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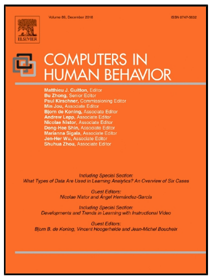

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Media multitasking, dual task ability and inhibitory control

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Media multitasking, impulsivity and dual task ability

Abstract

With recent developments in technology, media multitasking is an ever-increasing phenomenon. Although most studies associate media multitasking with high impulsivity and poorer cognitive performance, findings in the literature have been mixed, with some studies suggesting the opposite. The aim of this study was to investigate the relationship between media multitasking and the capacity to exert inhibitory control, as well as the ability to multitask in a multisensory setting. Results showed that media multitasking was associated with high attentional impulsivity and lower initiatory self-control, but not with inhibitory self-control. Relatedly, heavy media multitaskers were slower and showed more omission errors on the go/no-go task, suggestive of inattention; however, they were better at inhibiting already initiated motoric responses in the stop signal task. Media multitasking was further associated with faster responses when a letter and a tone task were temporally separated, but not when they were presented closer in time. Taken together, the results suggest a more nuanced relationship between media multitasking, personality and cognitive ability than has previously been thought. This has important real life implications for media multitasking, showing both advantages and disadvantages.

Key words: media multitasking, impulsivity, self-control, dual task, multisensory, psychological refractory period (PRP)

1. Introduction

Recent improvements in the accessibility and portability of technology have resulted in people spending more time on devices and having the ability to perform several digital tasks at once, known as media multitasking (Carrier, Rosen, Cheever, & Lim, 2015). For example, people often listen to music, answer messages on the phone, check updates on social media, while studying or working. However, most theories of human cognition posit that we are not particularly well suited to it, as our attentional systems have a limited capacity to process multiple streams of information (Broadbent, 1958; Deutsch & Deutsch, 1963; Treisman, 1960). This has led to scientific enquiries into individual differences in media multitasking, in particular, whether a particular personality trait is associated with media multitasking and if frequent media multitasking is linked to any specific deficits in cognitive abilities.

Previous studies on media multitasking have associated frequent media multitasking with impulsivity (e.g., Minear, Brasher, McCurdy, Lewis, & Younggren, 2013). Impulsivity is commonly defined as "a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individuals or to others" (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001, p. 1784). It is suggested that impulsive individuals are more likely to engage in media multitasking than those who are not, as they have more difficulty inhibiting distractions despite the detrimental effect on task performance (Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013). Consistently, media multitasking is further associated with a greater sensation seeking tendency (Jeong & Fishbein, 2007) and poorer self-control (Minear et al., 2013), indicating that heavy media multitaskers are more likely to seek pleasure and excitement while engaged in a boring task, but possess poorer ability to control these impulses.

However, results from previous studies on the relationship between media multitasking and impulsivity using self-report and cognitive measures have been inconclusive. For example, although self-report measures of impulsivity have been consistently associated with media multitasking (Minear et al., 2013; Sanbonmatsu et al., 2013), studies that have used cognitive measures of impulsivity such as the go/no-go task and the stop signal task have failed to show a relationship between media multitasking and sustained attention (e.g., Ophir, Nass, & Wagner, 2009; Ralph, Thomson, Seli, Carriere, & Smilek, 2015). This inconsistency in the literature warrants further investigation into the way in which impulsivity influences multitasking behavior.

Furthermore, impulsivity has been linked to poorer cognitive performance ─ impulsive individuals show poorer sustained attention, vigilance (Helton, 2009) and executive functioning (Cheung, Mitsis, & Halperin, 2010). In support, initial studies found that heavy media multitasking is associated with poorer cognitive performance, in particular, with cognitive constructs that are important for efficient multitasking. For example, frequent media multitasking has been linked to poorer ability in suppressing distractors (Cain & Mitroff, 2011), greater task switching costs (Ophir et al., 2009), reduced working memory capacity (Sanbonmatsu et al., 2013) and poorer long-term memory (Uncapher, Thieu, & Wagner, 2015). This suggests that individuals who are less capable of efficient multitasking are more likely to engage in media multitasking due to an inability to suppress distracting information. However, recent studies on multitasking have shown that some individuals may have superior multitasking abilities and are capable of performing multitasking with little costs (Medeiros-Ward, Watson, & Strayer, 2015; Watson & Strayer, 2010). Some heavy media multitaskers may also acquire superior multitasking abilities due to practice as they are, by definition, those who frequently engage in multitasking.

Indeed, Alzahabi and Becker (2013) showed that heavy media multitaskers actually performed better than light media multitaskers on measures of task switching without speed-accuracy trade off, and in a dual task, the performance of heavy media multitaskers was comparable to that of light media multitaskers. Further, Lui and Wong (2012) found that heavy media multitaskers were better able to integrate information from multiple sources. In their task, the colour of a target and distractors alternated between red and green at different frequencies. When a tone was presented in synchrony with the changing of the target colour, heavy media multitaskers were better at utilizing the unexpected tone to boost their visual task performance. This suggests that the strength of heavy media multitaskers may lie in multisensory integration, and that the dual tasks used in previous studies (mostly consisting of two visual tasks) may not be best suited to detect subtle differences in the characteristics of heavy and light media multitaskers. Indeed, in real life, media multitasking often involves tasks in different modalities that are more compatible (often visual and auditory, such as writing a report and listening to music) rather than tasks in the same modality, which are more likely to be incompatible (Kool, McGuire, Rosen, & Botvinick, 2010; Wang, Irwin, Cooper, & Srivastava, 2015). Therefore, a dual task that combines tasks of different modalities would be more suitable for examining the abilities associated with media multitasking. Furthermore, the dual tasks used in previous studies presented a series of stimuli in a predetermined sequence and time frame. For instance, Alzahabi and Becker (2013) presented their two tasks at the same time with equal emphasis on each task. However, in real life, media multitasking involves managing concurrent tasks initiated at different intervals. Therefore, a dual task involving different modalities within each task, and which are initiated at varying intervals may be most suitable for measuring the actual multitasking ability of media multitaskers.

1.1. The present study

The present study sought to further investigate individual differences in personality traits and cognitive abilities associated with media multitasking. The aim of the current experiments was two-fold. First, we investigated the relationship between media multitasking and impulsivity more closely across a range of both self-report and cognitive task measures of impulsivity. By doing so, we sought to resolve the discrepancy in the findings regarding media multitasking and impulsivity. Second, we examined whether media multitasking is associated with better performance in a dual task paradigm with tasks of different modalities that are initiated at varying intervals, to measure real life multitasking ability of media multitaskers. To this end, we used the well-known psychological refractory period (PRP) task (Pashler, 1994b; Ulrich & Miller, 2008; van Selst, Ruthruff, & Johnston, 1999; Welford, 1952), which presents a visual and an auditory task at a set of different intervals.

2. Experiment 1

In Experiment 1, we sought to expand on the relationship between media multitasking and impulsivity. Previous studies on media multitasking have associated frequent media multitasking with greater impulsivity and poorer self-control. It has been shown that heavy media multitaskers exhibit higher scores on the Barratt Impulsiveness Scale (Sanbonmatsu et al., 2013) and on the ADHD index (Uncapher et al., 2015), and lower scores on the Self-Control Scale (Minear et al., 2013). The relationship between media multitasking and impulsivity has also been explored using cognitive tasks, such as the go/no-go task (Murphy, McLauchlan, & Lee, 2017; Ralph et al., 2015; Wilmer & Chein, 2016) and the stop-signal task (Ophir et al., 2009) to measure the ability to inhibit prepotent responses. Contrary to the results from self-report measures, however, these showed no significant differences in performance among participants with different levels of media multitasking (go/no-go task; Ralph et al., 2015; stop signal task; Ophir et al., 2009). Therefore, in Experiment 1, we sought to examine more closely the relationship between media multitasking and impulsivity on a range of self-report and cognitive task measures of impulsivity. Moreover, previous studies have used either the go/no-go or the stop signal task to examine the relationship between media multitasking and response inhibition. In the current experiment, we included both the go/no-go and the stop signal tasks. Although the two tasks are similar, there is an important difference in the timing of inhibition. In the go/no-go task, participants inhibit a pre-potent response that has not yet been initiated, whereas in the stop signal task, they inhibit an already triggered motor response (Zheng, Oka, Bokura, & Yamaguchi, 2008). By using both tasks, we sought to determine where the difference associated with media multitasking lies in the course of response inhibition.

2.1. Method

2.1.1. Participants

One hundred and forty-four participants aged 18-48 years (*M* = 31.8, *SD* = 11.7, 96 females) were recruited. Of these, 104 participants were first year psychology students at Charles Sturt University who participated for course credit. The remaining forty participants were first year psychology students at Flinders University who were entered into a draw to win two $100 gift vouchers. Ethics approval was obtained from the Faculty of Business, Justice and Behavioral Sciences Human Ethics Committee (Charles Sturt University).

2.1.2. Materials

There were three self-report measures, the media use questionnaire (Ophir et al., 2009), the Barratt Impulsivity Scale (BIS-11; Patton, Stanford & Barratt, 1995) and the Self-Control Scale (Tangney, Baumeister & Boone, 2004), and two computerized cognitive tasks, the cued go/no-go task (Fillmore, Rush, & Hays, 2006) and the stop signal task (Verbruggen, Logan, & Stevens, 2008).

2.1.2.1. Media multitasking questionnaire.

The media use questionnaire developed by Ophir, Nass and Wagner (2009) surveys 12 distinct media forms consisting of print media, television, computer-based video (e.g., YouTube or Stream Services), music, non-music audio, video or computer games, telephone and mobile voice calls, instant messaging, SMS (text messaging), e-mail, web surfing, and other computer based applications (e.g., word processing). Respondents are asked to report the total number of hours per week spent utilising a primary medium. They are then asked if they utilise a secondary medium concurrently “Most of the time”, “Some of the time”, “A little of the time”, or “Never”. A media multitasking index (MMI) is calculated by summing the number of secondary media used while engaged in a primary medium weighted by the percentage of time spent with each primary medium as per Ophir et al. (2009). The mean MMI score was 3.32 with a standard deviation of 1.62.

2.1.2.2. Barratt Impulsivity Scale (BIS-11).

The Barratt Impulsivity Scale (BIS-11) is a 30 item self-report scale designed to measure impulsiveness (Patton et al., 1995), with individual items such as “I buy things on impulse” and “I say things without thinking”. Eleven items are reverse scored such as “I plan tasks carefully”. The scale includes three subscales, attentional (8 items), motor (11 items) and non-planning (11 items) impulsiveness. Each item is rated on a 4-point scale, ranging from 1 = rarely/never to 4 = almost always/always. Possible scores range from 30 to 120, with higher scores indicating greater impulsiveness. Cronbach’s alpha of the current sample was .83.

2.1.2.3. Self-Control Scale (SCS).

The Self-Control Scale is a 36 item self-report scale designed to assess aspects of self-control (e.g., self-discipline, deliberate non-impulsive action, healthy habits and reliability; Tangney et al., 2004), with individual items such as “I am good at resisting temptation” and “People can count on me to keep on schedule”. The scale includes 24 reverse scored items such as “I say inappropriate things”. Items are rated on a 5-point scale ranging from 1 = not at all to 5 = very much. Possible scores range from 36 to 180, with higher scores indicating higher levels of self-control. Cronbach’s alpha of the current sample was .89. Separate scores were also calculated for the subscales of inhibitory and initiatory self-control, as in de Ridder, de Boer, Lugtig, Bakker, and van Hooft (2011).

2.1.2.4. Cued go/no-go task.

In the cued go/no-go task (Fig. 1a), participants were presented with a cue, a rectangle (presented either horizontally or vertically) framed in a black outline against a white background. A target was presented as a solid hue (either green or blue) that filled the interior of the rectangle. Participants were to press the spacebar if the colour was green (‘go’ target) and to withhold their response if the colour was blue (‘no go’ target). The orientation of the cue signalled the probability that a go or no-go target would be displayed. The go target occurred on 80% of the vertically presented rectangles, and the no-go target occurred on 80% of the horizontally presented rectangles. Mean RTs for go trials, omission errors (i.e., failure to respond on go trials) on go trials, and commission errors (i.e., responding on no-go trials) on no-go trials were calculated.

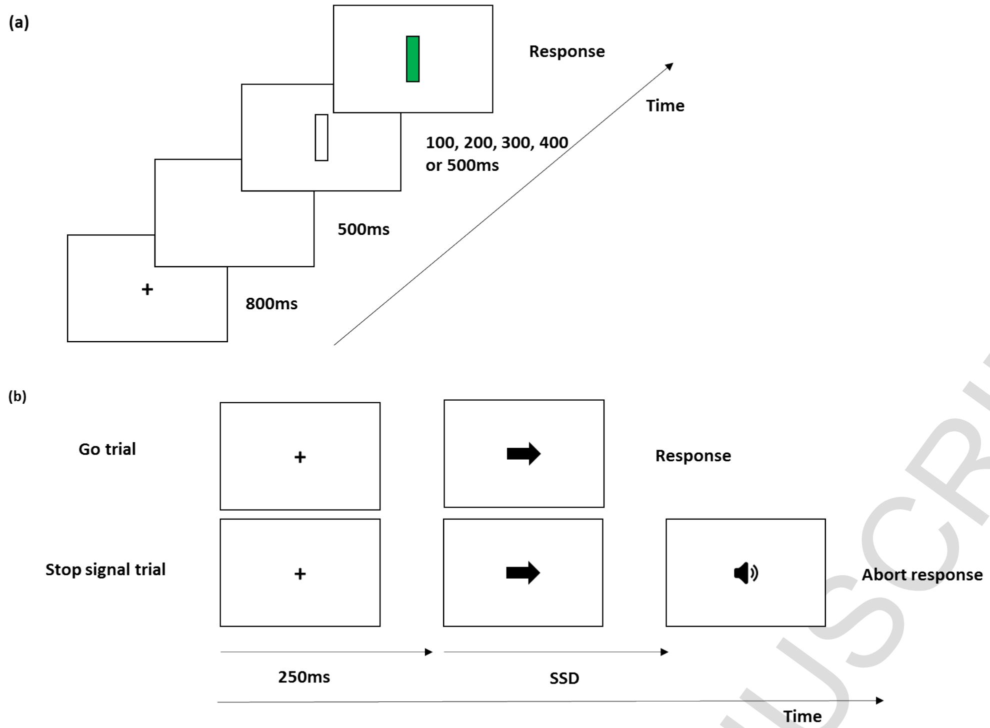

Figure 1. Sequence of (a) the cued go/no-go and (b) the stop signal task.

2.1.2.5. Stop signal task.

In the stop signal task (Fig. 1b), participants responded to an arrow pointing either left or right ('go' trial). In 25% of trials, an audio signal was presented at random, before, during or after the presentation of the arrow, and participants refrained from responding ('stop' trial). The onset of the audio signal varied continuously with a staircase-tracking procedure – a stop-signal delay (SSD) started from 250ms, which increased by 50ms following successful stopping, or decreased by 50ms after unsuccessful stopping. Stop signal reaction time (SSRT) was measured by subtracting mean SSDs from mean RTs on go trials (Logan, Schachar, & Tannock, 1997). Omission errors (i.e., failure to respond on go trials) and commission errors (i.e., responding on stop trials) were also calculated.

2.1.3. Procedure

After giving informed consent, participants completed the go/no-go task and the stop signal task. They then completed the three self-report measures, the media use questionnaire, BIS-11 and SCS. Of the 104 participants recruited from Charles Sturt University, 70 participants completed the experiment online via the Charles Sturt University research participation program and 34 participants completed it in-person in a quiet room. The 40 students recruited from Flinders University also completed the experiment in-person in a quiet room. The in-person testing was carried out individually. Completing the two cognitive tasks and the three self-report measures took approximately 50 mins.

2.2. Results

As can be seen in Table 1, media multitasking was significantly correlated with the attentional impulsivity subscale of the BIS, the overall SCS score (and specifically with initiatory self-control) and go trial RTs in the go/no-go task, showing that frequent media multitasking was associated with higher attentional impulsivity and lower self-control, but with slower responses on go trials in the go/no-go task.

Table 1.

Results from the Self-Report and Cognitive Performance Measures

	Overall Mean (*S.D.*)	Correlations[1] with MMI	
		r	*p*
MMI	3.32 (1.62)	–	–
BIS-11	62.88 (10.01)	0.156	.062
Attentional	17.29 (3.80)	0.165	.037
Motor	21.79 (3.92)	0.140	.094
Non-planning	23.80 (4.80)	0.022	.792
SCS	118.06 (18.46)	-0.198	.012
Initiatory	14.13 (2.88)	-0.168	.037
Inhibitory	18.29 (4.56)	-0.130	.102
Go/no-go task			
Go trial RT	378ms (44.39)	0.224	.005
Omission errors	0.63% (1.9)	0.152	.069
Commission errors	1.28% (2.6)	0.092	.275
Stop signal task			
No-signal trial RT	588ms (149)	0.116	.166
SSD	330ms (165)	0.114	.173
SSRT	258ms (62.5)	0.043	.582
Omission errors	2.43% (3.0)	-0.077	.358
Commission errors	49.02% (7.4)	-0.158	.058

[1] Age was significantly correlated with media multitasking, r(144)=-.386, r<.001, the attentional impulsivity, r(144)=-.207, p=.013, and the overall SCS score (and the subscales) (all *r*(144)s>.214, all *p*s<.010), go trial RT in the go/no-go task, r(144)=.304, p<.001, and SSRT in the stop signal task, r(144)=.171, p=.041. Therefore, age was controlled for in correlational analyses involving these variables.

We further performed a series of exploratory regression analyses to determine which aspect(s) of impulsive personality best predict(s) media multitasking (Table 2). We included the attentional impulsivity subscale of the BIS and the initiatory self-control subscale of the SCS as measures of impulsivity and self-control, respectively, as they were significantly correlated with media multitasking. Go trial RTs, omission and commission errors from the go/no-go task, and no signal trial RTs, omission and commission errors from the stop signal task were included as measures of response inhibition. Age was also included because of its correlation with media multitasking (r=-.386, p<.001). As attentional impulsivity (BIS subscale) and initiatory self-control (SCS subscale) were highly correlated (r= -.633, p<.001), we fitted these variables one at a time (Tabachnick & Fidell, 1996). The regression analyses showed that go trial RTs and omission errors from the go/no-go task were the strongest predictors of media multitasking, followed by commission errors from the stop signal task, initiatory self-control and attentional impulsivity.

Table 2.

Results of regression analyses on media multitasking and different aspects of impulsivity

	t	*p*	β	F	*df*	*p*	Adj.R^2
Regression 1							
Overall model				7.07	8,135	.000	.254
Attentional impulsivity	2.182	.031	.165				
Go/no-go task							
Go trial RT	2.741	.007	.214				
Omission errors	2.174	.031	.217				
Commission errors	-.540	.590	-.056				
Stop signal task							
No signal RT	.361	.718	.033				
Omission errors	-1.112	.268	-.087				
Commission errors	-2.112	.037	-.192				
Age	-5.575	.000	-.434				
Regression 2							
Overall model				7.16	8,135	.000	.256
Initiatory self-control	-2.332	.021	-.177				
Go/no-go task							
Go trial RT	2.885	.005	.225				
Omission errors	2.153	.033	.224				
Commission errors	-.341	.733	-.036				
Stop signal task							
No signal RT	.242	.809	.022				
Omission errors	-1.001	.319	-.078				
Commission errors	-2.116	.036	-.192				
Age	-5.335	.000	-.421				

2.3. Discussion

The results from the correlational analyses on the self-report measures showed that media multitasking was positively correlated with attentional impulsivity, and negatively with self-control, in particular with initiatory self-control. These findings are generally consistent with previous research on media multitasking and impulsivity (Minear et al., 2013; Sanbonmatsu et al., 2013; Wilmer & Chein, 2016) which has shown greater impulsivity and poorer self-control in heavy media multitaskers. Interestingly, however, the current results showed that media multitasking was associated with self-reported initiatory self-control rather than inhibitory self-control.

Self-control refers to “the capacity for altering one’s own responses, especially to bring them into line with standards such as ideals, values, morals, and social expectations, and to support the pursuit of long-term goals” (Baumeister, Vohs, & Tice, 2007, p.351). de Ridder et al. (2011) further divided self-control into two sub-categories: (1) initiatory self-control which relates to engaging in desired or goal-directed behavior (all behavior associated with personal goals to meet one's responsibilities and social norms, e.g., concentrating on study to prepare for an exam), and (2) inhibitory self-control which refers to refraining from an undesired behavior (e.g., resisting temptation or impulses to engage in web-surfing or checking social media during study). The current results suggest that frequent media multitasking is associated more with difficulties to engage in desired behavior, rather than with difficulties to resist or inhibit undesired behavior (i.e., impulse control) per se.

We further examined the relationship between media multitasking and impulsivity with two cognitive task measures: the go/no-go task and the stop signal task. Initial correlational analyses showed that media multitasking was positively correlated with RTs in the go/no-go task, suggesting that heavy media multitaskers were generally slower on go trials. In the stop signal task, frequent media multitasking was marginally associated with fewer commission errors (i.e., failing to withhold a response to the stop signal), indicating that heavy media multitaskers were more likely to be successful at suppressing already initiated motor responses. However, subsequent exploratory regression analyses taking into account self-report measures (i.e., attentional impulsivity and self-control) and age revealed that omission error in the go/no-go task was a significant predictor of media multitasking. In fact, slower RTs and more omission errors on go trials in the go/no-go task best predicted media multitasking, closely followed by commission errors in the stop signal task, which are indicative of a superior ability to inhibit pre-planned motor responses. Interestingly, commission errors in the go/no-go task and omission errors in the stop signal task did not reach significance.

The finding that media multitasking was positively correlated with omission errors on the go/no-go task, but not with omission errors on the stop signal task is interesting because one would think that participants who are more likely to fail to respond on go trials in the go/no-go task would also be likely to fail to respond on no signal trials (which is the go trial equivalent in the stop signal task). One possible explanation for these seemingly contradictory findings may pertain to differences in how the two tasks were presented (i.e., the time line and stimuli used). The go/no-go task consisted of a slow paced, cued go/no-go paradigm where participants had to wait 1400-1800ms (the duration of the fixation point, blank screen and cue) on each trial for the target to which they had to respond. The stop signal task, by contrast, was more dynamic. The fixation cross was presented for only 250ms followed by the target (an arrow). Moreover, the stop signal was presented as a tone, which makes the task multisensory, and thus more stimulating. Omission errors often occur because of inattention (Barkley, 1991; Bezdjian, Baker, Lozano, & Raine, 2009). Heavy media multitaskers, characterized by greater attentional impulsivity and a sensation seeking tendency, may have found it more difficult to concentrate on the slow paced, go/no-go task than did light media multitaskers. In fact, heavy media multitaskers were better at suppressing already initiated motor responses in the fast-paced stop signal task, suggesting that they do possess the ability to inhibit planned responses. Interestingly, Ralph and Smilek (2017) reported a similar finding whereby heavier media multitaskers exhibited a higher proportion of omission errors on an n-back task. They interpreted this as heavier media multitaskers having the propensity to disengage from ongoing tasks. Furthermore, Ralph and colleagues showed that heavy media multitaskers tended to *allow* themselves to be more distracted (Ralph et al., 2015) and to mind-wander (Ralph, Thomson, Cheyne, & Smilek, 2014), rather than having poorer sustained attention ability per se. This is consistent with the current results from the self-reported measures which showed that frequent media multitasking was associated with poor initiatory self-control, rather than poor inhibitory self-control. This may also explain why frequent media multitasking could in some instances be associated with better performance in inhibitory control, such as suppressing already initiated motor responses, as is required in the stop signal task. However, as we did not directly measure inattention or engagement in the current study, the interpretation of an association between media multitasking and inattention in the current study should be taken with caution.

To examine the relationship between media multitasking and impulsivity more comprehensively, we used a set of measures that target different aspects of impulsivity. Results from the regression analyses showed that cognitive measures (i.e., slower RTs and more omission errors in the go/no-go task, and commission errors in the stop signal task) best predicted media multitasking. Self-reported attentional impulsivity and initiatory self-control showed the least predictive power in the model. Thus it appears that the aspects of impulsivity that were measured by the cognitive tasks (go/no-go and stop signal tasks) were stronger predictors of media multitasking than those measured by the self-report questionnaires (BIS and SCS). This suggests that it is important to include both self-report and cognitive measures when examining the relationship between media multitasking and impulsivity.

3. Experiment 2

Experiment 1 showed that frequent media multitasking is associated with greater attentional impulsivity and poorer initiatory self-control. Considering that media multitasking is also associated with poorer cognitive abilities (Cain & Mitroff, 2011; Ophir et al., 2009), the results support the idea that individuals who are more likely to engage in media multitasking are those who are less equipped for efficient multitasking. However, findings on media multitasking and multisensory integration (Lui & Wong, 2012) suggest that frequent media multitasking may be associated with superior performance on a dual task in a multisensory setting. Therefore, in Experiment 2, we investigated whether media multitasking is linked to any advantageous effects on a multisensory dual task.

To this end, Experiment 2 used the psychological refractory period (PRP) paradigm (Pashler, 1994b) to examine the relationship between media multitasking and dual task performance. In the PRP task, two different tasks, one visual and one auditory (e.g., a letter detection and a tone detection task), are presented, separated by varying stimulus onset asynchrony (SOA = the time from the presentation of the tone to the presentation of the letter) of -1000ms, -500ms, 0ms, 500ms or 1000ms; participants are asked to respond to each task as quickly as they can. Due to limited mental resources, performance on the second task suffers as the two tasks are presented closer to each other in time (for a review of the proposed mechanisms, see Logan & Gordon, 2001). The response to the second task is slower as the SOA is closer to 0ms; this is known as the PRP effect. Previous studies have shown that extensive practice can reduce dual task interference (i.e., the PRP effect) by shortening or even eliminating the central bottleneck (van Selst et al., 1999). Therefore, we expected that frequent media multitasking would be associated with superior performance at SOA 0ms, leading to a smaller PRP effect, as heavy media multitaskers are more practiced at media multitasking than light media multitaskers.

When participants are not required to respond to each task as soon as these are presented in a PRP task (e.g., if the visual task is presented first, they respond to the visual task first), a strategy called *response grouping* is observed (Borger, 1963; Miller & Ulrich, 2008; Pashler, 1994a; Pashler & Johnston, 1989) - participants withhold their response to the first task until they are ready to respond to the second task. In response grouping, reaction times on the first task increase as the SOA increases. Response grouping is most commonly observed in a dual task setting in which participants are required to make two separate manual responses to each task. Participants may adopt this strategy because the coordination of two bimanual responses (i.e., motor pre-programming and execution) is easier when they are elicited at the same time rather than in close temporal proximity (Rinkenauer, Ulrich, & Wing, 2001). Response grouping is most common at SOA 0ms and tends to decrease as the SOA increases (Miller & Ulrich, 2008). In the current experiment, we expected that media multitasking would be associated with less response grouping at SOAs -500 and 500 ms, and particularly at SOAs -1000 and 1000ms (i.e., when response grouping is least likely) as heavy media multitaskers are more practiced at making separate responses to different sources of information than light media multitaskers.

3.1. Method

3.1.1. Participants

Eighty-three participants aged 18-35 years were recruited (M = 24.02, SD = 5.46, 62.8% females). Thirty-six participants were first year students from Charles Sturt University and received course credit. The rest were recruited from the general public via advertisements and were entered into a draw to win two $100 gift vouchers. Ethics approval was obtained from the Faculty of Business, Justice and Behavioral Sciences Human Ethics Committee (Charles Sturt University).

3.1.2. Materials

3.1.2.1. Media use questionnaire

The media use questionnaire (Ophir et al., 2009) was administered as in Experiment 1. The mean MMI score was 4.29 with a standard deviation of 1.54.

3.1.2.2. PRP paradigm

The PRP paradigm consisted of a visual (i.e., letter) and an auditory (i.e., tone) task. At the beginning of each trial, a fixation cross was displayed for 1000ms with a 500ms offset to alert the participant and act as a focal point. Then, the letter and the tone tasks were presented with a stimulus onset asynchrony (SOA = the time from the presentation of the tone to the presentation of the letter) of either -1000ms, -500ms, 0ms, 500ms or 1000ms (Fig. 2). The letter task presented the letters Q, T or V (0.6°×1.3°) in white on a black background in the centre of the computer screen, at a viewing distance of 60cm. Participants responded to the letter by pressing the comma, period and slash keys on the keyboard using the index, middle and ring fingers of the right hand, respectively. The letter remained on the screen until participants responded to both the letter and the tone task. For the tone task, a low tone (300Hz) or a high tone (900Hz) was presented for 150ms. Participants responded to the low and high tones by pressing the Z or A keys, using their index and middle fingers of the left hand, respectively. In the event of an incorrect response (when the response to at least one of the tasks was incorrect) a visual warning was displayed followed by an additional 800ms recovery period. The task consisted of 12 blocks of 40 trials, for a total of 480 trials, with an inter-trial interval of 1500ms. There were 96 trials per SOA, which varied randomly across trials and participants.

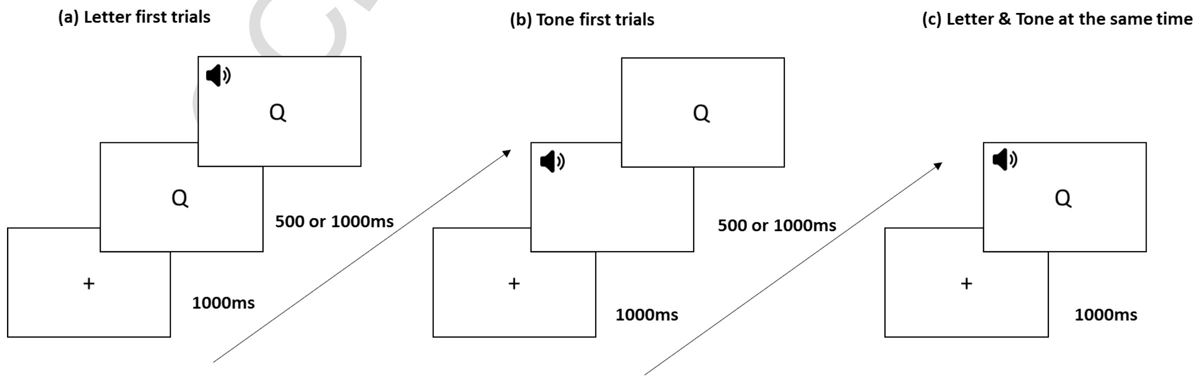

Figure 2. Sequence of (a) a letter first trial, (b) a tone first trial and (c) a letter & tone trial

3.1.3. Procedure

Participants were tested individually in a quiet room in a session of approximately 40 mins. After providing informed consent, participants first completed the media multitasking questionnaire and then performed the PRP task. Participants were instructed to keep their fingers on the keys during the PRP task. They were also instructed to respond as quickly and accurately as possible to each task, placing equal emphasis on responding to the letter and the tone task. If a participant responded to the tasks in a fixed order (e.g., responding to the letter task first regardless of which task was presented first), the participant was made aware of this by the experimenter. Participants were given the opportunity to take a short break between blocks of trials.

3.2. Results

Incorrect responses (*M*=8.4%, *SD*=0.5%) were excluded from analyses. Trials with RTs below 150ms (0.4% for the letter task, 0.7% for the tone task) or above 3000ms (1.5% for the letter task, 0.7% for the tone task) were also excluded (Zentzsch, Leuthold, & Ulrich, 2007).

3.2.1. Overall PRP task performance

Figure 3 shows the mean RTs at each SOA for the letter and the tone tasks. A one way repeated measures ANOVA showed a significant main effect of SOA for both the letter task, F(4, 328)=160.5, $p<.001$, $\eta_p^2=.662$, and the tone task, F(4, 328)=102.4, $p<.001$, $\eta_p^2=.55$. In the letter task, mean RTs for SOA -1000, -500 and 0ms were not significantly different from one another (all *p*s>.295). However, reaction times decreased significantly from 0ms to 1000ms (all *p*s<.001), indicative of a PRP effect. In the tone task, mean RTs increased significantly from SOA -1000ms to 0ms (all *p*s<.001), again indicative of a PRP effect, which then decreased from SOA 0ms to 500ms ($p<.001$). There was no difference between mean reaction times at SOA 500ms and 1000ms ($p=.497$).

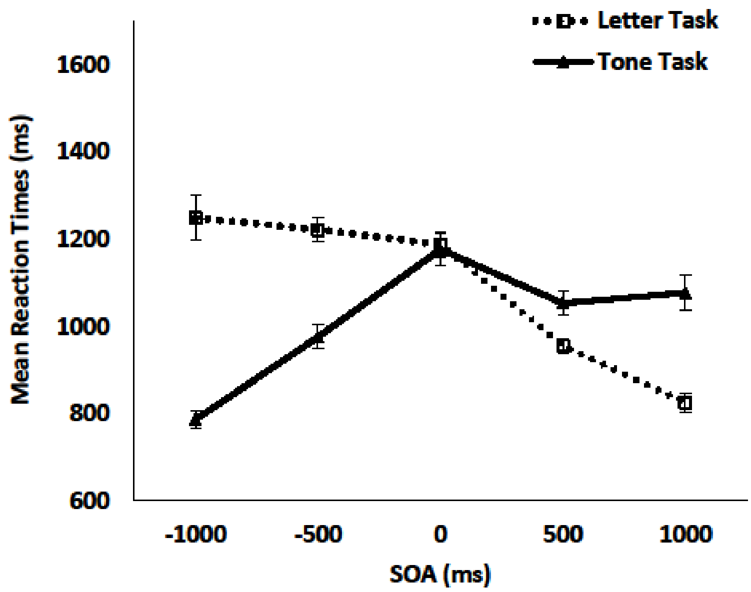

Figure 3. Mean reaction times at each SOA for the letter and tone tasks.

3.2.2. Media multitasking and PRP task performance

3.2.2.1. Letter task

3.2.2.1.1. Reaction times

Media multitasking was significantly correlated with RT in the letter task at SOA 0ms, $r(83)=-.286$, $p=.009$, suggesting that heavy media multitaskers were faster than light media multitaskers in their responses to the letter task, when the letter and the tone tasks were presented at the same time. Media multitasking was also significantly correlated with RT at SOAs 500ms, *r*(83)=-.258, *p*=.019, and 1000ms, *r*(83)=-.288, *p*=.008. These results indicate that heavy media multitaskers were overall faster than light media multitaskers. However, this overall faster RT did not lead to a smaller PRP effect in heavy media multitaskers. To calculate the PRP effect, the RT at SOA 1000ms was subtracted from that of SOA 0ms. Media multitasking was not significantly correlated with the PRP effect, *r*(83)=-.058, *p*=.602.

In addition, to examine response grouping, the lag between RTs for the letter task and RTs for the tone task at SOAs 0ms (letter task RT – tone task RT), 500ms (letter task RT + 500 – Tone task RT) and 1000ms (letter task RT + 1000 – Tone task RT) were calculated. The correlation between media multitasking and response grouping was not significant at 0ms, *r*(83)=-.185, *p*=.094, nor at 500ms, *r*(83)=.012, *p*=.912, or 1000ms *r*(83)=.162, *p*=.143.

3.2.2.1.2. Accuracy

Mean accuracy on the letter task was 97.2% (*SD*=0.4%). There were no significant correlations between media multitasking and SOA at 0ms, *r*(83)=-.082, *p*=.464, nor at 500ms, *r*(83)=-.153, *p*=.168, or 1000ms, *r*(83)=-.124, *p*=.263.

3.2.2.2. Tone task

3.2.2.2.1. Reaction times

Media multitasking was not significantly correlated with RT in the tone task at SOA 0ms, *r*(83)=-.169, *p*=.127. However, there was a significant correlation at SOAs -500ms, *r*(83)=-.263, *p*=.016, and -1000ms, *r*(83)=-.372, *p*=.001. Together, these findings show that heavy media multitaskers were faster than light media multitaskers in responding to each task when the two tasks were presented apart (i.e., SOAs -500 and -1000ms), but they were no better when the two tasks were presented at the same time (i.e., SOA 0ms), at the response selection bottleneck. To calculate the PRP effect, the RT at SOA -1000ms was subtracted from that of SOA 0ms. Media multitasking was significantly correlated with the PRP effect, $r(83)=.302$, $p=.006$, suggesting that media multitasking was associated with a bigger PRP effect.

To examine response grouping, the lag between RT for the letter task and RT for the tone task at SOA -500ms (Tone task RT +500 – letter task RT) and -1000ms (tone task RT +1000 – letter task RT) was again calculated. The correlation between media multitasking and response grouping was not correlated with response grouping, neither at -500ms, $r(83)=.061$, $p=.581$, nor at -1000ms, $r(83)=.057$, $p=.609$.

3.2.2.2.2. Accuracy

Mean accuracy on the tone task was 94.2% (*SD*=0.4%). There were no significant correlations between media multitasking and SOA at 0ms, $r(83)=-.045$, $p=.689$, -500ms, $r(83)=-.088$, $p=.431$, 500ms, r(83)=.061, p=.581, -1000ms, $r(83)=-.046$, $p=.678$, nor at 1000ms, $r(83)=-.205$, $p=.063$.

3.2.2.3. PRP performance of different media multitasker groups

To directly compare the performance by different levels of media multitaskers in the letter and the tone task, a series of 3 (media multitasking group)[2] × 3 (SOA) mixed model ANOVAs was performed on the reaction times for each of the letter and the tone tasks. Media multitasker group was the between subjects variable and SOA was the within subjects variable. Table 3 presents the inferential statistics. Figures 4 and 5 show the mean RTs by media multitasking group at each SOA in

[2] Participants with a MMI score one standard deviation below the mean were classified as light media multitaskers, while those with a MMI score one standard deviation above the mean were classified as heavy media multitaskers. The remaining participants were classified as intermediate media multitaskers. This resulted in 16 light, 57 intermediate and 10 heavy media multitaskers. The majority of studies in media multitasking have explored extremes of media multitasking behaviour by comparing heavy and light media multitaskers (Alzahabi & Becker, 2013; Cain & Mitroff, 2011; Ophir et al., 2009). The assumption is that the performance of intermediate media multitaskers would fall somewhere between heavy and light media multitaskers. However, a recent study suggested that the association between cognitive control and media multitasking may follow an inverted U curve, in which intermediate media multitaskers perform better than heavy or light media multitaskers (Cardoso-Leite et al., 2015). Moderate level of media multitasking may be associated with an optimal level of cognitive control. Therefore, the present study included intermediate media multitaskers to allow for the inverted U curve account of the relationship between media multitasking and dual task ability.

the letter and the tone tasks, respectively. Overall, the results from the mixed model ANOVAs were consistent with the findings from the correlational analyses.

Table 3.

Results from a series of 3 (media multitasking group) × 3 (SOA) mixed model ANOVAs

	df	F	p	η_p^2
Letter task				
Reaction times				
Media multitasking	2,80	5.70	.005	.125
SOA	2,160	262.26	.000	.766
Media multitasking × SOA	4,160	.53	.715	.013
Accuracy				
Media multitasking	2,80	.63	.535	.016
SOA	2,160	2.41	.093	.029
Media multitasking × SOA	4,160	1.12	.349	.027
Tone task				
Reaction times				
Media multitasking	2,80	6.22	.003	.135
SOA	2,160	267.68	.000	.770
Media multitasking × SOA	4,160	4.86	.001	.108
Accuracy				
Media multitasking	2,80	.16	.851	.004
SOA	2,160	7.96	.001	.090
Media multitasking × SOA	4,158	.226	.924	.006

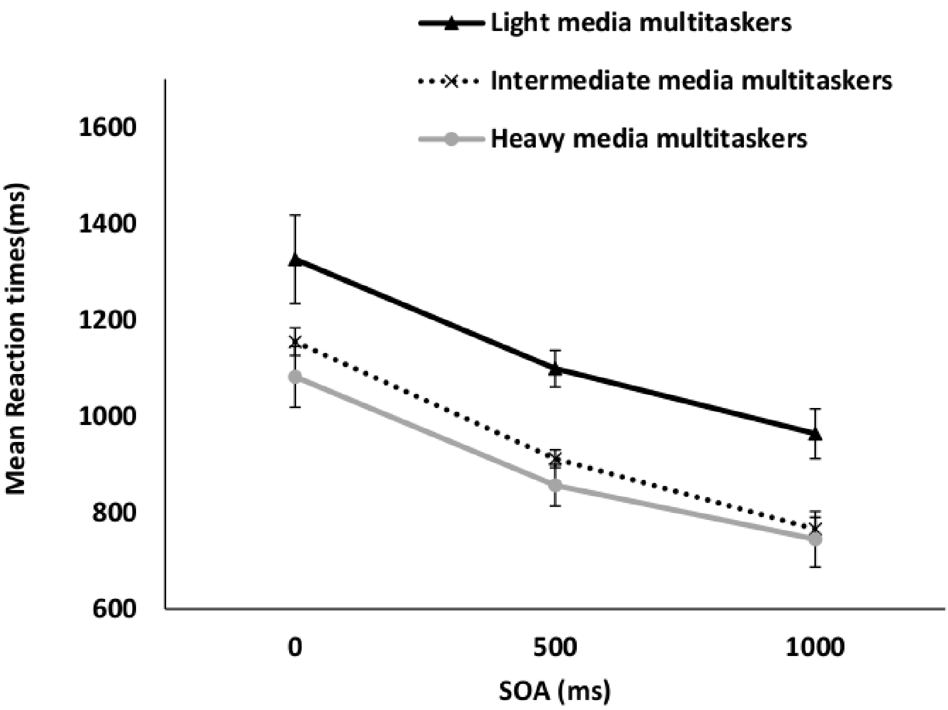

Figure 4. Mean RTs by light, intermediate and heavy media multitaskers at SOAs 0ms, 500ms and 1000ms in the letter task. Light media multitaskers were significantly slower than intermediate and heavy media multitaskers at all SOAs (all *p*s<.032). However, there were no significant differences between intermediate and heavy media multitaskers (all *ps*>.492).

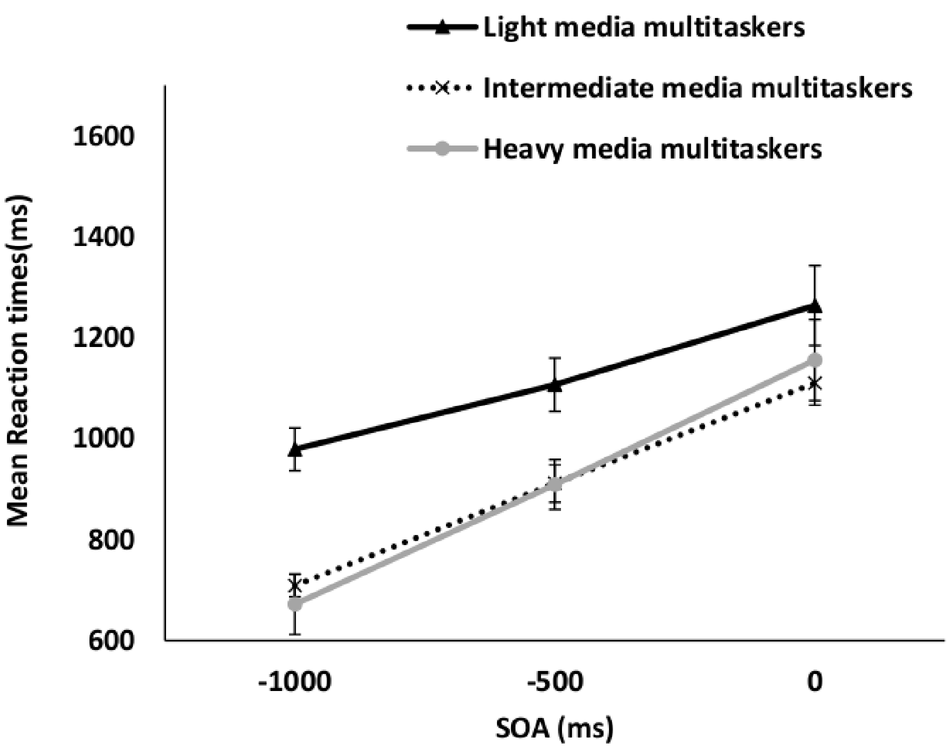

Figure 5. Mean RTs by light, intermediate and heavy media multitaskers at SOA -1000, -500 and 0ms in the tone task. Light media multitaskers were significantly slower than intermediate and heavy media multitaskers at SOA -1000ms (all *p*s<.001). However, there were no significant differences between intermediate and heavy media multitaskers (*p*s=1).

3.3. Discussion

Results showed that media multitasking was associated with generally faster responses to both the letter and the tone task without a speed-accuracy trade-off. However, a closer inspection of the responses in each of the letter and tone tasks revealed that heavy and light media multitaskers did not differ in their ability to respond to the two tasks when the tasks were presented close in time. More specifically, in the letter task, although heavier media multitaskers showed faster responses overall, the rate at which the RT slowed from SOA 1000ms to 0ms (i.e., PRP effect) did not change as a function of media multitasking. By contrast, in the tone task, media multitasking was associated with faster responses when the two tasks were presented temporally apart, but not when the two tasks were presented at the same time (i.e., a bigger PRP effect). Further, response grouping was not associated with media multitasking.

It was expected that heavy media multitaskers would perform better in dual tasks that involve stimuli of different modalities, as media multitasking often involves tasks of different modalities in real life. However, we found no clear evidence that heavy media multitaskers are better than light media multitaskers in their ability to simultaneously respond to the letter and tone task (i.e., SOA 0ms). The finding contradicts that of Lui and Wong (2012) who showed that heavy media multitaskers were better than light media multitaskers on a task that also involves integration of stimuli from different modalities. Rather, our result is consistent with Alzahabi and Becker (2013), where heavy and light media multitaskers were presented with a letter task and a number task at the same time. They too found that the performance of heavy media multitaskers did not significantly differ from that of light media multitaskers. Although the two tasks used by Alzahabi and Becker (2013) were both visual whereas the tasks here involved different modalities, we observed similar results.

One possible explanation for the lack of a multitasking benefit in the current dual task may be that all levels of media multitaskers showed a floor effect at SOA 0ms where everybody performed poorly. An alternative explanation may be that participants were asked to make manual responses to both the letter and the tone tasks. Previous studies that have shown a benefit from extensive practice at dual tasks generally required participants to make manual responses to the visual task and vocal responses to the auditory task (Ruthruff, Van Selst, Johnston, & Remington, 2006; van Selst et al., 1999). Notably, in the Lui and Wong (2012) study, participants were not required to respond to the auditory stimulus at all. Thus, it is possible that the benefit of frequent media multitasking at SOA 0ms had been eclipsed by the coordination of two separate manual responses to the letter and the tone task here. If this were indeed the case, it would suggest that potential benefit associated with media multitasking may only appear when both the tasks and the response modes are of different modalities.

Following Pashler (1994b), the PRP task required participants to coordinate two manual responses (i.e., the right hand for the letter task and the left hand for the tone task), rather than a manual and a vocal response (e.g., one hand for the letter task and a verbal response for the tone task). As mentioned earlier, using the same response modality for both tasks could have introduced additional peripheral interference on top of the central cognitive interference the PRP task is designed to examine. Pashler (1990) suggests that this peripheral interference is greater when the order of the tasks is unknown to the participants (as in the current study). However, it is currently not known whether this additional interference affects different levels of media multitaskers differently. Thus, future research could usefully investigate whether heavy and light media multitaskers differ in their ability to coordinate responses in different modalities as opposed to the same modality.

In the current experiment, the benefit of frequent media multitasking was observed only when the tasks were presented temporally apart. Pashler (1994b) suggests that a faster RT to the second task at long SOAs is due to being able to predict and prepare for the upcoming task. Thus, in the present experiment, heavier media multitaskers appeared to be better prepared for the second task (the tone task) at SOAs 1000 and -1000ms. The finding suggests that having a sufficiently large interval between tasks is important in successful multitasking (1000ms in the current experiment). Any benefit associated with media multitasking seemed to disappear when the tasks were presented at the same time, i.e., when the perceptual processing load (Broadbent, 1958) and/or response selection (Welford, 1952) load was the heaviest.

In addition to the correlational analyses, we conducted a series of ANOVAs to directly compare dual task ability of different groups of media multitaskers (as in Ophir et al., 2009; Uncapher et al., 2015). Both analyses (ANOVAs and correlations) showed similar results, supporting a linear relationship between media multitasking and dual task ability rather than an inverted U-curve, in which intermediate media multitaskers perform better than heavy or light media multitaskers (as suggested in Cardoso-Leite et al., 2015). Interestingly, however, comparisons between the different media multitasking groups showed that heavy and intermediate media multitaskers did not significantly differ in their responses to the letter and the tone tasks (Fig. 4 and 5), in contrast to the light media multitaskers. This suggests that light media multitaskers may differ from heavy or intermediate media multitaskers in their dual task ability or approach to duals tasks in general. Previous studies have suggested that light media multitaskers perform better than heavy media multitaskers in task switching (Ophir et al., 2009) and possess greater working memory capacity (Sanbonmatsu et al., 2013). The present results suggest that light media multitaskers may choose to single task and, thus in the case of dual tasking, perform more poorly than heavy or intermediate media multitaskers due to a lack of practice at multitasking, rather than due to an inability to multitask.

4. General Discussion

The current study investigated individual differences in personality and cognition associated with media multitasking. More specifically, Experiment 1 examined a range of impulsivity indicators as predictors of media multitasking. Experiment 2 subsequently examined whether media multitasking is associated with a superior dual task ability in a multisensory setting. In Experiment 1, we found that frequent media multitasking was associated with greater attentional impulsivity and poorer self-control, as other studies have also shown. However, the latter association was statistically significant for initiatory self-control (i.e., focusing on the task at hand), rather than for inhibitory self-control (i.e., impulse control), in contrast to recent studies which associated media multitasking with overall high impulsivity and a general lack of self-control (e.g., Minear et al., 2013). This is consistent with findings from the cognitive measures – media multitasking was associated with poorer performance in the go/no-go task (i.e., higher omission errors, suggestive of inattention), but not in the stop signal task (i.e., fewer commission errors). The findings that media multitasking is associated with initiatory self-control rather than inhibitory self-control may be directly relevant to heavy media multitaskers in real life, particularly when devising strategies to minimize multitasking during an important main task. Our results suggest that focusing on completing the main task on time (and the detrimental effects of failing to do so) may be more effective in reducing multitasking behavior than simply removing potential distractors.

In Experiment 2, frequent media multitasking was not associated with superior dual task ability when the letter and the tone tasks were presented at the same time (i.e., SOA 0ms); however, frequent media multitasking was beneficial when the two tasks were presented temporally apart (i.e., SOA 1000ms). Considering that multitasking in real life is sometimes unavoidable (e.g., at work), it may be beneficial to devise a strategy to reduce the disadvantage of multitasking, rather than trying to avoid multitasking altogether. The current result suggests that the pitfall of frequent multitasking may be avoided if there are sufficiently large intervals (as short as 1000ms in the current study) between the tasks. To this end, it might be useful to reinforce the idea that multitasking is a series of pausing and resuming of multiple tasks, and thus perform the tasks accordingly, rather than regarding it as a dual task situation whereby tasks need to be completed simultaneously.

Previous studies have associated media multitasking with greater impulsivity and poorer multitasking ability (e.g., Sanbonmatsu et al., 2013). This has led researchers to conclude that heavy media multitaskers are individuals who are more susceptible to multitasking although they are less capable of it because they have a highly impulsive personality and poorer cognitive control (e.g., poorer ability to filter out distractors). However, the current findings suggest that the relationship between media multitasking, personality and cognitive abilities is more nuanced than previously suggested. Given that media multitasking was shown to be associated specifically with a difficulty to focus on the task at hand, rather than a general lack of self-control (Experiment 1), it is possible that heavy media multitaskers may exert better cognitive control than light media multitaskers in certain situations. It has been suggested that the relationship between impulsivity and cognitive functioning is not always negative, and that highly impulsive individuals can be more accurate than those who are less impulsive when the experimental task is simple and the time available to complete the task is brief (Dickman & Meyer, 1988). Indeed, in Experiment 1, heavy media multitaskers performed better than light media multitaskers in the stop signal task (i.e., better able to inhibit already initiated motoric responses). In Experiment 2, heavy media multitaskers performed better than light media multitaskers when the two tasks were presented sequentially (at SOAs -1000 and 1000ms). The current findings are encouraging for heavy media multitaskers as they indicate that media multitasking also comes with advantages. This puts heavy media multitaskers in good stead in real-world settings that require them to engage in, and switch between, multiple tasks.

As media multitasking is an ever-increasing phenomenon, it is important to understand its effects on our cognitive processes. Consequently, a growing number of studies have investigated the relationship between media multitasking and personality traits, and the way it interacts with cognitive performance. The current study sought to resolve inconsistency in the literature on the relationship between media multitasking and impulsivity. Furthermore, the study addressed an important gap in the literature regarding the relationship between media multitasking and dual task ability in a multisensory setting. In sum, frequent media multitasking was associated specifically with a difficulty to focus on the task at hand, rather than a general lack of self-control. We also found that media multitasking is linked to a superior ability in a dual task when the two tasks were presented temporally apart, but not when they were presented at the same time.

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Highlights

- Media multitasking was linked to initiatory but not inhibitory self-control
- Heavy multitaskers were impulsive, inattentive, but inhibited motor responses better
- Multitasking was linked to better dual task ability with tasks temporally separated