the current study we find that higher levels of media multitasking are further associated with a greater propensity to omit trials, as well as to media multitasking *during* the experiment itself and, to a lesser extent, respond randomly. Collectively, these findings may suggest that heavier media multitasking is associated with a higher threshold of engagement (craving more, immediate stimulation), less willingness to commit effort to complete tasks (e.g., CRT and difficult Raven's Matrices), and accordingly a greater propensity to disengage from ongoing tasks in favour of pursuing alternative actions (as found here, such as consuming additional media).

Unfortunately, ability and strategy choices are often tightly linked. At present, the findings in the current media multitasking literature are insufficient for conclusively assessing whether heavier media multitaskers are *less able* to, for instance, exert top-down control over attention (the ability hypothesis), or are simply *less willing to* exert such control (the strategic hypothesis). Even in the current experiment, it is unclear whether higher omissions for heavier media multitaskers (and higher false alarms, even when controlling for omissions) reflect a failure of sustained attention, or a loss of interest and motivation to perform well on the task. Hopefully in future pursuits, we may gain some ground separating ability and affective influences when examining the relation between media multitasking tendencies and performance measures.

Before concluding, it is also worthwhile to consider how the two MMIs compared in our investigation. Here we utilized two similar, albeit slightly different versions of the MMI. For example, while MMI-2 contains items referencing homework, studying, and writing papers, the MMI-1 does not. Similarly, while MMI-1 contains questions about computer applications (e.g., Word), the MMI-2 does not. Furthermore, while the MMI-1 asks participants to aggregate their media multitasking behaviour over the course of a typical *week*, the MMI-2 asks participants to estimate their media multitasking tendencies over the course of a typical *day*. Although the MMI-1 and MMI-2 were highly correlated and often predicted the same performance measures, these structural differences might explain why the MMI-2 was often a significantly stronger predictor of performance measures than the MMI-1. In terms of item composition, the MMIs are an aggregate of a vast array of activities that differ between the questionnaires. Within any given sample, how heavily participants are loading on particular activities may have consequences for correlations with behavioural measures. For example, it might be the case that media multitasking while doing homework / studying / writing papers is a particularly important or representative media multitasking behaviour that is only included in the MMI-2 (hence the stronger associations with performance metrics). After all, it is certainly reasonable to assume that not all media multitasking behaviours are equal. Second, in terms of the temporal window in which the MMIs require participants to estimate their multitasking behaviour, it might be the case that aggregating one's information over the shorter time span of a typical day may be easier than aggregating one's information over the larger time span of a typical week. Lastly, all participants completed the MMI-1 near the beginning of the study, and the MMI-2 near the end of the study. It is therefore conceivable that the order in which the MMIs were completed may play a role in how strongly they were associated with performance metrics.

By treating media multitasking as a continuous variable and using a large sample of participants, we were able to conclude with reasonable confidence that higher levels of media multitasking (as indexed by two different versions of the MMI) are associated with poorer performance on the n-back. These findings are important because they begin to adjudicate between several sets of seemingly inconsistent findings within the media multitasking literature. Moving forward, we encourage the field to begin treating media multitasking as the continuous variable that it is consistently found to be, and utilize larger samples of participants so that we may gain a better understanding of expected effect sizes and improve our ability to find consistent results.

Chapter 3: Objective and subjective reports of performance during moments of media multitasking

Chapter Introduction

Recall for a moment the introductory example of BR media multitasking while performing his primary task of writing his dissertation. One key aspect of many media multitasking scenarios in everyday situations, like this one, is that engagement with the additional media are non-required activities and volitional in nature. Therefore, 'success' or 'performance' on such activities – such as listening to music, watching a video, or browsing social-networking sites – is not particularly relevant or meaningful to the individual in comparison to their accomplishment on some primary task (such as dissertation-writing, studying, or driving). The additional media activities are also often likely to be irrelevant to the task-at-hand, opening the door for participants to strategically ignore the simultaneous media streams in favour of primary-task performance. With the foregoing in mind, the goals of Chapter 3 are thus to examine (1) how a concurrently available, non-required, task-irrelevant media stream influences performance on an attentionally demanding primary task, and (2) how the presence versus absence of the irrelevant media stream influences subjective estimates of performance. Throughout the studies presented in Chapter 3, the media used was that of a concurrently streaming video, and the primary task was the n-back (as in Chapter 2). Participants were presented with a concurrently streaming video as to consume the same type of cognitive resources as the primary task (i.e., visuospatial), and thereby maximize the likelihood of influencing performance on the primary task. This allows for a more direct assessment of the importance of the volitional nature of media multitasking, since a lack of an effect on performance cannot be attributed to modality-independent processing (e.g., listening to music during a mundane motor task).

With regard to the first goal, it is unclear as to the extent to which a non-required, task-irrelevant video will impact performance on a primary, attentionally demanding task. As noted in

Chapter 1, one possibility is that the video may interfere with performance on the primary task, as has been demonstrated in numerous other dual-task experiments in which both tasks are required (e.g., Baddeley et al., 1984; Bourke et al., 1996; Cauwenberge et al., 2014; Craik et al., 1996; Drews et al., 2008; Fox et al., 2009; Hancock et al., 2003; Helton & Russell, 2013; Horrey et al., 2008; Jacoby et al., 1989; Lesch et al., 2004; Medeiros-Ward et al., 2014; Risko et al., 2013; Sana et al., 2013; Strayer et al., 2003; Strayer & Johnston, 2001; Wood et al., 2012). If individuals engage with the optional video as a secondary cognitive task, then the video ought to interfere with performance as it would consume the same type of domain-specific cognitive resource as the primary task (visuospatial; e.g., Baddeley & Hitch, 1974; Wickens, 2002). Or, the demands of the primary task may be sufficiently high as to tax cognitive-control, and thereby lead to a greater failure of control and greater inadvertent processing of task-irrelevant information (Lavie et al., 2004). On the other hand, it is also conceivable that since the video is both (a) non-required, and (b) irrelevant to the primary task, individuals may be able to readily ignore the video, thereby foregoing any costs to performance on the primary task. Many studies have demonstrated, for instance, that when attention is focused on a primary task, people readily ignore information that is not relevant to the task-at-hand (e.g., Buetti & Lleras, 2016; Cool et al., 1994; Fougnie & Marois, 2007; Lin et al., 2009; Lleras et al., 2014; Mack & Rock, 1998; Neisser & Becklen, 1975; Pool et al., 2000; Simons & Chabris, 1999; Strayer & Johnston, 2001). It might also be the case that because the video is construed as non-required, participants may feel they have a sense of choice in engaging with the video, and such feelings of choice may be motivating and confer benefits even to primary task performance (Dember et al., 1992; Szalma & Hancock, 2006).

With regard to the second goal, it is also unclear how participants will evaluate their performance on a primary task when a non-required, task-irrelevant video is simultaneously presented. Assuming there will be performance costs on the primary task associated with a simultaneously playing video, one possibility is that the presence of the video will disrupt the ability to accurately monitor performance. This might occur due to the video consuming sufficient information-processing resources as to disrupt performance monitoring, or because engagement with the video de-couples information-processing from the primary task-at-hand, reducing the number of task-errors that enter consciousness. Alternatively, it also seems reasonable to predict that attention may not be fully absorbed by many of the tasks we perform, thereby allowing for, minimally, partially-accurate judgements of performance.

To evaluate the foregoing possibilities, in Chapter 3, data is presented from four studies using a paradigm wherein participants completed the n-back – an attentionally demanding task also used in Chapter 2 – either alone (i.e., 'No Video' trials) or while a non-required video was embedded in the upper portion of the visual display (i.e., 'Video' trials). Importantly, it was conveyed to participants that the video was non-required insofar that there would be no test on the content from the video. When creating instructions to convey to participants that the video was non-required, it was important to tell participants *why* the video was presented in the first place, so that participants were not led to ponder upon (i.e., mind wander about) the reasons for the presence of the video during the study. At the same time, it was not desirable to make the video an explicit task to attend to (thus defeating the non-required purpose), nor was it desirable to tell participants to explicitly ignore the video (as this too makes an explicit, required task out of the video – the required task of not attending). With these considerations in mind, the following wording, used in Studies 3.1, 3.2, and 3.3, was generated: "…while you complete the task, there will be a video for you to watch in the upper portion of the screen. There will be no test on the content of this video, it is simply for you to watch while you do the task." These instructions were further improved upon in Study 3.4, wherein findings of Chapter 3 were replicated using a set of instructions that more clearly construed the video as non-required. Specifically, the instructions stated: “There will be no test on the content of this video, and you are not required to watch it. However, you may watch the video while you do the task, if you wish.”

The overall design of studies presented in Chapter 3 allowed for a comparison of *objective performance* between these conditions (No Video vs. Video trials), addressing the first goal of examining how a non-required, task-irrelevant video influences performance on an attentionally demanding primary task (n-back). In Study 3.1, exposure to the video was manipulated between-groups, whereas in Studies 3.2, 3.3, and 3.4, exposure to the video was manipulated within-subjects. To address the second goal of how individuals evaluate their performance under such conditions, *subjective estimates* of key performance metrics were also collected.

Study 3.1

Introduction

Study 3.1 used the same attentionally demanding primary task as the study in Chapter 2, such that participants completed the n-back at two levels of cognitive load (2-back followed by 3-back). To begin the investigation, the presence of the non-required, task-irrelevant video was manipulated between-groups. The ‘No Video’ group of participants completed the 2-back and 3-back in a standard fashion, without the presence of the video, whereas participants in the ‘Video’ group completed the 2-back and 3-back with a video simultaneously playing in the upper portion of the visual display. This allowed for the assessment of whether differences in subjective estimates between conditions matched mean differences in objective measures, as well as whether differences in objective and subjective estimates correlate (providing a measure of how sensitive participants are to changes in their objective performance).

Method

Participants. One hundred and forty participants (33 male, 107 female) from the University of Waterloo completed the study in exchange for course credit. Of these 140 participants, 68 were run under the No Video condition and 72 were run under the Video condition.

Stimuli and procedure. Participants completed 192 trials of the 2-back, followed by 192 trials of the 3-back, similar to Chapter 2. While Chapter 2 included brief breaks in between each block of trials (48), here the blocks within each load were collapsed in order to have a more continuous task. Cognitive Load (2-back vs. 3-back) was not counterbalanced in favour of reducing variance for planned correlations of differences in objective performance across load with differences in subjective estimates of performance across load. As in Chapter 2, participants were once again instructed that on each trial, they were to indicate whether the current letter matched the letter presented *n* items back by pressing one of two response keys (L for 'match' or A for 'non-match'). A reminder of these keys ("Press A for NON-MATCH" and "Press L for MATCH") was again displayed in the lower portion of the screen on each trial.

Media multitasking was manipulated between-groups by allowing one group of participants to watch a video while they completed the 2-back and 3-back (the 'Video' condition), while the other group received no video to watch (the 'No Video' condition). For participants in the Video condition, the video was embedded in the upper portion of the screen while they completed the 2-back and 3-back (see Figure 4), and participants were provided with a pair of Sony MDR-MA100 Headphones to listen to the video. The video was of Keith Barry's TED Talk entitled "Brain Magic." Participants in the Video condition were told that "…while you complete the task, there will be a video for you to watch in the upper portion of the screen. There will be no test on the content of this video, it is simply for you to watch while you do the task." Participants in the No Video condition received no such video to watch or additional instructions.

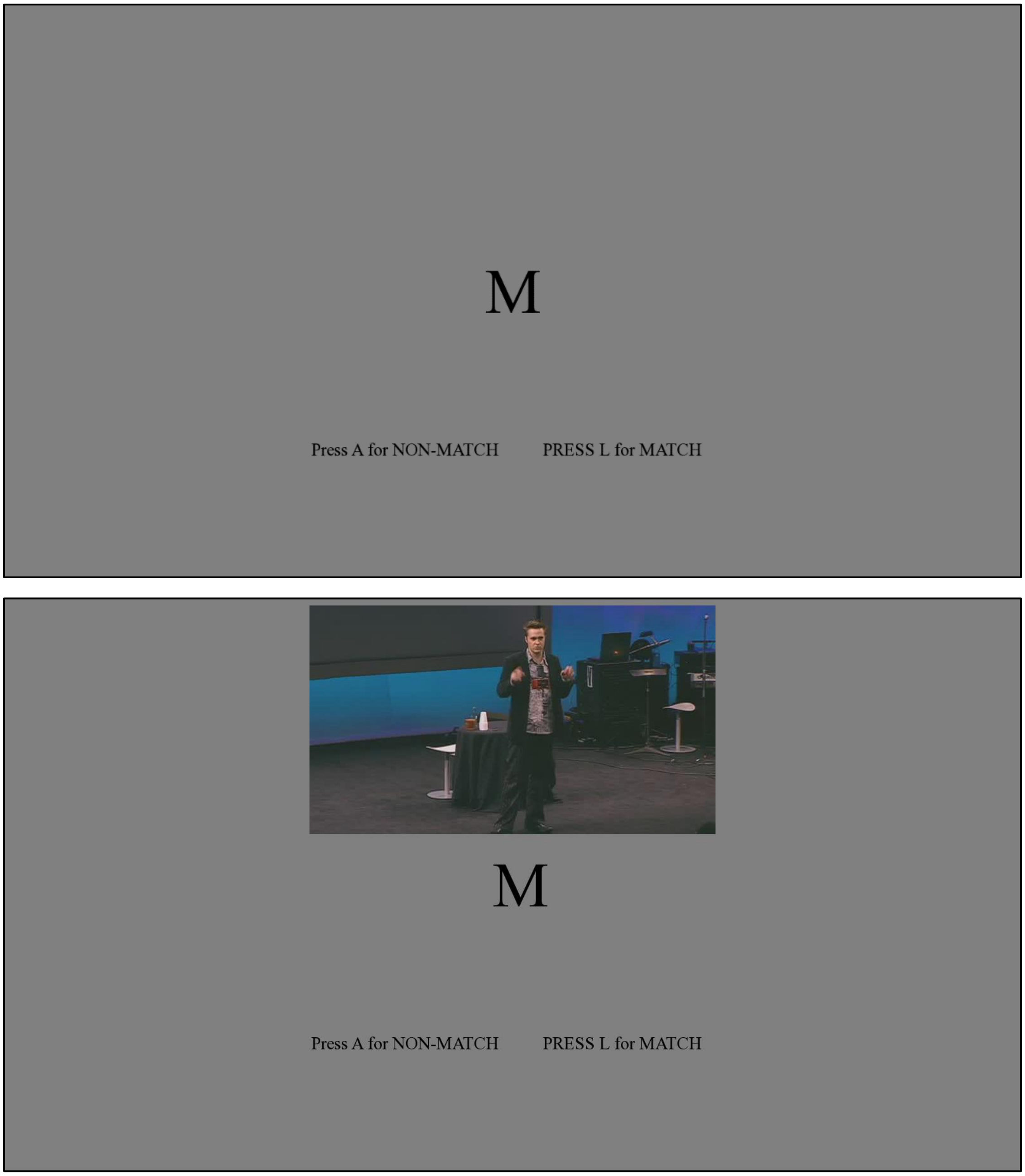

Figure 4. Example of display screens for participants in the No Video condition (top) and Video condition (bottom).

At the end of the 2-back and 3-back, participants were asked to estimate their performance on the task they just completed (i.e., the 2-back or the 3-back). Thus, all participants provided two sets of performance estimates – one set after completing the 2-back, and one set after completing the 3-back (see Figure 5). For each set of performance estimates, participants answered two questions: (1) “What percentage of MATCHING trials do you think you CORRECTLY endorsed as ‘MATCHING’ on the task you just performed (i.e., the 2-back)?”, and (2) “What percentage of NON-MATCHING trials do you think you INCORRECTLY endorsed as ‘MATCHING’ on the task you just performed (i.e., the 2-back)?” These items were changed accordingly when inquiring about their estimated performance on the 3-back.

Lastly, after providing estimates of their performance, participants also provided subjective reports of overall task demand, again at the end of the 2-back and 3-back (responding twice), by responding to four questions taken from the NASA Task Load Index (NASA-TLX; Hart, 2006). These four items were of Mental Demand (“How mentally demanding was the task?”), Temporal Demand (“How hurried or rushed was the pace of the task?”), Performance (“How successful were you in accomplishing what you were asked to do?”), and Effort (“How hard did you have to work to accomplish your level of performance?”). All four items were responded to using a 10-point scale. The Mental Demand, Temporal Demand, and Effort items had anchors “Very Low” (1) to “Very High” (10), whereas the Performance item had the anchors of “Perfect” (1) to “Failure” (10). An overall rating of ‘task demand’ was taken by averaging responses across these four items, whereby higher ratings indicated higher levels of perceived task demand.

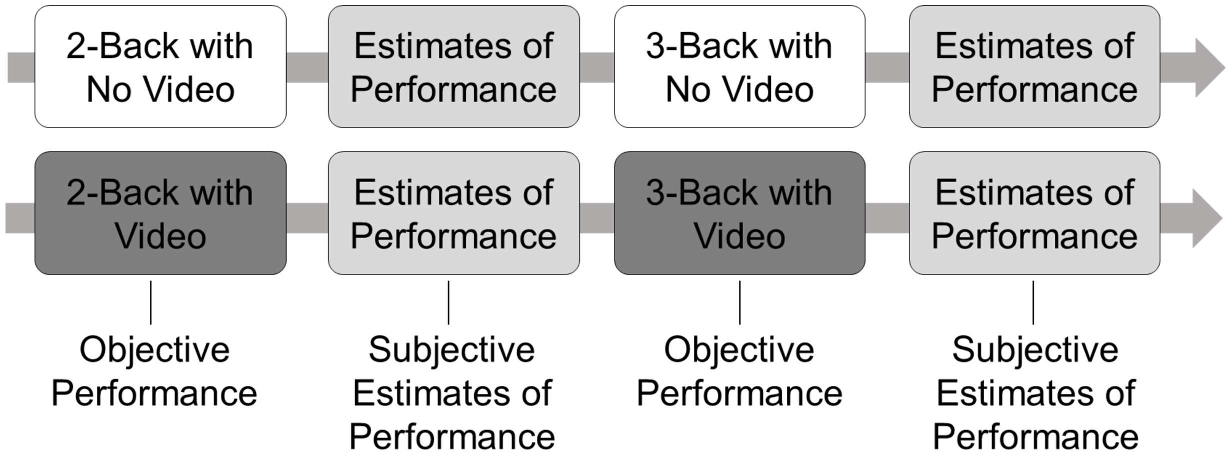

Figure 5. Visualization of task procedure and between-group conditions in Study 3.1. Video Presence (No Video vs. Video) was manipulated between-groups, and Cognitive Load (2-back vs. 3-back) was manipulated within-subjects.

Results

Performance on the n-back (2-back and 3-back) was assessed in terms of hits (the proportion of target trials that were correctly identified as targets), false alarms (the proportion of non-target trials that were incorrectly endorsed as targets), correct rejections[2] (the proportion of non-target trials that were correctly endorsed as non-targets), and omissions (the proportion of trials for which no response was provided). Similarly, two types of subjective performance

[2] We opted to include correct rejections as an objective measure for consistency as it is later used as a subjective estimate in Study 3.3.

estimates were obtained: (1) estimated hits and (2) estimated false alarms[3]. Lastly, self-report ratings of task demand were collected by averaging response to the four included NASA-TLX items.

One participant in the Video condition reported ear pain upon arriving to the study and did not wish to wear the headphones provided. Given that this participant would not have heard the audio of the embedded video, it was decided to remove their data prior to analysis. Thus, data from 139 participants (33 male, 106 female) are reported below, 68 of which were in the No Video condition and 71 of which were in the video condition.

Objective performance. To examine how Cognitive Load (2-back vs. 3-back) and Video Presence (No Video vs. Video) influenced objective performance metrics, a mixed repeated-measures ANOVA was conducted with Cognitive Load entered as the within-subjects variable, Video Presence entered as the between-groups variable, and either proportion hits, false alarms, correct rejections, or omissions entered as the dependent variable. Means and associated standard errors for each dependent variable as a function of Cognitive Load and Video Presence are shown in Figure 6.

[3] Although subjective estimates of performance are reported on the same scale as objective performance measures (i.e., proportions), it is important to keep in mind that subjective judgments of performance likely rely upon different processes than objective measures of performance. Furthermore, it is unclear how such processes scale with one another. As such, directly comparing subjective and objective estimates as a function of other manipulated variables (i.e., Cognitive Load and Video Presence) should be done with caution (see Wagenmakers, Krypotos, Criss, & Iverson, 2012). Nevertheless, I report the Cognitive Load by Video Presence by Performance Type (Objective vs. Subjective) mixed repeated-measures ANOVAs for Study 3.1 in Appendix F, and the Video Presence by Performance Type repeated-measures ANOVAs for Studies 3.2, 3.3, and 3.4 in Appendix G, H, and I, respectively.

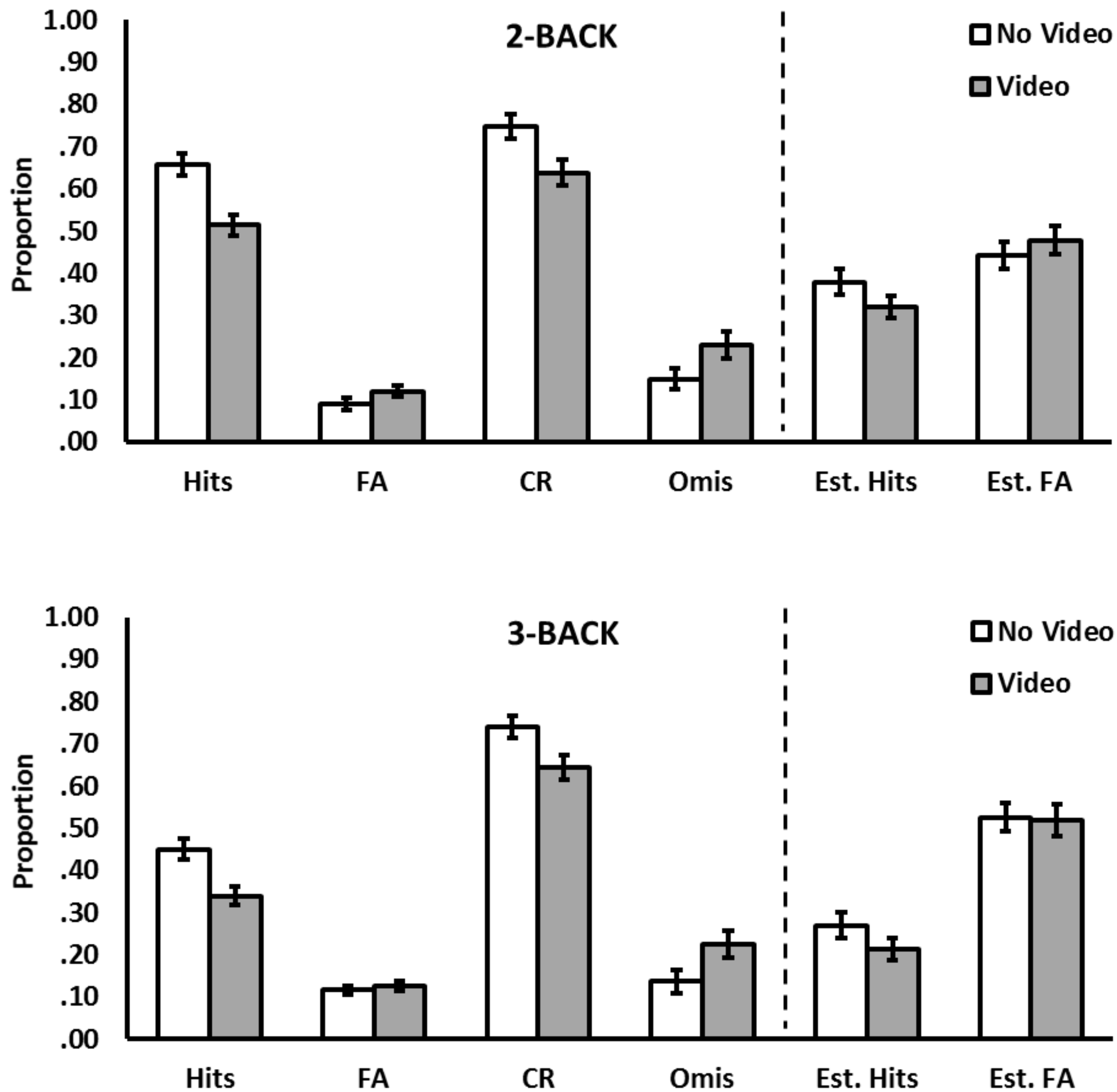

Figure 6. Objective performance and subjective estimates of performance on the n-back in Study 3.1. Cognitive Load (2-back vs. 3-back) was manipulated within-subjects and Video Presence (No Video vs. Video) was manipulated between-groups. Dependent variables include proportion hits (Hits), false alarms (FA), correct rejections (CR), omissions (Omis), estimated hits (Est. Hits), and estimated false alarms (Est. FA). Error bars represent one standard error of the mean.

As seen in Figure 6, there was a main effect of Cognitive Load on hits such that participants had fewer hits in the 3-back than the 2-back, $F(1,137) = 165.76$, $p < .001$, $\eta^2_p = .55$. There was also a main effect of Video Presence such that participants who completed the n-backs with the non-required, irrelevant video present had fewer hits than participants who did not receive a video to watch, $F(1,137) = 17.07$, $p < .001$, $\eta^2_p = .11$. However, there was no Cognitive Load by Video Presence interaction for hits, $F(1,137) = 1.17$, $p = .281$, $\eta^2_p = .01$.

In terms of false alarms, there was a marginal main effect of Cognitive Load such that participants had slightly more false alarms in the 3-back compared to the 2-back, $F(1,137) = 3.35$, $p = .069$, $\eta^2_p = .02$ (see Figure 6). There was no main effect of Video Presence on false alarms, $F(1,137) = 1.75$, $p = .188$, $\eta^2_p = .02$, nor was there a Cognitive Load by Video Presence interaction, $F(1,137) = 1.28$, $p = .260$, $\eta^2_p = .01$.

There was no main effect of Cognitive Load on correct rejections, nor was there a Cognitive Load by Video Presence interaction, both *F*'s < 1 (see Figure 6). However, a significant main effect of Video Presence on correct rejections was observed, whereby participants in the Video condition correctly rejected fewer non-targets than participants in the No Video condition, $F(1,137) = 6.98$, $p = .009$, $\eta^2_p = .05$.

Like correct rejections, there was no main effect of Cognitive Load on omissions, nor was there a Cognitive Load by Video Presence interaction, both *F*'s < 1 (Figure 6). There was, however, a main effect of Video Presence on omissions whereby participants in the Video condition omitted (i.e., did not respond to) a greater number of trials than those in the No Video condition, $F(1,137) = 4.34$, $p = .039$, $\eta^2_p = .03$.

Subjective estimates of performance. Next, it was investigated how Cognitive Load (2-back vs. 3-back) and Video Presence (No Video vs. Video) influenced *subjective estimates* of performance. To this end, two mixed repeated-measures ANOVAs were conducted with Cognitive Load entered as the within-subjects variable, Video Presence entered as the between-groups variable, and subjective estimates of hits or false alarms entered as the dependent variable. Means and standard errors for subjective estimates of hits and false alarms as a function of Cognitive Load and Video Presence are shown in Figure 6.

Like objective hits, there was a main effect of Cognitive Load on subjective estimates of hits, wherein participants estimated their hits to be lower following the 3-back compared to the 2-back, $F(1,137) = 17.32$, $p < .001$, $\eta^2_p = .11$. There was also a marginal main effect of Video Presence on estimated hits, such that participants estimated their hits to be slightly lower in the Video condition compared to those in the No Video condition, $F(1,137) = 3.46$, $p = .065$, $\eta^2_p = .03$, however this difference was not statistically significant. There was no Cognitive Load by Video Presence interaction, $F < 1$.

While the effect of Cognitive Load on objective false alarms was observed to be only marginally significant, there was a significant main effect of Cognitive Load on *subjective estimates* of false alarms such that participants estimated their false alarms to be higher in the 3-back compared to the 2-back, $F(1,137) = 8.58$, $p = .004$, $\eta^2_p = .06$. Like objective false alarms, there was also no main effect of Video Presence on estimated false alarms, $F < 1$, nor was there a Cognitive Load by Video Presence interaction, $F(1,137) = 1.08$, $p = .302$, $\eta^2_p = .01$.

Correlation between objective and subjective estimates of performance. The last aspect of the data that was examined was how ‘calibrated’ participants were to *changes* in performance between levels of Cognitive Load (2-back vs. 3-back), in both the No Video and Video Group. To examine whether the presence of the video disrupted performance monitoring, differences in objective performance (hits and false alarms) between the 2-back and 3-back were correlated with differences in subjective estimates of performance (estimated hits and false alarms) between the 2-back and 3-back, for both the No Video and Video group separately. While participants in the No Video group were moderately well-calibrated to changes in their hits across Cognitive Load, $r(66) = .25$, $p = .044$, in the Video group, this relation did not reach statistical significance and actually went in the opposite direction, $r(69) = -.21$, $p = .079$. Upon visual inspect of the data, this negative correlation appeared to be driven by a single participant. When this participant was removed, the correlation of changes in objective hits between 2-back and 3-back with changes in subjective estimates of hits between the 2-back and 3-back was eliminated, $r(68) = -.05$, $p = .714$. It should also be noted that these correlations ($r = .25$ and $r = -.05$) were not significantly different from one another, $z = 1.76$, $p = .079$ (two-tailed; as per Preacher, 2002). Neither groups were able to accurately predict changes in false alarms, $r(66) = .20$, $p = .099$ and $r(69) = .07$, $p = .578$ (for the No Video and Video groups, respectively), and these correlations were also not-significantly different from one another, $z = .07$, $p = .445$ (two-tailed; Preacher, 2002).

Ratings of task demand. Lastly, following subjective estimates of performance, participants' ratings of task demand were also obtained via items from the NASA-TLX. This allowed for the assessment of how demanding participants perceived the task to be under various conditions. To that end, a mixed repeated-measures ANOVA was conducted with Cognitive Load (2-back vs. 3-back) entered as the within-subjects variable, Video Presence (No Video vs. Video) entered as the between-groups variable, and ratings of task demand (obtained by averaging responses to each of the included NASA-TLX items) entered as the dependent variable (see Table 5). There was a main effect of Cognitive Load on ratings of task demand, $F(1,137) = 12.46$, p

< .001, η^2_p = .09, whereby participants rated the 3-back to be more demanding than the 2-back. However, there was no main effect of Video Presence, $F(1,137) = 2.22$, $p = .138$, η^2_p = .02, nor was there a Cognitive Load by Video Presence interaction, $F(1,137) = 1.11$, $p = .294$, η^2_p = .01.

Table 5. Mean subjective ratings of task demand as a function of Cognitive Load (2-back vs. 3-back) and Video Presence (No Video vs. Video). Standard errors are provided in parentheses.

		Cognitive Load	
		2-back	3-back
Video Presence	No Video group	7.06 (.16)	7.61 (.20)
	Video group	6.85 (.17)	7.14 (.20)

Discussion

The purpose of Study 3.1 was to assess whether the presence of a task-irrelevant, non-required video interfered with performance on an attentionally demanding primary task, and whether subjective estimates of performance were influenced by the presence versus absence of the video. On the whole, the presence of the video negatively impacted performance on the n-back, as observed by decreased hits, correct rejections, and an increase in the number of omitted trials, compared to participants who performed the n-back alone. In terms of subjective estimates of performance, although participants clearly reported performing more poorly during the 3-back compared to the 2-back, those in the Video group estimated their performance to be similar to those in the No Video group, both in terms of hits and false alarms. Furthermore, the accuracy with which participants gauged their performance (i.e., the correlation of differences in objective performance with differences in subjective estimates across cognitive load), although slightly better in the No Video Group, was not found to be significantly different between-groups. Lastly, while participants self-reported task demand (indexed by averaging responses to the four items on the NASA-TLX) to be higher in the 3-back compared to the 2-back, there was again no between-group (i.e., Video Presence) difference. Thus, it appears that all of the included subjective-report measures (estimated hits, estimated false alarms, and self-reported task demand) did not vary with the presence or absence of the video.

It is worth noting that the non-significant difference in subjective performance assessments across the No Video and Video conditions might be specific to the between-groups design of the present study. Some would argue that evaluative judgments of performance are assessed most purely when collected in a between-groups design (e.g., Hsee & Zhang, 2004). The logic is that when a variable is manipulated in a within-participant design, the manipulated dimension can become salient to the participants, allowing their judgments to be biased by their metacognitive theories about the relation between the manipulated variable and the judged variable. It is argued that this defect is eliminated when the variable is manipulated between groups, as each participant is only exposed to one level of the variable. On this view, a between-groups design, as was used here, is the optimal way to assess how a variable influences evaluative judgments. When this view is applied to the present study, one could argue that the absence of a robust and significant difference in judgments of performance across video groups, even though there were large objective performance differences across groups, means that participants' judgments were not sensitive to the objective influence of the non-required video.

However, there might be an alternative way to construe the results of Study 3.1. It could be that participants are simply not very precise in making *absolute* judgments about their performance. If this were the case, then the influence of a variable manipulated between-groups (such as the presence or absence of a video) might not be detected by the imprecise absolute judgments necessitated by the between-groups design. In contrast, participants might be better able to make relative judgments of performance. That is, while participants might not know precisely if they detected 70% or 80% of the targets, they might know that they detected more targets in one condition than another, if they were given the opportunity to experience both conditions in a within-subjects design. A strength of a within-subjects manipulation of Video Presence is that participants may be better able to anchor themselves during the first subjective estimate of performance, and provide a more accurate *relative* judgment of their performance during the second estimate. On this interpretation, the between-groups design used in the present study could be construed as being inferior to a within-subjects design, and that in a within-participant design, the present/absence of the video might in fact be shown to influence subjective judgments of performance.

In addition to the foregoing case for examining the influence of the presence/absence of a non-required video on performance in a within-subjects design, it is important to consider lay theories about the relation between video presence and performance. Concretely, people are often exposed to the strong (yet seldom scientific) opinions of others (e.g., parents) about the distracting effects of multimedia, and may or may not adopt such views themselves. Here I would highlight that any contamination of judgments by lay theories about the relation between video presence and performance would not be all that problematic. Indeed, the interest here is much more general and given that many real world judgments are likely influenced by both momentary assessments as well as lay theories, a within-subjects design, which might include both influences, might be preferable. For these reasons, in Study 3.2, Video Presence was manipulated within-subjects and subjective estimates of performance were collected after participants performed the n-back alone, and after performing the n-back with the concurrent video playing.

Study 3.2

Introduction

The purpose of Study 3.2 was again to assess (1) how a non-required, task-irrelevant video might influence performance on an attentionally demanding task, and (2) whether the presence or absence of the video influenced subjective estimates of performance. This time, however, Video Presence (No Video vs. Video) was manipulated within-subjects, such that all participants performed the n-back (2-back) both alone and while the non-required, task-irrelevant video was played in the upper portion of the screen. In Study 3.2, only the 2-back was used for simplicity as it appeared sufficiently demanding for the present purposes.

Method

Participants. Seventy-three participants (22 male, 51 female) from the University of Waterloo completed the study in exchange for course credit.

Stimuli and procedure. In Study 3.2 participants completed 384 trials of the 2-back only (i.e., equivalent to the total number of trials completed in Study 3.1). As before, participants were instructed to indicate, on each trial, whether the current letter matched the letter presented *two* items back by pressing one of two response keys (L for ‘match’ or A for ‘non-match’), with a reminder of these keys (“Press A for NON-MATCH” and “Press L for MATCH”) displayed in the lower portion of the screen on each trial. During either the first portion of the task (i.e., first 192 trials) or last portion of the task (i.e., last 192 trials; counterbalanced for order; see Figure 6), participants were given a video to watch, embedded in the upper portion of the screen, while they completed the 2-back (see Figure 4). This video was the same as that used in Study 3.1 (i.e., Keith Barry’s TED Talk entitled “Brain Magic”) and participants were again told that “…while you complete the task, there will be a video for you to watch in the upper portion of the screen. There will be no test on the content of this video, it is simply for you to watch while you do the task."

At the end of the first portion of the task (i.e., first 192 trials), and last portion of the task (i.e., last 192 trials), participants were asked to estimate their performance on the 2-back. Thus, all participants provided two sets of performance estimates – one set after completing the 2-back without a video, and one set after completing the 2-back with a concurrent video. For each set of performance estimates, participants answered two questions: (1) "What percentage of MATCHING trials do you think you CORRECTLY endorsed as 'MATCHING' on the task you just performed (i.e., the 2-back)?", and (2) "What percentage of NON-MATCHING trials do you think you INCORRECTLY endorsed as 'MATCHING' on the task you just performed (i.e., the 2-back)?".

Lastly, after providing estimates of their performance, participants also provided subjective ratings of task demand by responding to four items from the NASA-TLX (Hart, 2006). As in Study 3.1, these four items were of Mental Demand ("How mentally demanding was the task?"), Temporal Demand ("How hurried or rushed was the pace of the task?"), Performance ("How successful were you in accomplishing what you were asked to do?"), and Effort ("How hard did you have to work to accomplish your level of performance?"). All four items were responded to using a 10-point scale. The Mental Demand, Temporal Demand, and Effort items had anchors "Very Low" (1) to "Very High" (10), whereas the Performance item had the anchors of "Perfect" (1) to "Failure" (10). Higher scores on each of the items indicate higher levels of task demand. Subjective ratings of task demand were obtained by averaging responses to these four items. Higher ratings of task demand indicated that participants perceived the task to be more demanding.

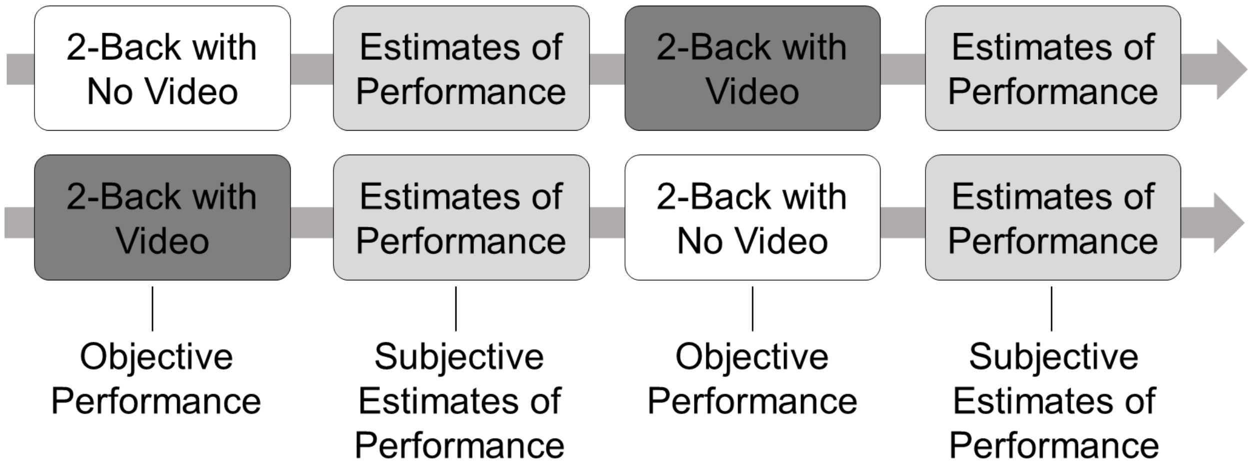

Figure 7. Visualization of task procedure in Study 3.2, Study 3.3, and Study 3.4. Video Presence (No Video vs. Video) was manipulated within-subjects. The order of No Video versus Video was counterbalanced between-groups, shown stacked on top of each other in the above figure.

Results

Performance on the 2-back was assessed in terms of hits (the proportion of target trials that were correctly identified as targets), false alarms (the proportion of non-target trials that were incorrectly endorsed as targets), correct rejections (the proportion of non-target trials that were correctly endorsed as non-targets), and omissions (the proportion of trials for which no response was provided). Similarly, two types of performance estimates were obtained: (1) estimated hits, and (2) estimated false alarms[4]. Lastly, as in Study 3.1, self-reports of task demand were collected by averaging responses to the four items from the NASA-TLX.

[4] For exploratory purposes, a subjective estimate of elapses time was also included (i.e., "How long do you think it took you to complete the last four blocks of trials?").

Prior to analysis, data from three participants were excluded due to visibly not paying attention or listening to instructions as noted by a research assistant. Upon inspecting the data, one additional participant was removed for providing an impossible estimate of their false alarms (215%). As such, data from 69 participants (21 male, 48 female) were submitted to the following analyses[5].

Objective performance on the 2-back. To assess how a non-required, task-irrelevant media might influence performance on an attentionally demanding task (here, 2-back), four repeated-measures ANOVAs were conducted with Video Presence (No Video vs. Video) entered as the within-subjects variable and either proportion hits, false alarms, correct rejections, or omissions entered as the dependent variable. Means and associated standard errors for each of these dependent variables as a function of Video Presence are displayed in Figure 8.

[5] The effects of Counterbalance Order (No Video, Video vs. Video, No Video) for Studies 3.2, 3.3, and 3.4 are provided in appendices J, K, and L, respectively.

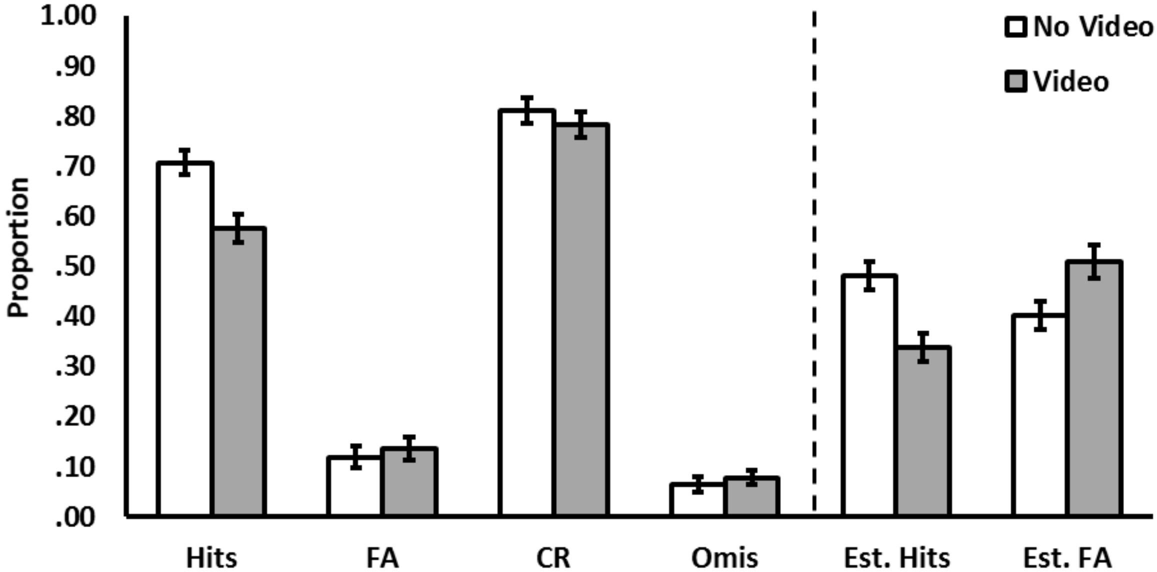

Figure 8. Objective performance and subjective estimates of performance on the 2-back in Study 3.2. Video Presence (No Video vs. Video) was manipulated within-subjects. Dependent variables include proportion hits (Hits), false alarms (FA), correct rejections (CR), omissions (Omis), estimated hits (Est. Hits), and estimated false alarms (Est. FA). Error bars represent one standard error of the mean.

As shown in Figure 8, there was a main effect of Video Presence on hits such that participants had fewer hits when the non-required, task-irrelevant video was present compared to when the video was absent, $F(1,68) = 29.37$, $p < .001$, $\eta^2_p = .30$. There was also a main effect of Video Presence on false alarms such that participants had slightly more false alarms when the video was playing compared to when the video was not playing, $F(1,68) = 4.77$, $p = .032$, $\eta^2_p = .07$. Lastly, there was a main effect of Video Presence on correct rejections, $F(1,68) = 6.82$, $p = .011$, $\eta^2_p = .09$, wherein participants correctly rejected fewer non-targets when the video was playing than when no video was playing. Video Presence did not appear to have an effect on omissions,

$F(1,68) = 1.30$, $p = .258$, $\eta^2_p = .02$. Overall, these findings demonstrate that having a non-required, task-irrelevant video playing impairs performance on a primary, attentionally demanding task.

Subjective estimates of performance on the 2-back. Two repeated-measures ANOVAs were conducted with Video Presence (No Video vs. Video) entered as the within-subjects variable, and either estimated hits or estimated false alarms entered as the dependent variable. There was a main effect of Video Presence on estimated hits, such that participants judged themselves to have scored fewer hits when the video was present than when the video was absent, $F(1,68) = 39.52$, $p < .001$, $\eta^2_p = .37$ (see Figure 8). There was also a main effect of Video Presence on estimated false alarms wherein participants reported themselves as having more false alarms when the video was present than when the video was absent, $F(1,68) = 13.19$, $p = .001$, $\eta^2_p = .16$ (Figure 8). Like the objective costs to performance, these data demonstrate that participants subjectively report a cost of the irrelevant video to primary-task performance.

Correlation between objective and subjective estimates of performance. To evaluate how sensitive participants were to changes in their performance between completing the 2-back alone versus with the presence of the additional media, differences in objective performance (for both hits and false alarms) across the No Video and Video task segments were correlated with differences in subjective estimates of performance (for both estimated hits and false alarms) across the No Video and Video task segments. There was a significant positive correlation for the differences in hits, such that larger objective changes in hits were accompanied by participants providing larger differences in subjective estimates of hits, $r(67) = .28$, $p = .020$. However, differences in objective false alarms were not correlated with differences in subjective estimates of false alarms, $r(67) = .02$, $p = .866$.

Ratings of task demand. A repeated-measures ANOVA was conducted with Video Presence (No Video vs. Video) entered as the within-subjects variable and the ratings of task demand entered as the dependent variable. There was a marginal main effect of Video Presence such that participants rated the 2-back to be slightly more demanding when performed while the video was playing (M = 7.21, SE = .17) compared to when no video was playing (M = 6.89, SE = .17). However this difference was not statistically significant, $F(1,68) = 3.51$, $p = .065$.

Discussion

Results from Study 3.2 present several interesting findings. First, replicating findings from Study 3.1, the concurrent video stream had a detrimental effect on performance on the primary task (2-back), even though engagement is non-required and the video is irrelevant to the task-at-hand. Second, in addition to participants systematically *under-estimating* their performance, participants also subjectively reported that they performed more poorly when the video was playing compared to when the video was not playing. Lastly, at least in terms of hits, participants were somewhat attuned to changes in their performance across the No Video and Video segments of the task, as noted by the significant correlation of objective changes in hits with changes in subjective estimates of hits.

Before making strong conclusions about the current pattern of results, I first sought to replicate findings from Study 3.2 by using a larger sample in Study 3.3. In addition, given that in both Study 3.1 and 3.2, participants (a) grossly over-estimated their false alarms and (b) showed no sensitivity in changes in the metric (i.e., a lack of correlation between objective and subjective false alarms), it also seemed worthwhile to see whether participants could estimate their performance along the perhaps more intuitive metric of correct rejections.

Study 3.3

Introduction

The purpose of Study 3.3 was to replicate findings from Study 3.2 with a much larger sample. One concern in the previous studies of Chapter 3 (3.1 and 3.2), which was also addressed in Study 3.3, is that participants may have had difficulty interpreting the self-report question indexing subjective estimates of false alarms. This concern was generated by the substantially high proportion of self-reported false alarms. To address this issue, in addition to asking participants to report upon what proportion of matching letters they correctly endorsed as matching (i.e., hits), in Study 3.3 participants were asked to report upon the proportion of non-matching letters they correctly endorsed as non-matching (i.e., correct rejections).

Lastly, the MMI-2 was included as an individual differences measure of media multitasking. This allowed for another attempt to replicate Chapter 2's findings in the laboratory. In addition, this also allowed us to observe how individual differences in habitual media multitasking relate to (a) the impact of a non-required, task-irrelevant media on performance, and (b) subjective estimates of performance under no video and video conditions.

Method

Participants. One hundred and sixty-three participants (42 Male, 121 Female) from the University of Waterloo completed the study in exchange for course credit.

Stimuli and procedure. The stimuli and procedure mirrored that of Study 3.2 with two exceptions. First, before completing the 2-back, participants completed the MMI-2 (a modified version of the original MMI; see Chapter 2 for details) online using a laboratory computer. Second, while in Study 3.1 and 3.2 participants were asked to provide two reports of their false alarms (one after the No Video segment, and another after the Video segment of the task), in Study 3.3

participants were asked to provide two subjective estimates of their *correct rejections* instead. Here, participants were asked "What percentage of NON-MATCHING trials do you think you CORRECTLY endorsed as 'NON-MATCHING' on the task you just performed (i.e., the 2-back)?" This was done due to the concern that false alarms may be inherently difficult for participants to introspect and report, or that they perhaps misunderstood the question.

Results

As in Study 3.2, performance on the 2-back was assessed in terms of hits (the proportion of target trials that were correctly identified as targets), false alarms (the proportion of non-target trials that were incorrectly endorsed as targets), correct rejections (the proportion of non-target trials that were correctly endorsed as non-targets), and omissions (the proportion of trials for which no response was provided). Similarly, two types of performance estimates were obtained: (1) estimated hits, and (2) estimates correct rejections. Means and standard errors for the aforementioned dependent variables are displayed in Figure 8. Lastly, we also collected self-reports of task demand via averaging response to four items from the NASA-TLX, as in Study 3.1 and 2.

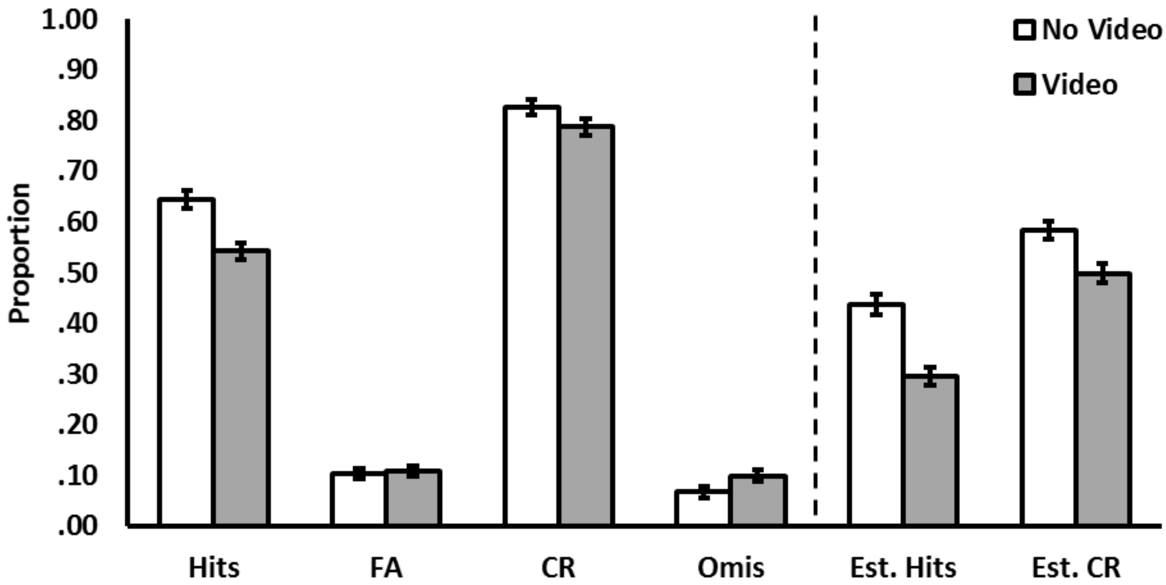

Figure 9. Objective performance and subjective estimates of performance on the 2-back in Study 3.3. Video Presence (No Video vs. Video) was manipulated within-subjects. Dependent variables include proportion hits (Hits), false alarms (FA), correct rejections (CR), omissions (Omis), estimated hits (Est. Hits), and estimated correct rejections (Est. CR). Error bars represent one standard error of the mean.

Objective performance on the 2-back. Four repeated-measures ANOVAs were conducted with Video Presence (No Video vs. Video) entered as the within-subjects variable and either proportion hits, false alarms, correct rejections, or omissions entered as the dependent variable. Similar to Study 3.2, there was a main effect of Video Presence on hits and correct rejections, such that participants scored fewer hits, and made fewer correct rejections, when the video was playing than when no video was playing, $F(1,162) = 48.86$, $p < .001$, $\eta^2_p = .23$ and $F(1,162) = 15.25$, $p < .001$, $\eta^2_p = .09$, respectively (see Figure 9). Unlike findings from Study 3.2, there was no effect of the irrelevant media on false alarms, $F < 1$, but there was a main effect of Video Presence on omissions such that participants had more omissions when the video was present than when the video was absent, $F(1,162) = 13.04$, $p < .001$, $\eta^2_p = .07$ (see Figure 9). Thus, while overall these findings replicate the general finding that a non-required, irrelevant video may impair performance on an attentionally demanding primary task, the effect on specific performance variables appear to vary.

Subjective estimates of performance on the 2-back. Two repeated-measures ANOVAs were conducted with Video Presence (No Video vs. Video) entered as the within-subjects variable and either estimated hits or estimated correct rejections entered as the dependent variable (see Figure 9). Replicating the pattern of results observed in Study 3.2, Video Presence was found to have a significant effect on both subjective estimates, whereby participants estimated themselves to have scored fewer hits when the video was present than when the video was absent, $F(1,162) = 86.77$, $p < .001$, $\eta^2_p = .35$, and also reported correctly rejecting fewer non-targets when the video was present compared to when the video was absent, $F(1,162) = 48.27$, $p < .001$, $\eta^2_p = .23$.

Correlation between objective and subjective estimates of performance. To once again assess how sensitive participants were to differences in their performance when completing the 2-back alone versus with the presence of a non-required task-irrelevant video, differences in objective performance (for both hits and correct rejections) between the No Video and Video task segments were correlated with differences in subjective estimates of performance (for both estimated hits and correct rejections) between the No Video and Video task segments. Replicating findings from Study 3.2, in Study 3.3 larger objective differences in hits (between No Video and Video task segments) were accompanied by larger subjectively reported differences in hits, $r(161) = .34$, $p < .001$. However, as was the case with false alarms, objective changes in correct rejections were not correlated with changes in subjective estimates of correct rejections, $r(160) = .07$, $p = .351$, despite, on the whole, reporting fewer correct rejections when the video was present compared to when the video was absent.

Ratings of task demand. To assess perceived differences in task demand when completing the 2-back alone versus with the addition of the non-required irrelevant video, a repeated-measures ANOVA was conducted on ratings of task demand with Video Presence (No Video vs. Video) entered as the within-subjects variable. Following the previously observed non-significant trend observed in Study 3.2, using a much larger sample, here the difference in ratings of task demand between No Video (M = 6.73, SE = .11) and Video (M = 7.34, SE = .11) task segments was significant, $F(1,162) = 26.05$, $p < .001$, $\eta^2_p = .14$. Given the comparable means between Study 3.2 and 3, it is likely we lacked sufficient power to detect the effect in Study 3.2.

Individual differences in media multitasking. Lastly, in Study 3.3, the MMI-2 was included as an individual differences measure of media multitasking. This provided the opportunity to attempt to replicate findings from Chapter 2 by correlating MMI-2 scores with performance variables during the No Video task segments. Novel to Study 3.3, inclusion of the MMI-2 also allowed for exploring how habitual media multitasking is related to performance on an attentionally demanding task when one has the opportunity to media multitask (i.e., during the Video trials), and how individual differences in media multitasking relate to subjective estimates of performance and ratings of task demand. The correlation of scores on the MMI-2 with objective and subjective performance indices (and ratings of task demand) are presented in Table 6. Four participants did not complete the MMI-2 and were thus dropped from the subsequent correlation matrix.

When performing the task without the presence of the video (i.e., No Video trials), akin to the task environment in Chapter 2, no significant relation between scores on the MMI and any performance variable, including hits, false alarms, correct rejections, and omissions was observed (see Table 6). Thus, Study 3.3 did not replicate the pattern of results observed in Chapter 2. A similar series of non-significant correlations were observed under the multitasking-enabled context (Video trials) as well. As seen in Table 6, the only dependent measure that MMI-2 scores appeared to correlate with was estimated hits, such that heavier trait-level media multitaskers reported scoring fewer hits on the 2-back (both with and without the presence of the video).

Table 6. Correlation of scores on the Media Multitasking Index (MMI-2) with objective performance indices (hits, false alarms [FA], correct rejections [CR], and omissions), subjective performance estimates (estimated hits [Est. Hits] and correct rejections [Est. CR]), and ratings of task demand for both No Video and Video trials, $N = 159$.

		Hits	FA	CR	Omissions	Est. Hits	Est. CR	Task demand
MMI-2	No Video	-.15	.08	-.08	-.14	-.21**	-.06	.05
	Video	-.09	.14	-.08	-.10	-.18*	.03	.03

*$p < .05$, **$p < .01$

Despite MMI-2 scores not being associated with omissions, as they were in Chapter 2, to be thorough and consistent, the aforementioned correlations were re-calculated while controlling for omissions, as was done in Chapter 2 (see Table 7). Perhaps not surprisingly, the general pattern of results did not change; MMI-2 scores were not associated with hits, false alarms, correct rejections, subjective estimates of correct rejections, or reports of task demand. MMI-2 scores continued to be negatively correlated with estimates hits.

Table 7. Partial correlations of scores on the Media Multitasking Index (MMI-2) with objective performance indices (hits, false alarms [FA], correct rejections [CR], and omissions), subjective performance estimates (estimated hits [Est. Hits] and correct rejections [Est. CR]), and ratings of task demand for both No Video and Video trials, controlling for omissions, $N = 159$.

		Hits	FA	CR	Est. Hits	Est. CR	Task demand
MMI-2	No Video	-.16	.11	-.11	-.24**	-.08	.05
	Video	-.09	.11	-.06	-.18*	.02	.06

*$p < .05$, **$p < .01$,

Discussion

Study 3.3 replicated the general pattern of results observed in Study 3.2. The presence of a non-required, task-irrelevant video impaired performance on the 2-back, albeit the exact performance metrics that are affected seemed to vary across studies. In addition to participants systematically under-estimating their performance, participants estimated their performance to be worse when performing the 2-back with the video playing than when the video was not playing. Also replicated was the finding from Study 3.2 whereby objective changes in hits between No Video and Video segments of the task were positively correlated with changes in subjective estimates of hits between No Video and Video task segments. However, much like false alarms, participants were not well-calibrated to estimating changes in their correct rejections.

In addition to providing a replication of Study 3.2, in Study 3.3 another aim was to replicate the previously documented relation between individual differences in media multitasking and performance metrics on the n-back (Chapter 2). Study 3.3 did not, however, replicate the relation between individual differences in media multitasking and specific performance metrics of the n-back discussed in Chapter 2. In fact, the only significant relation observed was between scores on the MMI-2 and *subjective estimates* of hits, whereby heavier trait-level media multitaskers reported performing more poorly (scoring fewer hits). These findings contribute to the significant variability in the literature as to the relation between scores on the MMI and performance on the n-back (Cain et al., 2016; Cardoso-Leite et al., 2016; Ophir et al., 2009; Ralph & Smilek, 2017). However, two substantial differences between the study reported in Chapter 2 and the present study were that (1) the study in Chapter 2 was conducted in an online environment where participants have broader opportunities to multitask while performing the experiment, and (2) the sample size in the present study is much smaller than that of Chapter 2.

Study 3.4

Introduction

One concern in interpreting findings from the aforementioned studies of Chapter 3 is that, despite our intentions for the video to be a non-required task, participants may have interpreted the instructions as meaning that watching the video was a required task. Specifically, the potentially problematic part of the instructions were the statements: "...there will be a video for you *to watch…"* and "…it is simply *for you to watch while you do the task*." (Italics added for emphasis). To address this concern, Study 3.4 was conducted as an online replication of Study 3.3 using a novel set of instructions that more clearly construed the video as being non-required. These instructions were: "…you will have the opportunity to watch a video … while you complete the task. There will be no test on the content of this video, and you are not required to watch it. However, you may watch the video while you do the task, if you wish." To emphasis the required nature of the primary task (2-back), the instructions were ended with: "…please do your best to respond to each letter, and perform the task (the n-back) to the best of your ability."

A second limitation of the studies presented in Chapter 3 thus far is that metacognitive beliefs about the impact of the media (video) on performance were not directly assessed. While participants subjectively reported their performance to be lower when the video was present versus absent (Studies 3.2 and 3.3), it is important to keep in mind that this does not imply that participants are attributing changes in their performance to the video. To address this issue, in Study 3.4, a new metacognitive self-report item was added to index beliefs about the video's influence on performance. The specific question was worded as follows: "To what extent did the video influence your performance on the task (n-back) relative to when you performed the task without the video?" (See Method below).

Method

Participants. The goal was to collect the same sample size as in Study 3.3. However, given that online data tend to have more noise and include a higher attrition of participants (either due to non-compliance or a failure to complete the study), the sample size was increased by approximately 25%. As such, data was collected from 201 participants (114 male, 86 female, 1 unknown) with an age range of 18 to 62 years old (M = 33.39, SD = 9.32)[6] who signed-up for the study via Amazon Mechanical Turk and received \$3.00 as compensation for their time.

Stimuli and procedure. When participants signed-up for the study, they first completed a demographics questionnaire (as in Chapter 2, see Appendix A). Participants then completed the

[6] One participant indicated their age to be four years old, and were excluded from the age-range calculation.

MMI-2[7] and 2-back as per Study 3.3. As in Study 3.3, participants completed the 2-back both with and without the presence of a video. Video Presence (No Video vs. Video) was thus manipulated within-subjects, and the order in which participants received the video was also counterbalanced between-groups (see Figure 7). At the end of No Video and Video task segments, participants were again asked to provide subjective estimates of their hits and correct rejections, and responded to the previously included four items from the NASA-TLX.

Novel to Study 3.4 was the following set of instructions, designed to more clearly construe the video as non-required:

"…you will have the opportunity to watch a video, embedded in the upper portion of the window, while you complete the task. There will be no test on the content of this video, and you are not required to watch it. However, you may watch the video while you do the task, if you wish. Please make sure your audio is turned on throughout the task and adjusted to a comfortable level."

To emphasis the required nature of the primary task, the instructions were ended with: "Please do your best to respond to each letter, and to perform the task (the n-back) to the best of your ability." At the end of the study, after participants had performed the 2-back both with and without the presence of the non-required video, participants also responded to the following metacognitive belief item (provided in Appendix M), designed to index participants' thoughts about the influence of the video on their performance: "To what extent did the video influence

[7] The "doing homework/studying/writing papers" item of the MMI-2 was expanded to include "work" given the broader demographic of participants.

your performance on the task (n-back) relative to when you performed the task without the video?" Participants responded to this 'video impact' item using a 7-point scale with response options "Hindered Performance A Lot" (1), "Hindered Performance Moderately" (2), "Hindered Performance A Little" (3), "No Impact" (4), "Improved Performance A Little" (5), "Improved Performance Moderately" (6), and "Improved Performance A Lot" (7). For scoring purposes, responses were reverse-coded such that higher scores on this video-impact item indicated that participants thought the video *hindered* performance on the 2-back, whereas lower scores on this item indicated that participants thought the video *improved* performance on the 2-back.

Given that Study 3.4 was conducted online, various compliance-checks were also included, similar to Chapter 2. These included: "Did you respond randomly at any point during the survey of media use?", "Did you mute the volume to the video during the attention task (n-back)?", and "Lastly, given that this study is about media use and multitasking, we are also interested in whether you multitasked with media while you completed this study. Were you multitasking with any other media, besides the provided video, while you completed the attention task (n-back)?" Each of these compliance-check items (provided in Appendix M) were responded to with either a "Yes" or "No" and were presented at the conclusion of the study.

Results

Before analyzing the data, participants who responded "Yes" to any of the three compliance-check items, including responding randomly to the media use survey (i.e., MMI-2), muting the volume of the video, and / or multitasking with other media during the study, were removed under the condition of non-compliance. This led to the removal of 43 participants, and the subsequent analysis of 158 participants (90 male, 67 female, 1 unknown). As in Study 3.3, performance on the 2-back was assessed in terms of hits, false alarms, correct rejections, and omissions. Subjective estimates of hits and correct rejections were also analyzed. Means and standard errors for these metrics are presented in Figure 10. In addition, subjective ratings of task demand were also collected (via averaging responses to the four NASA-TLX items), as were individual differences in media multitasking (via the MMI-2), and metacognitive beliefs about the impact of the video on performance.

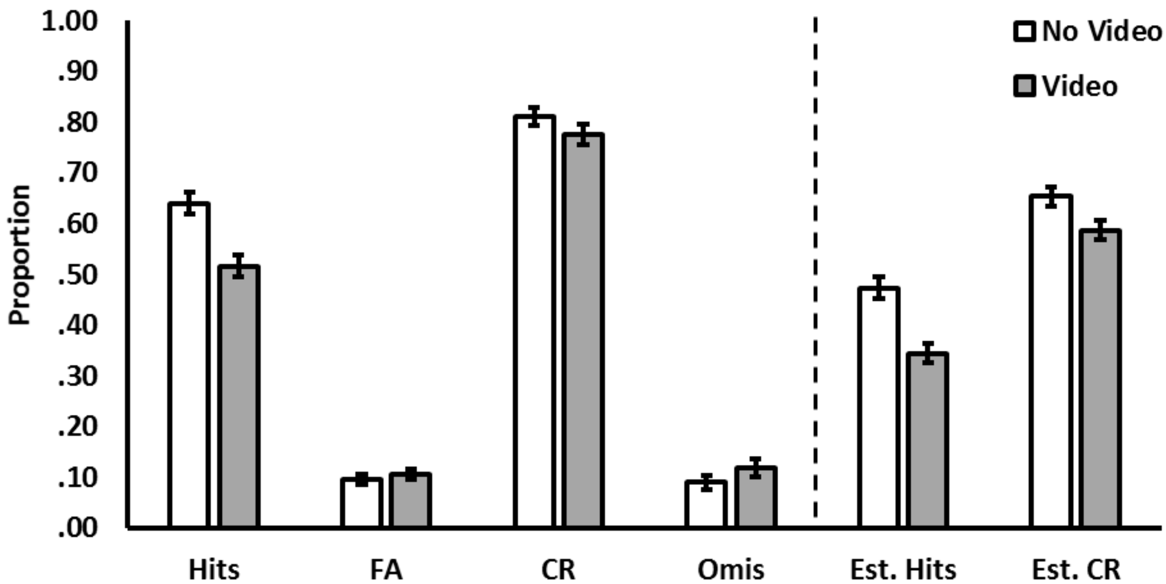

Figure 10. Objective performance and subjective estimates of performance on the 2-back in Study 3.4. Video Presence (No Video vs. Video) was manipulated within-subjects. Dependent variables include proportion hits (Hits), false alarms (FA), correct rejections (CR), omissions (Omis), estimated hits (Est. Hits), and estimated correct rejections (Est. CR). Error bars represent one standard error of the mean.

Objective performance on the 2-back. Behavioural data from the 2-back were submitted to four repeated-measures ANOVAs with Video Presence (No Video vs. Video) entered as the within-subjects variable and either proportion hits, false alarms, correct rejections, or omissions entered as the dependent variable. There was a main effect of Video Presence on hits, $F(1,157) = 52.71$, $p < .001$, $\eta^2_p = .2$, correct rejections, $F(1,157) = 7.97$, $p = .005$, $\eta^2_p = .05$, and omissions, $F(1,157) = 4.28$, $p = .04$, $\eta^2_p = .03$, but no main effect of Video Presence on false alarms, $F(1,157) = 1.74$, $p = .19$, $\eta^2_p = .01$ (see Figure 10). Thus, with a new set of instructions that more explicitly highlights the non-required nature of the video, these findings from Study 3.4 replicate the impact of the video on objective performance indices as observed in Study 3.3, and the general pattern of impairments observed in Study 3.2.

Subjective estimates of performance on the 2-back. Subjective estimates of performance were submitted to two repeated-measures ANOVAs with Video Presence (No Video vs. Video) entered as the within-subjects variable and either subjective estimates of hits or subjective estimates of correct rejections entered as the dependent variable. There was a main effect of Video Presence on estimated hits, $F(1,157) = 57.46$, $p < .001$, $\eta^2_p = .27$, such that participants reported their hits to be lower when the video was present compared to when the video was absent (see Figure 10). Also replicating findings from Study 3.3, there was a main effect of Video Presence on estimated correct rejections, $F(1,157) = 15.53$, $p < .001$, $\eta^2_p = .09$, such that participants reported fewer correct rejections when the video was present compared to when the video was absent (see Figure 10). Like the pattern of results pertaining to objective performance indices, the data from Study 3.4 also replicated the effects of Video Presence on subjective estimates of performance with a set of instructions that more clearly defines the video as non-required.

Correlation between objective and subjective estimates of performance. To examine how sensitive participants were to the difference in their performance when completing the 2-back without the video versus with the video playing, differences in objective performance (for both hits and correct rejections) between No Video and Video task segments were correlated with differences in subjective estimates of performance (for both estimates hits and correct rejections) between No Video and Video task segments. Once again replicating findings from Study 3.2 and 3.3, changes in objective hits were positively correlated with changes in subjective estimates of hits, $r(156) = .33$, $p < .001$, but, like Study 3.3, changes in objective correct rejections were not correlated with changes in subjective estimates of correct rejections, $r(156) = .07$, $p = .410$.

Subjective reports of the influence of the video on performance. Novel to Study 3.4 was the inclusion of the self-report item, "To what extent did the video influence your performance on the task (n-back), relative to when you performed the task without the video?" Interestingly, the majority of participants indicated that the video had a negative effect on performance, such that approximately 37% of participants indicated that the video "Hindered Performance A Lot," 25% indicated that the video "Hindered Performance Moderately," and 20% indicated that the video "Hindered Performance A Little." Only approximately 11% of participants reported "No Impact" of the video on performance, while a cumulative 6% indicated some benefit of the video. This item also provided the opportunity to examine how changes in objective and subjective estimates of performance correlated with participants' direct evaluation of how the video impacted their performance. To this end, responses to this item were correlated with changes in objective performance (hits and correct rejections) and changes in subjective estimates of performance (estimated hits and correct rejections), obtained in the foregoing section. Recall that following a reverse-coding of the response-options, higher scores on this metacognitive-belief item indicate that participants thought the video *hindered* their performance on the 2-back, whereas lower scores indicate that participants thought the video *improved* their performance on the 2-back. Subjective reports of the video's impact were positively correlated with objective changes in hits, $r(156) = .23$, $p = .004$, suggesting that the greater impact the video had on objective hit rates, the more participants explicitly indicated that the video hindered their performance. Similarly, reports of the video's impact were positively correlated with changes in subjective estimates of hits, $r(156) = .21$, $p = .008$, such that participants who reported their hits to be lower following Video trials relative to No Video trials also directly reported the video to negatively impact their performance to a greater extent. Reports of the video's impact were not correlated with changes in objective correct rejections, $r(156) = .02$, $p = .835$, but were positively correlated with changes in subjective estimates of correct rejections, $r(156) = .25$, $p = .001$.

Ratings of task demand. The perceived demands of the 2-back were assessed as a function of Video Presence (No Video vs. Video) via a repeated-measures ANOVA. There was a main effect of Video Presence on subjective reports of task demand, $F(1,157) = 6.90$, $p = .009$, $\eta^2_p = .04$, such that participants rated the No Video segment of the task to be more demanding ($M = 7.35$, $SE = 0.10$) than the Video segment of the task ($M = 7.16$, $SE = 0.10$). This is in contrast to the pattern of results observed in Study 3.2 and 3.3 whereby participants rated the Video task-segments to be more demanding than the No Video task segments.

Individual differences in media multitasking. Inclusion of the MMI-2 provided a measure of individual differences in media multitasking, as per Chapter 2 and Study 3.3. To once again observe how individual differences in media multitasking were related to performance on the 2-back, scores on the MMI-2 were correlated with objective and subjective estimates of performance on the 2-back, both during No Video and Video segments separately (see Table 8). Given that for this portion of the results, the interest is on individual differences in media multitasking, participants who reported that they were media multitasking during the 2-back were re-included as removal of these participants would mean selecting-out part of the primary behaviour of interest. This led to the analysis of 164 participants. In addition, given the wide age range of the online sample, the relation of MMI-2 scores with objective and subjective performance estimates are provided while controlling for age (see Table 8).

As seen in Table 8, in Study 3.4 scores on the MMI-2 were positively correlated with false alarms both with and without the presence of the video, but not with any other objective or subjective metric. This pattern of results does not replicate the pattern of results observed in Study 3.3 in which only the MMI-2 and estimated hits were correlated, and partially replicates the pattern of results reported in Chapter 2, whereby MMI-2 scores were correlated with false alarms and omissions. When controlling for omitted trials (as per the study in Chapter 2, and Study 3.3, for consistency), scores on the MMI-2 remain positively correlated with false alarms, and negatively correlated with correct rejections (see Table 9).

Table 8. Partial correlation of scores on the Media Multitasking Index (MMI-2) with objective performance indices (hits, false alarms [FA], correct rejections [CR], and omissions), subjective performance estimates (estimated hits [Est. Hits] and correct rejections [Est. CR]), and ratings of task demand for both No Video and Video trials, controlling for age, $N = 164$.

		Hits	FA	CR	Omissions	Est. Hits	Est. CR	Task demand
MMI-2	No Video	-.08	.32***	-.15	-.03	.03	-.01	-.07
	Video	.04	.32***	-.11	-.07	.12	.04	-.01

***$p \leq .001$

Table 9. Partial correlation of scores on the Media Multitasking Index (MMI-2) with objective performance indices (hits, false alarms [FA], correct rejections [CR], and omissions), subjective performance estimates (estimated hits [Est. Hits] and correct rejections [Est. CR]), and ratings of task demand for both No Video and Video trials, controlling for age and omissions, $N = 164$.

		Hits	FA	CR	Est. Hits	Est. CR	Task demand
MMI-2	No Video	-.12	.32***	-.30***	.02	-.02	-.08
	Video	.01	.32***	-.27***	.11	.02	-.01

***$p \leq .001$

Discussion

Study 3.4 provides an important replication of findings observed in Study 3.2 and Study 3.3 using a set of instructions that more clearly articulates the non-required nature of the included video, with the added utility of extending findings to a broader demographic of participants. One concern with interpreting findings from the previous studies of Chapter 3 is that participants may have interpreted the video as a required task. That is, although they were not going to be tested on the content of the video, some participants may have believed that they were nevertheless required to attend to the video. Findings from Study 3.4 mitigate this concern, as a highly similar pattern of results is obtained when an alternative instruction set, that more explicitly describes the video as being non-required, is used.

Findings from Study 3.4 also suggest that participants are aware that the video is negatively impacting their performance. A limitation to interpreting the difference in subjective estimates of performance between No Video and Video task segments is that it is unclear whether participants are explicitly attributing changes in performance to the presence of the video. To address this limitation, in Study 3.4, a metacognitive self-report item about the influence of the video on performance was included. The obtained findings suggest the majority of participants (approximately 83%) indicated that the video hindered performance to some degree on the primary task. It also appears to be the case that the more the video interfered with performance (at least in terms of objective hits), and the lower participants rated their performance to be during Video trials relative to No Video trials (in terms of both estimated hits and correct rejections), the more participants reported the video to be directly hindering their performance on the task.

At the individual differences level, findings pertaining to the relation between scores on the MMI-2 and performance metrics add to the variable nature of individual differences research observed in the media multitasking literature. While in Chapter 2 scores on the MMI-2 were correlated with false alarms and omissions, in Study 3.3 scores on the MMI-2 were not correlated with either of these metrics. Here, in Study 3.4, scores on the MMI-2 were correlated with false alarms, supporting findings from Chapter 2, but were not found to be correlated with omissions.

Chapter Discussion

The first goal of Chapter 3 was to examine whether the presence of a concurrently presented video, that is both non-required and irrelevant to the primary task, influences performance on the primary task. In each of the studies presented here, the video was found to have a negative impact on n-back performance, although the specific performance metrics affected may vary. It therefore seems to be the case that simultaneously available video media will interfere with performance on an attentionally demanding task, much like one would expect from classic dual-task paradigms. There are several possible interpretations to this pattern of results.

One interpretation of the interference effect induced by the video in Studies 3.1, 3.2, and 3.3, is that participants engaged with the video as a required task, because the instructions were ambiguous and participants interpreted them stating that watching the video was required.

However, this concern is mitigated by findings in Study 3.4, wherein a highly similar pattern of results was obtained when an alternative set of instructions were used that more clearly articulated the video to be non-required. It is also possible that participants either could not or did not want to ignore the video. For example, even if participants were motivated to focus attention on the n-back and ignore the video stream, by virtue of being embedded in the upper portion of the visual display, the video may have continued to occupy some proportion of perceptual and cognitive-control resources. Indeed, considering that a relatively demanding task was used, it's possible that cognitive-control resources were sufficiently taxed, leading to the processing of task-irrelevant information, as one might predict from Load Theory (Lavie et al., 2004). On the other hand, since performance on the laboratory task is ostensibly meaningless to the participants in that their compensation does not depend on their level of performance, and the video is comparatively much more interesting, participants may have not been sufficiently motivated to focus their attention on the primary task, opting instead of engage more heavily with the video. Tied to this notion of motivation, yet another interpretation of the interference effect is that participants may have tried to ignore the video, but this act of ignoring consumed attentional resources that could otherwise be deployed to the primary task. Without giving participants the opportunity to remove the video from the visual display, or acquiring some measure of participants' motivation to do well on the primary task, these explanations are difficult to disentangle.

The second goal of Chapter 3 was to see whether subjective estimates of performance on the primary task was influenced by the presence or absence of the video. In Study 3.1, when Video Presence was manipulated between-groups, none of the included self-report measures (estimated hits, estimates false alarms, and task demand) were found to vary with the presence or absence of the video. Despite objective hits being lower in the Video group compared to the No Video group, subjective estimates of hits did not vary significantly between the No Video and Video groups of participants. Although subjective estimates of false alarms were no different between conditions, objective false alarms also did not vary as a function of Video Presence. Furthermore, ratings of task demand did not seem to vary between the two groups of participants, despite participants in the Video group performing more poorly than those in the No Video group. Findings from Study 3.2, Study 3.3, and Study 3.4, wherein Video Presence was manipulated within-subjects, were much clearer. In Studies 3.2, 3.3, and 3.4, participants estimated their hits to be lower following the Video trials compared to No Video trials, coinciding with the pattern of results found for objective hits. In Study 3.2, participants also subjectively reported having more false alarms during Video trials compared to No Video trials, mirroring the effect of Video Presence on objective false alarms. Using a different performance estimate in Study 3.3 and Study 3.4, participants also reported fewer correct rejections during Video trials compared to No Video trials, again matching the effect of Video Presence on objective correct rejections. Interestingly, in Studies 3.2, 3.3, and 3.4, a significant positive correlation was observed between changes in objective hits and subjective hits across No Video and Video task segments, but no such correlation was observed for false alarms or correct rejections. Taken together, these findings demonstrate that participants are relatively sensitive to the magnitude of changes in their performance, albeit the extent of this depends on the metric in question.

The finding that participants are sensitive to the size of media-induced interference effects (i.e., relative changes in performance between No Video and Video trials) seems to be at odds with findings by Horrey et al. (2008). Similar to how participants here reported performing more poorly on the n-back when the video was present versus absent, Horrey et al. (2008) found that participants reported their driving performance to be lower when they were multitasking with a cellphone while driving, compared to when they were driving without using a cellphone. However, Horrey et al. (2008) failed to find a significant correlation between the objective differences in performance (across cellphone and cellphone-free driving periods) and differences in subjective ratings of performance. Here, however, a significant positive correlation was found between differences in objective performance and differences in subjective estimates of performance across No Video and Video conditions, at least in terms of hit rates. One likely explanation is that participants' sensitivity to changes to in their performance depends on the precise performance metric in question. While changes in subjective estimates of hits correlated with changes in objective hits, neither subjective estimates of false alarms, nor correct rejections, correlated with their objective counterparts.

Overall, participants' estimates of performance were influenced by the presence of the video, but only when Video Presence was manipulated within-subjects, and not when Video Presence was manipulated between-groups. There are at least two possible interpretations of this general pattern of results. The first is that participants are unable to make highly precise *absolute* judgments about their performance (which would be required when video presence is manipulated between-groups) but that they are able to make more precise *relative* judgments of their objective performance (when they are afforded a readily available comparison of video conditions in a within-subjects design). Another possibility is that varying video presence within-subjects makes the video presence a salient difference across conditions, thus allowing participants' judgments to be influenced by their lay theories about how video presence might influence performance, an opportunity not afforded when video presence is varied between-groups. While the present studies cannot adjudicate between these two alternatives, they do support the more general claim that when participants have experience performing a task both with and without a video, their subjective rating of performance are systemically influenced by the presence of the video.

It is important to keep in mind that the foregoing differences in subjective estimates of performance as a function of video presence do not necessarily imply that participants are consciously attributing changes in their performance to the presence of the video. However, this assertion – that participants explicitly attribute performance differences to the presence of the video – was tested in Study 3.4 by the inclusion of a metacognitive item asking participants to indicate the extent to which they felt the video influenced their performance, compared to when no video was present. Indeed, the majority of participants (approximately 83%) explicitly reported that the video hindered their performance on the n-back to some degree. Ratings of the video's impact also appeared to correlate with changes in some objective performance metrics (hits) from no video to video trials, as well as with changes in both included measures of subjective estimates of performance (estimated hits and correct rejections).

Another way to test whether participants consciously attribute changes in their performance to the presence of the video is by handing control of the video over to the participants, allowing them to modulate their exposure to the video. This, of course, assumes participants are motivated enough to perform the primary task well. If participants do not attribute changes in their performance to the presence of the video, one would predict that participants should not modulate their exposure to the video. If, however, participants are explicitly aware that it is the presence of the video that is leading to their poorer performance, as appears to be the case in Study 3.4, the alternative prediction is that participants should modulate their exposure to the video when the primary task is sufficiently demanding. This scenario is explored in Chapter 4.

Chapter 4: Modulation of media multitasking in response to demands of a primary task

Chapter Introduction

In real-world contexts, one key component of media multitasking is that people often have control over how and when they engage with multiple media. Recall that in the introductory example, BR is not required to listen to music or watch videos while he writes his dissertation, but chooses to do so willingly. Similarly, BR can be flexible in how he chooses to engage with his primary task (i.e., writing his dissertation) and the additional media, sometimes paying more attention to his primary task, other times perhaps being more attentive to his music, or even splitting his attention more equally between his primary task and available media. When considering many studies of multitasking performance however (e.g., Cauwenberge et al., 2014; Drews et al., 2008; Fox et al., 2009; Hancock et al., 2003; Horrey et al., 2008; Lesch & Hancock, 2004; Medeiros-Ward et al., 2014; Risko, et al., 2013; Sana et al., 2013; Strayer et al., 2003; Strayer & Johnston, 2001; Wood et al., 2012), such control is rarely given to the participants. The goal of Chapter 4 was to capture this fundamental aspect of control by again having participants complete a primary task (n-back) with a concurrently available video stream and observing how participants modulate their exposure to the video – by allowing them to turn off and on the video at their leisure – while completing a primary task.

Participants' modulation of their exposure to the non-required, task-irrelevant video is likely to depend on several factors. First, as noted in Chapter 1, engagement with concurrently available media may depend on the availability of cognitive (or perceptual) resources. When more cognitive or perceptual resources are available, individuals may allocate these free resources to the processing of task-irrelevant information, such as a simultaneously streaming video. However, when such resources become scarce, individuals may minimize their exposure to task-irrelevant information in order to avoid decrements in primary task performance. Of course, such modulation in response to task demand would also likely depend on a second factor – whether participants explicitly attribute performance declines to the presence of the simultaneously streaming video media. In Chapter 3, the presence of the video interfered with performance on a demanding task, and participants were subjectively sensitive to such changes in their performance (at least in terms of their hit rate). It also appears to be the case that participants directly attribute performing more poorly when the video is present (versus absent) to the presence of the video (Study 3.4). One clear hypothesis that follows is that participants ought to be more likely to turn the video off when the task is difficult compared to when the task is easy. Yet a third factor that might influence participants' modulation of video exposure is the benefit that participants might receive from leaving the video playing. For instance, leaving the video on during a low-demanding task may help to increase the overall difficulty of the task-context, which may assist with sustaining motivation to do well and reduce boredom. Many of the beneficial effects of listening to music have been found when workers are performing mundane, minimally demanding tasks (e.g., Fox & Embrey, 1972; Konz, 1962; Oldham et al., 1995). Kennedy, Miele, and Metcalfe (2014) have also found that participants will volitionally increase the difficulty of a computer game when the game is set too easy, but will also decrease the difficulty when it is set too hard.

Prior studies have also provided some evidence suggesting that individuals will modulate their exposure to task-irrelevant information based on the demands of a primary task. For instance, Lleras et al. (2016; see also Buetti & Lleras, 2016) found that participants modulate their oculomotor behaviour in response to task-difficulty, making less eye movements towards task-irrelevant pictures during a more difficult task (2-back) compared to an easier task (1-back). In the mind wandering literature, researchers have also found that participants mind wander less during more demanding tasks (Seli et al., 2016; Smallwood & Schooler, 2006; Rummel et al., 2016;

Thomson et al., 2013). More specifically, this reduction in mind wandering during difficult tasks can be attributed to a reduction in intentional mind wandering (Seli et al., 2016).

Building upon this literature, in Chapter 4, the paradigm used in Chapter 3 was modified in two important ways. First, the attentional demands of the primary task was manipulated by having participants complete either a low-demanding task (0-back), or high-demanding task (2-back). This created a situation in which many resources ought to be available for media multitasking (i.e., when performing the 0-back), and another situation in which relatively fewer resources ought to be available for media multitasking (i.e., when performing the 2-back). Second, participants were given control over the video, such that participants could turn the video off and on whenever they wished by pressing a button on the keyboard. The general prediction was that, if participants do attribute changes in their performance to the presence of the video, then participants should be less likely to have the video playing during the more difficult task – when the interference on the primary task should be greatest due to fewer resources being available for media multitasking – and more likely to have the video playing during an easier task – when interference from the video should be minimal due to more resources being available for media multitasking. This feature of Chapter 4 – providing participants with direct control over the presence or absence of the video – also conveniently addresses two limitations of studies described in Chapter 3, in that it allows us to further reinforce in the minds of our participants that the video is truly non-required (as was done in Study 3.4), and it eliminates potential situations whereby participants want to ignore the video but cannot. An additional interest was in capturing participants' perceptions of task demand (as in Chapter 3), their feelings of motivation to do well on the primary task, and feelings of boredom. The general notion here was that participants may choose to allow the video to play in favour of sustaining motivation and reducing boredom, possibly due to inflating the perceived demand of the task context.

Method

Participants. Three hundred and forty-two participants (90 Male, 252 Female) from the University of Waterloo completed the study in exchange for course credit.

Stimuli and Procedure. The experiment in Chapter 4 was conducted using two 'Experimental Groups' of participants. In the first group, hereafter referred to as the 'Toggle Group,' participants completed either a 0-back (i.e., a low-demanding task) or a 2-back (i.e., a high-demanding task). Task Demand (0-back vs. 2-back) was therefore manipulated between-groups. For both the 0-back and 2-back, participants viewed the same series of stimuli used in Chapter 3 (i.e., B, F, K, H, M, Q, R, X), but were only required to make a single key press in response to specific target stimuli. In the 0-back, participants were instructed to respond when the current letter was the letter 'K' but to withhold responding for all other letters. In the 2-back, participants were instructed to respond when the current letter matched the letter presented two items back, but to withhold responding if the current letter did not match the letter presented two items back. Unlike the studies reported in Chapter 3, there was no on-screen reminder of the key assignments (given that there was only one button to be pressed).

Importantly, there were also two distinct 'phases' to the experiment. In Phase 1 (i.e., the first 192 trials of either the 0-back or 2-back), participants simply completed their assigned task (0-back or 2-back). The critical manipulation occurred in Phase 2, whereby participants in the Toggle Group received a video to watch, embedded in the upper portion of the visual display, as in Chapter 3 (see Figure 4). However, while participants in Chapter 3 had no control over the video, here, participants were allowed to toggle the video on and off, thereby affording them the ability to remove the video completely from the visual display. At the beginning of Phase 2, participants received the following set of instructions:

> "The first part of the experiment is now over. For the second part of the experiment, we would like you to complete the same task as before. However, this time, you will have the opportunity to watch a video while you complete the task. There will be no test on the content of this video, it is simply for you to watch while you do the task, if you wish. The video will start playing once you begin the task again, but you may toggle the video on and off at your leisure using the 't' key (remember t for Toggle)."

At the end of each 'Task Phase' (Phase 1 and Phase 2), subjective estimates of performance were collected. While in Chapter 3 subjective estimates of hits and false alarms, or hits and correct rejections were collected, in Chapter 4, only subjective estimates of hits were collected. Estimates of false alarms were not included due to concerns that participants may have misunderstood the question (given the substantially high proportion of false alarms that participants reported). Estimates of correct rejections were also not collected as we could not compute objective correct rejections using the single-response methodology. The wording of the subjective estimate of hits item varied slightly from Chapter 3, in that participants were asked either: "What percentage of targets do you think you correctly identified on the task you just performed (i.e., 0-back)? Here, targets refer to instances of the letter 'K'."; or "What percentage of targets do you think you correctly identified on the task you just performed (i.e., 2-back)? Here, targets refer to letters that matched the letter presented two items back". Ratings of task demand were again collected using the same four items from the NASA-TLX (as in Chapter 3). In addition, two new items were included, asking participant to indicate their motivation to do well, e.g., "How motivated were you to do well on the primary task (i.e., 0-back)?" and feelings of boredom, "How bored are you right now?" For both of these items, participants responded using a 10-point scale, with responses ranging from 1 (Not Motivated At All / Not Bored At All) to 10 (Very Motivated / Very Bored)[8].

Lastly, participants complete the MMI (more specifically, the MMI-2; see Chapter 2) at the end of the experiment. This was done (a) to provide another replication of the relation between individual differences in media multitasking and performance metrics on the 2-back, given the disparity in findings between Chapter 2, Study 3.3, and Study 3.4, and (b) for exploratory purposes, to see how habitual media multitasking in everyday life relates to objective performance, subjective estimates, and modulation of the video in response to task demand.

In a second Experimental Group, hereafter referred to as the 'Control Group,' participants completed the 0-back or 2-back as above, except that participants in the Control Group did not receive a video. Instead, in Phase 2, they simply completed another 192 trials of the primary task. It is important to note that data for these participants were collected *after* data collection for the Toggle Group had finished. These participants were run in order to observe how performance, and subjective ratings of performance, task demand, motivation, and boredom, changed across Task Phase in the absence of any video stimuli, allowing for the separation of 'video' effects from 'time-on-task' effects in Phase 2 of the experiment.

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[8] Also included during Phase 2 for participants in the Toggle Groups were the following items: "How often did you watch / attend to the video?"; "How interested did you find the content of the video?"; "How boring did you find the primary task?"; "While you performed the primary task, how distracting was the video?"; and "While you performed the primary task, how often were you distracted by the video?". Four of these items, that reference the video, were omitted from the current analyses because their interpretation becomes ambiguous, given the self-selection of participants as to how long the video was left playing. The task-boredom item was omitted for brevity, as it appeared highly similar to the general boredom item.

To summarize, Chapter 4 was conducted as a 2 (Experimental Group: Toggle Group vs. Control Group) by 2 (Task Demand: 0-back vs. 2-back) by 2 (Task Phase: Phase 1 vs. Phase 2) design. Experimental Group and Task Demand was manipulated between-groups, and Task Phase was manipulated within-subjects. A visual representation of these conditions and overall procedure is presented in Figure 11.

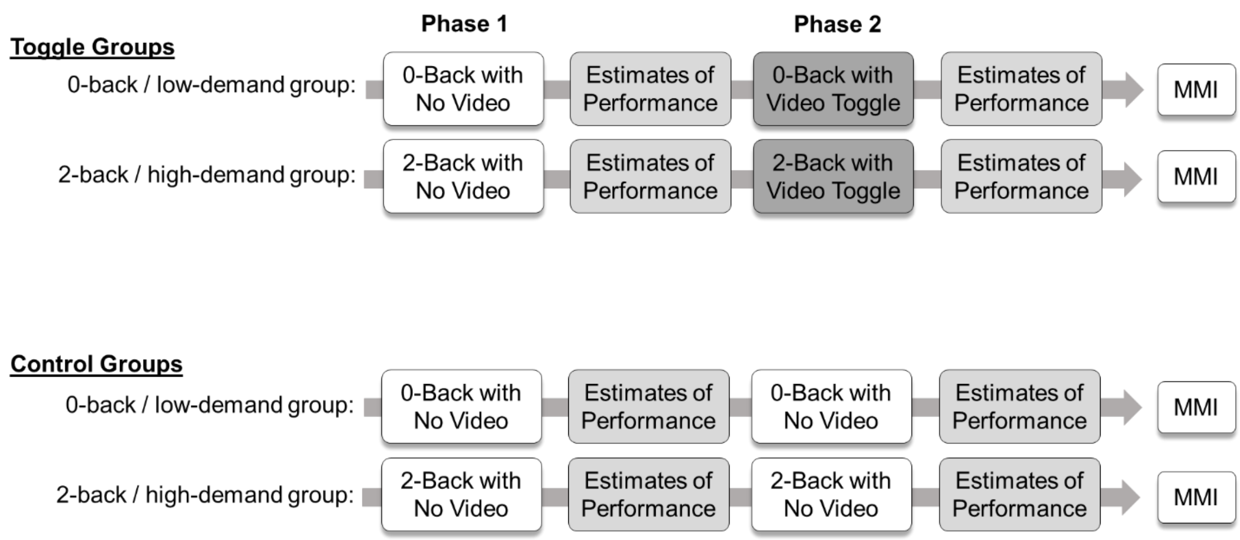

Figure 11. Visualization of task procedure in Chapter 4. The experiment was conducted as a 2 (Task Difficulty) by 2 (Task Phase) by 2 (Experimental Group) design. Task Demand (0-back vs. 2-back) was manipulated between-subjects. Task Phase (Phase 1 vs. Phase 2) was manipulated within-subjects and Experimental Group (Toggle Group vs. Control Group) was manipulated between-subjects. At the end of the experiment, all participants completed the MMI.

Results

Reported here are data from 83 participants in the Easy Toggle Group, 81 participants in the Difficult Toggle Group, 87 participants in the Easy Control Group, and 91 participants in the Difficult Control Group.

Number of Trials the Video was ON. To test whether participants modulated their exposure to the video based on the demands of the primary task, the number of trials for which the video was set in the 'ON' state (during Phase 2) was compared between the 0-back and 2-back for participants in the Toggle Group. Given the highly-skewed nature of the data (see Figure 12), a Mann-Whitney U test was used for this comparison, indicating that participants performing the 2-back (high-demanding task) were significantly less likely to watch the video than those performing the 0-back (low-demanding task), *Mean Rank* = 69.94 versus 94.76 (respectively), $p < .001$. These data suggest that participants modulated their exposure to the video in response to primary-task demand.

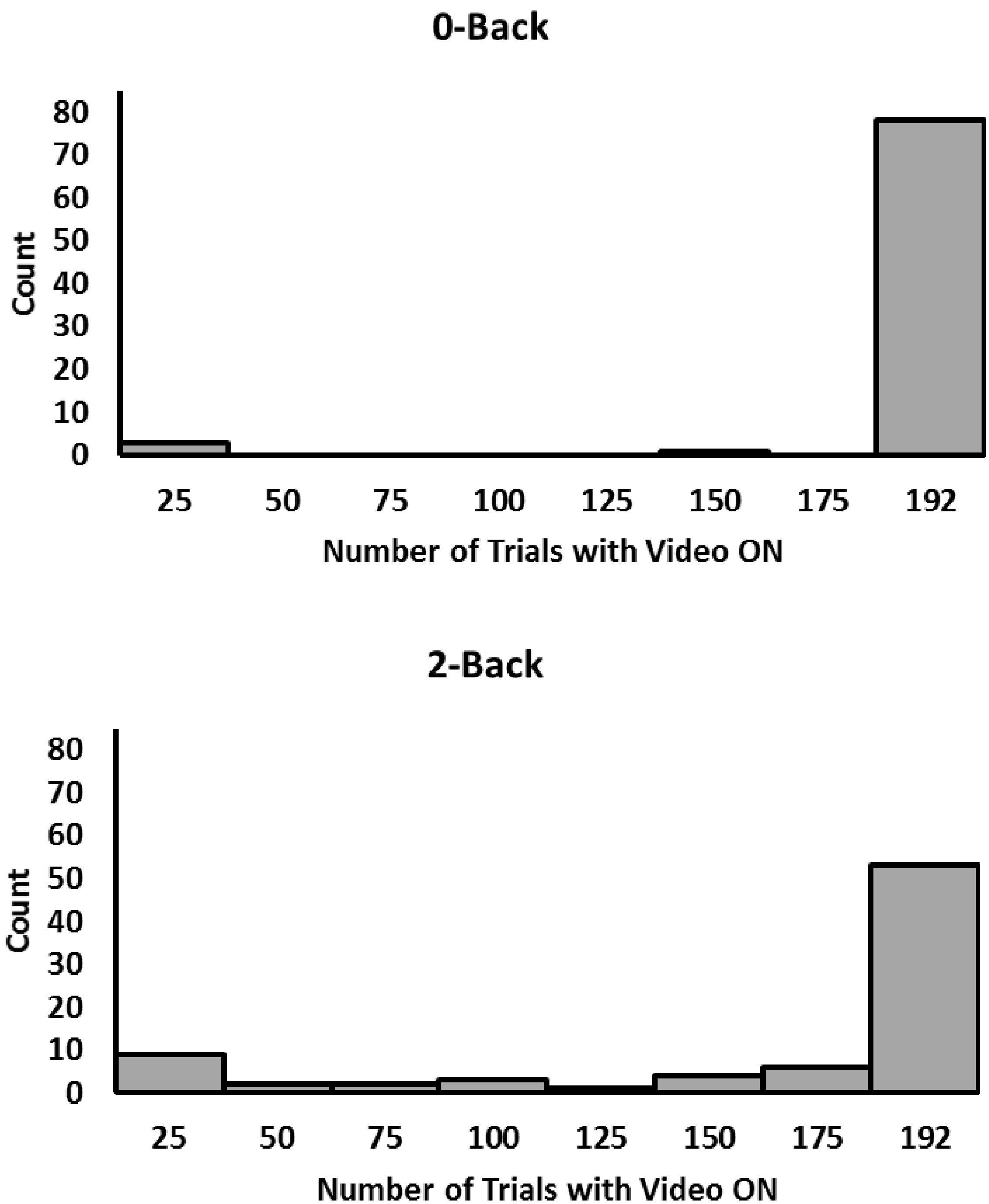

Figure 12. Histogram of the number of participants in the Toggle Groups that had the video set in the 'ON' state while performing either the 0-back (low-demanding task) or 2-back (high-demanding task). Task Demand was manipulated between-groups.

Objective Performance. Two mixed repeated-measures ANOVAs with Experimental Group (Toggle Groups vs. Control Groups) and Task Demand (0-back vs. 2-back) entered as the between-groups factors, Task Phase (Phase 1 vs. Phase 2) entered as the within-subjects factor, and either proportion hits or false alarms entered as the dependent variable.

Hits. In terms of hits, there was a main effect of Experimental Group such that participants in the Control Groups had a greater proportion of hits than those in the Toggle Groups, $F(1,338) = 17.95$, $p < .001$, $\eta^2_p = .05$ (Figure 13). As one might expect, there was also a main effect of Task Demand whereby participants performing the 0-back scored more hits than those performing the 2-back, $F(1,338) = 249.40$, $p < .001$, $\eta^2_p = .43$ (Figure 13). There was also a main effect of Task Phase on hits, such that participants generally performed better during Phase 1 (the initial phase) than Phase 2 (when approximately half of the participants could watch the video), $F(1,338) = 28.30$, $p < .001$, $\eta^2_p = .08$ (Figure 13). Perhaps most importantly, there was an Experimental Group by Task Phase interaction, $F(1,338) = 11.49$, $p = .001$, $\eta^2_p = .03$, a Task Phase by Task Demand interaction, $F(1,338) = 9.41$, $p = .002$, $\eta^2_p = .03$, and an Experimental Group by Task Demand interaction, $F(1,338) = 8.88$, $p = .003$, $\eta^2_p = .03$, all of which were qualified by the three-way Experimental Group by Task Demand by Task Phase interaction, $F(1,338) = 8.34$, $p = .004$, $\eta^2_p = .02$.

To deconstruct the three-way interaction on hits, the data were split on the Task Demand variable to compare how performance changed across phases (i.e., from Phase 1 to Phase 2) between the Toggle Groups and Control Groups, for each level of Task Demand (0-back and 2-back) separately. This facilitated determining whether: (1) there was a decline in performance with time-on-task (i.e., from Phase 1 to Phase 2); and (2) having the option to watch the video during Phase 2 negatively impacted performance over and above possible time-on-task effects. To this end, data were submitted to a mixed repeated-measures ANOVA at each level of Task Demand (0-back and 2-back) separately, with Experimental Groups (Toggle Groups vs. Control Groups) entered as the between-groups factor and Task Phase (Phase 1 vs. Phase 2) entered as the within-subjects factor. In terms of hits for the 0-back (i.e., the low-demanding task), there was a main effect of Task Phase, $F(1,168) = 5.04$, $p = .026$, $\eta^2_p = .03$, such that participants scored slightly fewer hits during Phase 2 than Phase 1, indicating a general time-on-task effect. There was no effect of Experimental Group, $F(1,168) = 2.52$, $p = .115$, $\eta^2_p = .02$, nor was there an Experimental Group by Task Phase interaction, $F(1,168) = .25$, $p = .618$, $\eta^2_p = .00$, indicating that there was no overall difference in hits between the Toggle Groups and Control Groups, and that the opportunity to engage in the optional video did not negatively impact performance on the 0-back (low-demanding task).

In terms of hits for the 2-back (i.e., the high-demanding task), there was a main effect of Task Phase such that participants scored fewer hits during Phase 2 than Phase 1, $F(1,170) = 23.65$, $p < .001$, $\eta^2_p = .12$, again indicating the presence of a time-on-task effect for 2-back / high-demanding task. There was also a main effect of Experimental Group such that those in the Toggle Group scored fewer hits than those in the Control Group, $F(1,170) = 15.57$, $p < .001$, $\eta^2_p = .08$. This was true for Phase 2, $t(170) = 4.56$, $p < .001$, wherein participants in the Toggle Group had the opportunity to watch the video while those in the Control Group did not, but also for Phase 1, $t(170) = 2.45$, $p = .015$, indicating the existence of general group differences in a period where there was, experimentally, no difference in the task procedure. Importantly, however, there was a significant Experimental Group by Task Phase interaction, $F(1,170) = 13.26$, $p < .001$, $\eta^2_p = .07$, whereby the change in hits from Phase 1 to Phase 2 was greater for the Toggle Group than the

Control Group. The opportunity to engage in the optional video therefore had a negative impact on hits in the 2-back (high-demanding task).

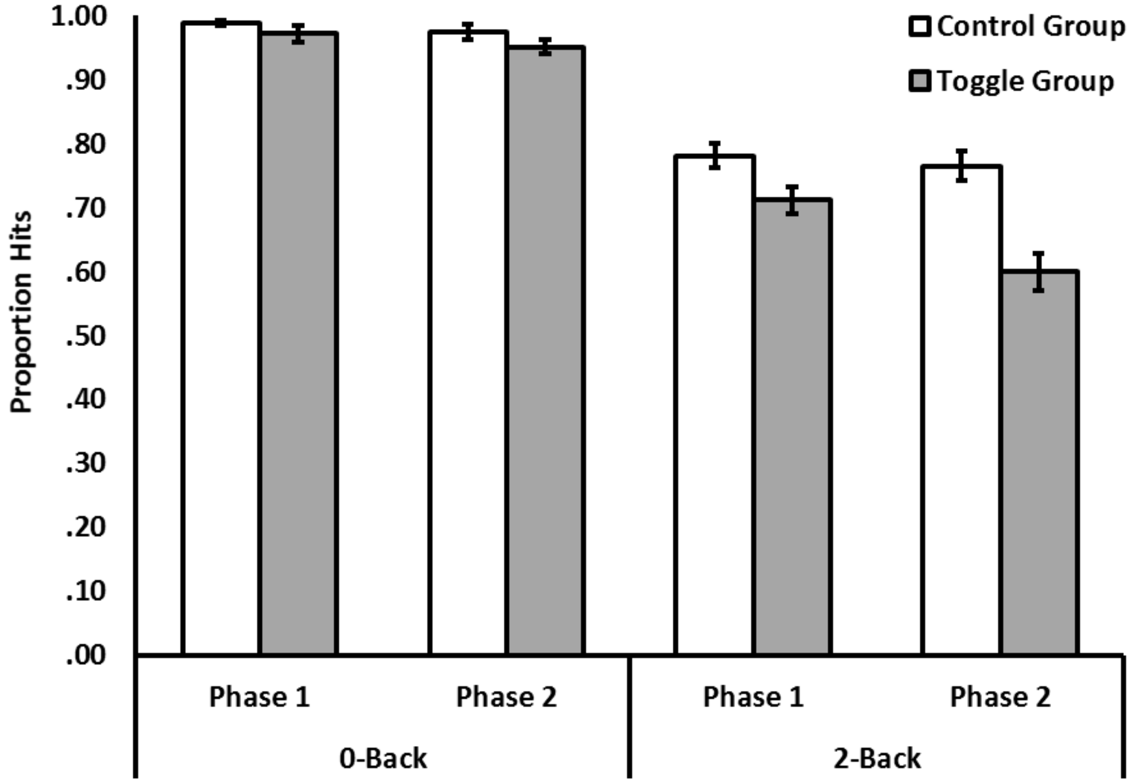

Figure 13. Proportion hits by Experimental Group (Control Group vs. Toggle Group), Task Demand (0-back vs. 2-back) and Task Phase (Phase 1 vs. Phase 2). Error bars represent one standard error of the mean.

False alarms (FA). In terms of false alarms, there was a main effect of Experimental Group whereby participants in the Control Groups had fewer false alarms (i.e., better performance) than participants in the Toggle Groups, $F(1,338) = 5.45$, $p = .020$, $\eta^2_p = .02$ (Figure 14). There was also a main effect of Task Demand, $F(1,338) = 106.48$, $p < .001$, $\eta^2_p = .24$, such that participants performing the 0-back (low-demanding task) had significantly fewer false alarms than participants performing the more 2-back (high-demanding task; see Figure 14). There was also a main effect of Task Phase on false alarms, $F(1,338) = 29.77$, $p < .001$, $\eta^2_p = .08$, such that false alarms were lower in Phase 2 compared to Phase 1 (Figure 14). Unlike hits, there was no three-way interaction between Experimental Group, Task Demand, and Task Phase, $F(1,338) = 1.26$, $p = .262$, $\eta^2_p = .00$, nor was there an Experimental Group by Task Phase interaction, $F(1,338) = 2.42$, $p = .12$, $\eta^2_p = .01$. There was, however, a Task Phase by Task Demand interaction, $F(1,338) = 21.34$, $p < .001$, $\eta^2_p = .06$, as well as an Experimental Group by Task Demand interaction, $F(1,338) = 4.41$, $p = .037$, $\eta^2_p = .01$ (see Figure 14).

Decomposing the Task Phase by Task Demand interaction in false alarms, the data were split on the Task Demand variable and false alarms were compared across Task Phase via a repeated-measures ANOVA. The reduction in false alarms from Phase 1 to Phase 2 was significant for participants completing the 2-back / high-demanding task, $F(1,171) = 25.78$, $p < .001$, $\eta^2_p = .13$, as well as for participants completing the 0-back / low-demanding task, $F(1,169) = 4.51$, $p = .035$, $\eta^2_p = .03$ (as shown in Figure 14). Evidently, as indicated by the interaction, this reduction in false alarms from Phase 1 to Phase 2 must be larger for one group (2-back) than the other (0-back).

To follow-up the Experimental Group by Task Demand interaction, the data were split on the Task Demand variable and false alarms were compared between the Toggle Group and Control Group. False alarm data were submitted to a univariate ANOVA, with Experimental Group entered as the between-groups variable. In terms of false alarms on the 2-back, false alarms were higher in the Toggle Group than Control Group, $F(1,170) = 5.08$, $p = .025$, $\eta^2_p = .03$ (see Figure 14). In contrast, there was no significant difference in false alarms between the Toggle and Control Group for participants who completed the 0-back, $F(1,168) = .61$, $p = .44$, $\eta^2_p = .00$.

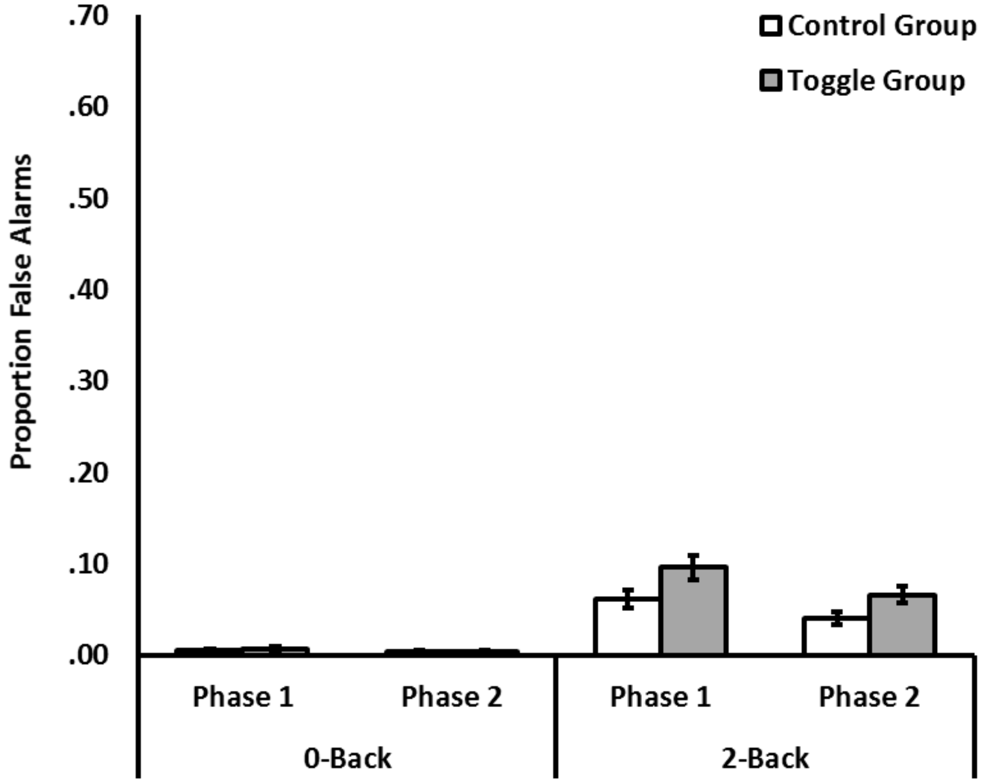

Figure 14. Proportion false alarms by Experimental Group (Control Group vs. Toggle Group), Task Demand (0-back vs 2-back) and Task Phase (Phase 1 vs. Phase 2). Error bars represent one standard error of the mean.

Subjective Estimates of Performance. To determine whether subjective estimates of hits matched the pattern of results observed in objective hits, estimated hit data were submitted to a mixed repeated-measures ANOVA with Experimental Group (Toggle Group vs. Control Group) and Task Demand (0-back vs. 2-back) entered as the between-groups variables and Task Phase (Phase 1 vs. Phase 2) entered as the within-subjects variable (see Figure 15). There was a main effect of Experimental Group on estimated hits such that participants in the Toggle Groups reported their hits to be lower than those in the Control Groups, $F(1,336) = 16.24$, $p < .001$, $\eta^2_p = .05$. Estimated hits also varied as a function of Task Demand, such that participants performing the 2-back (i.e., high-demanding task) reported their hits to be lower than those performing the 0-back (i.e., low-demanding task), $F(1,336) = 333.71$, $p < .001$, $\eta^2_p = .50$. Furthermore, there was a main effect of Task Phase on estimated hits such that participants judged their hits to be lower in Phase 2 than Phase 1, $F(1,336) = 48.57$, $p < .001$, $\eta^2_p = .13$. There was no Task Phase by Task Demand interaction, $F(1,336) = .01$, $p = .918$, $\eta^2_p = .00$, nor was there a significant Experimental Group by Task Demand interaction, $F(1,336) = 3.08$, $p = .08$, $\eta^2_p = .01$. There was, however, a significant Experimental Group by Task Phase interaction, $F(1,336) = 49.46$, $p < .001$, $\eta^2_p = .13$. Unlike objective hits, the three-way interaction of Experimental Group by Task Difficult by Task Phase was non-significant, $F(1,336) = 1.07$, $p = .301$, $\eta^2_p = .00$.

To explore the Experimental Group by Task Phase interaction, the data was split on the Experimental Group variable and estimated hits were compared across Task Phase, for the Toggle Groups and Control Groups separately. In the Toggle Groups, estimated hits were lower in Phase 2 than Phase 1, $F(1,162) = 80.82$, $p < .001$, $\eta^2_p = .33$, whereas in the Control Groups, estimated hits did not change over time / across task phase, $F(1,176) = .01$, $p = .94$, $\eta^2_p = .00$. This pattern of results suggests that when participants performed either the 0-back (low-demanding task) or 2-back (high-demanding task alone) alone (i.e., without the presence of the video), their subjective estimates of their performance did not change over time / across task phases. However, when the video was made available in Phase 2 for the Toggle Groups, participants reported their hits to be lower in Phase 2 – when the video was available – than Phase 1 (the initial phase).

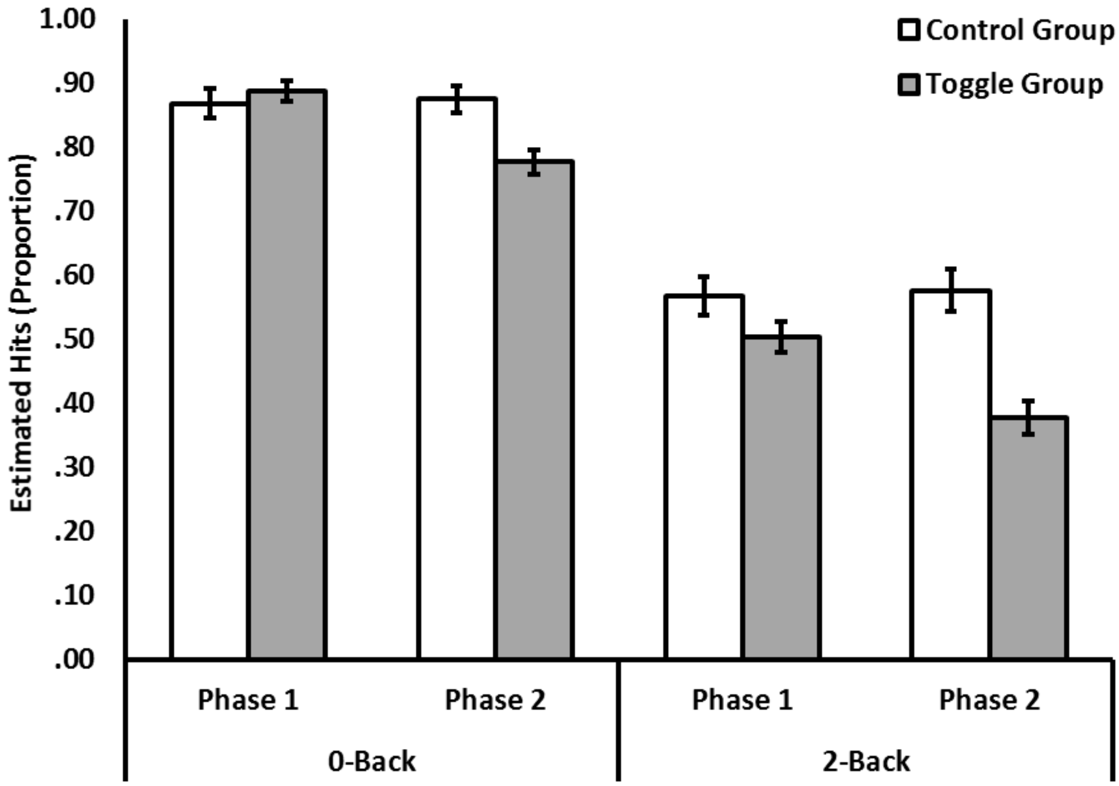

Figure 15. Subjective estimates of hits by Experimental Group (Toggle Group vs. Control Group), Task Demand (0-back vs. 2-back) and Task Phase (Phase 1 vs. Phase 2). Error bars represent one standard error of the mean.

Correlation between Objective and Subjective Estimates of Performance. To evaluate whether participants could accurately monitor changes in their performance (hits), differences in objective hits between Phase 1 and Phase 2 were correlated with differences in subjective estimates of hits between Phase 1 and Phase 2. Table 10 displays these correlations as a function of Experimental Group (Toggle Groups vs. Control Groups) and Task Demand (0-back vs. 2-back). As can be seen in Table 10, changes in objective hits were found to be positively correlated with changes in subjective estimates of hits, primarily in the 2-back (both Toggle and Control groups), but also to a lesser extent in the 0-back (Toggle Group only). The correlation of objective and subjective hits was significantly greater for participants performing the 2-back in the Toggle Group compared to participants performing the 2-back in the Control Group, $z = 2.71$, $p = .007$, and compared to participants performing the 0-back in the Toggle Group, $z = 3.64$, $p < .001$. For participants completing the 0-back, this correlation was not significantly different between the Toggle and Control Group, $z = 1.55$, $p = .121$ (all of which were two-tailed; as per Preacher, 2002).

Table 10. Correlations of changes in objective hits with changes in subjective estimates of hits between Phase 1 and Phase 2.

		Task Difficulty	
		0-back	2-back
Experimental Group	Toggle Group	$r(81) = .282$, $p = .010$	$r(78) = .702$, $p < .001$
	Control Group	$r(84) = .047$, $p = .669$	$r(89) = .421$, $p < .001$

Ratings of Task Demand. Subjective ratings of task demand, computed by averaging responses to the four included items of the NASA-TLX, were submitted to a mixed repeated-measures ANOVA with Experimental Group (Toggle Groups vs. Control Groups) and Task demand (0-back vs. 2-back) entered as the between-groups variables and Task Phase (Phase 1 vs. Phase 2) entered as the within-subjects variable (see Figure 16). There was a main effect of Experimental Group such that participants in the Toggle Groups reported the primary task to be more demanding than participants in the Control Groups, $F(1,338) = 6.91$, $p = .009$, $\eta^2_p = .02$. A main effect of Task Demand on subjective ratings of task demand also validated the anticipated difference in difficulty between conditions, such that participants performing the 2-back rated the task to be more demanding than participants performing the 0-back, $F(1,338) = 216.22$, $p < .001$, $\eta^2_p = .39$. A main effect of Task Phase also indicated that participants reported the task to be more demanding in Phase 2 than Phase 1, $F(1,338) = 25.96$, $p < .001$, $\eta^2_p = .07$. Lastly, there was an Experimental Group by Task Phase interaction, $F(1,338) = 26.45$, $p < .001$, $\eta^2_p = .07$, a Task Demand by Task Phase interaction, $F(1,338) = 36.60$, $p < .001$, $\eta^2_p = .10$, and an Experimental Group by Task Demand interaction, $F(1,338) = 4.45$, $p = .036$, $\eta^2_p = .01$, all of which were qualified by the three-way Experimental Group by Task Demand by Task Phase interaction, $F(1,338) = 9.28$, $p = .003$, $\eta^2_p = .03$.

Following-up on the three-way interaction, data were split on the Task Demand variable and changes in ratings of task demand as a function of Task Phase and Experimental Group were examined for the 0-back and 2-back separately. As such, ratings of task demand were submitted to a mixed repeated-measures ANOVA with Experimental Group (Toggle Group vs. Control Group) entered as the between-groups variable and Task Phase (Phase 1 vs. Phase 2) entered as the within-subjects variable. As can be seen in Figure 16, in the 2-back, ratings of task demand did not differ across Task Phase, $F(1,170) = .58$, $p = .448$, $\eta^2_p = .00$, nor Experimental Groups, F1,170) $= .16$, $p = .686$, $\eta^2_p = .00$. There was also no interaction between Experimental Groups and Task Phase for the 2-back, $F(1,170) = 2.79$, $p = .097$, $\eta^2_p = .02$. When examining ratings of task demand for the 0-back, there was a main effect of Task Phase, $F(1,168) = 51.06$, $p < .001$, $\eta^2_p = .23$, whereby Phase 2 was rated as more demanding than Phase 1 (see Figure 16). There was also a main effect of Experimental Groups, $F(1,168) = 0.54$, $p = .002$, $\eta^2_p = .05$, whereby participants in the Toggle Group rated the 0-back as more demanding than participants in the Control Group. These differences appeared to be driven by a significant Experimental Group by Task Phase interaction, $F(1,168) = 27.57$, $p < .001$, $\eta^2_p = .14$. As can be seen in Figure 16, ratings of task demand were much higher during Phase 2 for participants in the Toggle Group – which is precisely when participants in the Toggle Group had the opportunity to modulate their exposure to the optional video.

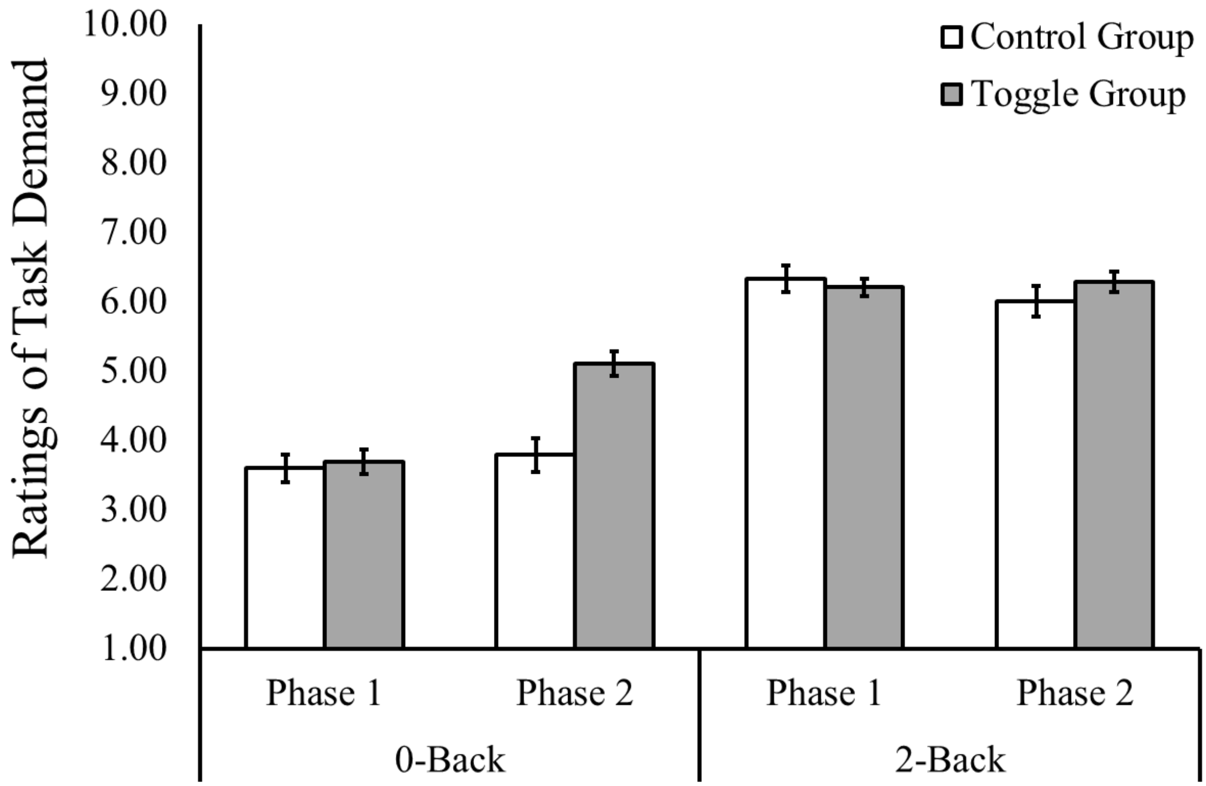

Figure 16. Ratings of task demand as a function of Experimental Group (Control Groups vs. Toggle Groups), Task Demand (0-back vs. 2-back) and Task Phase (Phase 1 vs. Phase 2). Error bars represent one standard error of the mean.

Ratings of Motivation. Ratings of motivation to do well on the primary task (0-back or 2-back) were submitted to a mixed repeated-measures ANOVA with Experimental Group (Toggle Group vs. Control Group) and Task Demand (0-back vs. 2-back) entered as the between-groups variables and Task Phase (Phase 1 vs. Phase 2) entered as the within-subjects variable (see Figure 17). There was no main effect of Experimental Group, $F(1,338) = 2.6$, $p = .106$, $\eta^2_p = .01$, nor was there a main effect of Task Demand, $F(1,338) = .63$, $p = .426$, $\eta^2_p = .00$. Ratings of motivation did appear to be higher in Phase 1 than Phase 2 (see Figure 17), as indicated by the main effect of Task Phase, $F(1,338) = 10.37$, $p = .001$, $\eta^2_p = .03$. There was no interaction between Experimental Group and Task Phase, $F(1,338) = 1.15$, $p = .285$, $\eta^2_p = .00$, Task Phase and Task Demand, $F(1,338) = 2.29$, $p = .131$, $\eta^2_p = .01$, or Experimental Group and Task Demand, $F(1,338) = 1.39$, $p = .239$, $\eta^2_p = .00$. The three-way interaction was also non-significant, $F(1,338) = 1.69$, $p = .194$, $\eta^2_p = .01$. Thus, the primary effect we saw in terms of self-reports of motivation was that motivation to do well decreased with time-on-task.

Upon visual inspection of motivation scores in Figure 17, a trend that stood out to us was that, for participants performing the easy task (0-back), motivation appeared to remain stable across Task Phase for participants in the Toggle Group, but declined across Task Phase for participants in the Control Group. To further explore this visual trend, a mixed-repeated measures ANOVA was conducted on ratings of motivation for the 0-back only, with Experimental Group (Toggle Group vs. Control Group) entered as the between-groups variable and Task Phase (Phase 1 vs. Phase 2) entered as the within-subjects variable. However, the Experimental Group by Task Phase interaction for ratings of motivation in the 0-back only was non-significant, $F(1,168) = 2.74$, $p = .100$, $\eta^2_p = .02$. Thus, although visually tempting, it appears that motivation to do well on the 0-back was not substantially influenced by the opportunity to engage with the optional video.

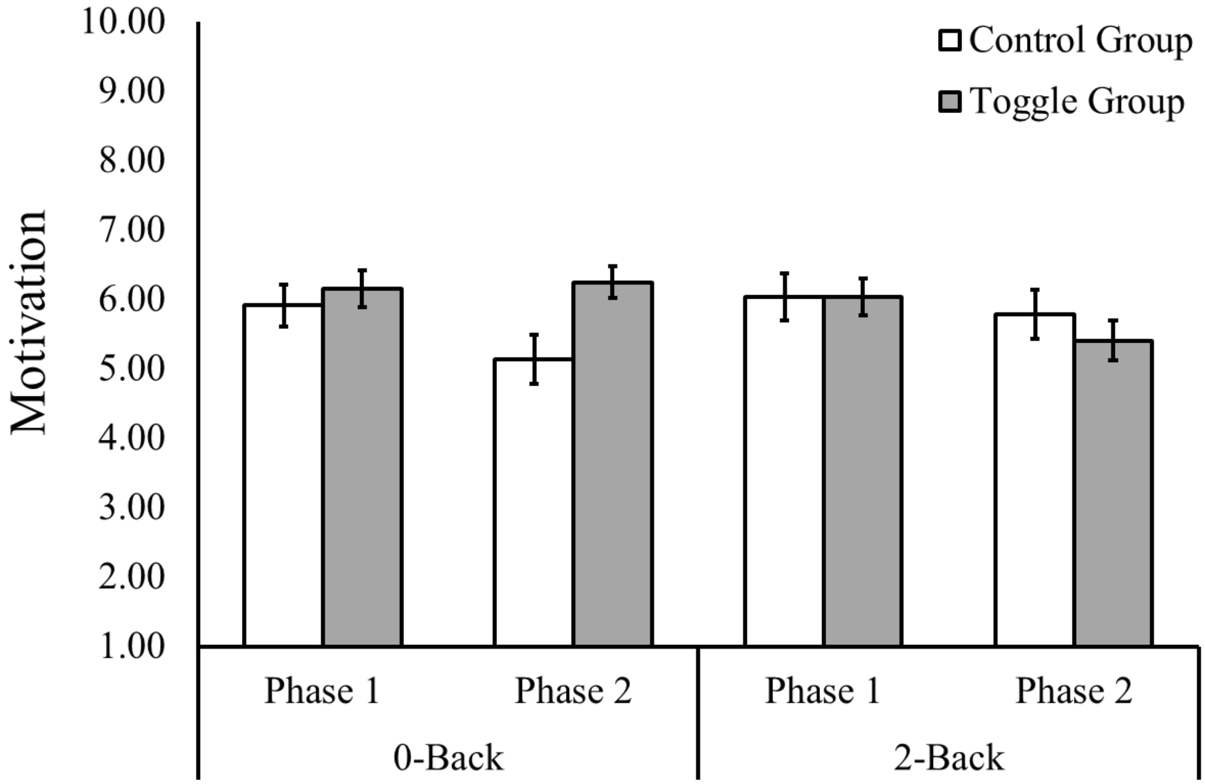

Figure 17. Ratings of motivation to do well on the primary task as a function of Experimental Group (Control group vs. Toggle group), Task Demand (0-back vs. 2-back) and Task Phase (Phase 1 vs. Phase 2). Error bars represent one standard error of the mean.

Ratings of Boredom. Like ratings of task demand and motivation, ratings of boredom were submitted to a mixed repeated-measures ANOVA with Experimental Group (Toggle Group vs. Control Group) and Task Demand (0-back vs. 2-back) entered as the between-groups variables and Task Phase (Phase 1 vs. Phase 2) entered as the within-subjects variable (see Figure 18). There was a main effect of Experimental Group such that those in the Control Groups reported being more bored than those in the Toggle Groups, $F(1,338) = 67.98$, $p < .001$, $\eta^2_p = .17$ (Figure 18). There was also a main effect of Task Demand whereby participants who performed the 0-back (i.e., low-demanding task) reported being more bored than those performing the 2-back (i.e., high-demanding task), $F(1,338) = 11.53$, $p = .001$, $\eta^2_p = .03$. In addition, there was a main effect of Task

Phase such that participants were actually *more bored* in Phase 1 than Phase 2, $F(1,338) = 27.32$, $p < .001$, $\eta^2_p = .08$. There was no interaction between Task phase and Task Demand, $F(1,338) = 2.31$, $p = .130$, $\eta^2_p = .01$, and the interaction between Experimental Group and Task Demand was only marginal, $F(1,338) = 3.38$, $p = .067$, $\eta^2_p = .01$. However, there was a significant Task Phase Experimental Group by Task Phase interaction, $F(1,338) = 53.82$, $p < .001$, $\eta^2_p = .14$, which was further qualified by the three-way Experimental Group by Task Demand by Task Phase interaction, $F(1,338) = 17.41$, $p < .001$, $\eta^2_p = .05$.

To further explore the three-way interaction on subjective ratings of boredom, data were split on the Task Demand variable to compare how ratings of boredom changed across Task Phase (Phase 1 vs. Phase 2) between the Control Group and Toggle Group, for each level of Task Demand (0-back and 2-back) separately. In terms of boredom ratings on the 0-back / low-demanding task, there was a main effect of Experimental Group, $F(1,168) = 66.52$, $p < .001$, $\eta^2_p = .28$, whereby participants in the Control Group reported being more bored than participants in the Toggle Group (Figure 18). There was also a main effect of Task Phase, $F(1,168) = 24.07$, $p < .001$, $\eta^2_p = .13$, whereby participants were more bored during Phase 1 than Phase 2. The interaction between Experimental Group and Task Phase on the 0-back was also significant, $F(1,168) = 70.05$, $p < .001$, $\eta^2_p = .29$. Subjective ratings of boredom were further split on the Experimental Group variable to examine how ratings of boredom changed from Phase 1 to Phase 2 for the Control Group and Toggle Group separately. For participants in the Control Group (performing the 0-back), ratings of boredom *increased* from Phase 1 to Phase 2, $F(1,86) = 7.35$, $p = .008$, $\eta^2_p = .08$ (see Figure 18). However, for participants in the Toggle Group (performing the 0-back), ratings of boredom *decreased* from Phase 1 to Phase 2, $F(1,82) = 73.41$, $p < .001$, $\eta^2_p = .47$. This is quite interesting because it indicates that, while boredom tends to increase with time-on-task when performing the 0-back alone, the addition of the optional video in Phase 2 drastically decreased boredom for those in the Toggle Group.

Changes in boredom ratings from Phase 1 to Phase 2 as a function of Experimental Group (Toggle Group vs. Control Group) were next examined in the context of the 2-back / high-demand task. There was a main effect of Experimental Group, $F(1,170) = 16.67$, $p < .001$, $\eta^2_p = .09$, such that participants in the Control Group reported being more bored than participants in the Toggle Group (see Figure 18). There was also a main effect of Task Phase, $F(1,170) = 6.52$, $p = .012$, $\eta^2_p = .04$, whereby participants reported being more bored in Phase 1 than Phase 2, as well as an Experimental Group by Task Phase interaction, $F(1,170) = 4.75$, $p = .03$, $\eta^2_p = .03$. To follow-up on this interaction, data were further split on the Experimental Group variable and ratings of boredom were compared between Phase 1 and Phase 2 for the Control Group and Toggle Group separately. For participants in the Control Group (performing the 2-back), ratings of boredom did not change between Phase 1 and Phase 2, $F(1,90) = .10$, $p = .748$, $\eta^2_p = .00$. However, for participants in the Toggle Group (performing the 2-back), ratings of boredom were significantly lower in Phase 2 – when the optional video was available – than Phase 1, $F(1,80) = 8.05$, $p = .006$, $\eta^2_p = .09$. Thus, the opportunity to engage with the optional video also appears to reduce boredom in the more attentionally demanding task (i.e., 2-back).

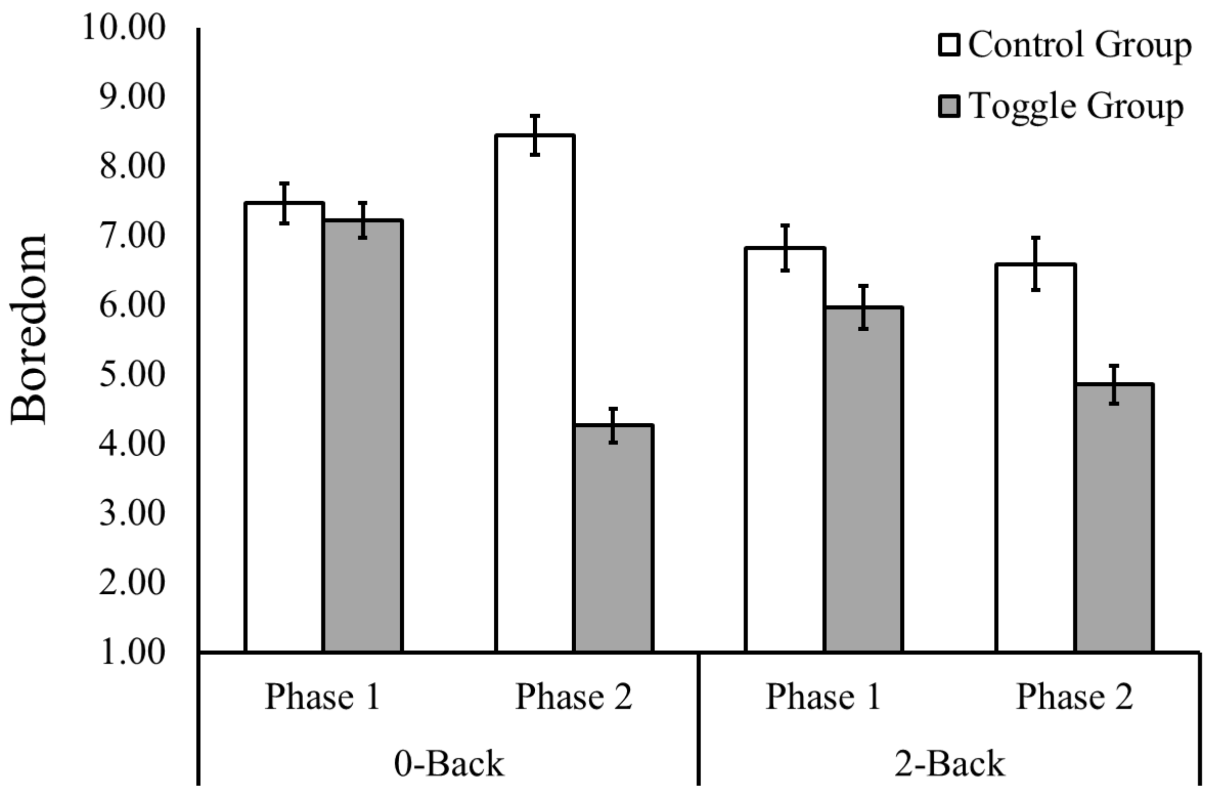

Figure 18. Ratings of boredom as a function of Experimental Group (Control Group vs. Toggle Group), Task Demand (0-back vs. 2-back) and Task Phase (Phase 1 vs. Phase 2). Error bars represent one standard error of the mean.

Individual Differences in Media Multitasking (MMI-2 Scores). Before concluding, I also report upon the relation between scores on the MMI-2 and the main performance metrics (hits and false alarms), as well as subjective reports (estimated hits, ratings of task demand, motivation, and boredom) on the 2-back. The relation between scores on the MMI-2 and performance on the 0-back was omitted given the inherent lack of variability in performance variables (i.e., ceiling effects).

The correlations of scores on the MMI-2 with the aforementioned dependent variables as a function of Experimental Group (Toggle Group vs. Control Group) and Task Phase (Phase 1 vs.

Phase 2) are provided in Table 11. As evident in Table 11, scores on the MMI-2 were positively correlated with false alarms across the board, replicating the relation between MMI-2 scores and false alarms observed in Chapter 2. Interestingly, the negative correlation between MMI-2 scores and hits only begins to emerge for participants in the Toggle Group – particularly during Phase 2 when the video was available. Perhaps aiding to interpreting this finding, individuals who scored higher on the MMI-2 (i.e., heavier trait-level media multitaskers) were also more likely to leave the video on during Phase 2, $r_s(79) = .34$, $p = .002$. Thus, it might be that scores on the MMI-2 negatively correlate with hits in Phase 2 for the Toggle Group because heavier media multitaskers (higher scorers on the MMI-2) are also more likely to watch the video while performing the 2-back. However, it is unclear why we observed a negative correlation between scores on the MMI-2 and hits in Phase 1 of the Toggle Group and not the Control Group.

Table 11 also presents a series of correlations between scores on the MMI-2 and our aforementioned self-report measures. The main finding in terms of the relation between habitual media multitasking, as indexed by scores on the MMI-2, and subjective experiences during the 2-back, is that heavier media multitaskers report performing more poorly in terms of fewer hits, but also report being less motivated to do well. There is, however, considerable variability to these findings, as the relation between MMI-2 scores and estimated hits was not found for the Control Group, which is particularly problematic for Phase 1 wherein there were no differences between Experimental Groups. The relation between MMI-2 scores and motivation is also found in Phase 2 for the Toggle Group (when the video was available), but also for Phase 1 of the Control Group. The likely explanation for much of this variability in significant correlations between scores on the MMI-2 and self-report measures is the small sample size used here. Perhaps with a substantially larger sample size, as used in Chapter 2, we may find more consistent relations.

Table 11. Correlation of MMI-2 scores with objective performance on the 2-back (hits, false alarms) and self-reports (estimated hits, task demand, motivation, and boredom) by Experimental Group (Control vs. Toggle Group) and Task Phase (Phase 1 vs. Phase 2).

	Control Group		Toggle Group	
	Phase 1	Phase 2	Phase 1	Phase 2
Hits	-.05	-.15	-.25*	-.35**
False Alarms	.22*	.22*	.42***	.40***
Estimated Hits	-.06	-.07	-.32**	-.34**
Task Demand	-.06	-.07	-.02	-.06
Motivation	-.21*	-.19	-.15	-.26*
Boredom	.19	.09	.24*	.07

*$p < .05$, **$p < .01$, ***$p \leq .001$

General Discussion

The primary goal of Chapter 4 was to see whether participants would actively modulate the presence and absence of the video in response to the task environment. Recall that in Chapter 3, it was found that the presence of the non-required, task-irrelevant video disrupted performance on an attentionally demanding primary task (i.e., 2-back). As well, participants reported their performance to be lower when the video was present versus absent, and explicitly attributed drops in their performance to the presence of the video. With these findings in mind, in Chapter 4 it was hypothesized that, if participants explicitly attribute shifts in their performance to the presence or absence of the video, then participants should be more likely to turn the video off when performing a high-demanding task (i.e., 2-back) – where interference ought to be the greatest due to less available cognitive resources – than when performing low-demanding task (i.e., 0-back) – where interference ought to be minimal due to cognitive resources being more readily available. Consistent with this hypothesis, participants completing the 2-back (i.e., high-demanding task) watched the video for significantly less time than participants completing the 0-back (i.e., low-demanding task).

The finding that participants modulate the presence of an optional video in response to task demand fits well with observations of how mind wandering operates as a function of task demand. Recall that in the mind-wandering literature, participants mind wander less during more demanding tasks (e.g., Rummel et al., 2016; Seli et al., 2016; Thomson et al., 2013; see also Smallwood & Schooler, 2006). More specifically, participants mitigate their *intentional* mind wandering when the demands of a primary task are high (Seli et al., 2016). Here, we find that participants actively remove the video from the visual display, when the demands of a primary task are high, but readily engage with the video (i.e., leave the video playing) when the demands of the primary task are low. Considered together, it may be the case when the attentional demands of a primary task are low and sufficient cognitive resources are available, individuals may 'make-use' of these available resources by deploying them towards other activities. Sometimes, individuals may turn these resources inward towards task-unrelated thought (i.e., mind wandering). Other times, individuals may deploy these resources towards external, task-unrelated streams of information – for example, towards available media. Thus, media multitasking may be a close cousin to mind wandering, in that both may reflect the deployment of available cognitive resources – outwardly when media multitasking and inwardly when mind wandering.

In terms of the impact of the video on performance during the 2-back / high-demanding task, findings from Chapter 4 extended those of Chapter 3 by demonstrating that, even when participants had the ability to turn off and remove the video completely from the visual display completely, the opportunity to engage with the non-required video interfered with performance on the 2-back. While it is true that participants were more likely to turn the video off in the more demanding 2-back condition, several participants continued to watch the video. One possibility is that some participants may have felt confident in their ability to multitask (i.e., perform the 2-back while watching the video), and thus opted to leave the video on. However, subjective reports of such beliefs were never collected, so I cannot do more than speculate on the matter. Another possibility, however, is that individuals may have knowingly opted to sacrifice their performance in favour of affective benefits – such as reducing boredom. This is likely to be the case for several reasons. First, overall, participants performing the 2-back with the video available (i.e., during Phase 2) subjectively estimated their performance (hits) to be lower than when they performed the task without the video (i.e., Phase 1), and lower than what one might expect from general time-on-task effects (as indexed in the Experimental Group by Task Phase interaction). Second, changes in objective hits between Phase 1 and Phase 2 were highly positively correlated with changes in subjective estimates of hits between Phase 1 and Phase 2, suggesting that participants were able to successfully track relative changes in their performance. Lastly, and perhaps most importantly, ratings of boredom were found to be lower when the video was available (in Phase 2) than when the video was not available (in Phase 1). Taken together, this constellation of findings seems to point towards a willful sacrifice of performance for the benefit of reducing boredom while performing the task.

In Chapter 4, there is also evidence supporting the notion that in certain situations, people might be able to media multitask without a cost to performance. In particular, it was found that having the video playing during the 0-back (i.e., low-demanding task) did not lead to substantial costs to performance as it did for the 2-back (i.e., high-demanding task). Presumably, the 0-back requires a minimal commitment of perceptual and cognitive resources, and so plenty are left-over to devote towards other activities, such as mind wandering or watching a video. In fact, simultaneously watching the video while performing the low-demanding task (0-back) appeared to be more beneficial than harmful, in that participants reported being less bored. This general pattern of results also fits with prior literatures documenting a beneficial effect of listening to music while performing low-demanding tasks (e.g., Fox & Embrey, 1972; Konz, 1962; Oldham et al., 1995), or having a television program running in the background (e.g., Lin et al., 2009; albeit during a reading comprehension task).

The finding that in the 0-back / low-demanding task, the opportunity to engage with the optional video led to increased reports of task demand and reduced boredom, might also be understood from the vantage point of the literature examining the state of *Flow* (Csikszenthmihalyi, 2000; Nakamura & Csikszenthmihalyi, 2002). Generally speaking, the flow state is thought to refer to an optimal level of task-engagement wherein the perceived demand of a task is matched with the individual’s ability to perform the task. That is, flow is experienced when the task difficulty is neither too far below an individual’s skill level, nor too far above. Naturally, such a zone of engagement is suggested to be quite pleasing and beneficial (e.g., Asakawa, 2010; Csikszenthmihalyi, 2000; Keller, Ringelhan, & Blomann, 2011; Nakamura & Csikszenthmihalyi, 2002), and so represents a state of engagement that ought to be actively sought out. Indeed, Kennedy, Miele, and Metcalfe (2014) recently demonstrated that participants will actively manipulate the difficultly of a primary task to their level of skill-challenge balance. Here too, it might be the case that individuals performing the low-demanding task engage with the video strategically as to artificially make the primary task more challenging, driving up their level of engagement for affective payoffs (such as reduced boredom).

Chapter 4 also included a measure of individual differences in media multitasking – the MMI, allowing for the examination of how, in yet another sample, MMI scores relate to performance metrics on an attentionally demanding cognitive task (i.e., the n-back). Consistent with findings from Chapter 2 and Study 3.4, scores on the MMI were correlated more generally with false alarms, and less so with hits. However, we did observe significant correlations between scores on the MMI and hits in one of the experimental groups (i.e., the Toggle Group) but not the other. While this can certainly be rationalized when considering the difference between the two experimental groups in Phase 2, it is more difficult to justify the relation in one group but not the other in Phase 1 where there were no procedural differences. The only apparent explanation is that the relation between MMI scores and performance metrics on cognitive tasks is quite noisy and highly variable – as there is good reason to believe based on prior literature (Alzahabi & Becker, 2013; Cain et al., 2016; Cardoso-Leite et al., 2016; Minear et al., 2013; Ophir et al., 2009; Sanbonmatsu et al., 2013; Uncapher et al., 2016). Thus, it is likely important to use generously large samples (as in Chapter 2) when trying to tie individual differences in media multitasking in everyday life to specific performance metrics of laboratory-based cognitive tasks.

Lastly, it is also worth noting that in Study 3.1, there was no between-groups effect of Video Presence on subjective estimates of hits; however, in Chapter 4, there was a between-groups effect such that participants with the opportunity to engage with the optional video (Toggle Groups) estimated their hits to be lower than participants without the video option (Control Groups). A key difference between Study 3.1 and the present study in Chapter 4 that might explain this apparent discrepancy is the opportunity to make relative judgments across No Video and Video conditions. That is, in Study 3.1, participants were never able to judge their performance with the video playing relative to when no video was playing because they were each only exposed to one of those conditions (either video present or video absent). However, in the study presented in Chapter 4, participants in the Toggle Groups had the opportunity to make judgments about their performance both during a phase in which no video was available (Phase 1), and a phase in which the video was available (Phase 2). Thus, in the present study (Chapter 4), participants in the Toggle groups were able to make relative judgments across Video and No Video conditions. As discussed in Chapter 3, one possibility is that it is difficult for participants to make precise absolute judgments about their performance (as would be required in Study 3.1). Indeed, subjective estimate data throughout Chapter 3 and Chapter 4 indicate that participants grossly under-estimate their actual performance. However, participants may be comparably better at making relative judgments about changes in their performance (as done in Studies 3.2, 3.3, 3.4, and Chapter 4).

To summarize, the study described in Chapter 4 showed that: (1) the opportunity to engage in a non-required, task-irrelevant video impairs performance on a high-demanding but not on a low-demanding cognitive task; (2) participants are generally sensitive to the interference induced by the video; (3) participants will modulate their exposure to the video based on the demands of a primary task, watching the video less when the task is high in cognitive demand and more when the task is low in cognitive demand; and (4) participants may use the video to augment the difficulty of a low-demanding task as to reduce boredom.

Chapter 5: Conclusions and Future Directions

Summary of Findings

This dissertation has sought to address three broad goals related to media multitasking and performance on attentionally demanding cognitive tasks. The first goal, addressed in Chapter 2, was to evaluate how individual differences in media multitasking relate to key performance metrics on an attentionally demanding cognitive task that has so far yielded highly variable findings (i.e., the n-back; Cain et al., 2016; Cardoso-Leite et al., 2016; Ophir et al., 2009). Importantly, the study presented in Chapter 2 improved upon the methodology used in prior research by treating individual differences in media multitasking as a continuous variable (rather than comparing extreme-groups) and utilizing a large sample of participants (in contrast to many prior studies, which have relied on very small samples; e.g., Cain et al., 2016; Cain & Mitroff, 2011; Cardoso-Leite et al., 2016; Ophir et al., 2009). Consistent with some prior work (Ophir et al., 2009) but not others (Cain et al., 2016; Cardoso-Leite et al., 2016), we found that higher trait-levels of media multitasking were associated with a greater proportion of false alarms on the n-back. Another, perhaps more important observation was made however: Higher trait-levels of media multitasking were also associated with a greater proportion of omitted trials, suggesting that heavier media multitaskers may have simply been more likely to willfully disengage from the cognitive task.

The second broad goal of this dissertation was to ascertain how the presence or absence of a video that was not intended to be a required task, and that was irrelevant to the primary task-at-hand, might influence objective performance metrics on attentionally demanding cognitive tasks as well as subjective judgments of performance (Chapter 3). Quite consistently, it was observed that the presence of the video interfered with performance on the attentionally demanding 2-back task (and 3-back in Study 3.1). When using a between-groups design (Study 3.1) wherein only some participants were exposed to the video, while others were not, we did not find that participants were sensitive to the impact of the video on performance – perhaps reflecting a difficulty in making absolute judgments of performance. On the other hand, when using a within-subjects design (Studies 3.2, 3.3, and 3.4) wherein all participants completed the task both with and without the video playing, participants were fairly good at making judgments about the difference in their performance between no video and video task segments (perhaps relying on relative assessment of performance across conditions). In addition, a large number of participants (approximately 83%) reported that the presence of the video disrupted their performance relative to when the video is absent, suggesting that they are aware of the impact of the video on performance.

Lastly, the third broad goal was to assess whether individuals would modulate their exposure to a non-required video based on the attentional-demands of a primary task, and this was examined in Chapter 4. To do so, a novel laboratory-based media multitasking paradigm was generated by giving participants direct control over the presence or absence of the optional video. When the demands of the primary task were high (i.e., 2-back) and presumably consumed a greater proportion of cognitive resources, participants were less likely to watch the video and therefore more likely to turn the non-required video off. On the other hand, when the demands of the primary task were low (i.e., 0-back) and more cognitive resources were presumably available, almost all of the participants watched the video for the duration of the task. In addition, participants' subjective reports seemed to indicate that (a) participants were again fairly good at making relative judgments about the changes in their performance between no video and video task segments, and (b) the inclusion of the video increased the overall perceived demand of the task-context and reduced boredom, particularly in the case of the low-demanding task (i.e., 0-back).

Theoretical Framework

Thus far, individual differences in media multitasking have been associated with a variety of performance differences on numerous cognitive tasks (e.g., Alzahabi & Becker, 2013; Cain et al., 2016; Cain & Mitroff, 2011; Lui & Wong, 2012; Minear et al., 2013; Ophir et al., 2009; Sanbonmatsu et al., 2013, Uncapher et al., 2016). Despite a number of mixed findings, the over-arching trend seems to be that heavier media multitasking is associated with poorer performance (e.g., see Cain et al., 2016; Cain & Mitroff, 2011; Minear et al., 2013; Ophir et al., 2009; Sanbonmatsu et al., 2013). One way that these findings might be interpreted is that the tendency to media multitask may be associated with differences in cognitive ability. Such a perspective is referred to in Chapter 2 as an *ability hypothesis of media multitasking*. As Cain et al. (2016) write, for instance, "… [it is] precisely those executive functions that would be most useful for repeatedly switching focus [that] are inversely correlated with habitual simultaneous media consumption." The implication is that habitual media multitasking may change particular cognitive processes over time, or alternatively, that individuals lacking in certain cognitive ability (such as filtering out distractions; e.g., Cain & Mitroff, 2011) may gravitate towards media multitasking.

Another consideration is that the relation between media multitasking and performance on various cognitive tasks might reflect a preference for how individuals choose to engage with the world. In Chapter 2, this line of reasoning is referred to as a *strategic hypothesis of media multitasking*. For instance, while Cain and Mitroff (2011) found that heavier media multitaskers are less likely to ignore distractors, it is unclear whether heavier media multitaskers cannot ignore such distractors, or whether they simply choose not to ignore such distractors. Similarly, although Minear et al. (2013) found that heavier media multitaskers performed more poorly on difficult Raven's Matrices problems – indexed by faster *and* less accurate responding – it is unclear whether this reflects an inability to complete the problems or task-abandonment. Relatedly, in Chapter 2, one important finding was that higher trait-level media multitaskers were more likely to media multitask *during* the actual experiment (conducted online), and were also more likely to simply omit responses to trials (despite being instructed to respond on every trial). Thus, even though a relation between media multitasking and false alarms were found after controlling for omitted trials, it still remains unclear whether that relation is driven by an inability to perform the task or whether it is a product of a willful choice to disengage from the task.

The constellation of findings presented in Chapter 4 also provides evidence that people may media multitask strategically and in an intelligent way. As Katz, Gurevitch, and Hass (1973) put it, "…people [may] bend the media to their needs more readily than the media over power them." (pg. 2). In particular, despite having direct control over the video stimuli, a fair portion of the participants (66%) completing the attentionally demanding 2-back left the video on for the duration of the task. In addition, participants reported performing more poorly during the video-enabled phase (i.e., Phase 2) than the initial Phase (Phase 1), over and above time-on-task effects. While this pattern might suggest that people are engaging in media multitasking only to their detriment, there were several additional observations to consider. Specifically, (a) participants were fairly 'well-calibrated' to relative changes in their performance between Phase 1 and Phase 2 of the task – that is, changes in subjective estimates of hits were positively correlated with changes in objective hits; and (b) participants reported being less bored after having the opportunity to engage with the video. Taken together, this array of findings seem to suggest that participants *know* the video is having a negative impact on their performance, but some leave it on anyways to make the task less boring. In other words, it seems that participants are taking more factors into consideration than just performance on the primary task when they are media multitasking; they may also be taking into account their overall emotional state and are willing to sacrifice some performance for the benefit of experiencing less boredom.

The notion that the link between media multitasking and performance on cognitive tasks might be driven by differences in strategic engagement, rather than differences in ability per se, is consistent with another aspect of the media multitasking literature looking at affective profiles among media multitaskers (e.g., Duff et al., 2015; Sanbonmatsu et al., 2013; Wilmer & Chein, 2016) and subjective reports of *why* individuals media multitask in the first place (e.g., Chang, 2016; Hwang, Kim, & Jeong, 2014; Wang & Tchernev, 2012). For instance, higher levels of habitual media multitasking have been linked with greater sensation seeking (Duff et al., 2015; Sanbonmatsu et al., 2013; Wilmer & Chein, 2016), suggesting that heavier media multitaskers have a higher threshold for engagement, requiring more stimulation to feel satisfied than individuals who tend to limit their media multitasking. In addition, when inquiring about the reasons as to why individuals choose to media multitask in the first place, researchers have found that more frequent media multitaskers are less concerned with task-efficiency (Chang, 2016; but see Hwang et al., 2014) and that they engage in media multitasking, as one might expect, for entertainment (i.e., "because it's fun"; Hwang et al., 2014) and social purposes (Chang, 2016; Cotton, 2008; Junco & Cotton, 2011; Hwang et al., 2014; Kononova & Chiang, 2015). On the whole, then, it may very well be the case that compared to lighter media multitaskers, heavier media multitaskers are more prone to boredom and will engage in additional tasks to alleviate boredom, or have other concerns (e.g., social concerns) on their mind that trump primary-task performance concerns.

Methodological Contributions

In prior work, the study of media multitasking has typically been approached from one of three methodological angles. One approach has been to consider media multitasking from an individual differences point of view. Given the inherent difficulty in tapping the behaviour directly, the individual differences approach seems reasonable in that it allows researchers to correlate the tendency to engage in media multitasking in everyday life, with performance on various laboratory-based cognitive tasks (e.g., Alzahabi & Becker, 2013; Cain et al., 2016; Cain & Mitroff, 2011; Cardoso-Leite et al., 2016; Lui & wang, 2012; Minear et al., 2013; Ophir et al., 2009; Ralph et al., 2015; Sanbonmatsu et al., 2013; Uncapher et al., 2016) and socio-affective profiles (Becker et al., 2013; Chang, 2016; Duff et al., 2015; Malivoire et al., *Under Review*; Pea et al., 2012; Ralph et al., 2014; Sanbonmatsu et al., 2013; Schutten et al., 2017; Shih, 2013; Wilmer & Chein, 2016). One weakness of such an approach, however, is the inability to infer causation. For instance, based on the correlational findings, it is unclear whether it is the tendency to media multitask that leads to poorer performance on some cognitive tasks, or differences in a cognitive ability indexed by the tasks that has led individuals to media multitask (e.g., see Cain & Mitroff, 2011). Another drawback of the individual differences approach, is that it does not capture what occurs during actual moments of media multitasking.

A second method for studying particular forms of media multitasking involves utilizing dual-task-like scenarios in which participants are required to perform two or more tasks concurrently, with performance or success being measured across all tasks (e.g., Cauwenberge et al., 2014; Drews et al., 2008; Fox et al., 2009; Hancock et al., 2003; Horrey et al., 2008; Lesch & Hancock, 2004; Medeiros-Ward et al., 2014; Risko et al., 2013; Sana et al., 2013; Strayer et al., 2003; Strayer & Johnston, 2003; Wood et al., 2012). The limitation to findings generated by this line of work is that a fundamental component of media multitasking in many real-world scenarios is lost; namely, the freedom over whether, how and when one engages with the additional media.

Yet a third methodological approach for studying media multitasking has been to take a more observational perspective, and observe participants doing activities they might normally do (such as studying), but within the confines of a laboratory-room as to allow monitoring by researcher (e.g., Brasal & Gips, 2011; Calderwood, Ackerman, & Conklin, 2014; Rosen, Carrier, & Cheever, 2013). This observational approach has great utility in that it allows for a more naturalistic observation of how and when individuals engage in media multitasking. The primary drawback of this approach, however, is that it may often be difficult to manipulate particular experimental variables, such as task demand, that could provide further insight into the behaviour.

In the work presented here, a novel laboratory-based paradigm for studying media multitasking has been developed. Importantly, the final form of the paradigm used in Chapter 4 represents a holistic picture of how media multitasking may unfold in many real-world scenarios. That is, individuals may engage with a non-required, optional media, over which they have control in terms of its presence and absence (i.e., their engagement with the media), while performing a primary task wherein performance and success are clearly measurable. In addition for allowing the measurement of objective performance on a given primary task under such conditions, the paradigm also allows for the capture of subjective experiences following moments of media multitasking, and the correlation of habitual use with aforementioned performance and subjective-experience outcomes.

Limitations

There are, of course, a few limitations to the present work that are worth noting. One limitation to the work presented here is that metacognitive beliefs about the impact of media multitasking – such as the presence of the video during the n-back – were not directly assessed in many of the studies. While subjective estimates of performance were collected following video present versus absent task segments, the fact that participants reported performing more poorly when the video was present does not necessitate that they are explicitly attributing such performance changes to the presence of the video. Indeed, it is possible that participants may judge themselves to have performed more poorly when the video was present without attributing such a decline in performance to the video itself. However, this limitation is largely mitigated by findings from Study 3.4 and Chapter 4. In Study 3.4, participants were directly asked: "To what extent did the video influence your performance on the task (n-back), relative to when you performed the task without the video?" with the ability to indicate that the video either hindered or improved performance on the primary task to various degrees. Consistent with the notion that participants explicitly attribute changes in their performance to the presence of the video, larger decreases in both objective (hits) and subjective estimates (hits and correct rejections) of performance were linked with participants reporting the video to be directly hindering their performance on the primary task. In Chapter 4, more indirect evidence was obtained, as it was reasoned that, if participants are aware and do attribute performance declines to the presence of the video, then they ought to modulate their exposure to the video in response to the demands of the primary task. While it was certainly found to be the case that participants were more likely to turn the video off when the primary task was demanding and interference was therefore most likely, in future work, the paradigm presented in Chapter 4 would benefit from the inclusion of a metacognitive probe, similar to that of Study 3.4, asking participants to report their beliefs about the influence of the optional video.

A second limitation of the present work is that only one media, one cognitive task (i.e., the n-back), and indeed one media-task combination were explored. Of course, keeping variables (e.g., video and task selection) constant across the studies reported here allowed for systematic development of methodology and unambiguous attributions of causality to manipulated variables. However, this approach naturally brings with it particular drawbacks. For example, the observed pattern of results could hinge on particular features of the video, such as how interesting the average participant found the video, or the degree to which the video engages both visual and auditory attention. Similarly, the extent to which the additional media interfered with performance on the primary task might have depended on the particular cognitive processes that were involved in the primary task. Indeed, some evidence for this comes from the current observation that the presence of a video interfered with performance on the 2-back task but not on the 0-back task.

A third limitation, one pertaining to many of the studies described in Chapter 3, was the wording of the instructions intended to construe the video as being ‘non-required.’ Recall that in Study 3.1, 3.2, and 3.3, participants were told: “…while you complete the task, there will be a video for you to watch in the upper portion of the screen. There will be no test on the content of this video, it is simply for you to watch while you do the task.” The intention was to construe the video as being ‘non-required’ since participants would not be tested on it. However, these instructions may have been ambiguous enough as to lead some participants to attend to the video as a ‘required’ component of the experiment. This limitation of Studies 3.1, 3.2, and 3.3 was mitigated by Study 3.4 and Chapter 4, wherein the same pattern of results was obtained using a differently worded set of instructions. In fact, Study 3.4 provided a direct replication of Study 3.3 while more explicitly telling participants: “…you will have the opportunity to watch a video…while you complete the task” and “There will be no test on the content of this video, and you are not required to watch it. However, you may watch the video while you do the task, if you wish." In Chapter 4, participants were similarly told: "…you will have the opportunity to watch a video while you complete the task. There will be no test on the content of this video, it is simply for you to watch while you do the task, if you wish". These instructions, together with the fact that the participants were given the option to turn the video off in Chapter 4, made it unambiguously clear that watching the video was not required.

Future Directions

The present work, particularly the development of a laboratory-based paradigm for studying media multitasking, has opened numerous avenues for future research. One avenue might be to more thoroughly assess people's metacognitive beliefs about the influence of additional, available media (e.g., a video). Given that many participants (approximately 66%) in the study presented in Chapter 4 left the video on during the attentionally demanding 2-back, it would be informative to ask participants *why* they left the video on, despite being associated with costs to performance. This would provide insight into potential benefits of the video that participants might have in mind. For instance: "Did the presence of the video make the task more enjoyable, compared to when the video was absent?" In the case of a low-demanding task (e.g., 0-back), whereby the majority of participants in the study reported in Chapter 4 left the video playing for the full duration of the task without costs to performance, it might also be informative to ask participants: "Did the presence of the video help you sustain attention on the primary task, relative to when the video was absent?" Relatedly, one could more directly asked participants if they employed any particular strategies in engaging with the video, such as actively trying to ignore the video (in cases where control is not provided; i.e., Chapter 3), or attempting to interleave attention to the video with attention to the primary task. Lastly, given that the opportunity to engage with the non-required video increased reports of task demand for the low-demanding 0-back in Chapter 4, it would be worthwhile to ask participants whether they attribute this increase in task demand to the presence of the video.

In Chapter 4, one of the nuances to the methodology was that the video started in the *on* position and participants were able to toggle it off and back-on again at their leisure. It would be worthwhile to examine whether similar findings occur when the video is conversely started in the *off* position. That is, would participants be more likely to show the initiative and turn the video on in the low-demanding 0-back than the high-demanding 2-back? Based on a partial dataset currently being collected, this seems to be the case, replicating the current pattern of results.

A third direction for future work is to extend the paradigm used here with a wider variety of media. Given that 'control' and 'choice' were highlighted as key components of media multitasking in real-world scenarios, a feasible and ecologically valid extension is to allow participants to choose between different types of media. More specifically, it would be interesting to provide participants with a choice among media that primarily involve different modalities (e.g., visual vs. auditory; video vs. music) and then examine how their choice of media corresponds with the modality of the primary task. Previous work has demonstrated, for instance, that when concurrently performed tasks tap different domain-specific resources (e.g., visuospatial vs. verbal), there will be less interference than when the concurrent tasks require the same domain-specific resource (Baddeley & Hitch, 1974; Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004; Wickens, 2008). Furthermore, in the present work, it appears that people are sensitive to changes in their performance. One clear prediction, then, is that if participants are performing an attentionally demanding visuospatial primary, they ought to be more likely to select an auditory-based media activity as to reduce interference between the media and the primary task. Likewise, if participants are performing an attentionally demanding auditory task, they ought to be more likely to select a visual-based media activity to reduce primary-task interference. Evidence for these predictions – that people will strategically choose particular task-combinations as to reduce interference – comes from work by Wang, Irwin, Cooper, and Srivastava (2015) who found that individuals were most likely to media multitask when the degree of shared-modal resources was low (i.e., cross-modal) compared to high (i.e., the same modality).

In addition to including different media in future studies, it would also be worth considering alternative cognitive tasks. As mentioned earlier, one limitation to the observed pattern of results is that they may be specific to particular features of the primary task (n-back). One distinct feature that many cognitive tasks, including the one used here, is that the pace of the experiment (e.g., the inter-stimulus-intervals) is controlled and set by the researcher. But, is such pacing relevant to many of the tasks we perform in everyday situations? It seems that in most situations, the individual is in control of how quickly and efficiently they perform their various tasks (including the writing of a dissertation). Therefore, one particular feature of a laboratory-based cognitive task that might be worth manipulating is the participants' control over task-pace. For instance, how would the opportunity to engage with an optional media influence performance and / or efficiency on a primary task if the primary task was self-paced?

Lastly, it might be worth further exploring the direct effects of motivation on media multitasking and primary-task performance. In Chapter 4, we asked participants to report how motivated they were to do well on the primary task, and found no compelling evidence that the opportunity to media multitask (i.e., watch the video while performing the n-back) influenced motivation. However, a related but slightly different issue is how manipulations of motivation to do well might influence the decision to media multitask. For instance, if participants performing the n-back were rewarded based on their level of performance (say, by monetary compensation), would they be more likely to turn the video off than participants who received no such compensation?

Concluding Remarks

Media multitasking is investigated here as engaging with superfluous media while performing a primary task. At the individual differences level (Chapter 2), it appears that higher levels of habitual media multitasking is associated with poorer performance on the n-back (as indexed by a rise in false alarms) but also a greater tendency to disengage from the task (as evidenced by a rise in omitted trials). During actual moments of media multitasking – operationalized here by allowing participants to simultaneously watch a video while performing a primary task (n-back) – the opportunity to engage with additional media appears to interfere with performance on attentionally demanding tasks (2-back; Chapter 3 and Chapter 4), despite the video being construed as non-required (at least in Chapter 4). However, the opportunity to media multitask (watch a video) did not interfere with performance on a low-demanding task (0-back; Chapter 4). Participants also appeared to be able to report relative changes in their performance between segments of the task when the video is present versus absent, generally rating their performance to be lower when the additional video is available compared to when the video is unavailable (Chapters 3 and 4). When participants were in control over the presence or absence of video media, participants performing the attentionally demanding task were more likely to turn the video off, whereas those performing the low-demanding task (wherein performance was not influenced by the presence of the video) were more likely to leave the video on. Lastly, particularly during situations of low demand, simultaneously watching a video while performing the low-demanding task appears to artificially drive-up perceived task demand and reduce boredom.

References

Alzahabi, R., & Becker, M. W. (2013). The Association between Media Multitasking, Task-Switching, and Dual-Task Performance. *Journal of Experimental Psychology: Human Perception and Performance, 39*(5), 1485-1495. Doi: 10.1037/a0031208

Armstrong, G. B., & Chung, L. (2000). Background Television and Reading Memory in Context Assessing TV Interference and Facilitative Context Effects on Encoding Versus Retrieval Processes. *Communication Research*, *27*(3), 327-352. Doi: 10.1177/009365000027003003

Asakawa, K. (2010). Flow Experience, Culture, and Well-Being: How Do Autotelic Japanese College Students Feel, Behave, and Think in Their Daily Lives? *Journal of Happiness Studies*, *11*(2), 205-223. Doi: 10.100/s10902-008-9132-3

Baddeley, A. D., & Hitch, G. J. (1974). Working Memory. In G. H. Bower (Ed.). *The psychology of learning and motivation: Advances in research and theory,* (pp. 47-90). New York: Academic.

Baddeley, A. Lewis, V., Eldridge, M., & Thomson, N. (1984). Attention and Retrieval From Long-Term Memory. *Journal of Experimental Psychology: General*, *113*(4), 518-540.

Barak, M., Lipson, A., & Lerman, S. (2006). Wireless Laptops as Means For Promoting Active Learning in Large Lecture Halls. *Journal of Research on Technology in Education, 38*(3), 245-263. Doi: 10.1080/15391523.2006.10782459

Becker, M. W., Alzahabi, R., & Hopwood, C. J. (2013). Media Multitasking Is Associated with Symptoms of Depression and Social Anxiety. *Cyberpsychology, Behavior, and Social Networking, 16*(2), 132-135. Doi: 10.1080/cyber.2012.0291

Bourke, P. A., Duncan, J., & Nimmo-Smith, I. (1996). A General Factor Involved in Dual-Task Performance Decrement. *The Quarterly Journal of Experimental Psychology, 49A*(3), 525-545. Doi: 10.1080/713755635

Brasel, S. A., & Gips, J. (2011). Media Multitasking Behavior: Concurrent Television and Computer Usage. *Cyberpsychology, Behavior, and Social Networking, 14*(9), 527-534. Doi: 10.1089/cyber.2010.0350

Buetti, S., & Lleras, A. (2016). Distractibility is a function of engagement, not task difficulty: Evidence from a new oculomotor capture paradigm. *Journal of Experimental Psychology: General*, *145*(10), 1382-1405. Doi: 10.1037/xge0000213

Button, K. S., Ioannidis, J. P., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S., & Munafò, M. R. (2013). Power failure: why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience, 14*(5), 365-376. Doi: 10.1038nrn3475

Cain, M. S., Leonard, J. A., Gabrieli, J. D. E., & Finn, A. S. (2016). Media multitasking in adolescence. *Psychonomic Bulletin & Review*, *23*(6), 1932-1941. Doi: 10.3758/s13423-016-1036-3

Cain, M. S., & Mitroff, S. R. (2011). Distractor filtering in media multitaskers. *Perception, 40*(10), 1183-1192. Doi: 10.1068/p7017

Calderwood, C., Ackerman, P. L., & Conklin, E. M. (2014). What else do college students "do" while studying? An investigation of multitasking. *Computers & Education*, *75,* 19-29. Doi: 10.1016/j.compedu.2014.02.004

Cardoso-Leite, P., Kludt, R., Vignola, G., Ma, W. J., Green, C. S., & Bavelier, D. (2016). Technology consumption and cognitive control: Contrasting action video game experience with media multitasking. *Attention, Perception, & Psychophysics, 78*(1), 218-241. Doi: 10.3758/s13414-015-0988-0.

Carrier, L. M., Cheever, N. A., Rosen, L. D., Benitez, S., & Chang, J. (2009). Multitasking across generations: Multitasking choices and difficulty ratings in three generations of Americans. *Computers in Human Behavior, 25*(2), 483-489. Doi: 10.1016/j.chb.2008.10.012

Cassidy, G., & MacDonald, R. A. (2007). The effect of background music and background noise on the task performance of introverts and extroverts. *Psychology of Music, 35*(3), 517-537. Doi: 10.1177/0305735607076444

Cauwenberge, A. V., Schaap, G., & van Roy, R. (2014). "TV no longer commands our full attention": Effects of second-screen viewing and task relevance on cognitive load and learning from news. *Computers in Human Behavior, 38*, 100-109. Doi: 10.1016/j.chb.2014.05.021

Chang, Y. (2016). Why do young people multitask with multiple media? Explicating the relationships among sensation seeking, needs, and media multitasking behavior. *Media Psychology*. Online Publication, 1-19. Doi: 10.1080/15213269.2016.1247717

Cheyne, J. A., Solman, G. J. F., Carriere, J. S. A., & Smilek, D. (2009). Anatomy of an error: A bidirectional state model of task engagement/disengagement and attention-related errors. *Cognition, 111*(1), 98-113. Doi: 10.1016/j.cognition.2008.12.009

Chinchanachokchai, S., Duff, B. R., & Sar, S. (2015). The effect of multitasking on time perception, enjoyment, and ad evaluation. *Computers in Human Behavior*, *45*, 185-191. Doi: 10.1016/j.chb.2014.11.087

Cool, V. A., Yarbrough, D. B., Patton, J. E., Runde, R., & Keith, T. Z. (1994). Experimental effects of radio and television distractors on children's performance on mathematics and reading assignments. *The Journal of Experimental Education, 62*(3), 181-194. Doi: 10.1080/00220973.1994.9943839

Craik, F. I. M., Govoni, R., Naveh-Benjamin, M., & Anderson, N. D. (1996). The Effects of Divided Attention on Encoding and Retrieval processes in Human Memory. *Journal of Experimental Psychology: General, 125*(2), 159-180. Doi: 10.1037/0096-3445.125.2.159

Csikszentmihalyi, M. (2000). *Flow: The psychology of optimal experience*. New York: Harper & Row.

Dember, W. N., Galinsky, T. L., & Warm, J. S. (1992). The role of choice in vigilance performance. *Bulletin of the Psychonomic Society*, *30*(3), 201-204. Doi: 10.3758/BF03330441

Drews, F. A., Pasupathi, M., & Strayer, D. L. (2008). Passenger and Cell Phone Conversations in Simulated Driving. *Journal of Experimental Psychology: Applied, 14*(4), 392-400. Doi: 10.1037/a0013119

Duff, B. R. L., Yoon, G., Wang, Z., & Anghelcev, G. (2014). Doing it all: An exploratory study of predictors of media multitasking. *Journal of Interactive Advertising*, *14*(1), 11-23. Doi: 10.1080/15252019.2014.884480

Fougnie, D., & Marois, R. (2007). Executive working memory load induces inattentional blindness. *Psychonomic Bulletin & Review*, *14*(1), 142-147. Doi: 10.3758/BF03194041

Fox, J. G., & Embrey, E. D. (1972). Music - an aid to productivity. *Applied ergonomics*, *3*(4), 202-205. Doi: 10.1016/00003-6870(72)90101-9

Fox, A. B., Rosen, J., & Crawford, M. (2009). Distractions, distractions: Does instant messaging affect college students' performance on a concurrent reading comprehension task? *CyberPsychology & Behavior*, *12*(1), 51-53. Doi: 10.1089/cpb.2008.0107

Furnham, A., & Bradley, A. (1997). Music while you work: The differential distraction of background music on the cognitive test performance of introverts and extraverts. *Applied Cognitive Psychology*, *11*(5), 445-455. Doi: 10.1002/(SICI)1099-0720(199710)11:5<445:AID-ACPA472>3.0.CO;2-R

Furnham, A., Gunter, B., & Peterson, E. (1994). Television Distraction and the Performance of Introverts and Extroverts. *Applied Cognitive Psychology*, *8*(7), 705-711. Doi:10.1002/acp.2350080708

Furnham, A., & Strbac, L. (2002). Music is as distracting as noise: the differential distraction of background music and noise on the cognitive test performance of introverts and extraverts. *Ergonomics, 45*(3), 203-217. Doi: 10.1080/00140130210121932

Furnham, A., Trew, S., & Sneade, I. (1999). The distracting effects of vocal and instrumental music on the cognitive test performance of introverts and extraverts. *Personality and Individual Differences*, *27*(2), 381-392. Doi: 10.1016/S0191-8869(98)00249-9

Gronau, N., & Izoutcheev, A. (2017). The necessity of visual attention to scene categorization: Dissociating "task-relevant" and "task-irrelevant" scene distractors. *Journal of Experimental Psychology: Human Perception and Performance, 43*(5), 954-970. Doi: 10.1037/xhp0000365

Hancock, P. A., Lesch, M., & Simmons, L. (2003). The distraction effects of phone use during a crucial driving maneuver. *Accident Analysis and Prevention, 35*(4), 501-514. Doi: 10.1016/S0001-4575(02)00028-3

Hart, S. G. (2006). NASA-Task Load Index (NASA-TLX); 20 Years Later. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 50, pp. 904-908). Thousand Oaks, CA: SAGE.

Helton, W. S., & Russell, P. N. (2013). Visuospatial and verbal working memory loads: effects on visuospatial vigilance. *Experimental Brain Research, 224*(3), 429-436. Doi: 10.1007/s00221-012-3322-2

Hembrooke, H., & Gay, G. (2003). The Laptop and the Lecture: The Effects of Multitasking in Learning Environments. *15*(1), 46-64. Doi: 10.1007/BF02940852

Horrey, W. J., Lesch, M. F., & Garabet, A. (2008). Assessing the awareness of performance decrements in distracted drivers. *Accident Analysis and Prevention, 40*(2), 675-682. Doi: 10.1016/j.aap.2007.09.004

Hsee, C. K., & Zhang, J. (2004). Distinction bias: misprediction and mischoice due to joint evaluation. *Journal of personality and social psychology, 86*(5), 680-695. Doi: 10.1037/0022-3514.86.5.680

Hwang, Y., Kim, H., & Jeong, S. (2014). Why do media users multitask? Motives for general, medium-specific, and content-specific types of multitasking. *Computers in Human Behavior, 36*, 542-548. Doi: 10.1016/j.chb.2014.04.040

Jacoby, L. L., Woloshyn, V., & Kelley, C. (1989). Becoming Famous Without Being Recognized: Unconscious Influences of Memory Produced by Dividing Attention. *Journal of Experimental Psychology: General, 118*(2), 115-125. Doi: 10.1037/0096-3445.118.2.115

Junco, R., & Cotton, S. R. (2011). Perceived academic effects of instant messaging use. *Computers & Education, 56*, 370-378. Doi: 10.1016/j.compedu.2010.08.020

Kahneman, D. (1973). Attention and Effort. Englewood Cliffs, NJ: Prentice-Hall.

Kane, M. J., Conway, A. R. A., Miura, T. K. M., & Colflesh, J. H. (2007). Working Memory, Attention Control, and the N-back Task: A Question of Construct Validity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(3), 615-622. Doi: 10.1037/0278-7393.33.3.615

Kane, M. J., Hambrick, D. Z., Tuholski, S. W., Wilhelm, O., Payne, T. W., & Engle, R. W. (2004). The Generality of Working Memory Capacity: A Latent-Variable Approach to Verbal and Visuospatial Memory Span and Reasoning. *Journal of Experimental Psychology: General, 113*(2), 189-217. Doi: 10.1037/0096-3445.133.2.189

Katz, E., Gurevitch, M., & Hass, H. (1973). On the use of the mass media for important things. *American Sociological Review, 38*(2), 164-181. Doi: 10.2307/2094393

Keller, J., Ringelhan, S., & Blomann, F. (2011). Does skills-demands compatibility result in intrinsic motivation? Experimental test of a basic notion proposed in the theory of flow-experiences. *The Journal of Positive Psychology, 6*(5), 408-417. Doi: 10.1080/17439760.2011.604041

Kennedy, P., Miele, D. B., & Metcalfe, J. (2014). The cognitive antecedents and motivational consequences of the feeling of being in the zone. *Consciousness and Cognition, 30*, 48-61. Doi:10.1016/j.concog.2014.07.007

Kirkpatrick, F. H. (1943). Take the mind away. *Personnel Journal*, 22, 225–228.

Kline, R. B. (1998). Principles and practices of structural equation modeling. New York: Guilford.

Kononova, A., & Chiang, Y. H. (2015). Why do we multitask with media? Predictors of media multitasking among Internet users in the United States and Taiwan. *Computers in Human Behavior*, *50*, 31-41. Doi: 10.1016/j.chb.2015.03.052

Konz, S. (1962). The effect of background music on productivity of two different monotonous tasks. Paper to Human Factors Society. New York.

Lang, A. (2000). The Limited Capacity Model of Mediated Message Processing. *Journal of Communication, 50*(1), 56-70. Doi: 10.1111/j.460-2466.2000.tb02833.x

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load Theory of Selective Attention and Cognitive Control. *Journal of Experimental Psychology: General*, *133*(3), 339-354. Doi: 10.1037/0096-3445.133.3.339

Lesch, M. F., & Hancock, P. A. (2004). Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? *Accident Analysis and Prevention, 36*(3), 471-480. Doi: 10.1016/S0001-4575(03)00042-3

Lesiuk, T. (2005). The effect of music listening on work performance. *Psychology of music, 33*(2), 173-191. Doi:10.1177/0305735605050650

Lin, L., Robertson, T., & Lee, J. (2009). Reading Performances Between Novices and Experts in Different Media Multitasking Environments. *Computers in the Schools, 26*(3), 169-186. Doi: 10.1080/07380560903095162

Lleras, A., Buetti, S., & Mordkoff, J. T. (2014). When do the effects of distractors provide a measure of distractibility? Definition. Definition. In B. H. Ross (Ed.),*The psychology of learning and motivation*. Elsevier Inc.: Academic Press. 261-316.

Lui, K. F. H., & Wong, A. C. N. (2012). Does media multitasking always hurt? A positive correlation between multitasking and multisensory integration. *Psychonomic Bulletin & Review, 19*(4), 647-653. Doi: 10.3758/s13423-012-0245-7.

Mack, A., & Rock, I. (1998). *Inattentional blindness* (Vol. 33). Cambridge, MA: MIT press.

Malivoire, B. L., Mazachowsky, T., & Arnell, K. M. (*Under Review*). Affect and Personality Measures Predict Media Multitasking and Texting Frequency.

Mattay, V. S., Fera, F., Tessitore, A., Hariri, A. R., Berman, K. F., Saumitra, D., …Weinberger, D. R. (2006). Neurophysiological correlates of age-related changes in working memory capacity. *Neuroscience Letters, 392*(1-2). 32-37. Doi: 10.1016/j.neulet.2005.09.025

McGehee, W., & Gardner, J. E. (1959). Music in a complex industrial job. *Personnel Psychology, 2*(4), 405-417. Doi: 10.1111/j.1744-6570-1959.tb01412.x

Medeiros-Ward, N., Cooper, J. M., & Strayer, D. L. (2014). Hierarchical Control and Driving. *Journal of Experimental Psychology: General, 143*(3), 953-958. Doi: 10.1037/a0035097

Minear, M., Brasher, F., McCurdy, M. Lewis, J., & Younggren, A. (2013). Working memory, fluid intelligence, and impulsiveness in heavy media multitaskers. *Psychonomic Bulletin & Review, 20*(6). 1274-1281. Doi: 10.3758/s13423-013-0456-6

Moray, N. (1959). Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly journal of experimental psychology*, *11*(1), 56-60. Doi: 10.1080/17470215908416289

Nakamura, J., & Csikszentmihalyi, M. (2002). The concept of flow. *Handbook of positive psychology*, 89-105.

Neisser, U., & Becklen, R. (1975). Selective looking: Attending to visually specified events. *Cognitive psychology*, *7*(4), 480-494. Doi: 10.1016/0010-0285(75)90019-5

Newman Jr, R. I., Hunt, D. L., & Rhodes, F. (1966). Effects of music on employee attitude and productivity in a skateboard factory. *Journal of Applied Psychology, 50*(6), 493-496. Doi: 10.1037/h0024046

Oberauer, K. (2005). Binding and inhibition in working memory: Individual and age differences in short-term recognition. *Journal of Experimental Psychology: General, 134*(3), 368-387. Doi: 10.1037/0096-3445.134.3.368

Oldham, G. R., Cummings, A., Mischel, L. J., Schmidtke, J. M., & Zhou, J. (1995). Listen while you work? Quasi-experimental relations between personal-stereo headset use and employee work responses. *Journal of Applied Psychology*, *80*(5), 547-563. Doi: 10.1037/0021-9010.80.5.547

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences of the United States of America (PNAS), 106*(37), 15583-15587. Doi:10.1073/pnas.0903620106

Pea, R., Nass, C., Meheula, L., Rance, M., Kumar, A., Bamford, H., … Zhou, M. (2012). Media Use, Face-to-Face Communication, Media Multitasking, and Social Well-Being Among 8- to 12-Year-Old Girls. *Developmental Psychology, 48*(2), 327-336. Doi: 10.1037/a0027030

Pool, M. M., Koolstra, C. M., & Van der Voort, T. H. A. (2003). Distraction effects of background soap operas on homework performance: An experimental study enriched with observational data. *Educational Psychology*, *23*(4), 361-380. Doi: 10.1080/01443410303211

Pool, M, M., Van der Voort, T. H. A., Beentjes, J. W. J., & Koolstra, C. M. (2000). Background television as an inhibitor of performance on easy and difficult homework assignments. *Communication Research, 27*(3), 293-326. Doi:10.1177/009365000027003002

Preacher, K. J. (2002). Calculation for the test of the difference between two independent correlation coefficients [Computer software].

Ralph, B. C. W., & Smilek, D. (2017). Individual differences in media multitasking and performance on the n-back. *Attention, Perception, & Psychophysics, 79*(2), 582-592. Doi: 10.3758/s13414-016-1260-y

Ralph, B. C. W., Thomson, D. R., Cheyne, J. A., & Smilek, D. (2014). Media multitasking and failures of attention in everyday life. *Psychological Research, 78*(5), 661-669. Doi: 10.1007/s00426-013-0523-7

Ralph, B. C. W., Thomson, D. R., Seli, P., Carriere, J. S., & Smilek, D. (2015). Media multitasking and behavioral measures of sustained attention. *Attention, Perception, & Psychophysics, 77*(2), 390-401. Doi: 10.3758/s13414-014-0771-7

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

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). Generations M [superscript 2]: Media in the Lives of 8- to 18-Year-Olds. *Henry J. Kaiser Family Foundation.*

Risko, E. F., Buchanan, D., Medimorec, S., & Kingstone, A. (2013). Everyday attention: mind wandering and computer use during lectures. *Computers & Education, 68*, 275-283. Doi: 10.1016/j.compedu.2013.05.001

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

Rummel, J., Smeekens, B. A., & Kane, M. J. (2016). Dealing With Prospective Memory Demands While Performing an Ongoing Task: Shared Processing, Increased On-Task Focus, or Both? *Journal of Experimental Psychology: Learning, memory, and Cognition.* Advanced online publication. Doi: 10.1037/xlm0000359

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

Sanbonmatsu, D. M., Strayer, D. L., Mederois-Ward, N., & Watson, J. M. (2013). Who Multi-Tasks and Why? Multi-Tasking Ability, Perceived Multi-Tasking Ability, Impulsivity, and Sensation Seeking. *PLoS ONE, 8*(1). Doi: 10.1371/journal.pone.0054402

Schutten, D., Stokes, K. A., & Arnell, K. M. (2017). I want to media multitask and I want to do it now: Individual differences in media multitasking predict delay of gratification and system-1 thinking. *Cognitive Research: Principles and Implications*, *2*(1), 8. Doi: 10.1186/s41235-016-048-x.

Seli, P., Risko, E. F., & Smilek, D. (2016). On the necessity of distinguishing between unintentional and intentional mind wandering. *Psychological Science, 27*(5), 685-691. Doi: 10.1177/0956796716634068

Shih, S-I. (2013). A Null Relationship between Media Multitasking and Well-Being. *PLoS ONE, 8*(5): e64508. Doi: 10.1371/journal.pone.0064508

Simons, D. J., & Chabris, C. F. (1999). Gorillas in our midst: sustained inattentional blindness for dynamic events. *Perception*, *28*(9), 1059-1074. Doi: 10.1068/p281059

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin, 132*(6), 946-958. Doi: 10.1037/0033-2909.132.6.946

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, *117*(1), 34-50. Doi: 10.1037/0096-3445.117.1.34

Strayer, D. L., & Drews, F. A. (2007). Cell-Phone Induced Driver Distraction. *Current Directions in Psychological Science*, *16*(3), 128-131. Doi: 10.1111/j.1467-8721.2007.00489.x

Strayer, D. L., Drews, F. A., & Crouch, D. J. (2006). A Comparison of the Cell Phone Driver and the Drunk Driver. *Human Factors*, *48*(2), 381-393.

Strayer, D. L., Drews, F. A., & Johnston, W. A. (2008). Cell Phone-Induced Failures of Visual Attention During Simulated Driving. *Journal of Experimental Psychology: Applied*, *9*(1), 23-32. Doi: 10.1037/1076-898X.9.1.23

Strayer, D. L., & Johnston, W. A. (2001). Driven to Distraction: Dual-Task Studies of Simulated Driving and Conversing on a Cellular Telephone. *Psychological Science*, *12*(6), 462-466. Doi: 10.1111/1467-9280.00386

Szalma, J. L., & Hancock, P. A. (2006, October). Performance, workload, and stress in vigilance: The power of choice. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 50, No. 16, pp. 1609-1613). Sage CA: Los Angeles, CA: Sage Publications.

Thomson, D. R., Besner, D., & Smilek, D. (2013). In pursuit of off-task thought: mind wandering-performance trade-offs while reading aloud and color naming. *Frontiers in Psychology*, *4*, 360. Doi: 10.3389/fpsyq.2013.00360

Tractinsky, N., Ram, E. S., & Shinar, D. (2013). To call or not to call – That is the question (while driving). *Accident Analysis and Prevention*, *56*, 59-70. Doi: 10.1016/j.aap.2013.03.017

Uncapher, M. R., Thieu, M. K., Wagner, A. D. (2016). Media multitasking and memory: Differences in working memory and long-term memory. *Psychonomic Bulletin & Review*, *23*(2), 483-490. Doi: 10.3758/s13423-015-0907-3

Unsworth, N., Redick, T. S., McMillan, B. D., Hambrick, D. Z., Kane, M. J., & Engle, R. W. (2015). Is playing video games related to cognitive abilities? *Psychological Science*, *26*(6), 759-774. Doi: 10.1177/0956797615570367

Vogel, E. K., McCollough, A. W., & Machizawa, M. G. (2005). Neural measures reveal individual differences in controlling access to working memory. *Nature*, *438*, 500-503. Doi: 10.1038/nature0417

Wagenmakers, E.J., Krypotos, A.M., Criss, A. H., & Iverson, G. (2012). On the interpretation of removable interactions: A survey of the field 33 years after Loftus. *Memory & Cognition*, *40*(2), 146-160. Doi: 10.3758/s13421-011-0158-0

Wang, Z., Irwin, M., Cooper, C., & Srivastava, J. (2015). Multidimensions of Media Multitasking and Adaptive Media Selection. *Human Communication Research*, *41*(1), 102-127. Doi: 10.1111/hcre.12042

Wang, Z., & Tchernev, J. M. (2012). The “Myth” of Media Multitasking: Reciprocal Dynamics of Media Multitasking, Personal Needs, and Gratifications. *Journal of Communication*, *62*(3), 493-513. Doi: 10.1111/j.1460-2466.2012.01641.x

Wickens, C. D. (2002). Multiple resource and performance prediction. *Theoretical Issues in Ergonomics Science, 3*, 159-177. Doi: 10.1080/14639220210123806

Wilmer, H. H., & Chein, J. M. (2016). Mobile technology habits: patterns of association among device usage, intertemporal preference, impulse control, and reward sensitivity. *Psychonomic Bulletin & Review*. Online First Publication. Doi: 10.3758/s13423-016-1011-z

Wood, E., Zivcakova, L., Gentile, P., Archer, K., De Pasquale, D., & Nosko, A. (2012). Examining the impact of off-task multi-tasking with technology on real-time classroom learning. *Computers & Education, 58*, 365-374. Doi: 10.1016/j.compedu.2011.08.029

Appendices

Appendix A: Chapter 2 – Demographic Questionnaire

1) Biological Gender
    - Male
    - Female
2) Age (in years):
3) What is the highest level of education you have completed?
    - Less than high school
    - High school / GED
    - Some college/university
    - 2-year college/university degree
    - 4-year college/university degree
    - Master’s degree
    - Doctoral degree
    - Professional degree (JD, MD)
4) What is your combined annual household income?
    - Less than 30,000
    - 30,000 – 39,999
    - 40,000 – 49,999
    - 50,000 – 59,999
    - 60,000 – 69,999
    - 70,000 – 79,999
    - 80,000 – 89,999

- 90,000 – 99,999
- 100,000 or more

5) Are you currently employed (outside of Mechanical Turk)?

- Yes – Full Time
- Yes – Part Time
- No

Appendix B: Chapter 2 – First Media Use Questionnaire (MMI-1)

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)

Print media: _____

Television: _____

Computer-based video (e.g., YouTube): _____

Music: _____

Non-music audio: _____

Video/Computer Games: _____

Telephone/Cell phone voice calls: _____

Instant messaging: _____

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.

Please use the following number scheme:

0 = "Never"

1 = "A little of the time"

2 = "Some of the time"

3 = "Most of the time"

	Print Media	Television	Computer-based Video	Music	Non-music Audio	Vide/Computer games	Phone/cellphone voice calls	Instant messaging	Text-messaging	Email	Web surfing	Computer Applications
Print media												
Television												
Computer-based video												
Music												
Non-music Audio												
Video/computer games												
Phone/cell voice calls												
Instant messaging												
Text-messaging												
Email												
Web surfing												
Computer applications												

Appendix C: Chapter 2 – Second Media Use Questionnaire (MMI-2)

Q1.1 On an average day, how many hours do you spend talking face-to-face with a person? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0.

Q1.2 While you are talking face-to-face with a person, what percentage of time are you also doing each of these other activities? Please use the sliders do indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ 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 TV and Movies (online and off-line) or YouTube

______ Playing video games or online games

______ Doing homework/studying/writing papers

______ Talking face-to-face with a second person

Q2.1 On an average day, how many hours do you spend using print media (including print books, print newspapers, etc.)? 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 using print media, what percentage of time are you also doing each of these other activities? Please use the sliders to indicate the percentage of time.

______ Using a second print medium (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ 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 TV and Movies (online and off-line) or YouTube

______ Playing video games or online games

______ Doing homework/studying/writing papers

______ Talking face-to-face with a person

Q3.1 On an average day, how many hours do you spend texting, instant messaging, or emailing? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0.

Q3.2 While you are texting, instant messaging, or emailing, what percentage of time are you also doing each of these other activities? Please use the sliders to indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Having a second texting, instant messaging, or email session

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ 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 TV and Movies (online and off-line) or YouTube

______ Playing video games or online games

______ Doing homework/studying/writing papers

______ Talking face-to-face with a person

Q4.1 On an average day, how many hours do you spend using social sites (e.g., Facebook, Twitter, etc., except games)? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0.

Q4.2 While you are Using social sites (e.g., Facebook, Twitter, etc., except games), what percentage of time are you also doing each of these other activities? Please use the sliders to indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using a second social site (e.g., Facebook, Twitter, etc., except games)

______ 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 TV and Movies (online and off-line) or YouTube

______ Playing video games or online games

______ Doing homework/studying/writing papers

______ Talking face-to-face with a person

Q5.1 On an average day, how many hours do you spend using non-social text-oriented sites (e.g., online news, blogs, eBooks)? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0.

Q5.2 While you are using non-social text-oriented sites (e.g., online news, blogs, eBooks), what percentage of time are you also doing each of these other activities? Please use the sliders to indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ Using a second non-social text-oriented site (e.g., online news, blogs, eBooks)

______ Talking on the telephone or video chatting (e.g., Skype, iPhone video chat)

______ Listening to music

______ Watching TV and Movies (online and off-line) or YouTube

______ Playing video games or online games

______ Doing homework/studying/writing papers

______ Talking face-to-face with a person

Q6.1 On an average day, how many hours do you spend talking on the telephone or video chatting (e.g., Skype, iPhone video chat)? Please feel free to use decimals.   If you do not do this activity on the average day, please enter 0.

Q6.2 While you are talking on the telephone or video chatting (e.g., Skype, iPhone video chat), what percentage of time are you also doing each of these other activities?   Please use the sliders to indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ Using non-social text-oriented sites (e.g., online news, blogs, eBooks)

______ Talking on the telephone or video chatting with someone else (e.g., Skype, iPhone video chat)

______ Listening to music

______ Watching TV and Movies (online and off-line) or YouTube

______ Playing video games or online games

______ Doing homework/studying/writing papers

______ Talking face-to-face with a person

Q7.1 On an average day, how many hours do you spend listening to music? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0.

Q7.2 While you are listening to music, what percentage of time are you also doing each of these other activities? Please use the sliders to indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ 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 a second source of music

______ Watching TV and Movies (online and off-line) or YouTube

______ Playing video games or online games

______ Doing homework/studying/writing papers

______ Talking face-to-face with a person

Q8.1 On an average day, how many hours do you spend doing homework/studying/writing papers? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0.

Q8.2 While you are doing homework/studying/writing papers, what percentage of time are you also doing each of these other activities? Please use the sliders to indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ 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 TV and Movies (online and off-line) or YouTube

______ Playing video games or online games

______ Doing a second section of homework/studying/writing papers

______ Talking face-to-face with a person

Q9.1 On an average day, how many hours do you spend watching TV and Movies (online and off-line) or YouTube? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0.

Q9.2 While you are watching TV and Movies (online and off-line) or YouTube, what percentage of time are you also doing each of these other activities? Please use the sliders to indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ 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 a second TV, second Movie (online and off-line), or second YouTube session

______ Playing video games or online games

______ Doing homework/studying/writing papers

______ Talking face-to-face with a person

Q10.1 On an average day, how many hours do spend playing video games or online games? Please feel free to use decimals. If you do not do this activity on the average day, please enter 0.

Q10.2 While you are playing video games or online games, what percentage of time are you also doing each of these other activities? Please use the sliders to indicate the percentage of time.

______ Using print media (including print books, print newspapers, etc.)

______ Texting, instant messaging, or emailing

______ Using social sites (e.g., Facebook, Twitter, etc., except games)

______ 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 TV and Movies (online and off-line) or YouTube

______ Playing a second video game or online game

______ Doing homework/studying/writing papers

______ Talking face-to-face with a person

Appendix D: Chapter 2 – Compliance Checks

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

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 the attention task (i.e., the N-Back)?

Please answer honestly. You will receive your HIT regardless of your response.

- Yes
- No

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: Chapter 2 – Results when removing multitasking participants

Table 12. Partial correlations among media multitasking indices (MMI-1 and MMI-2), hits, and false alarms (FA) when controlling for omissions (above the diagonal), and when controlling for omissions together with age (below the diagonal), after removing participants who responded with "*I was multitasking during this study"* to Compliance Check #4, *N* = 231.

	MMI-1	MMI-2	2-back hits	2-back FA	3-back hits	3-back FA
MMI-1	--	.57***	.02	.14*	.03	.20**
MMI-2	.56***	--	-.11	.33***	.01	.36***
2-back hits	.05	-.08	--	-.31***	.41***	-.23***
2-back FA	.13	.32***	-.31***	--	-.11	.71***
3-back hits	.07	.04	.38***	-.10	--	-.02
3-back FA	.20**	.36***	-.23***	.71***	-.01	--

$*p \leq .05$, $**p \leq .01$, $***p \leq .001$

Appendix F: Study 3.1 – Objective versus Subjective Estimates of Performance

Objective versus Subjective Estimates of Performance. To compare the difference between objective performance metrics and subjective estimates of performance, and how these differences change as a function of Cognitive Load (2-back, 3-back) and Video Presence (No Video vs. Video), two mixed repeated-measures ANOVAs were conducted with Cognitive Load and Performance Type (Objective vs. Subjective) entered as the within-subjects variables, Video Presence entered as the between-groups variable, and either proportion hits or false alarms entered as the dependent variable.

Hits. There was a main effect of Cognitive Load on hits, $F(1,137) = 228.02$, $p < .001$, $\eta^2_p = .63$, such that hits were lower in the 3-back compared to the 2-back, as well as a main effect of Video Presence on hits, such that participants in the Video condition had fewer hits than those in the No Video condition, $F(1,137) = 12.84$, $p < .001$, $\eta^2_p = .09$. The Cognitive Load by Video Presence interaction was non-significant, $F(1,137) = 3.27$, $p = .073$, $\eta^2_p = .02$. Interestingly, there was a main effect of Performance Type on hits, wherein participants tended to *under-estimate* their hits (i.e., their subjective estimates of their hits were systematically lower than their objectively measured hits), $F(1,137) = 267.80$, $p < .001$, $\eta^2_p = .66$. Performance Type (Objective vs. Subjective) was also found to interact with Video Presence (No Video vs. Video), $F(1,137) = 10.97$, $p = .001$, $\eta^2_p = .07$. The difference between objective and subjective estimates of performance were smaller for participants in the Video group than for participants in the No Video group. There was no Cognitive Load by Performance Type interaction, $F(1,137) = 2.27$, $p = .134$, $\eta^2_p = .02$, nor was there a Cognitive Load by Video Presence by Performance Type interaction, $F < 1$.

False alarms. There was a main effect of Cognitive Load on false alarms, $F(1,137) = 10.57$, $p = .001$, $\eta^2_p = .07$, such that false alarms were higher in the 3-back than the 2-back. There was no main effect of Video Presence, $F < 1$, nor was there a Cognitive Load by Video Presence interaction, $F(1,137) = 1.76$, $p = .187$, $\eta^2_p = .01$. There was a main effect of Performance Type on false alarms, $F(1,137) = 310.49$, $p < .001$, $\eta^2_p = .69$, such that participants greatly over-estimated how many false alarms they made, compared to their objective metrics. While there was no Performance Type by Video Presence interaction, $F < 1$, there was a significant Cognitive Load by Performance Type interaction, $F(1,137) = 4.51$, $p = .035$, $\eta^2_p = .03$, such that the difference between objective and subjective estimates of false alarms was smaller in the 2-back than in the 3-back. There was no three-way interaction between Cognitive Load, Video Presence, and Performance Type, $F < 1$.

Appendix G: Study 3.2 – Objective versus Subjective Estimates of Performance

Objective versus Subjective Estimates of Performance. To compare the difference between objective performance metrics and subjective estimates of performance, and how these differences changed as a function of Video Presence (No Video vs. Video), two mixed repeated-measures ANOVAs were conducted with Video Presence and Performance Type (Objective vs. Subjective) entered as the within-subjects variables, and either proportion hits or false alarms entered as the dependent variable.

Hits. There was a main effect of Video Presence on hits such that hits were lower when the video was present compared to when the video was absent, $F(1,68) = 53.26$, $p < .001$, $\eta^2_p = .44$. There was also a main effect of Performance Type wherein participants' subjective estimates of hits were lower than their objectively measured hits, $F(1,68) = 65.40$, $p < .001$, $\eta^2_p = .49$. There was no Video Presence by Performance Type interaction, $F < 1$.

False alarms. There was a main effect of Video Presence on false alarms such that false alarms were higher when the video was present compared to when the video was absent, $F(1,68) = 16.45$, $p < .001$, $\eta^2_p = .20$. There was also a main effect of Performance Type, $F(1,68) = 82.70$, $p < .001$, $\eta^2_p = .55$, such that participants' subjective estimates of false alarms were greater than their objectively measured false alarms. There was also a Video Presence by Performance Type interaction, $F(1,68) = 8.70$, $p = .004$, $\eta^2_p = .11$, wherein the difference between objective and subjective estimates of false alarms was greater when the video was present and smaller when the video was absent.

Appendix H: Study 3.3 – Objective versus Subjective Estimates of Performance

Objective versus Subjective Estimates of Performance. As in Study 3.2, the difference between objective performance metrics and subjective estimates of performance was compared as a function of Video Presence (No Video vs. Video). Two mixed repeated-measures ANOVAs were conducted with Video Presence and Performance Type (Objective vs. Subjective) entered as the within-subjects variables, and either proportion hits or correct rejections entered as the dependent variable.

Hits. There was a main effect of Video Presence on hits, $F(1,162) = 99.57$, $p < .001$, $\eta^2_p = .38$, such that hits were lower when the video was present compared to when the video was absent. There was also a main effect of Performance Type, $F(1,162) = 138.03$, $p < .001$, $\eta^2_p = .46$, indicating that subjective estimates of hits were lower than objective hits. There was also a Video Presence by Performance Type interaction, $F(1,162) = 5.49$, $p = .020$, $\eta^2_p = .03$, whereby the difference between objective and subjective hits were greater when the video was present compared to when the video was absent.

Correct rejections.[9] There was a main effect of Video Presence on correct rejections, $F(1,161) = 56.72$, $p < .001$, η^2_p = . 26, whereby participants had fewer correct rejections when the video was present compared to when the video was absent. There was also a main effect of Performance Type, $F(1,161) = 215.75$, $p < .001$, $\eta^2_p = .57$, such that participants subjectively reported fewer correct rejections than their objectively collected correct rejections. There was also

[9] One participant did not provide subjective estimates of hits or correct rejections following the video segment.

a Video Presence by Performance Type interaction, $F(1,161) = 9.92$, $p = .002$, $\eta^2_p = .06$, whereby the difference between objective and subjective estimates of correct rejections was greater when the video was present compared to when the video was absent.

Appendix I: Study 3.4 – Objective versus Subjective Estimates of Performance

Objective versus Subjective Estimates of Performance. The difference between objective performance metrics and subjective estimates of performance was compared as a function of Video Presence (No Video vs. Video). Two mixed repeated-measures ANOVAs were conducted with Video Presence and Performance Type (Objective vs. Subjective) entered as the within-subjects variables, and either proportion hits or correct rejections entered as the dependent variable.

Hits. There was a main effect of Video Presence on hits, $F(1,157) = 82.89$, $p < .001$, $\eta^2_p = .35$, such that hits were lower when the video was present versus absent. There was also a main effect of Performance Type, $F(1,157) = 64.62$, $p < .001$, $\eta^2_p = .29$, such that subjective estimates of hits were lower than objectively obtained hits. There was no Video Presence by Performance Type interaction for hits, $F < 1$.

Correct rejections. There was a main effect of Video Presence on correct rejections, $F(1,157) = 22.06$, $p < .001$, $\eta^2_p = .12$, such that correct rejections were lower when the video was present versus absent. There was also a main effect of Performance Type, $F(1,157) = 82.55$, $p < .001$, $\eta^2_p = .35$, such that subjective estimates of correct rejections were lower than objectively-obtained correct rejections. Lastly, there was no Video Presence by Performance Type interaction for correct rejections, $F(1,157) = 2.07$, $p = .152$, $\eta^2_p = .01$.

Appendix J: Study 3.2 – Effects of Counterbalance

Hits. There was no Video Presence by Counterbalance interaction in terms of hits, $F < 1$, nor was there a main effect of Counterbalance, $F(1,67) = 3.74$, $p = .057$, $\eta^2_p = .05$.

False Alarms. There was a significant Video Presence by Counterbalance interaction in false alarms, $F(1,67) = 5.00$, $p = .029$, $\eta^2_p = .069$, but no main effect of Counterbalance, $F < 1$. This interaction was further explored using paired-samples t-tests, comparing false alarm rates between No Video and Video trials for each Counterbalance Group (No Video, Video vs. Video, No Video; see Figure 7) separately. When No Video trials were presented first and Video trials were presented second, there was no difference in false alarms between No Video ($M = .13$, $SE = .03$) and Video trials ($M = .13$, $SE = .03$), $t(38) = .30$, $p = .763$. However, when participants first received Video trials, followed by No Video trials, false alarms were higher during Video trials ($M = .14$, $SE = .03$) than No Video trials ($M = .11$, $SE = .03$), $t(29) = 2.46$, $p = .020$.

Correct Rejections. There was a significant Video Presence by Counterbalance interaction in terms of correct rejections, $F(167) = 14.77$, $p < .001$, $\eta^2_p = .18$, but no main effect of Counterbalance, $F < 1$. This interaction was followed-up by paired-samples t-tests comparing the difference in correct rejections between No Video and Video trials for each Counterbalance Group (No Video, Video vs. Video, No Video) separately. When No Video trials were presented first, followed by Video trials, there was no difference in correct rejections between No Video ($M = .81$, $SE = .03$) and Video trials ($M = .81$, $SE = .03$), $t(38) = .36$, $p = .722$. However, when Video trials were presented first, followed by No Video trials, correct rejections were lower during Video trials ($M = .74$, $SE = .04$) than No Video trials ($M = .82$, $SE = .04$), $t(29) = 5.28$, $p < .001$.

Omissions. There was no Video Presence by Counterbalance interaction in terms of omissions, $F(1,67) = 3.22$, $p = .077$, $\eta^2_p = .05$, nor was there a main effect of Counterbalance, $F(1,67) = 2.08$, $p = .154$, $\eta^2_p = .03$.

Subjective Estimates of Hits. There was no Video Presence by Counterbalance interaction for subjective estimates of hits and no main effect of Counterbalance, both *F's* < 1.

Subjective Estimates of False Alarms. There was no Video Presence by Counterbalance interaction for estimated false alarms, $F < 1$, and no main effect of Counterbalance, $F(1,67) = 1.17$, $p = .284$, $\eta^2_p = .02$.

Ratings of Task Demand. There was no Video Presence by Counterbalance interaction in terms of ratings of task demand, $F(1,67) = 2.40$, $p = .126$, $\eta^2_p = .04$, nor was there a main effect of Counterbalance, $F < 1$.

Appendix K: Study 3.3 – Effects of Counterbalance

Hits. There was no Video Presence by Counterbalance interaction and no main effect of Counterbalance in terms of hits, both *F's* < 1.

False Alarms. There was a significant Video Presence by Counterbalance interaction for false alarms, $F(1,161) = 22.05$, $p < .001$, $\eta^2_p = .12$, but no main effect of Counterbalance, $F < 1$. This interaction was further explored using paired-samples t-tests to compare false alarms between No Video and Video trials for each Counterbalance Group (No Video, Video vs. Video, No Video) separately. When participants received No Video trials first and Video trials second, false alarms were higher during No Video trials ($M = .12$, $SE = .02$) and lower during Video trials ($M = .11$, $SE = .02$), $t(79) = 3.03$, $p = .003$. However, when participants received Video trials first and No Video trials second, false alarms were higher during Video trials ($M = .11$, $SE = .01$) and lower during No Video trials ($M = .08$, $SE = .13$), $t(82) = 3.62$, $p = .001$. This trend seems to indicate that false alarms tended to decrease over time, from the first period of the task to the second period of the task.

Correct Rejections. There was a significant Video Presence by Counterbalance interaction for correct rejections, $F(1,161) = 17.78$, $p < .001$, $\eta^2_p = .10$, but no main effect of Counterbalance, $F < 1$. Paired-samples t-tests were used to further explore this interaction, comparing correct rejections between No Video and Video trials for each Counterbalance Group (No Video, Video vs. Video, No Video) separately. When No Video trials were presented first and Video trials were presented second, there was no difference in correct rejections between No Video trials ($M = .80$, $SE = .02$) to Video trials ($M = .81$, $SE = .02$), $t(79) = .12$, $p = .904$. However, when participants received Video trials first and No Video trials second, correct rejections were lower during Video trials (*M* = .77, *SE* = .02) and higher during No Video trials (*M* = .85, *SE* = .02), $t(82) = 6.73$, $p < .001$.

Omissions. There was no Video Presence by Counterbalance interaction for omissions, and no main effect of Counterbalance, both *F's* < 1.

Subjective Estimates of Hits. There was no Video Presence by Counterbalance interaction and no main effect of Counterbalance for subjective estimates of hits, both *F's* < 1.

Subjective Estimates of Correct Rejections. There was no Video Presence by Counterbalance interaction for subjective estimates of correct rejections, $F(1,160) = 2.24$, $p = .137$, $\eta^2_p = .01$, an no main effect of Counterbalance, $F < 1$.

Ratings of Task Demand. There was no Video Presence by Counterbalance interaction for ratings of task demand, $F < 1$, and no main effect of Counterbalance, $F(1,161) = 4.39$, $p = .038$, $\eta^2_p = .03$.

Appendix L: Study 3.4 – Effects of Counterbalance

Hits. There was a significant Video Presence by Counterbalance interaction in terms of hits, $F(1,156) = 9.03$, $p = .003$, $\eta^2_p = .06$, but no main effect of Counterbalance, $F(1,156) = 1.82$, $p = .18$, $\eta^2_p = .01$. This interaction was further explored using paired-samples t-tests, comparing hits during No Video and Video trials for each Counterbalance Group (No Video, Video vs. Video, No Video) separately. When No Video trials were presented first and Video trials were presented second, hits were significantly lower during Video trials ($M = .52$, $SE = .03$) than No Video trials ($M = .69$, $SE = .03$), $t(79) = 6.43$, $p < .001$. Similarly, when Video trials were presented first and No Video trials were presented second, hits were still lower during Video trials ($M = .51$, $SE = .03$) than No Video trials ($M = .59$, $SE = .03$), $t(77) = 3.80$, $p < .001$. Evidently, the difference in hits between No Video trials and Video trials was greater for participants who received No Video trials first and Video trials second, than for participants who received Video trials first and No Video trials second.

False Alarms. There was no Video Presence by Counterbalance interaction, $F(1,156) = 1.77$, $p = .185$, $\eta^2_p = .01$, and no main effect of Counterbalance on false alarms, $F(1,157) = 1.24$, $p = .266$, $\eta^2_p =.01$.

Correct Rejections. There was no Video Presence by Counterbalance interaction, $F(1,156) = 7.90$, $p = .006$, $\eta^2_p = .05$, and no main effect of Counterbalance on correct rejections. $F < 1$.

Omissions. There was no Video Presence by Counterbalance interaction for omissions, $F(1,157) = 2.99$, $p = .086$, $\eta^2_p = .02$, and no main effect of Counterbalance, $F < 1$.

Subjective Estimates of Hits. There was a significant Video Presence by Counterbalance interaction for estimated hits, $F(1,156) = 4.29$, $p = .040$, $\eta^2_p = .03$, but no main effect of

Counterbalance, $F < 1$. Paired-samples t-tests were used to further explore this interaction, comparing subjective estimates of hits between No Video and Video trials for each Counterbalance Group (No Video, Video vs. Video, No Video) separately. When participants received the No Video trials first and Video trials second, subjective estimates of hits were significantly lower for the Video trials ($M = .31$, $SE = .03$) than No Video trials ($M = .48$, $SE = .03$), $t(79) = 6.32$, $p < .001$. Similarly, when Video trials were presented first and No Video trials were presented second, subjective estimates of hits were lower for Video trials ($M = .38$, $SE = .03$) than No Video trials ($M = .47$, $SE = .03$), $t(77) = 4.37$, $p < .001$. Like the pattern observed in objective hits, it appears to be the case that the difference in subjective estimates of hits between No Video and Video trials was greater when participants received No Video trials first and Video trials second, than for participants who received Video trials first and No Video trials second.

Subjective Estimates of Correct Rejections. There was no Video Presence by Counterbalance interaction for subjective estimates of correct rejections, $F(1,156) = 2.41$, $p = .122$, $\eta^2_p = .02$. However, there was a main effect of Counterbalance, $F(1,156) = 5.65$, $p = .019$, $\eta^2_p = .04$, such that subjective estimates of correct rejections were lower when participants received No Video trials first and Video trials second ($M = .58$, $SE = .03$) and higher when participants received Video trials first and No Video trials second ($M = .66$, $SE = .02$), $t(156) = 2.38$, $p = .019$.

Ratings of Task Demand. There was no Video Presence by Counterbalance interaction for ratings of task demand, $F(1,156) = 2.10$, $p = .149$, $\eta^2_p = .01$, and no main effect of Counterbalance, $F(1,156) = 1.05$, $p = .307$, $\eta^2_p = .01$.

Appendix M: Study 3.4 – Video Impact and Compliance Checks

To what extent did the video influence your performance on the task (n-back), relative to when you performed the task without the video?

1	2	3	4	5	6	7
Hindered Performance A Lot	Hindered Performance Moderately	Hindered Performance A Little	No Impact	Improved Performance A Little	Improved Performance Moderately	Improved Performance A Lot

Did you respond randomly at any point during the survey of media use?

Please answer honestly. You will receive your HIT regardless of your response.

- Yes
- No

Did you mute the volume to the video during the attention task (n-back)?

Please answer honestly. You will receive your HIT regardless of your response.

- Yes
- No

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.

Were you multitasking with any other media, besides the provided video, while you completed the attention task (n-back)?

Please answer honestly. You will receive your HIT regardless of your response.

- Yes
- No