Media multitasking and sustained attention

by

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A thesis

presented to the University of Waterloo

in fulfilment of the

thesis requirement for the degree of

Master of Arts

in

Psychology

Waterloo, Ontario, Canada, 2014

Author's declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Media multitasking describes a common, everyday behaviour that involves dividing or switching attention between multiple sources of media-based information. In the work reported here, I investigate the relation between individual differences in media multitasking and sustained attention. The over-arching hypothesis is that continually dividing or switching attention between multiple sources of information may work against the practice of sustaining attention on a single source of information. In Chapter 2, I report a study examining the relation between media multitasking and *subjective reports* of attention lapses, attention-related errors, mind wandering, and cognitive control. I find that media multitasking predicts subjective experiences of attention lapses and attention-related errors, as well as deliberate – and to a lesser degree spontaneous – mind wandering. Interestingly, however, no relation is found between media multitasking and self-perceived control over attention, both in terms of switching attention between sources of information and ignoring irrelevant environmental distractions (two apparent key components of media multitasking). In Chapter 3, I expand on these findings in a series of four studies (referred to as studies 1-4) examining the association of media multitasking with *objective measures* of sustained attention in three tasks: the Metronome Response Task (MRT), the Sustained Attention to Response Task (SART), and a vigilance task (here, operationalized as a modified SART). While media multitasking is found to predict poor performance on the MRT, no such relation was found with performance on the SART; a pattern of results that was subsequently replicated. Furthermore, media multitasking was not found to be correlated with performance on the vigilance task (both in terms of overall performance, and in terms of changes in performance over time). Taken together, these findings demonstrate little evidence for a decline in underlying sustained attention processes/cognitive ability associated with media multitasking. Rather,

differences in self-report inattention are likely due to differences in task strategy, whereby those with a greater propensity to media multitask are more promiscuous with their attention.

Acknowledgements

I would like to thank my supervisor, Dr. Daniel Smilek, for his continued support, guidance, and enthusiasm. I would also like to thank Dr. David Thomson for his ongoing collaboration and insightful comments towards this line of research, and Dr. Jonathan Carriere for his continued assistance with programming.

Table of Contents

List of Figures

List of Tables

Chapter 1: General Introduction

Whether it be at home, at work, or somewhere in between, the tendency to multitask is higher than ever (Carrier, Cheever, Rosen, Benitez, & Chang, 2009; Rideout, Foehr, & Roberts, 2010). Indeed, it is not uncommon to observe individuals on the bus engaging in behaviours such as listening to music while browsing the web or playing a game. In fact, the reader can likely attest that monitoring his/her email inbox while performing other work-related activities (such as writing a paper) is a common occurrence. Such activities describe an increasingly popular behaviour known as *media multitasking* – the concurrent consumption of two or more streams of media-based information. While the *immediate* impact of performing two or more tasks concurrently have been well-documented (e.g., the cost in reading comprehension while watching television; Lin, Robertson, & Lee, 2009), less well-studied are the affective and cognitive changes that might occur with repeated, or *habitual*, multitasking. In the work that follows, I examine how individual differences in media multitasking are associated with differences in the subjective experience of attention in everyday life, as well with a host of behavioural indices of one's ability to sustain attention, or remain vigilant, on laboratory-based attention tasks.

In order to empirically investigate media-multitasking, Ophir, Nass, and Wagner (2009) developed the Media Multitasking Index (MMI; derived from responses to their Media Use Questionnaire) to evaluate self-reported media multitasking across a variety of different mediums including: print media, texting, instant messaging, or emailing, using social sites, using non-social sites, talking on the phone or video chatting, listening to music, watching TV, movies, or YouTube, playing video or online games, and doing homework, studying, or writing paper.

Scores on the MMI are taken to measure the mean number of media a participant engages in during a typical hour of media consumption.

To date, several studies have adopted an individual differences approach, whereby self-reports of media multitasking are linked with affective well-being (Becker, Alzahabi, & Hopwood, 2013; Pea et al., 2012; Shih, 2013), personality traits (Minear, Brasher, McCurdy, Lewis, & Younggren, 2013; Ophir et al., 2009; Sanbonmatsu, Strayer, Mederois-Ward, & Watson, 2013) or beliefs about/reasons for multitasking behaviour (Sanbonmatsu et al., 2013; Wang & Tchernev, 2012). In general, these studies have indicated that increased levels of media multitasking are associated with increased symptoms of depression and social anxiety (Becker et al., 2013), decreased levels of social well-being (Pea et al., 2012), as well as heightened impulsivity (Minear et al; 2013; Sanbonmatsu et al., 2013) and sensation seeking (Sanbonmatsu et al., 2013). Moreover, researchers have suggested that people engage in media multitasking under the belief that they are well-equipped to do so (Sanbonmatsu et al., 2013), or because it satisfies certain affective needs (Wang & Tchernev, 2012).

Researchers have also begun to explore whether habitual engagement in media multitasking is associated with measurable changes in the cognitive processes that might be engaged during periods of multitasking (e.g., Alzahabi & Becker, 2013; Cain & Mitroff, 2011; Minear et al., 2013; Ophir et al., 2009). To that end, several recent studies have linked individual differences in media multitasking with performance on laboratory tasks that are thought to capture a core aspect of media multitasking.

One such core aspect of media multitasking is the continual switching of attention among several media sources (Alzahabi & Becker, 2013; Minear et al., 2013; Ophir et al., 2009). Researchers have examined how the propensity to engage in media multitasking may relate to general task-switching ability, although these endeavours have yielded somewhat mixed findings. Although Ophir and colleagues (2009) found that higher self-reports of media multitasking were indicative of poorer task-switching abilities, subsequent studies have come to different conclusions, with some finding that media multitasking is associated with *better* task-switching performance (Alzahabi & Becker, 2013), and still others failing to find any relation at all (Minear, et al., 2013).

Another key characteristic of media multitasking is the presence of ongoing distraction from concurrent media streams. Researchers have attempted to explore the link between self-reported media multitasking and performance on behavioural tasks thought to index an individual's susceptibility to distraction. Ophir and colleagues (2009) found that higher reports of media multitasking were linked with a decreased ability to ignore distractors; a finding that has been conceptually replicated in subsequent work by Cain and Mitroff (2011; but see Minear et al., 2013 for possible exceptions). Based on these findings, these researchers have suggested that heavy media multitaskers are less able (or less likely) to employ a 'top-down' processing style to deal with distracting information.

Here, we focus on another core characteristic of habitual media multitasking that has thus far been unexplored: the tendency to *avoid* sustaining attention on any one particular source of information. We reason that in order to effectively engage in media multitasking, one must either engage in the continuous switching of attention among multiple sources of information, or else divide one's attention among multiple media streams simultaneously. In either case, media multitasking appears to be the antithesis of continuously sustaining attention on a *single* source of information. It is therefore possible that individuals who chronically engage in media multitasking may develop deficits in sustained attention, or conversely, that individuals who have difficulty with sustained attention may engage in more frequent media multitasking. We therefore hypothesize that the degree to which an individual media multitasks will be negatively related to their ability to sustain attention on a *single* task.

To foreshadow, we begin our investigation in Chapter 2 by focusing on the association between media multitasking and *subjective* measures of inattention in everyday life. We then expand on these findings in Chapter 3 by exploring how media multitasking is associated with *objective* measures of sustained attention. Results from both chapters are then considered together in Chapter 4 to form a hypothesis of how heavy and light media multitaskers interact with their environment, and what that interaction means in terms of underlying cognitive mechanisms of attention.

Chapter 2: Media Multitasking and Failures of Attention in Everyday Life

Introduction

In the current study (Ralph, Thomson, Cheyne, & Smilek; 2013), we address the relation of media multitasking with perceived difficulty sustaining attention through self-reports of: (1) lapses of attention and attention-related cognitive errors, (2) spontaneous and deliberate mind wandering, and (3) attentional control with a focus on attentional switching and distractibility. Furthermore, we also explore both direct and indirect effects that media multitasking might have on the attentional measures included in our study. To that end, we provide a possible structural equation model based on the explicit causal hypothesis that media multitasking is the culprit in *causing* everyday attention failures. We postulate that repeatedly, and concurrently, engaging in multiple streams of media may atrophy endogenous/'top down' control mechanisms necessary for sustaining attention (e.g., McVay & Kane, 2010) and perhaps even potentiate exogenous/'bottom-up' environmental control of attention. We refer to this as the deficit-producing hypothesis.

First, we examine whether media multitasking (assessed via scores on the MMI) is associated with *everyday lapses of attention* and *attention-related errors*, as indicated by responses to the Mindfulness Attention Awareness Scale – Lapses Only (MAAS-LO; Carriere, Cheyne, & Smilek, 2008) and the Attention-Related Cognitive Errors Scale (ARCES; Carriere et al., 2008; Cheyne, Carriere, & Smilek, 2006). The MAAS-LO is a modified version of the original MAAS scale by Brown and Ryan (2003), and is a self-report measure of the occurrence of everyday lapses of attention, whereby higher scores on the MAAS-LO reflect greater proneness to attention lapses (i.e., the loss of attention to present events and experiences). These lapses of attention, or episodes of absent-mindedness, often result in only minor mistakes, but can sometimes lead to highly consequential errors. Similarly, the ARCES is used to assess the frequency with which individuals experience errors caused by attentional failures. Higher scores on the ARCES reflect a greater tendency to experience errors such as going to the fridge to get one thing, but taking something else instead. Although scores on the MAAS-LO and ARCES are often highly related, they differentially relate to response times and errors on the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) implying that the two scales measure distinct aspects of attention failures (see Cheyne et al., 2006); specifically, while the MAAS-LO more directly relates to response times in the SART (which are thought to occur due to lapses of attention), the ARCES more directly relates to the errors in the SART (which are thought to occur due to a speeding in response times). If media multitasking is associated with a general deficit in one's ability to maintain attention on any one particular event in the environment, then media multitaskers might differ in their attention to and awareness of events in their environment, as well as the extent to which they experience everyday attention-related foibles.

In order to separate attention-related errors from other failures of cognition, such as problems with memory (cf Cain & Mitroff, 2011), we included the Memory failures Scale (MFS; Carriere et al., 2008; Cheyne et al., 2006). The MFS addresses general, everyday subjective memory failures that are minimally explained by attentional failings, for example, "Even though I put things in a special place I still forget where they are" or "I forget to set my alarm" (Carriere et al., 2008; Cheyne et al., 2006). The MFS is not aimed at any one particular memory mechanism as it samples a variety of memory problems encountered in everyday life, including prospective, declarative, source, and episodic memory. If media multitasking is associated with problems of attention specifically, then we expect to observe associations between the MMI and MAAS-LO/ARCES, but not between the MMI and MFS.

In addition to these everyday experiences of absent-mindedness and attention-related errors, we also assess the subjective propensity to mind wander in everyday life. Mind wandering can be conceptualized as off-task thoughts that co-opt attention (Smallwood, Beach, Schooler, & Handy, 2008; Smallwood & Schooler, 2006) possibly due to a failure of executive control processes required to maintain the focus of one's attention on a primary task of interest (McVay & Kane, 2010). Here, we assessed whether media multitasking is associated with everyday tendencies to (a) have one's thoughts wander without intention (i.e., spontaneously) and/or (b) allow one's thoughts to wander on purpose (i.e., deliberately). We selected the Spontaneous and Deliberate Mind Wandering questionnaires (MW-S & MW-D, respectively; Carriere, Seli, & Smilek, 2013) to evaluate these tendencies. High scores to MW-S statements such as "It feels like I don't have control over when my mind wanders" reflect a greater tendency to unintentionally mind wander (i.e., spontaneously) and high scores to MW-D statements such "I allow myself to get absorbed in pleasant fantasy" reflect a greater tendency to intentionally mind wander (deliberately). Given that the bulk of previous research seems to suggest that heavy and light media multitaskers differ in their ability to block out distracting information (Alzahabi & Becker, 2013; Cain & Mitroff, 2011; Ophir et al., 2009; Sanbonmatsu et al., 2013) we postulate that media multitasking may similarly be associated with the propensity to attend to distracting thoughts. To the extent that media multitasking is associated with a broader spreading of attention (Cain & Mitroff, 2011; Ophir et al., 2009; Sanbonmatsu et al., 2013) thereby allowing more diverse information to enter working memory, media multitasking is predicted to be positively associated with mind wandering. Although the tendency to spontaneously and deliberately mind wander may often be related, they do not necessarily co-occur. For example, if it is the case that media multitasking is more strongly tied to the volitional shifting of attention between tasks, then we might further predict that media multitasking will be more strongly correlated with deliberate mind wandering. If media multitasking is more strongly linked to the uncontrollable capture of attention by external stimuli, however, then media multitasking may be more highly correlated with spontaneous mind wandering (or the uncontrollable capture of attention by internal thoughts).

Finally, given that findings from previous research on the association between media multitasking and task-switching ability remain inconclusive (Alzahabi & Becker, 2013; Minear et al., 2013; Ophir et al., 2009; Sanbonmatsu et al., 2013), we investigate the association between media multitasking and subjective ratings of the ability to shift attention between tasks and self-reported distractibility. To address this, we include a subjective report measure of attentional switching (AC-S; Carriere et al., 2013), and distractibility (AC-D; Carriere et al., 2013), using modified versions of Derryberry and Reed (2002) original attentional control scales. On the attentional switching scale, participants responded to statements such as “After being interrupted, I have a hard time shifting my attention back to what I was doing before.” High scores on this scale reflected greater perceived difficulty shifting attention between tasks. On the distractibility scale, participants responded to statements such as “When I am working hard on something, I still get distracted by events around me,” where high scores reflected greater feelings of distractibility. Note that these scales are measures of perceived shifting and distractibility and address a question different from that concerning objectively assessed abilities (e.g., Alzahabi & Becker, 2013; Minear et al., 2013; Ophir et al., 2009).

Method

Participants. Two hundred and two undergraduate students (146 female) from the University of Waterloo participated in the study in exchange for course credit[1].

Materials and procedure. We presented participants with nine online questionnaires in random order: the Media Use Questionnaire (used to calculate the MMI; Ophir et al., 2009), Mindfulness Attention Awareness Scale – Lapses Only (MAAS-LO; Carriere et al., 2008), Attention-Related Cognitive Errors Scale (ARCES; Carriere et al., 2008; Cheyne et al., 2006), Memory Failures Scale (MFS; Carriere, et al., 2008; Cheyne et al, 2006), Spontaneous Mind Wandering Questionnaire (MW-S; Carriere et al., 2013), Deliberate Mind Wandering Questionnaire (MW-D; Carriere et al., 2013), Attentional Switching Questionnaire (AC-S; Carriere et al., 2013; Derryberry & Reed, 2002), Attentional Distractibility Questionnaire (AC-D; Carriere et al., 2013; Derryberry & Reed, 2002) and Media Multitasking Beliefs Questionnaire (MMBQ; developed by the authors as a pilot for future studies).

Media Use Questionnaire and Media Multitasking Index (MMI). The Media Use Questionnaire (developed by Ophir et al., 2009) addresses 10 groupings of activities: (1) using print media (2) texting, instant messaging, or emailing (3) using social sites (4) using non-social sites (5) talking on the phone or video chatting (6) listening to music (7) watching TV, movies, or YouTube (8) playing video or online games (9) doing homework, studying, or writing papers, and (10) face-to-face communication. For each type of activity, participants report: (1) on an average day, how many hours they spend engaging in the activity, and (2) while engaging in the activity, the percentage of the time that they are also doing each of the other activities listed.

[1] Five subjects were removed due to missing data and nine subjects had their responses changed from fractions or strings to their equivalent digit representations for data analysis purposes.

Responses to the latter were selected from a drop-down menu with options "Most of the time," "Some of the time," "A little of the time," or "Never." These responses were assigned values of 1.0, 0.67, 0.33, and 0 (respectively) to reflect the proportion of time spent engaging in a given activity. MMI scores were then computed according to the formula outlined by Ophir and colleagues (2009), and are taken to reflect the degree of media multitasking in a typical hour of media use.

Mindfulness Attention Awareness Scale – Lapses Only (MAAS-LO). The MAAS-LO (Carriere, et al., 2008) is a 12-item questionnaire (derived from the 15-item MAAS by Brown & Ryan, 2003) that assesses the frequency with which an individual experiences lapses of attention in everyday situations. The MAAS-LO includes items such as "I snack without being aware that I'm eating" and responses are made using 6-point Likert scale range from (1) *almost never* to (6) *almost always*, with higher scores reflect greater frequencies of attention lapses.

Attention-Related Cognitive Errors Scale (ARCES). The 12-item ARCES (Carriere et al., 2008; Cheyne et al., 2006) was included as a measure of cognitive failures in everyday situations for which lapses of attention are the most likely cause. Responses are made using a 5-point Likert scale, with responses ranging from (1) *never* to (5) *very often*, with greater scores reflecting greater frequencies of cognitive failures. The ARCES includes items such as "I have gone to the fridge to get one thing (e.g., milk) and taken something else (e.g., juice)."

Memory Failures Scale (MFS). The MFS (Carriere et al., 2008; Cheyne et al., 2006) was included as a measure of everyday memory failures that are minimally explained by attentional errors. The MFS uses the same scoring system as the ARCES, with responses made using a 5-point Likert scale ranging from (1) *never* to (5) *very often*, and includes items such as "I forget to set my alarm."

Spontaneous (MW-S) and Deliberate (MW-D) Mind Wandering. We included the MW-S and MW-D questionnaires (Carriere at al., 2013) as measures of self-reported everyday mind wandering. Each scale consists of four questions such as "I find my thoughts wander spontaneously" (spontaneous) and "I allow my thoughts to wander on purpose" (deliberate). Responses are indicated using a 7-point Likert scale ranging from (1) *Rarely* to (7) *A Lot*, with higher scores reflecting a greater tendency to mind wander spontaneously or deliberately.

Attentional Control: Switching (AC-S) and Distractibility (AC-D). Attentional control was measured using the AC-S and AC-D questionnaires (Carriere et al., 2013; Derryberry & Reed, 2002). Both scales included four items such as "After being interrupted, I have a hard time shifting my attention back to what I was doing before" (switching) and "When I am working hard on something, I still get distracted by events around me" (distractibility). Items are answered using a 5-point Likert scale with responses ranging from (1) *Almost Never* to (5) *Always*, with higher scores reflecting greater difficulty in switching one's attention or greater distractibility.

Media Multitasking Beliefs Questionnaire (MMBQ). The MMBQ is a 24-item scale developed by the authors that was included as a pilot test for future research studies. The objective of this questionnaire was to get a sense of (1) how often students listen to music or watch videos while working or studying and (2) to assess individuals' beliefs regarding the consequences of these distractions. Eighteen items were answered using a 7-point Likert scale, three items were responded to via a yes / no choice response, and three items were short response. Items on this questionnaire include "I believe that listening to music while working or studying helps me focus" and "I find it easier to get started on something if I can watch TV shows, Movies, or YouTube videos while I do it."

Results

Descriptive statistics for each questionnaire are presented in Table 1, and correlations between measures in Table 2. Although we have provided correlations between all of the included measures, we were only interested in the correlations concerning the MMI; other correlations are provided for completeness. We discuss the results at an uncorrected level of significance, as well as with a more conservative significance level using the bonferroni correction for seven comparisons (MMI with each of the other measures; corrected p = . 0071).

Table 1

Descriptive Statistics for Media Multitasking Index (MMI), Mindfulness Attentional Awareness Scale –Lapses Only (MAAS-LO), Attention-Related Cognitive Errors Scale (ARCES), Memory Failures Scale (MFS), Spontaneous Mind Wandering (MW-S), Deliberate Mind Wandering (MW-D), Attentional Switching (AC-S), and Attentional Distractibility (AC-D). N = 197.

	Mean	Standard Deviation	Skew	Kurtosis
MMI	3.33	1.21	-0.08	-0.21
MAAS-LO	3.25	0.74	0.06	0.2
ARCES	2.85	0.62	0.62	0.3
MFS	2.43	0.53	0.25	0.14
MW-S	4.38	1.32	-0.09	-0.38
MW-D	4.43	1.41	-0.43	-0.28
AC-S	2.85	0.69	0.22	-0.28
AC-D	3.41	0.80	-0.1	0.02

Associations with Media Multitasking. To determine whether scores on the Media Multitasking Index (MMI) were associated with self-reported attention and memory failures, we examined Pearson correlations between scores on the MMI and scores on the MAAS-LO, ARCES, and MFS (Table 2)[2]. There was a significant positive correlation between scores on the MMI and MAAS-LO, as well as between the MMI and ARCES; however, there was no significant correlation between scores on the MMI and MFS. These relations held true for both the uncorrected and more conservative corrected significance level. Moreover, the correlation between MMI and MFS was significantly less by a Williams test than correlations between the MMI and MAAS-LO, $t(195) = 3.59$, $p < .001$, and MMI and ARCES, $t(195) = 3.76$, $p < .001$.

We next considered Pearson correlations between scores on the MMI and self-reported spontaneous and deliberate mind wandering (measured by the MW-S and MW-D, respectively; Table 2). There was a significant positive correlation between scores on the MMI and MW-S, as well as between scores on the MMI and MW-D. However, if we consider the more conservative significance level, the correlation between the MMI and MW-S becomes non-significant.

Finally, attentional control was measured by scores on the Attentional Switching (AC-S) and Attentional Distractibility (AC-D) questionnaires. Pearson correlations were calculated between the MMI and AC-S, and MMI and AC-D (Table 2). There was no significant correlation between either of the measures of attentional control and the MMI, even at the more liberal uncorrected significance criterion.

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[2] The significance pattern remains the same when examining Spearman correlation coefficients.

Table 2

Pearson product-moment correlation coefficients for Media Multitasking Index (MMI), Mindfulness Attentional Awareness Scale – Lapses Only (MAAS-LO), Attention-Related Cognitive Errors Scale (ARCES), Memory Failures Scale (MFS), Spontaneous Mind Wandering (MW-S), Deliberate Mind Wandering (MW-D), Attentional Switching (AC-S), and Attentional Distractibility (AC-D). N = 197.

	MMI	MAAS-LO	ARCES	MFS	MW-S	MW-D	AC-S	AC-D
MMI	-	.28	.28	.07	.15	.21	.08	-.03
MAAS-LO	.000	-	.66	.58	.61	.42	.44	.17
ARCES	.000	.000	-	.63	.59	.35	.40	.30
MFS	.364	.000	.000	-	.53	.34	.39	.23
MW-S	.031	.000	.000	.000	-	.49	.46	.22
MW-D	.004	.000	.000	.000	.000	-	.17	.04
AC-S	.294	.000	.000	.000	.000	.015	-	.27
AC-D	.732	.016	.000	.001	.002	.631	.000	-

Pearson product-moment correlation coefficients are given above the diagonal and significance values given below the diagonal.

Causal Modeling. The foregoing correlations are amenable to a variety of causal interpretations. We examine one possible causal model of the data that we have referred to above as the *deficit-producing* hypothesis. We should note that our modeling here is meant to provide only a tentative exploration of the causal relations among measures. According to the deficit-producing hypothesis, over-reliance on external (exogenous) stimulation (i.e., media stimulation) may cause deficits in one's ability to internally (endogenously) sustain the focus of attention. By using structural equation modeling it was possible for us to evaluate some of the plausible direct and indirect causal paths through which media multitasking might influence everyday attention performance. We chose to model only a subset of the measures shown in Table 2. There are several reasons for this choice. First, given that our hypothesis suggests that media multitasking results in poor attention control, we sought to model only non-deliberate everyday attention mechanisms; this led us to exclude the MW-D. Second, we used in our model only those measures significantly correlated the MMI (using the more liberal significance level of $p = .05$), which led us to exclude the MFS, AC-S and the AC-D scales. With these exclusions, we were left with the MMI, the MAAS-LO, the ARCES and the MW-S.

Figure 1 shows one possible version of the deficit-producing hypothesis, which is that media multitasking (MMI) ultimately leads to attention-related errors (ARCES), but that this relation is partly mediated by the occurrence of attention lapses (MAAS-LO) and spontaneous mind wandering (MW-S). Using AMOS 21 we were able to examine the putative direct and indirect causal effects among variables under this model. More specifically, there are four possible indirect (mediated) effects of interest in the model shown in Figure 1. MAAS-LO may mediate the effect of MMI on ARCES and/or on MW-S, and MW-S may mediate the effects of either or both of MMI and MAAS-LO on ARCES. There is a full mediation effect of MMI via MAAS-LO on MW-S. The indirect effect of MMI on MW-S is significant, $\beta = .17$, $p < .001$ (two-tailed, assessed via 10000 bootstrap samples). Moreover, although the bivariate correlation for MMI and MW-S was significant (Table 2), the path coefficient from MMI to MW-S was essentially zero, $p = .870$. There is, however, a significant indirect effect, $\beta = .18$, $p < .001$, of which .13 is mediated via MAAS-LO alone and .05 via MAAS-LO through MW-S. Finally, and conceptually most relevant, the direct effect of MMI on ARCES is reduced from the bivariate coefficient and no longer significant. There is, in addition, a significant indirect effect for MMI on ARCES, $\beta = .17$, $p < .001$. Thus, the deficit-producing model is corroborated in this analysis, though there remains a possible though small and non-significant, $p = .126$, direct effect of MMI on ARCES independent of attention lapses and mind wandering.

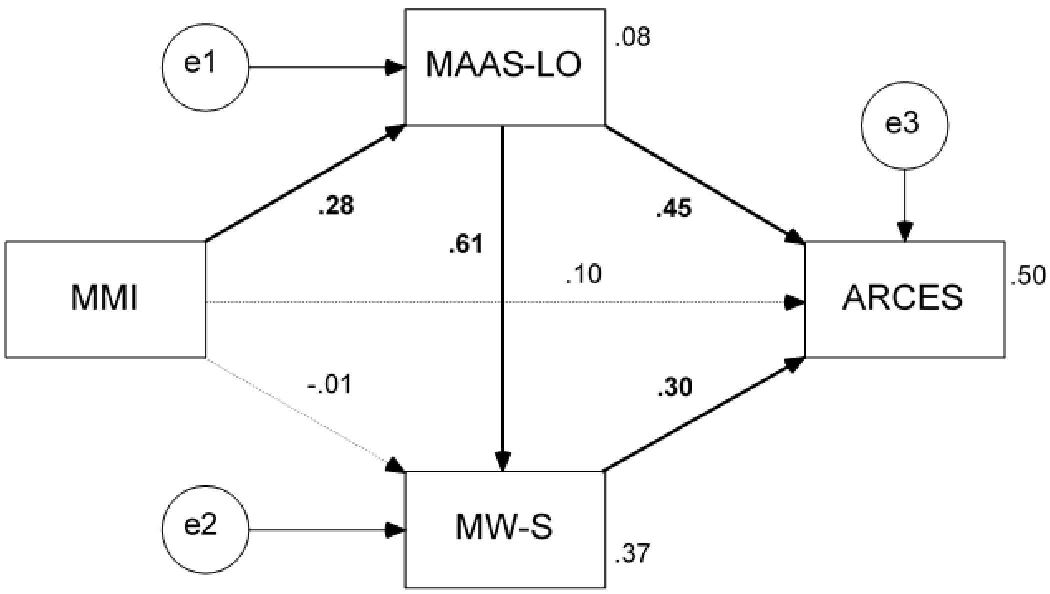

Figure 1. Media multitasking effects on attention-related errors mediated by attention lapses and mind wandering.

Discussion

In the present study, we investigated the relation between self-reports of media multitasking and self-reports of: (1) everyday lapses of attention and attention-related errors, (2) mind wandering, and (3) attentional control. Although research into the association between media multitasking and other attentional abilities (namely, task-switching) have yielded mixed findings (Alzahabi & Becker, 2013; Cain & Mitroff, 2011; Minear et al., 2013; Ophir et al., 2009;

Sanbonmatsu et al., 2013), we have assessed a deficit-producing hypothesis consistent with the associative framework of Cain and Mitroff (2011), Ophir and colleagues (2009), and Sanbonmatsu and colleagues (2013), whereby the degree to which people simultaneously engage multiple streams of media was predicted to be associated with experiences of inattention in everyday life. Although evidence concerning the association between media multitasking and objective laboratory-based measures of attentional abilities is mixed, we observed that at the subjective level, media multitasking is positively associated with experiences of attentional failures in everyday life through: (1) lapses of attention and attention-related errors (measured via the MAAS-LO and ARCES, respectively), and (2) tendencies to spontaneously and deliberately mind wander (measured via the MW-S and MW-D, respectively). Evidence from our causal model suggests a more parsimonious account whereby media multitasking is associated with general attention lapses, and that spontaneous mind wandering and attention-related errors are related to media multitasking through their shared variance with attention lapses measured via the MAAS-LO. Furthermore, there was no significant correlation between self-reported media multitasking and self-reported memory failures (measured via the MFS), allowing us to discriminate the apparent subjective attentional failures from cognitive errors in general. That is, although attention and memory failures may be highly related, they differentially relate to media multitasking. In addition, we failed to find a significant relation between media multitasking and either of the measures of self-reported attentional control (attentional-switching and distractibility; AC-S, AC-D, respectively).

The use of self-reports has allowed us to explore individuals' subjective awareness of their attentional experiences in everyday life. Our findings suggest that increased levels of media multitasking are accompanied by a self-perceived withdrawal of attention to and awareness of present real-world events and experiences, as well as increased incidences of attention-failure induced cognitive errors in engaging with real-word events and challenges. We find these results particularly interesting because attentional differences measured in the laboratory are, generally, relatively modest with sometimes tenuous relevance to real-world tasks, and, moreover may be sufficiently subtle to render conscious awareness doubtful as well (e.g., switch-costs tend to be on the order of hundreds of milliseconds). However, here we observed that participants with varying degrees of media multitasking activity reliably reported different subjective experiences of how their attention functions in everyday life. Building on this, we also found that increased levels of media multitasking were associated with the unintentional capture of attention by off-task thoughts, as well as with volitional shifts of attention between on-task and off-task thoughts; nominally, these volitional shifts were more strongly related to media multitasking than non-volitional shifts. This increased tendency to mind wander may reflect the increased distractibility of heavy media multitaskers compared to light media multitaskers reported by Cain and Mitroff (2011) and Ophir and colleagues (2009). In fact, it may be the case that heavy media multitaskers possess a larger threshold of arousal relative to light media multitaskers, causing them to seek additional mental stimulation in the form of off-task thought. Although speculative at present, the relation between mind wandering and media multitasking will undoubtedly be a topic of considerable interest for future study.

In contrast, we found no evidence of a significant relation between media multi-tasking and perceived ability to switch attention between tasks and, although we found an association between media multitasking and attention to *internal* distractions (i.e., off-task thoughts), we found no association between media multitasking and feelings of distractibility with regard to environmental, or *external*, stimuli. This is perhaps not surprising given that the available evidence regarding the association between media multi-tasking and behaviour in task-switching and distraction tasks is rather mixed (Alzahabi & Becker, 2013; Minear et al., 2013; Ophir et al., 2013). Our findings best fit with those of Minear and colleagues (2013) who found no evidence for a relation between degree of media multitasking and task-switching ability or susceptibility to distractions. Whether or not a true relation exists between media multitasking, task-switching ability, and distractibility, media multitaskers do not seem to differ in their *perceived* ability to switch attention between tasks, or in their perceived level of distractibility with regards to environmental stimuli.

We also examined a possible causal model of our data. This model was based on what we refer to as the deficit-producing hypothesis, which suggests that media multitasking leads to poorer attentional control. Specifically, in situations of media multitasking, attentional control may be readily 'outsourced' to the available external media. By frequently doing so, one may forfeit benefits associated with guiding attention in an endogenous way to a singular task (MacLean et al., 2010; Mrazek, Smallwood, & Schooler, 2012; Mrazek, Franklin, Phillips, Baird, & Schooler, 2013). In other words, media multitasking might produce results opposite to those produced by practices such as mindfulness training, which teaches individuals to bring wandering attention back to a single task or thought (MacLean et al., 2010; Mrazek et al., 2012; Mrazek et al., 2013). Although mindfulness training might boost endogenous executive control of attention, media multitasking might unintentionally atrophy endogenous executive control mechanisms and even further potentiate exogenous mechanisms. This proposition is consistent with the claims of Cain and Mitroff (2011) and Ophir and colleagues (2009) who suggested that, compared to heavy media multitaskers, light users appear to have greater 'top-down' control.

Although our structural equation modeling was intended to be only a preliminary exploration of the causal relations between media multitasking and attention failures (assuming such a relation exists based on self-reports), the model we explored did suggest several constraints to future theories. First, our results show that the association between self-reported media multitasking (MMI) and self-reported spontaneous mind wandering (MW-S) is fully mediated by self-reports of attention lapses (MAAS-LO). Second, the relation between media multitasking (MMI) and self-reported attention-related errors (ARCES) was mediated by people's reported propensity to experience attention lapses (MAAS-LO), suggesting that media multitasking might atrophy endogenous attentional control, which ultimately leads to a subjective increase in attention-related errors in everyday life. Discussing the work of Lin (2009), Cain and Mitroff (2011) also mention a similar causal relation to our own whereby "consistent practice with consuming multiple media has led to a broadening of HMMs' attentional filters" (p. 1190).

There are, of course, other possible causal models that could be considered under the assumption that media multitasking is negatively associated with everyday attention (and even more if we consider media multitasking may be positively associated with attentional abilities as reported by Alzahabi & Becker, 2013). For instance, using our current framework, rather than media multitasking *causing* attentional problems, it could be the case that individuals might gravitate towards multiple media consumption *because of* their attentional dispositions (a *self-selection hypothesis*). On this view, individuals might find themselves engaging in multiple sources of media because they are unable to remain engaged with any one medium and thus begin switching between multiple media streams. Again, Cain and Mitroff (2011) have also offered a similar causal relation, whereby those with broader attention filters, who know they will inevitably be distracted, ensure their distractions to be enjoyable ones (e.g., putting on a TV show while studying). Adjudicating between these causal alternatives would likely require a longitudinal experimental design and is beyond the scope of the present correlational study.

On a closing note, many of our self-reported attention measures have particular implications with respect to one's ability to sustain the focus of attention on any one particular task. The next logical step is to corroborating the present link between media multitasking and self-reported impairments in sustained attention with laboratory–based behavioural measures of sustained attention as opposed to self-report measure. Nonetheless, the work reported here demonstrates an important ecological association between the degree of media multitasking and the conscious experience of one's attentional functioning in everyday life.

Chapter 3: Media Multitasking and Behavioural Measures of Sustained Attention

Introduction

In Chapter 2, we reported on some evidence for a negative relation between media multitasking and sustained attention, whereby the association between self-reported media multitasking and self-reported attentional functioning in everyday life was investigated. It was found that higher reports of media multitasking were predictive of higher reports of attention lapses (i.e., being absent-minded or inattentive to present events and experiences), as well as attention-related cognitive errors (such as putting the milk in the pantry). In addition, a weak, but significant, positive correlation was found between media multitasking and the propensity to mind wander. Taken together, these findings suggest that media multitasking is associated with a deficit in one's ability to sustain attention on any one particular task goal over time. Given that this association was observed via subjective self-reports of attention lapses, one might conclude that media multitasking is associated with rather large (and noticeable) failures of sustained attention. It is an open question, however, as to whether media multitasking is associated with greater moment-to-moment fluctuations in sustained attention using *objective* measures. We explore this possibility in the empirical work that follows.

Across four studies, we investigate whether the self-reported degree of media multitasking is associated with sustained attention performance. There is no single agreed-upon 'measure' of sustained attention, and in fact, the term 'sustained attention' may be applied to a host of behaviours. As such, we have chosen not to simply assess the possible relation between media multitasking and a *single* laboratory task, but instead have employed three nominally 'sustained attention' tasks. These tasks included a relatively novel task developed in our laboratory – the Metronome Response Task (MRT; Seli, Cheyne, & Smilek, 2013) – as well as two other sustained attention tasks that have been employed extensively in sustained attention research in recent decades: the Sustained Attention to Response Task (SART; Robertson et al., 1997), and a vigilance task (employed here as a modified SART; Carter, Russell, & Helton, 2013). Next, we briefly introduce each task and describe the primary dependent measures of interest.

The MRT is a recently developed sustained attention task in which participants are presented with a tone at regular intervals (roughly one per second) and instructed to respond (via button press) *in synchrony* with the onset of each tone. In order to perform well on the task and minimize response variance, one must continually attend to the temporal structure of the task so as to anticipate the arrival of each tone. Variability in response times to the tones is thus taken as an indicator of sustained attention performance, with increased response variability reflecting poorer sustained attention (e.g., see Seli, Carriere et al., 2013; Seli, Cheyne et al., 2013; Seli, Jonker, Cheyne, & Smilek, 2013).

The SART is a GO-NOGO task in which participants are instructed to respond (via button press) as quickly as possible to *frequent* GO stimuli and to refrain from responding to *infrequent* NOGO stimuli. The primary behavioural measures in the SART include (1) failures to refrain from responding to NOGO stimuli (i.e., NOGO errors), and (2) response times (RTs) to GO stimuli. In the SART, poorer sustained attention performance is typically associated with increased NOGO errors and speeding of RTs (see Cheyne et al., 2006; Manly, Davison, Heutink, Galloway, & Robertson, 2000 ; Manly, Robertson, Galloway, & Hawkins, 1999; Robertson et al., 1997; Seli, Cheyne, Barton, & Smilek, 2012; Seli, Jonker, et al., 2013; Smilek, Carriere, & Cheyne, 2010). When attention lapses, individuals often fail to inhibit their responding, which is typically accompanied by a speeding of RTs to GO stimuli prior to making such errors.

Finally, we employ a vigilance task, perhaps the most well-studied task for indexing sustained attention (e.g., see Giambra, 1989; 1995; Mackworth N. H., 1948; 1950; Mackworth J. F., 1964). Vigilance tasks are GO-NOGO tasks (much like the SART) designed to replicate the attentional demands of real-world situations in which human operators must monitor automated systems for rare, but critical events (such as a radar operator monitoring for the characteristic 'blip' of an enemy combatant). While vigilance tasks have taken many forms, in all such tasks, participants are instructed to respond to the presentation of *infrequent* GO stimuli (i.e., targets) and to withhold responses to *frequent* NOGO stimuli (i.e., non-targets). Thus, the critical difference between the SART and a vigilance task is response frequency – in the SART participants respond to frequent distractors while withholding their response to relatively rare targets, however in a vigilance task, participants remain non-responsive for the majority of trials and respond only to the occurrence of relatively rare targets (for a comparison of standard and vigilance forms of the SART see Carter et al., 2013; McVay & Kane, 2012; McVay, Meier, Touron,& Kane, 2013). A common finding in the vigilance literature, and indeed the observation that triggered such investigations in the first place, is that one's ability to sustain attention, or remain vigilant, deteriorates as a function of time on task (e.g., Mackworth N. H., 1948, 1950; Mackworth J. F., 1964). This typically manifests in the form of decreasing response sensitivity and longer response times to targets (e.g., see Mackworth N. H., 1948; McCormack, 1958; and for a relatively recent example, Helton & Russell, 2012; see also Hancock, 2013 for a recent review). Thus the magnitude of the observed performance decrement can be taken as an index of sustained attention.

Given the previously documented link between media multitasking and self-reported failures of attention (Ralph et al., 2013), we hypothesize that media multitasking will be associated with poor performance on the sustained attention tasks employed here (i.e., the MRT, SART, and vigilance task). To assess habitual media multitasking behaviour, participants completed the Media Use Questionnaire (Ophir et al., 2009), which addresses media use and media multitasking across a variety of different mediums. From responses on the Media Use Questionnaire, a media multitasking index (MMI) was calculated as per Ophir et al. (2009), which indicates the degree of media multitasking a participant is engaged in during a typical hour of media consumption. We began our investigation of media multitasking and sustained attention with the MRT in Study 1. In Study 2, we attempted to extend our findings to the SART. Studies 3a and 3b replicated findings from studies 1 and 2 (respectively) using two large online samples from Mechanical Turk, and in Study 4, we implemented a vigilance task, again using a large online sample from Mechanical Turk.

Study 1

In Study 1 we examine the relation between self-reported media multitasking and performance on the Metronome Response Task (MRT). The dependent measure of interest in the MRT is response variability. As such, we hypothesize that higher reports of media multitasking will be associated with greater response variability on the MRT. Of secondary interest, we also explore whether media multitasking predicts two other correlates of sustained attention: mind wandering as indexed by responses to thought-probes (as per Smallwood, McSpadden, & Schooler, 2007) and fidgeting behaviour (Seli, Carriere, et al., 2013; see also Carriere, Seli, & Smilek, 2013). We included these measures because it has been shown that as sustained attention fails, reports of off-task thought increase (e.g., McVay & Kane, 2012; Seli, Cheyne, et al., 2013; Smallwood, Beach, Schooler, & Handy, 2008) as does the amount of superfluous body movement, colloquially referred to as ‘fidgeting’ (Seli, Carriere, et al., 2013).

Method.

Participants. Seventy-seven undergraduate students (34 female) from the University of Waterloo participated in exchange for course credit. Three participants were excluded for failing to complete the Media Use Questionnaire, and one for having greater than 10% omissions on the MRT (a standard exclusion criterion; see Seli, Cheyne et al., 2013) resulting in the inclusion of 73 participants (33 female) for subsequent analyses.

Stimuli and procedure. First, sustained attention was indexed by performance on the Metronome Response Task (MRT; Seli, Cheyne et al., 2013). In the MRT, participants are instructed to respond via button press in synchrony with the presentation of an auditory tone (see Figure 2). Participants held a computer mouse in their lap, and responded to the tones via mouse button presses. Each trial lasted 1300 ms and began with 650 ms of silence, followed by onset of the tone which lasted 75 ms, and finally another 575 ms of silence. Participants completed 18 practice trials followed by 900 experimental trials. Rhythmic Response Times (RRTs) were calculated as the relative time between the tone onset and the participant's response, where a response made prior to tone onset would yield a negative RRT and a response made after tone onset would yield a positive RRT. Variance in RRTs was computed across a moving five-trial window to limit the influence of outlier responses on overall RRT variability (as per Seli, Cheyne, et al., 2013).

Following the MRT, participants completed the Media Use Questionnaire (Ophir et al., 2009; as outlined in Chapter 2). To reiterate, this questionnaire addresses 10 groupings of activities: (1) using print media (2) texting, instant messaging, or emailing (3) using social sites (4) using non-social sites (5) talking on the phone or video chatting (6) listening to music (7) watching TV, movies, or YouTube (8) playing video or online games (9) doing homework, studying, or writing papers, and (10) face-to-face communication. For each type of activity, participants report: (1) on an average day, how many hours they spend engaging in the activity, and (2) while engaging in the activity, the percentage of the time that they are also doing each of the other activities listed. Responses to the latter were selected from a drop-down menu with options "Most of the time," "Some of the time," "A little of the time," or "Never." These responses were assigned values of 1.0, 0.67, 0.33, and 0 (respectively). MMI scores were then computed according to the formula outlined in Ophir et al. (2009), and are taken to reflect the degree of media multitasking in a typical hour of media use.

We also measured responses to mind wandering thought-probes and fidgeting behaviour. There were 18 thought-probes presented pseudo-randomly throughout the MRT, with one thought-probe presented in each block of 50 trials. Upon presentation of each thought-probe, the MRT was stopped and participants were asked to indicate whether, just prior to the probe, they were (a) 'on task' or (b) 'mind wandering'. Prior to beginning the MRT, participants were instructed on how to respond to each of the thought probes; specifically, they were instructed to report that they were 'on task' if they were thinking only about things related to the task (e.g., about their performance), or to report that they were 'mind wandering' if they were thinking about things unrelated to the task (e.g., about what to eat for dinner). After participants made their response, they were presented with a screen prompting them to click the mouse to resume the MRT.

Fidgeting behaviour was measured by having participants sit on a Wii Balance Board while completing the MRT. The balance board was placed on top of a flat bench approximately 18 cm from the ground (roughly chair height). Fidgeting was defined as the *total amount of movement* during each trial, measured using four sensors (one in each of the four feet of the Wii

Balance Board) that detected vertically applied force at a rate of approximately 60 Hz. Movement profiles were constructed using the same criteria outlined by Seli, Carriere, et al. (2013) such that if sensor values from two successive readings were more than 1.96 standard deviations away from the mean of a resting noise profile (constructed at the beginning of the study session with no weight or movement on the sensors), then a movement was deemed to have occurred, and these logged movements were then summed for each trial. As was the case with RRT variance, mean movement behaviour was calculated across a moving five-trial window.

Apparatus. The MRT program was created using E-Prime 1.2 software (Psychology Software Tools Inc., Pittsburgh, PA) and run on an Acer Aspire AX1930-ES10P desktop computer. The metronome tone was presented through Bose QuietComfort 15 Noise-cancelling Headphones, and movement data were collected using a separate program running under Python 2.6 (Python Software Foundation, http://www.python.org) and using Brian Peek's WiimoteLib 1.7 (Brian Peek, http://channel9.msdn.com/coding4fun/articles/Managed-Library-for-Nintendos-Wiimote). Movement data were synchronized using time-stamp data at the start of every MRT trial. Stimuli were presented on a 19" ViewSonic monitor at a resolution of 1440 by 900. Participants were seated approximately 57 cm from the display screen.

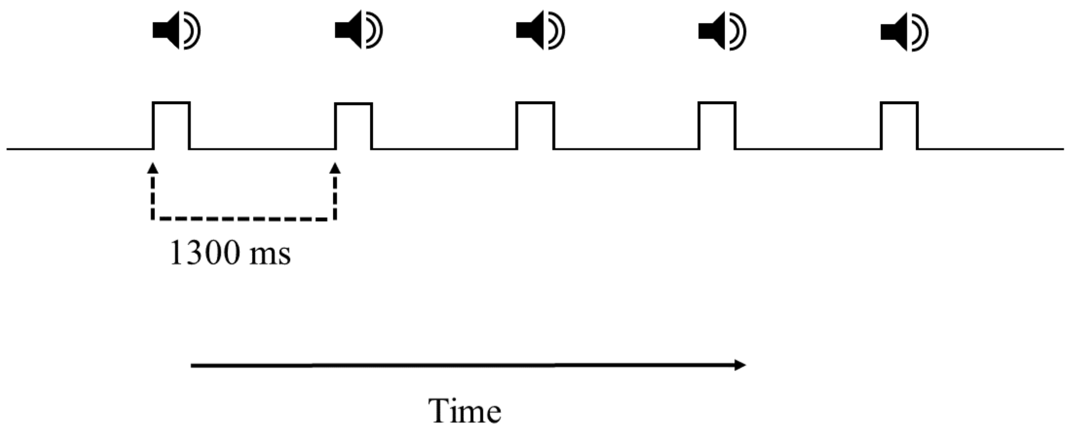

Figure 2. MRT trial sequence. Participants are instructed to respond in synchrony with the presentation of each tone (separated by 1300 ms).

Results and Discussion. Of primary interest is the relation between media multitasking and response variability. Response variance data from the MRT were highly positively skewed and were thus normalized using a natural logarithm transformation (as per Seli, Cheyne et al., 2013), resulting in a mean transformed RRT variance of 8.15 (SD = 0.67) on the MRT. The mean MMI score was 3.94 (SD = 1.24). Critically, a Pearson correlation between scores on the MMI and transformed RRT variability revealed a significant positive correlation, $r(71) = 0.27$, $p = 0.023$ (see Figure 3). Thus, consistent with our hypothesis, higher reports of media multitasking were associated with greater response variability on the MRT.

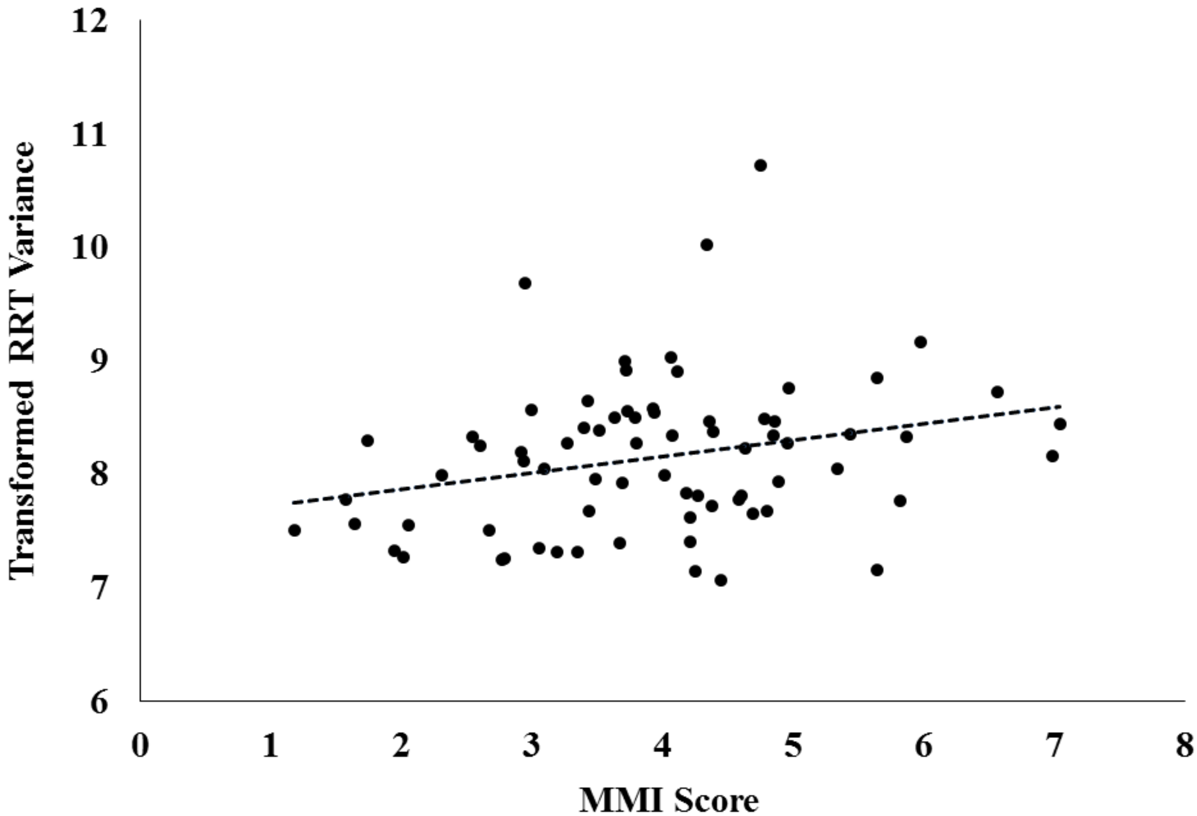

Figure 3. Scatterplot of the relation between scores on the MMI and transformed rhythmic response times (RRT) variance in Study 1. The dotted line represents the best linear fit to the data.

Of secondary interest were the relations between MMI scores and mind wandering rates, and between MMI scores and fidgeting. Overall-mind-wandering rates were calculated as the proportion of thought-probes to which participants indicated they were mind wandering (*M* = 54.11%, *SD* = 23.33%)[3]. A correlational analysis failed to show a significant relation between MMI scores and overall-mind-wandering rates, $r(71) = 0.08$, $p = 0.526$. Mean movement

[3] Replicating a previous finding (Seli, Cheyne, et al., 2013), paired-samples t-tests confirmed that transformed RRT variance was significantly higher for the five trials preceding reports of mind wandering (*M* = 8.21, *SD* = 0.88) than for the five trials preceding reports of being on-task (*M* = 7.92, *SD* = 0.82), $t(66) = 3.35$, *SE* = 0.09, $p = .001$.

(fidgeting) data were normalized using a natural logarithm transformation (as per Seli, Carriere, et al., 2013) resulting in a transformed mean movement of 4.04 (*SD* = 0.45)[4]. A Pearson correlation between MMI scores and transformed mean movement revealed no significant association, *r*(71) = 0.09, *p* = 0.429. Lastly, consistent with prior findings (Seli, Carriere, et al. 2013), no significant correlation between response variance and movement behaviour (i.e., fidgeting) was observed, *r*(71) = 0.03, *p* = 0.833.

In summary, media multitasking negatively predicts performance on the MRT, such that higher levels of media multitasking are associated with greater response variability. However, no significant relation was found between media multitasking and probe-caught mind wandering or superfluous body movements (i.e., fidgeting) while completing the MRT[5].

Study 2

In Study 2, we evaluate whether the relation between media multitasking and sustained attention observed in Study 1 would generalize to another well-studied performance task that has been used to index sustained attention. To that end, in Study 2 we measured sustained attention performance using the Sustained Attention to Response Task (SART; Robertson et al., 1997). The primary indices of sustained attention failures in the SART are NOGO errors and response times (RTs) to GO trials. We hypothesize that higher reports of media multitasking will be associated with a greater frequency of NOGO errors and shorter RTs on GO trials.

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[4] As in a previous report (Seli, Carriere, et al., 2013), transformed mean movement on the five trials preceding reports of mind wandering (*M* = 4.12, *SD* = 0.57) was nominally higher than on five trials preceding reports of being on-task (*M* = 4.04, *SD* = 0.58). However, unlike in the previous report, the difference found here did not reach significance using a two-tailed paired-samples t test, *t*(66) = 1.38, *SE* = 0.61, *p* = .172.

[5] Given that we found no relation between media multitasking and these two measures, we opted not to include them in subsequent studies.

Method.

Participants. Eighty-three undergraduate students (63 female) from the University of Waterloo participated in exchange for course credit. One participant was removed for not completing the MMI, and six participants were removed for having greater than 10% omissions on the SART (Seli, Cheyne et al., 2013; Seli, Jonker et al., 2013). This resulted in data from 76 participants (59 female) being submitted for subsequent analyses.

Stimuli and procedure. Sustained attention in Study 2 was indexed by performance on the SART (see Figure 4). Each trial of the SART involves the presentation of a single digit (1-9) in the center of the screen for 250 ms, followed by a double-circle mask for 900 ms, resulting in a total trial duration of 1150 ms. For each block of nine trials, a single digit was chosen without replacement and presented in white on a black background. Each digit's size was randomly selected to be of font size 48, 72, 94, 100, or 120, with equal sampling of the five possible font sizes. Participants were asked to place equal emphasis on both speed and accuracy while completing the task. Furthermore, participants were instructed to make a response (via pressing the space bar) whenever the digit was not a '3' (i.e., a GO digit), and withhold their response when the digit was a '3' (i.e., a NOGO digit). Following 18 practice trials (containing two NOGO digits), participants completed 900 experimental trials, 100 of which were NOGO trials. After completing the SART, participants completed the Media Use Questionnaire (Ophir et al., 2009) in the same fashion as in Study 1.

Apparatus. The SART program was constructed using Python 2.6 (Python Software Foundation, http://www.python.org) using the Pygame 1.9.1 (http://pygame.org/news.html) and run on an Apple Mini with OS X 10.6.6 and a 2.4GHz Intel Core 2 Duo processor. Stimuli were presented on a 24” Philips 244E monitor at a resolution of 1920 by 1080, and participants were seated approximately 57 cm from the display screen.

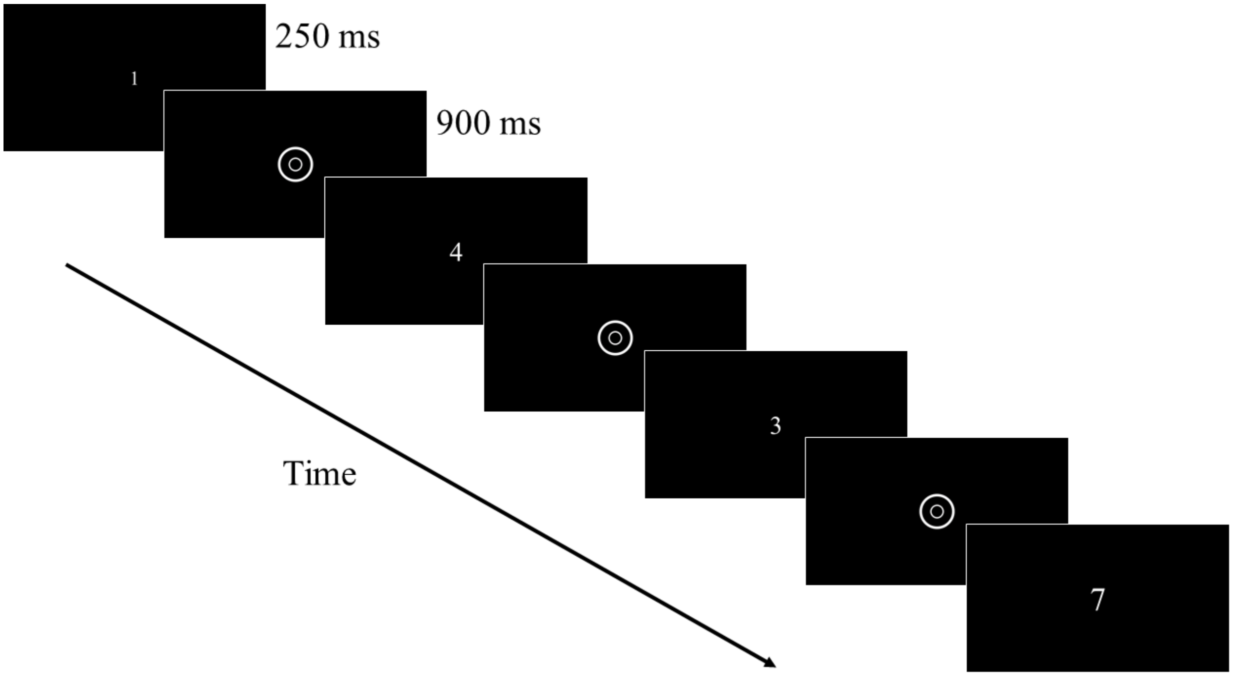

Figure 4. Example of four possible SART trials. Participants are instructed to respond to each digit, except for when that digit is a ‘3.’

Results and Discussion. The mean MMI score obtained from the Media Use Questionnaire was 3.46 (*SD* = 1.24), and the mean proportion of NOGO errors and mean RT on GO trials were 0.49 (*SD* = 0.24) and 406.57 ms (*SD* = 92.40 ms) respectively. A typical finding in the SART is that faster responding results in more NOGO errors and slower responding results in fewer NOGO errors (a speed-accuracy trade-off; Seli, Cheyne, & Smilek, 2012; Seli, Jonker et al., 2013; Seli, Jonker, Solman, Cheyne, & Smilek, 2013). Indeed, we observed a significant negative correlation between NOGO errors and RTs, $r(74) = -.67$, $p < .001$. Importantly however, there was no significant correlation between scores on the MMI and NOGO errors, $r(74) = 0.03$, $p = 0.793$ (Figure 5a), nor was there a significant correlation between MMI scores and RT, $r(74)$

= 0.08, p = 0.473 (Figure 5b)[6]. Given the co-variation of speed and accuracy within individuals across the task, we conducted a regression analysis to control for possible speed-accuracy trade-offs, seeking to determine whether NOGO errors and/or RT uniquely predicted scores on the MMI. As can be seen in Table 3, neither NOGO errors nor RT were found to significantly predict scores on the MMI. However, when controlling for RT, the partial correlation between MMI and NOGO errors increased from 0.03 to 0.12 (similarly, when controlling for errors, the partial correlation between MMI and RT increased from 0.08 to 0.14). Nonetheless, unlike in Study 1, here we found no evidence of an association between media multitasking and sustained attention performance.

Table 3

Regression of NOGO errors and RT predicting MMI

	β	*T*	*p*	Partial correlation
NOGO errors	0.16	1.0	.322	.12
RT	0.19	1.20	.233	.14

R = 0.14, F(2, 73) = 0.76, p = .473

[6] We also examined the relation between scores on the MMI and variance of GO RTs, computed along the same lines as that of Study 1 – using the natural logarithm transformed variability of a moving five-trial window. No significant correlation was observed, r(74) = 0.13, p = .265.

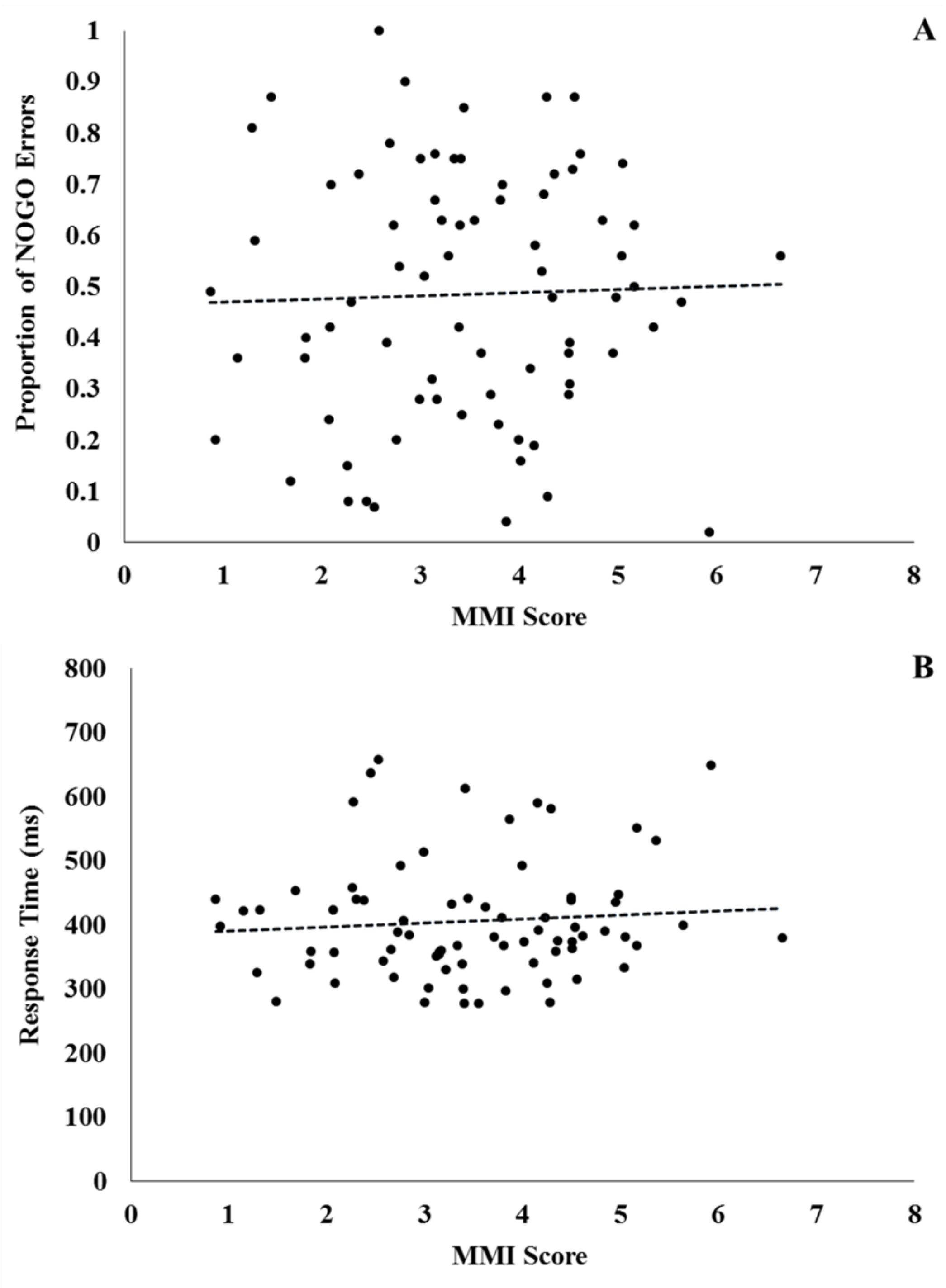

Figure 5. Scatterplots depicting the relation between MMI scores and NOGO errors (A) as well as response times to GO trials (B) on the SART. The dotted lines represent the best linear fit for the data.

Study 3a and 3b

The finding that MMI scores negatively predict performance on one sustained attention task (the MRT in Study 1) but not another (the SART in Study 2) was unexpected. That is, although the primary measures of sustained attention in these two tasks differ, one might imagine that if both tasks index the same general cognitive processes (the ability to 'sustain attention' to a single input source) then relations between media multitasking and performance should be observed either for both tasks, or for neither task. The fact that neither of these outcomes was observed is noteworthy and deserves further comment. But first, we sought to replicate the findings of both studies 1 and 2. Accordingly, in Study 3 we gather two large online samples and test the hypothesis that media multitasking is associated with increased response variability on the MRT (Study 3a) but that media multitasking is not associated with performance on the SART (Study 3b). Furthermore, we consider the possibility that because our assessments of trait-level media multitasking and our measures of sustained attention are gathered online, participants may actually engage in media multitasking during the experimental session. As a result, we also included a questionnaire to determine whether participants were media multitasking while completing the sustained attention tasks. We do this not to obtain a 'state'-level metric of media multitasking among individuals, but rather, to allow us to control for the potentially detrimental effects of media multitasking while participants complete the sustained attention tasks.

Method.

Participants. In Study 3 we aimed to collect large online samples with roughly double the sample sizes of Studies 1 and 2. In Study 3a, 174 participants (94 female) took part in an online study conducted through the Amazon Mechanical Turk and received $1.00 as compensation for their time. Participants with greater than 10% omissions were removed from subsequent analyses (as per Seli, Cheyne et al., 2013), resulting in the inclusion of 146 participants (77 female), with an age range of 18 to 67 years old (*M* = 37.5, *SD* = 13.).

Study 3b included 152 participants (77 female) who registered for the study via Amazon Mechanical Turk, and received $1.00 as compensation for their time. Participants with greater than 10% omissions were removed from subsequent analyses (Seli, Cheyne et al., 2013), resulting in the inclusion of 143 participants (74 female), with an age range of 18 to 68 years old (*M* = 35, *SD* = 12).

Stimuli and procedure. There were a few minor differences between the tasks used in this study and those used in the previous studies. In both Study 3a and Study 3b, the total number of trials in each task was reduced to facilitate affordable online data collection through Amazon Mechanical Turk. As such, participants in Study 3a completed 600 trials (and 18 practice trials). The SART used in Study 3b was similar to that of Study 2, except that participants completed 315 trials (and 18 practice trials) as per Smilek et al. (2010). This version of the SART included 35 NOGO trials and 280 GO trials. For both Study 3a and Study 3b, MMI scores were computed from responses to the Media Use Questionnaire in the same fashion as in Studies 1 and 2.

To assess in-the-moment media multitasking (since the study was conducted online), at the conclusion of the study we presented participants with a short questionnaire stating: “We are also interested in whether you were media multitasking while you completed this study. Please be honest, as your response will not affect your compensation or qualification for the study.” Participants were asked to indicate if they were engaged in any of the activities presented in a list, choosing as many as applied, by clicking a box next to each activity. The choices were: 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 textoriented sites (e.g., online news, blogs) or eBooks, talking on the telephone or video chatting (e.g., Skype, iPhone video chat), listening to music, watching TV and/or movies (online or off-line) or YouTube, playing video games, doing homework/studying/writing papers/other work, or other (in which case they were asked to specify the activity). Selecting even one of these options qualifies as media multitasking since the study itself constitutes a form of media consumption. Participants were also able to indicate that they did not engage in media multitasking while completing the study.

Results and Discussion.

Media multitasking and MRT performance (Study 3a). In Study 3a, we observed that MMI scores (M = 2.36, SD = 1.24) were significantly positively correlated with transformed RRT variance (M = 8.23, SD = 0.75), $r(144) = .21$, $p = .01$. Age was found to significantly and negatively correlate both with MMI scores, $r(144) = -.34$, $p < .001$, and transformed RRT variability, $r(144) = -.19$, $p = .019$. When controlling for the influence of age, the partial correlation between MMI and transformed RRT variance was marginal, $r_p(143) = .16$, $p = .055$ (two-tailed).

As noted above, we asked participants to indicate if they were media multitasking while completing the MRT. Of the 146 participants, 33 (22.6%) reported that they engaged with some other form of media while completing our online sustained attention task. Mean MMI scores for this group of multitasking participants was 2.82 (SD = 1.03). Since the present study was not intended to address how media multitasking affects performance *during* the MRT, data from participants who reported multitasking during the MRT were subsequently excluded, and the above analyses were re-computed for the remaining 113 participants. MMI scores (M = 2.23, SD = 1.27) remained significantly positively correlated with transformed RRT variance (M = 8.21, *SD* = 0.80), *r*(111) = .24, *p* = .01. While age remained negatively correlated with MMI scores, *r*(111) = -.29, *p* = .002, it was only marginally correlated with transformed RRT variance, *r*(111) = -.16, *p* = .089. Importantly, after 1) removing participants who were multitasking during the MRT, and 2) controlling for age, the partial correlation between MMI and transformed RRT variance was significant, $r_p(110) = .21$, *p* = .03 (see Figure 6).

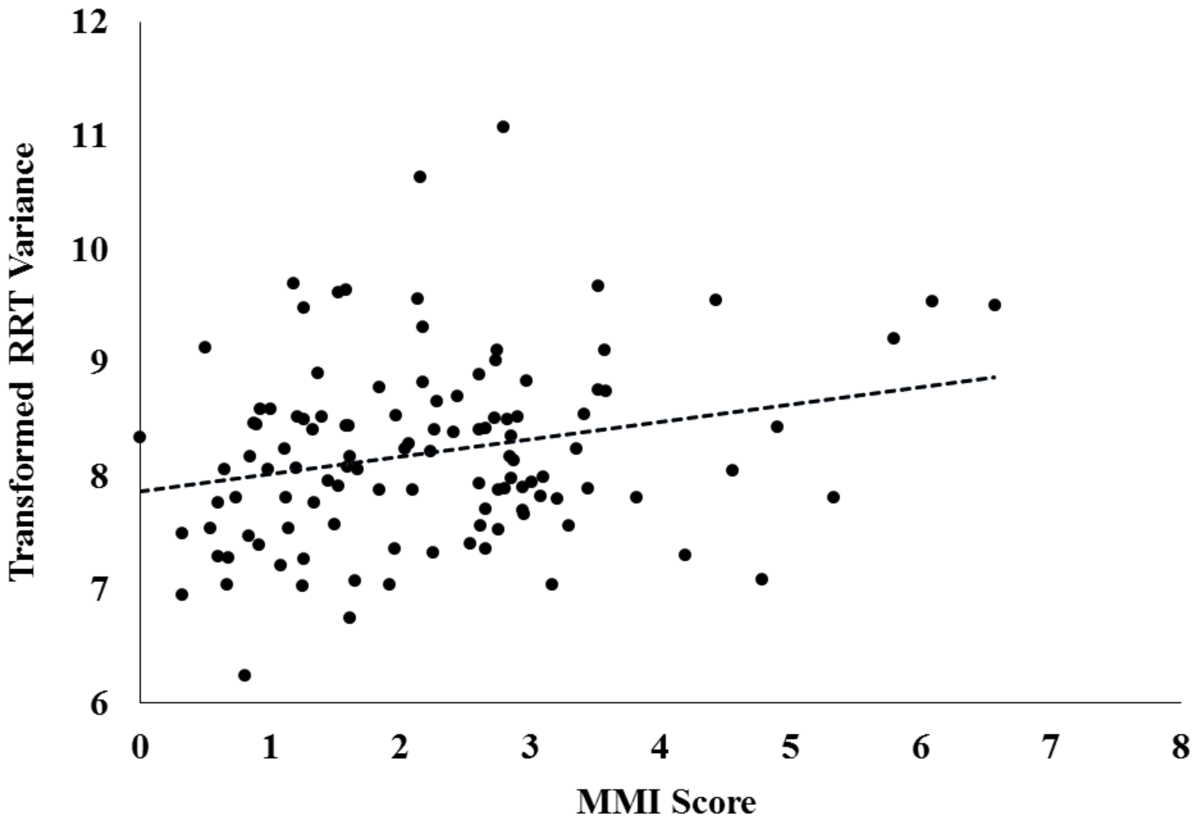

Figure 6. Scatterplot depicting the correlation between MMI scores and transformed rhythmic response time (RRT) variance for participants who reported not multitasking while completing the MRT (Study 3a). The dotted line depicts the best linear fit for the data.

Media multitasking and SART performance (Study 3b). In Study 3b, we examined the relation between MMI scores (*M* = 2.28, *SD* = 1.39), proportion of NOGO errors on the SART (*M* = .38, *SD* = .21), and RT on SART GO trials (*M* = 408.60 ms, *SD* = 89.22 ms). The expected speed-accuracy trade-off was again observed between NOGO errors and RT, *r*(141) = -.61, *p* < .001. This time, with a sample-size that was almost double that of Study 2, the correlation between MMI and NOGO errors bordered significance, *r*(141) = .16, *p* = .05, although the correlation between MMI and RT remained non-significant, *r*(141) = -.11, *p* = .195. Age was found to significantly and negatively correlate with MMI, *r*(141) = -.35, *p* < .001, NOGO errors, *r*(141) = -.19, *p* = .02, and positively with RT, *r*(141) = .25, *p* = .003. To control for the influence of age and the speed-accuracy trade-off, a regression was conducted to determine the unique contributions of age, NOGO errors, and RTs when predicting MMI scores (see Table 4). While age continued to significantly (negatively) and uniquely predict MMI scores (consistent with findings from Study 3) SART NOGO errors and RT did not.

Table 4

Regression of Age, NOGO errors, and RT predicting MMI

	β	*t*	*p*	Partial correlation
Age	-.34	-4.15	.000	-.33
NOGO errors	.13	1.35	.180	.114
RT	0.06	.57	.569	.05

R = 0.37 *F*(3,139) = 7.20, *p* < .001

In Study 3b we also asked participants if they were media multitasking while completing the SART. Seventeen participants (approximately 12%) of the original 143 reported that they were indeed engaging in another form of media while completing the SART. These participants had a mean MMI score of 2.84 (*SD* = 1.48). The 17 participants who reported multitasking while completing the SART were excluded and the above analyses re-computed for the remaining 126 participants. MMI scores (*M* = 2.21, *SD* = 1.36) were not found to significantly correlate with proportion of NOGO errors (*M* = 0.37, *SD* = 0.22), $r(124) = .13$, $p = .164$ (see Figure 7a), nor did they significantly correlate with RT (*M* = 406.13 ms, *SD* = 87.62 ms), $r(124) = -.14$, $p = .113$ (see Figure 7b). Furthermore, age remained significantly and negatively correlated with MMI, $r(124) = -.33$, $p < .001$, NOGO errors, $r(124) = -.22$, $p = .012$, and positively correlated with RT, $r(124) = .22$, $p = .012$. A regression was computed to assess the unique contribution of age, NOGO errors, and RTs when predicting MMI, with the multitasking participants removed (Table 5). No meaningful relation between MMI and SART performance, whether it be NOGO errors or RT, was found (although, consistent with Study 3a, age negatively and uniquely predicted MMI scores).

Table 5

Regression of Age, NOGO errors, and RT predicting MMI, after removing multitasking participants

	β	*t*	*P*	Partial correlation
Age	-.31	-.36	.001	-.31
NOGO errors	.01	.10	.918	.009
RT	-.07	-.56	.577	-.05

$R = 0.34$ $F(3,122) = 5.19$, $p = .002$

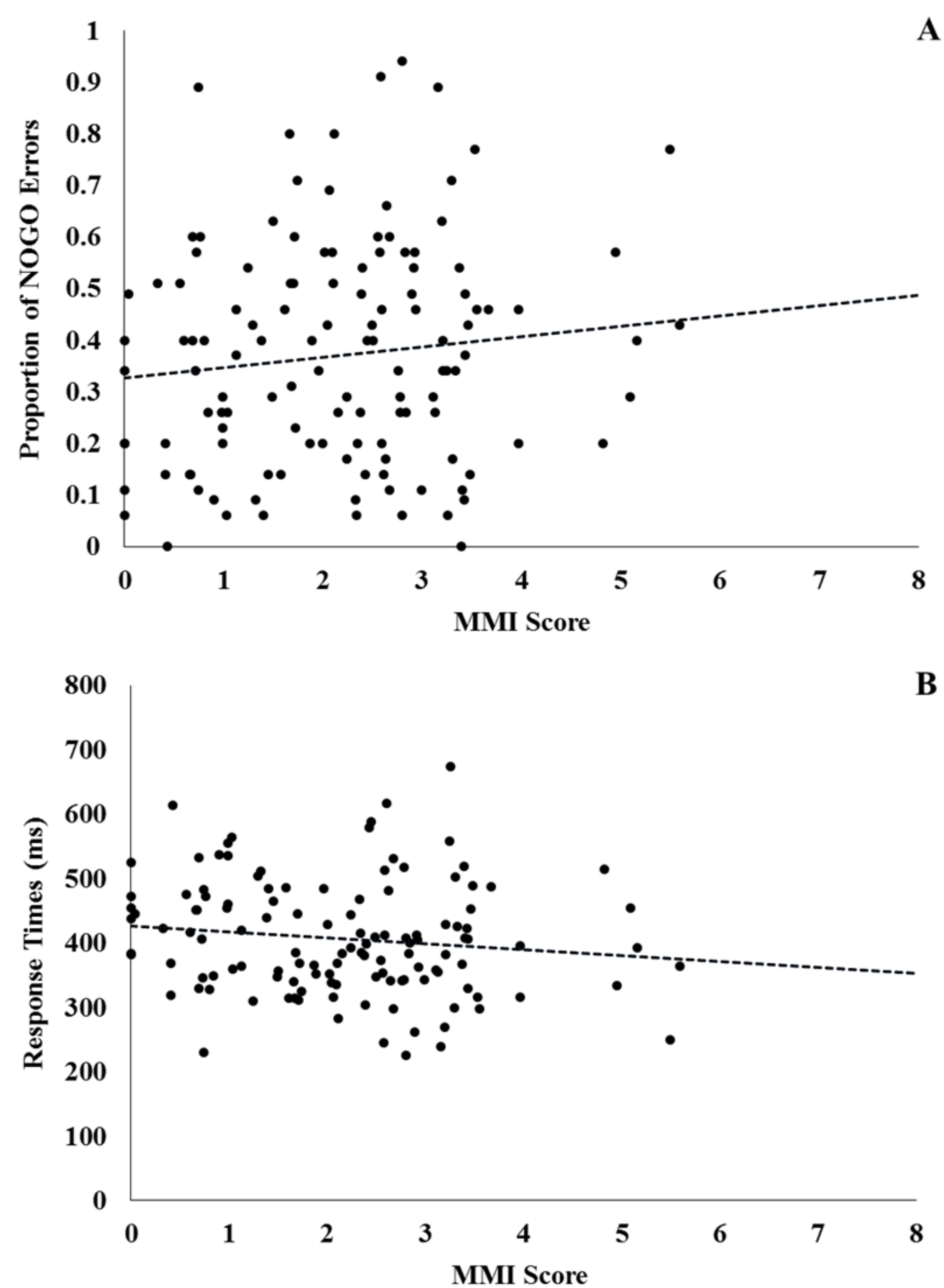

Figure 7. Scatterplots depicting the relation of MMI scores with performance in the SART (Study 3b; non-multitaskers). Panel A (top) shows the relation of MMI scores with proportion of NOGO errors on the SART, and Panel B (bottom) shows the relation between MMI scores and response times on GO trials. The dotted lines represent the best linear fit for the data.

In summary, the purpose of Study 3 was to replicate the findings of Study 1 and Study 2, in which we found that self-reports of media multitasking were negatively associated with performance on one sustained attention task (the MRT, Study 1), but not another (the SART, Study 2). These findings were replicated such that in Study 3a we found that media multitasking was significantly associated with response variability in the MRT, and in Study 3b, we found no association between MMI and either errors of commission or response speed in the SART.

As we noted earlier, there is no single agreed-upon measure of sustained attention. While a variety of behavioural measures may be employed to index sustained attention ability, each of these measures are, to some extent, unique. For instance Seli, Jonker and colleagues (2013) noted that both SART RTs and NOGO errors uniquely predict MRT RRT variance (when controlling for the speed-accuracy trade-off in the SART). Thus, rather than relying on any single measure of sustained attention, in the present series of studies, we opted to include a variety of behavioural measures to discern whether media multitasking is associated with a general ability to sustain attention, or task-specific components related to sustained attention. Based on the data analyzed thus far, it appears that media multitasking is associated with only a task-specific component of the MRT, rather than a general ability to sustain attention (in which case one would expect to see a relation with SART measures as well).

Study 4

The purpose of the current series of studies is to investigate whether media multitasking is related with a *general* ability to sustain attention on a single task. Given that in studies 1-3, media multitasking was found to predict performance on one sustained attention task (the MRT) but not another (the SART), we decided to examine performance on yet another sustained attention task to determine whether, on balance, media multitasking predicts performance in terms of the behavioural measures often used to index sustained attention. Thus, in Study 4 we employed perhaps the most well-studied test of sustained attention: a vigilance task. Generally, an observer's ability to sustain attention, or remain vigilant, decreases over time. This vigilance decrement typically manifests in the form of decreasing sensitivity to the critical targets and/or prolonged RTs on target detections (e.g., Mackworth N. H., 1948; McCormack, 1958; Helton & Russell, 2012). Thus, in Study 4 we tested whether scores on the MMI were associated with overall performance on the vigilance task as well as the size of the vigilance decrement.

Method.

Participants. This study included 130 participants (49 female) who signed-up via Amazon Mechanical Turk. In appreciation for their time, participants received $1.00. One participant was removed from subsequent data analysis for having greater than 25% false alarms (interpreted as misunderstanding task instructions), and 20 participants were removed for indicating that they were media multitasking during the vigilance task[7]. Accordingly, data was analyzed for the remaining 109 participants, with an age ranged of 20 to 82 years old (*M* = 40, *SD* = 13).

Stimuli and procedure. The vigilance task in Study 4 used the same stimuli and trial-sequence as the SART in Studies 2 and 4 (see Figure 4). Importantly, however, in Study 4 participant were instructed to respond to an infrequent GO digit (i.e., when the digit was a '3') but to withhold response to frequent NOGO digits (i.e., digits 1, 2, 4, 5, 6, 8, and 9; Carter et al., 2013). As such, participants received a total of 810 trials, 90 of which were GO trials, and 720

[7] MMI scores for this sub-group of 20 participants had a mean of 2.46 and a standard deviation of 1.34. While in studies 3a and 3b we analyzed data with-and-without these participants included, in Study 4 we simply decided to exclude them on the basis of violating the premise of the task.

were NOGO trials. Trials were divided into five Periods of Watch (i.e., blocks), each of which lasted approximately 3 minutes and contained 162 trials, 18 of which were GO trials and 144 of which were NOGO trials. At the end of the task, participants were asked to complete the same in-the-moment media multitasking question as in studies 3a and 3b, followed by the MMI.

Results and Discussion. Percent hits and false alarms for each participant in each Period of Watch were used to compute A' (as per Macmillan & Creelman, 2005), which is an appropriate measure of sensitivity when there are hit rates of 100% and/or false alarm rates of zero. Mean A' and RT (for hits) during each Period of Watch are plotted in Figures 8 and 9, respectively.

To determine whether performance decreased as a function of time on task, A' and correct RTs for each participant were submitted to a repeated measures analysis of variance (ANOVA) whereby Period of Watch (1, 2, 3, 4, 5) was entered as a within-subject factor. For A', Mauchly's test indicated a violation of sphericity, $\chi^2(9) = 547$, $p < .001$, and a Greenhouse-Geisser correction ($\varepsilon = .310$) was applied. As depicted in Figure 8, there was a significant main effect of Period of Watch, such that A' was found to decrease as a function of time on task, $F(1.24, 133.86) = 4.95$, $MSE = .01$, $p = .021$, $\eta_p^2 = .044$. Similarly, for RTs, Mauchly's test indicated a violation of sphericity, $\chi^2(9) = 98.1$, $p < .001$, and so a Greenhouse-Geisser correction was applied (ε = . 729). As shown in Figure 9, the ANOVA revealed a significant main effect of Period of Watch, such that RTs became longer as a function of time on task, $F(2.92, 315.01) = 43.66$, $MSE = 1726.45$, $p < .001$, $\eta_p^2 = .614$

Having demonstrated a vigilance decrement in both A' and RT, we next sought to test whether subjective reports of media multitasking were related with overall performance on the task, and/or size of the decrements (i.e., slopes) in both A' and RT. A weak, yet significant negative correlation of MMI (*M* = 2.10, *SD* = 1.20) with overall sensitivity (A'; *M* = .98, *SD* = .04) was found, $r(107) = -.19$, $p = 0.045$, however, this correlation returned non-significant when controlling for age, $r(104) = -.14$, $p = .142$. Furthermore, no association was observed between MMI and average RT (*M* = 515 ms, *SD* = 73 ms), $r(107) = .001$, $p = .995$. When looking at the slope of A' across the five Periods of Watch (i.e., change in A' over time; see Figure 10a), no significant relation with MMI scores was found, $r(107) = -.05$, $p = .621$. Similarly, MMI scores were not found to be significantly related to the slope of the RTs, $r(107) = .11$, $p = .264$ (see Figure 10b)[8]. Taken together, we found no evidence that media multitasking is associated with one's ability to remain vigilant over time.

[8] This pattern of significance remained true following the removal of outliers who were more than three standard deviations above or below the means of the variables of interest. A' slopes remained non-significantly correlated with MMI scores, $r(102) = -.07$, $p = .492$, and RT slopes remained non-significantly correlated with MMI scores, $r(103) = .11$, $p = .246$.

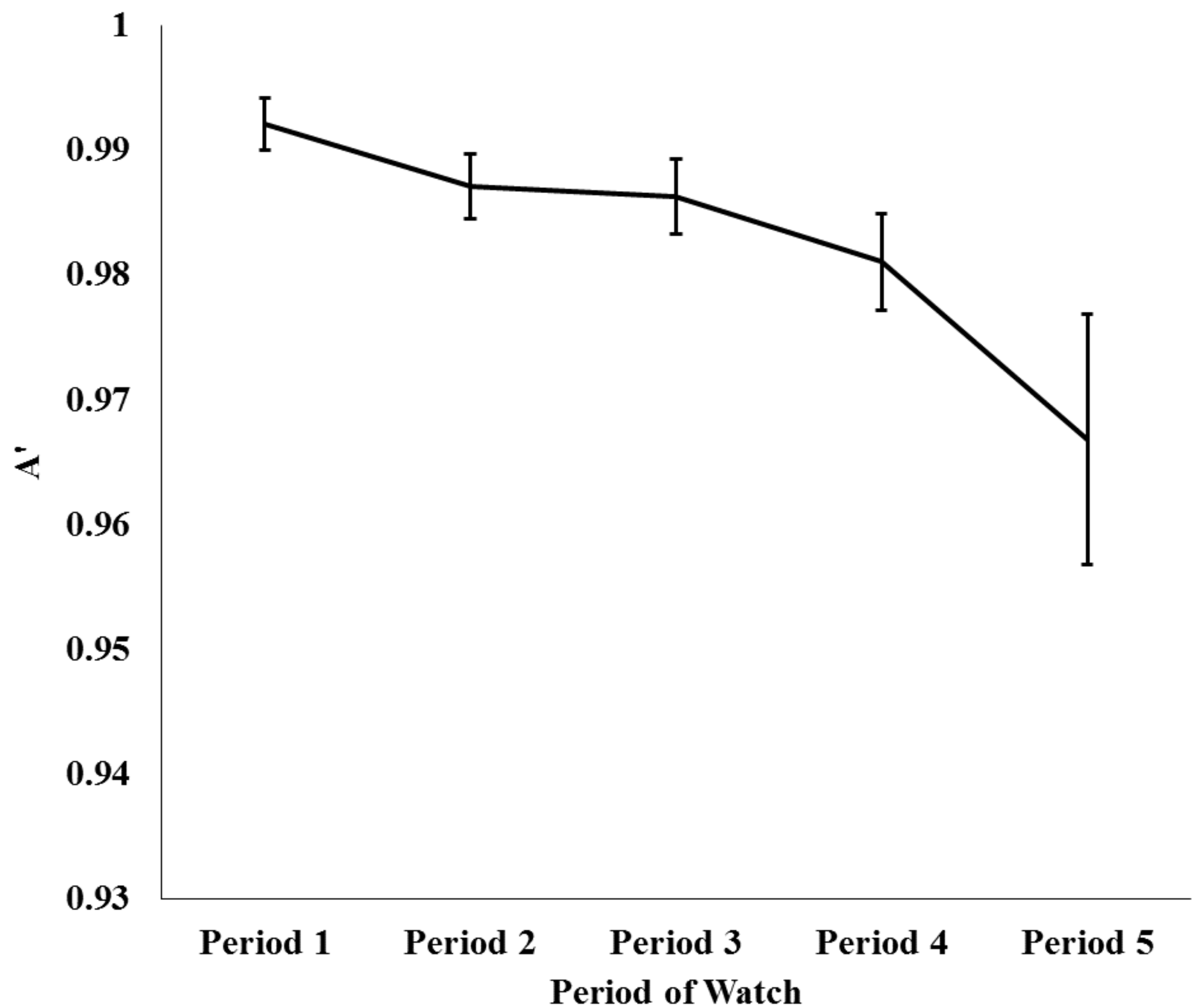

Figure 8. Sensitivity (A') in each watch period averaged across participants (Study 4). Error bars represent one standard error of the mean.

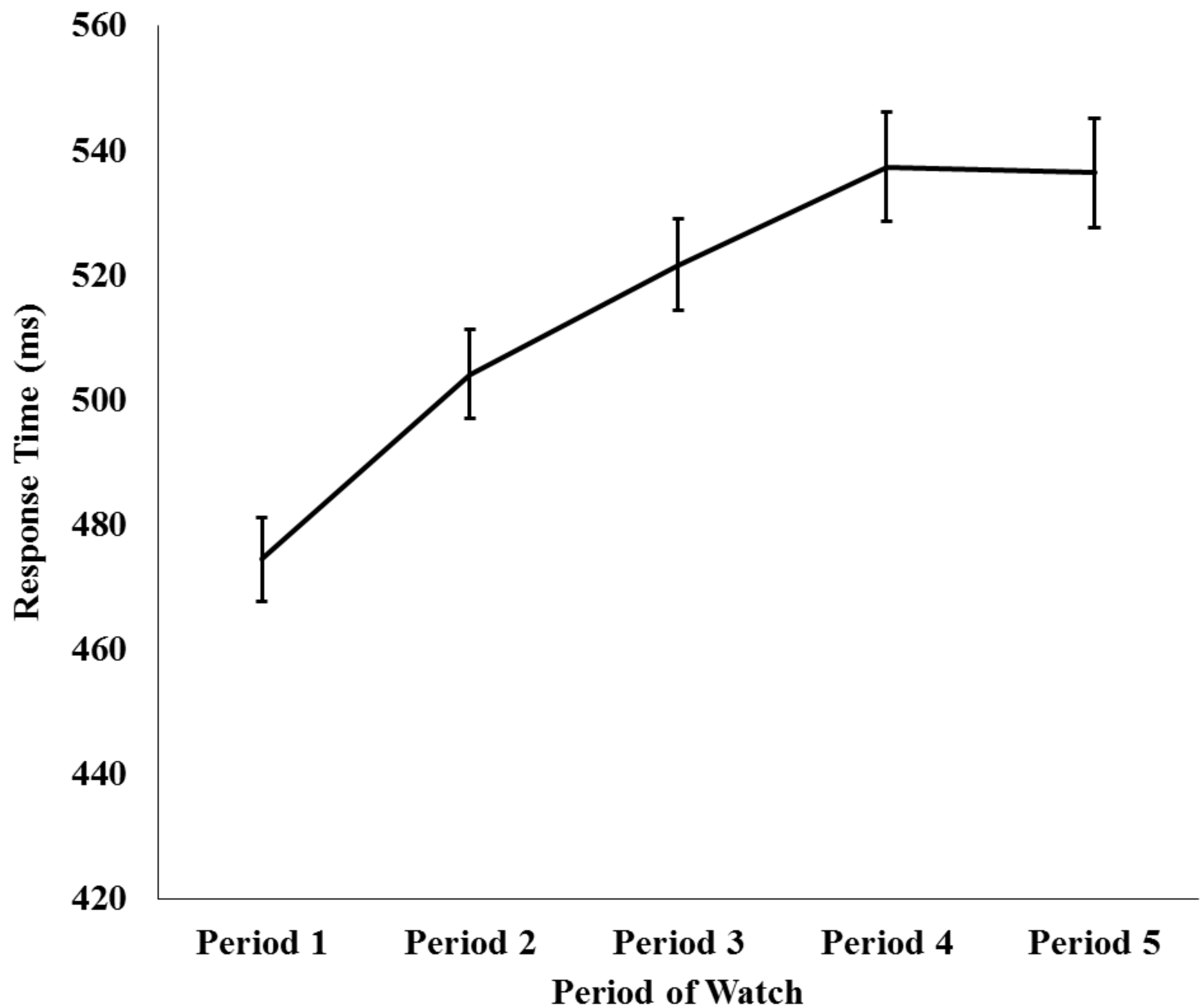

Figure 9. Response times to GO trials averaged across participants for each Period of Watch (Study 4). Error bars represent one standard error of the mean.

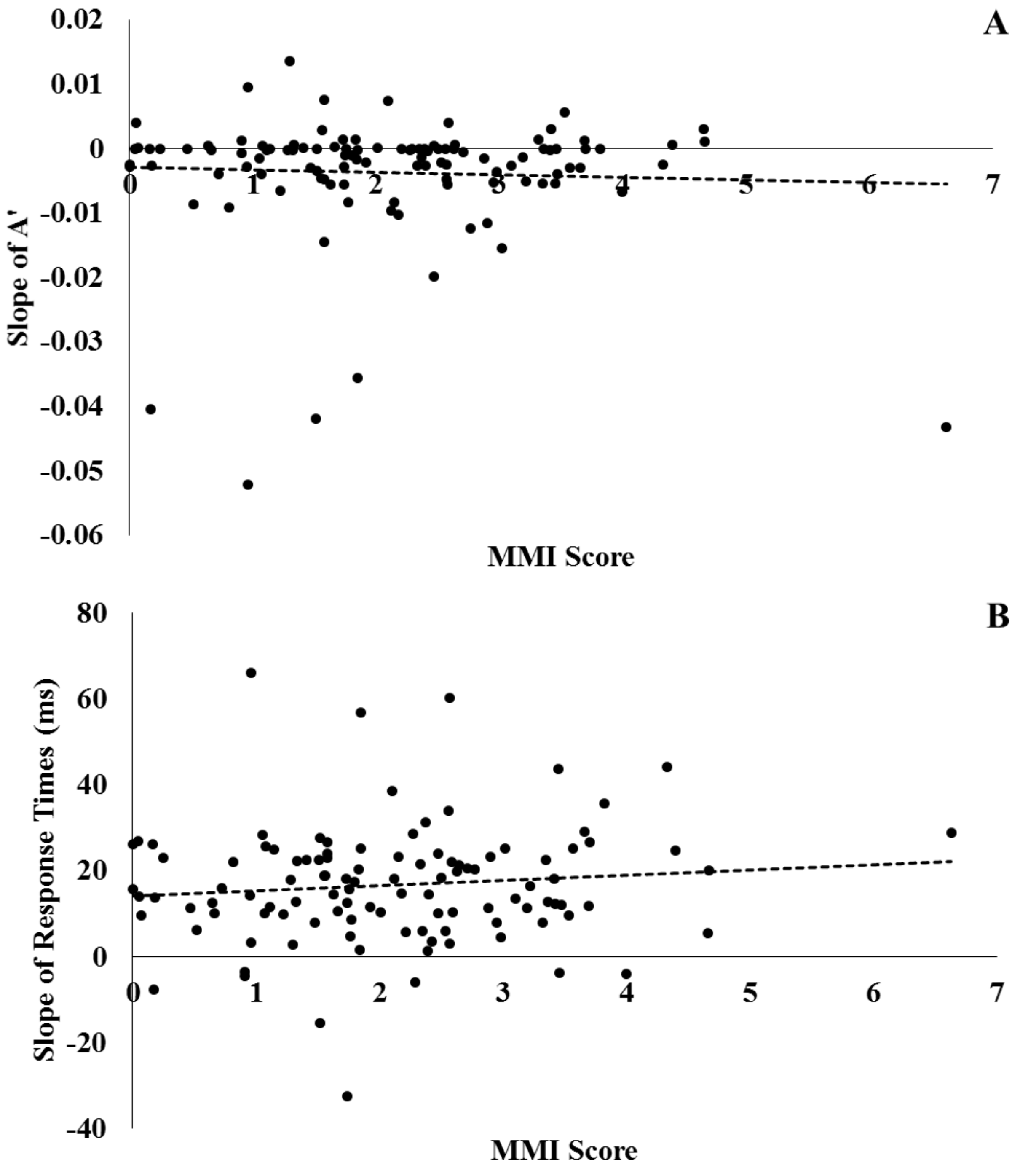

Figure 10. Scatterplots depicting the relation of MMI scores with performance on the vigilance task in Study 4. Panel A (top) shows the relation of MMI scores with the slope of A' across the five Periods of Watch, and Panel B (bottom) shows the relation of MMI scores with the slope of RTs across the five Periods of Watch. The dotted lines represent the best linear fit for the data.

Chapter 3 Summary

The purpose of the work reported in Chapter 3 was to examine the link between habitual engagement in media multitasking and one's ability to sustain attention on a *single* task. We hypothesized that individuals who frequently divide their attention among several streams of media may exhibit difficulties in sustaining their attention on any one particular source of information (as suggested by subjective reports in Chapter 2; Ralph et al., 2013). The results were clear: while the tendency to media multitask was associated with increased response variability (i.e., poor performance) on the Metronome Response Task (Study 1 and Study 3a), we found no relation between media multitasking and performance on the SART, both in terms of NOGO errors and RTs (Study 2 and 3b). Similarly, using a vigilance task in Study 4 (quite possibly the most venerable of sustained attention tasks), we found no association between media multitasking and overall performance or the size of the vigilance decrement both in terms of sensitivity and response time. We therefore conclude that habitual media-multitasking is not related to *general* impairments in sustained attention. That is, the positive relation we observed between self-reported media multitasking and response variance in the MRT seems highly specific to the paradigm and measure employed, and is likely not sub-served by a global deficiency in sustained attention.

Although not of primary focus, perhaps one of the most interesting findings to emerge from the work presented in Chapter 3 was that, in our online samples, approximately 23% of participants in Study 3a, 12% in Study 3b, and 16% in Study 4 confessed that they were media multitasking while they were supposed to be completing the *sustained attention* tasks. Moreover, in one of our samples (Study 3a), the inclusion or exclusion of these participants influenced whether the correlation between media multitasking and the behavioural measure of interest reached statistical significance, albeit marginally. The finding that nearly one-quarter of the individuals in one of our online samples was doing something other than the instructed task was quite surprising and even troubling given the apparent prevalence of media multitasking (Rideout et al., 2010), and the increasing use of online samples in psychological research (e.g., Paolacci, Chandler, & Ipeirotis, 2010; Riva, Teruzzi, & Anolli, 2003). Inquiring as to whether participants are actually media multitasking while completing online tasks might be a useful way to identify (and perhaps exclude) those who concurrently do something other than the experimental task. Although we conclude that trait measures of media multitasking do not predict underlying deficiencies in sustained attention, in-the-moment media multitasking is likely to impair one's ability to perform the primary task.

Chapter 4: General Discussion

Why is it that individual differences in media multitasking are associated with *subjective* reports of attention lapses (Chapter 2; Ralph et al., 2013) but not with *objective* indices of sustained attention ability as measured in the laboratory? One clear hypothesis is that media multitaskers may differ in terms of the way they approach tasks, rather than in their underlying ability to sustain attention on any given task. In the real world, attention failures may manifest more in heavy multitaskers than light multitaskers because they may simply surround themselves with more distractions and "allow" themselves to be more distracted. This may be reflected in Ralph et al.'s (2013) finding (Chapter 2) that media multitasking is more strongly tied to the general tendency to deliberately mind wander (i.e., "allow" one's attention to drift off-task) than it is with the tendency spontaneously (or unintentionally) mind wander. Furthermore, in Chapter 2 we also noted that heavy and light media multitaskers do not differ in terms of their perceived ability to control their attention and ignore distracting information (despite experiencing more attention failures). Indeed, these perceptions may be quite accurate, and are supported by the current data; when *required* in the laboratory to maintain attention on a single task, heavy and light media multitaskers show no compelling differences in terms of their general ability to sustain attention on the task.

Returning to our causal model from Chapter 2 (Figure 1), we originally proposed two hypotheses to explain the association between media multitasking and self-reported attention failures: 1) a *deficit-producing hypothesis* whereby repeatedly media multitasking might atrophy endogenous control mechanisms necessary for sustained attention (e.g., McVay and Kane, 2010), and alternatively 2) a *self-selection hypothesis* whereby attentional dispositions might cause individuals to gravitate towards media multitasking. Findings from Chapter 3, however, suggest a third possibility: heavier media multitaskers report experiencing more episodes of absent-mindedness/inattention and attention-related errors, not because they have poor sustained attention ability, but because they put themselves in situations that compromise their attention. While the questionnaires we used to assess attention lapses and errors in Chapter 2 (the MAAS-LO and the ARCES) may be used as indirect measures of cognitive ability, the questionnaires themselves only directly assess the tendency to experience attention lapses and errors in specific everyday situations. Accordingly, the questionnaires could also be sensitive to differences in attentional strategies people bring to everyday situations. That is, heavier media multitaskers likely report greater attention failures due to the way they interact with their environment, rather than due to some underlying impaired ability to focus attention. This might explain why in Chapter 2 we found no meaningful association between media multitasking and measures of attention control, attention switching and spontaneous mind wandering. Therefore, while the general causal direction of the model is likely correct (i.e., media multitasking leading to attention lapses and errors), the interpretation of the model changes – namely, it is not attention ability that is affected by media multitasking, but rather the approach to tasks a person might take in their daily life.

An alternative interpretation of the data is that heavy media multitaskers may simply *report* more lapses of attention and errors, rather than actually *experiencing* them. Perhaps it is the case, for example, that their propensity to multitask drives heavy media multitaskers to reflect more on, or be more aware of, their attentional fluctuations. However, such an interpretation implies that heavier media multitasking is actually linked with *greater* mindfulness, which should in turn lead to *better* performance on sustained attention tasks (MacLean et al., 2010; Mrazek et al., 2012; Mrazek et al., 2013). Clearly, this pattern was not found in the present studies.

A general concern that comes with the use of any subjective report measure is the inability on behalf of the participant to provide accurate self-assessment of the construct of interest. While it is certainly possible that participants are ill-equipped to provide an accurate account of their tendency to experience attention failures in their daily lives, previous studies have reliably found evidence that self-report measures of inattention (whether via questionnaires or thought-probes) are predictive of objective performance measures (e.g., Cheyne et al., 2006; McVay et al., 2013; Robertson et al., 1997; Seli, Cheyne et al., 2013; Smilek et al., 2010). In other words, individuals who report more attention failures tend to do worse on in-lab sustained attention tasks (e.g., Smilek et al., 2010). One limitation to the present series of studies is that subjective and objective measures of sustained attention were never combined in a single study, which precludes direct corroboration of the two types of measures. Instead, we must rely on the precedence set by previous work on the validity of subject reports of inattention.

To summarize, we investigated whether habitually dividing or switching attention between multiple streams of media-based information is associated with differences in the underlying ability to sustain attention on any one particular source of information. A priori, we reasoned that frequent engagement in media multitasking may atrophy one’s ability to sustain attention and hypothesized that media multitasking may function as a counter to practices such as mindfulness training, whereby individuals are trained to focus their attention on a single source of information We found that in everyday life, increased levels of media multitasking are certainly associated with greater reports of attention failures. Objectively, however, we find little evidence for actual changes in cognitive processing. Given that in-the-moment multitasking has been shown to compromise attention to the primary task (e.g., when trying to read while attending to a television program; Lin et al., 2009), we suggest the attention failures reported in everyday life are tied to the way that individuals approach situations, such that heavy media multitaskers simply choose to surround themselves with distracting information which compromises attention in-the-moment. The ‘good news’ is that among media multitaskers, these perceived attention failures do not translate to a decline in the fundamental ability to focus attention when necessary.

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