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Murphy, K, Creux, O

Published

2021

Journal Title

Computers in Human Behavior

Version

Accepted Manuscript (AM)

DOI

10.1016/j.chb.2020.106532

Examining the Association between Media Multitasking, and Performance on Working Memory and Inhibition Tasks

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Declarations of interest: none

Abstract

Media multitasking has been investigated for its links to executive functions (EFs). Research in the area has produced mixed outcomes which may in part be due to an extreme groups approach to data analysis. This study avoided this issue by using media multitasking as a continuous variable to examine its relationship with the EFs of working memory (WM) and inhibition. Participants completed tasks assessing WM (Digit Ordering Task), inhibition (Spatial Stroop Task) and a task employing both WM and inhibition (Go/No-Go task with low and high task loads). After controlling for the effect of age, IQ and attentional impulsivity, there was a marginally significant association between higher levels of media multitasking and greater WM capacity scores. Participants with higher media multitasking scores also had more efficient go trial performance (Go/No-Go task) which suggested superior processing speed. There was a trend towards significance for higher levels of media multitasking to be associated with poorer performance on the outcome measures of the inhibition tasks (lower accuracy in the Spatial Stroop task incongruent condition, and the Go/No-Go task; go trials low load congruent distractor condition and no-go trials high cognitive load incongruent distractor condition). The different pattern of performance outcomes for the WM and inhibition tasks further illustrates the complexity of understanding the relationship between media multitasking and EFs.

Keywords: media multitasking; working memory; inhibitory control; executive functions; Spatial Stroop; Go/No-Go task; digit ordering task

1. Introduction

This availability of portable digital technology has led to an increase in daily media use and the pervasive habit to multitask with media. Media multitasking has been defined as simultaneously using two or more types of media or rapid swapping between different media (e.g. listening to music or using instant messaging while watching television or using social media) (Minear, Brasher, McCurdy, Lewis, & Younggren, 2013; Ophir, Nass, & Wagner, 2009). It has been reported that the average youth spends approximately 9 hours daily using online media, and about one third of this time involves media multitasking (Rideout, Foehr, & Roberts, 2010). Given the substantial engagement in this past-time, researchers have sought to understand the link between this digital multitasking behavior and various cognitive functions (e.g., Author, 2020; Ophir et al., 2009; Seddon, Law, Adams, & Simmons, 2018; Shin, Linke, & Kemps, 2020; Shin, Webb, & Kemps, 2019; Uncapher, Thieu, & Wagner, 2016; Wiradhany & Nieuwenstein, 2017). This study further contributed to this research by examining the link between media multitasking and the executive functions of working memory and inhibitory control.

1.1. Executive Functions

Executive Functions (EFs) are the effortful top-down mental processes that play an important role in situations where self-regulation and attention are required (Diamond, 2013; Friedman & Miyake, 2017). It is well accepted that there are three core primary EFs; cognitive flexibility, inhibitory control (inhibition), and working memory (WM) (Diamond, 2013; Friedman & Miyake, 2017; Miyake et al., 2000). Cognitive flexibility or shifting refers to one's ability to modify spatial or interpersonal perceptions (e.g., adding information to action plans) and to think flexibly (Diamond, 2013; Miyake & Friedman, 2012; Miyake et al., 2000). Inhibitory control or inhibition is the ability to control one's behavior or attention in response to the environment or internal states (Diamond, 2013; Miyake & Friedman, 2012). It includes the ability to attend to selected stimuli while ignoring others (filtering) and the skills to prevent a pre-potent response to a stimulus (response inhibition) (Diamond, 2013; Miyake et al., 2000). WM refers to the ability to store, update and manipulate a limited amount of information mentally (Baddeley & Hitch, 1994; Friedman & Miyake, 2017; Miyake et al., 2000). While numerous studies to date have examined the link between media multitasking and measures of cognitive flexibility (e.g., Author, 2020; Alzahabi & Becker, 2013; Alzahabi, Becker, & Hambrick, 2017; Cardoso-Leite et al., 2016; Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017) less research has investigated the association between media multitasking, and the EFs of WM and inhibition which are the focus of this study. WM and inhibition often operate simultaneously and support one another when we complete everyday tasks (Diamond, 2013; Storm & Levy, 2012). Media multitasking relies heavily on both WM and inhibition and requires the use of inhibitory control to support WM processes and the use of WM to support inhibition. For example, retaining information read in an article during assignment writing, whilst inhibiting the desire to check a new text message, clearly involves both of these EFs. Training of EFs has been found to occur (Diamond, 2013; Klingberg, 2010) and it has been suggested that cognitive skills that are used during frequent media multitasking also develop and improve as a result of repeated practice (Elbe, Sörman, Mellqvist, Brändström, & Ljungberg, 2019; Lui & Wong, 2012; van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015). Thus given the reliance on WM and inhibition during media multitasking activities, it is possible that more media multitasking engagement is associated with better performance on standard measures of WM and inhibition.

1.2. Media Multitasking and Working Memory

One of the earliest investigations of the link between media multitasking and EFs was conducted by Ophir et al. (2009). To assess media multitasking, they designed the Media Multitasking Index (MMI) to measure the simultaneous use of 12 media during a typical week. Ophir et al. (2009) used an extreme groups approach to classify media multitaskers into two groups. Heavy media multitaskers (HMM) were those individuals who scored one or more standard deviations above the mean on the MMI and light media multitaskers (LMM) were those who had MMI scores at least one standard deviation below the mean. Ophir et al. (2009) found that HMM and LMM performance on a WM task (*n*-back) did not differ, indicating similar WM capacity for the two groups. However, HMM made more false alarms than LMM which was taken as evidence that they were less capable of ignoring irrelevant distracting information. Studies have also reported that higher levels of media multitasking were associated with overall poorer performance on the *n*-back (e.g., Cain, Leonard, Gabrieli, & Finn, 2016; Ralph & Smilek, 2016), a visual WM task (Uncapher et al., 2016) and the Operation Span Task (Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013). However, other studies have reported no significant relationship between levels of media multitasking and WM task performance (e.g., Baumgartner, Weeda, Heijden, & Huizinga, 2014 digit span task; Minear et al., 2013 a reading span task; Seddon et al., 2018 for backward digit span and Corsi block tasks) or that those who engage in intermediate amounts of media multitasking have better WM performance (Shin et al., 2020).

Since many of the above studies used the same or similar scale to measure media multitasking (the MMI by Ophir et al., 2009) it is possible that the mixed findings reported in the literature may be due to the various tasks assessing different aspects of WM (Ralph & Smilek, 2016). That is, while all the above studies used standard tasks, the multi-dimensional nature of WM processes (e.g., updating, maintenance, temporal ordering of information), means that different WM tasks may engage these processes to different degrees (Shipstead, Lindsey, Marshall, & Engle, 2014). Therefore the varied outcomes reported across the media multitasking and WM studies might be due to the tasks measuring different WM processes. For example, the *n*-back task assesses both updating of content and the maintenance of a goal state to determine if the current stimulus matches that presented *n*-trials back. The Operation Span task (a complex span task) measures the simultaneous storage and processing of information (word lists) whilst under conditions of interference (mathematical operations) (Wilhelm, Hildebrandt, & Oberauer, 2013). Thus these two tasks employ different WM processes and they also engage the cognitive flexibility and inhibition EFs to differing degrees (Redick & Lindsey, 2013) (see Seddon et al., 2018 for a discussion on task purity issues). For example, the n-back requires minimal cognitive flexibility (task-switching) as the goal is always to determine if the current stimulus matches that presented n-trials previously. The Operation Span task has a WM load (remember words to recall) and requires judgments about the correctness of math problems, which relative to the n-back task involves more cognitive flexibility (i.e., task-switching) and has been identified by some as a global EF measure rather than a specific WM measure (Diamond, 2013). Therefore, the mixed outcomes reported in the WM and media multitasking literature might be a function of the WM tasks assessing different processes (Ralph & Smilek, 2016) and/or the tasks involving other EFs to different degrees. Considering these issues, the current study used the Digit Ordering task (DOT), which is argued to be a pure measure of WM capacity (Cooper, Sagar, Jordan, Harvey, & Sullivan, 1991). The task requires participants to reorder a series of digits into increasing value for immediate recall at the end of each trial. The DOT requires the reorganization of material (i.e., updating digit order during presentation) and the maintenance of the memory load (digits) as the auditory information is being presented (Werheid et al., 2002).The DOT does not involve shifting between tasks or the inhibition of prior material as all digits are relevant until recall at the end of each trial, thereby ensuring the assessment of WM processes.

1.3. Media Multitasking and Inhibition

Research has also examined the link between media multitasking and the EF of inhibition (inhibitory control of a response or filtering irrelevant information). Studies examining filtering have shown that HMM tend to be more adversely affected by an increasing number of distractors compared to LMM (Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017). These results are consistent with numerous other studies that have reported poorer filtering skills for HMM compared to LMM (Cain & Mitroff, 2011; Cardoso-Leite et al., 2016; Gorman & Green, 2016). However, other studies that have reported no performance differences between HMM and LMM on filtering tasks (Author, 2017; Minear et al., 2013) or that greater engagement in media multitasking was associated with better Flanker task performance (Baumgartner et al., 2014). These mixed results could be due to some of the tasks employing multiple EFs. For example, Ophir et al. (2009) assessed distractor interference within a WM task (e.g., *n*-back) and the Attentional Network Test used by Minear et al. (2013) measures alerting, orienting and executive control. To assess filtering, this study employed a Spatial Stroop task (Lu & Proctor, 1995). This task requires participants to indicate the pointing direction of an arrow, whilst ignoring the irrelevant location of the arrow. This task has no WM requirements (Diamond, 2013) and does not rely on cognitive flexibility processes (e.g., task-switching) making it a suitable measure of filtering.

Studies have also reported mixed outcomes when examining the inhibition of responses in relation to media multitasking. Ophir et al. (2009) reported no difference between HMM and LMM in their performance on a stop-signal task and Seddon et al. (2018) reported no association between levels of media multitasking and stop-signal task performance. However, recently Shin et al. (2019) demonstrated that HMM performed better on a stop-signal task compared to LMM. Ralph, Thomson, Seli, Carriere, and Smilek (2015) used the Sustained-Attention-to-Response Task (SART), a variant of the Go/No-Go task, to assess inhibitory control in relation to media multitasking. They found no significant correlation between MMI scores and no-go trial errors or go trial RTs in experiment 2. However, in a follow up study with a larger sample size, there was a trend towards significance for higher MMI scores to be associated with more no-go trial errors.

As with the studies examining WM and media multitasking, it is possible that the mixed results could also be attributed to the different inhibition processes measured by a task (e.g., response control or response stopping), as well as the purity of the inhibition measure. For example, in the stop-signal task participants respond on every trial, except if a cue is presented (usually auditory signal) in which case they must cease making a response. Thus, this task requires inhibition of an in progress motor response. This differs from Go/No-Go task requirements where the signal not to respond is based on the stimulus and therefore precedes the initiation of a motor response. This study used a Go/No-Go task with two conditions. One condition assessed response inhibition (low load condition) and the other response inhibition with additional WM requirements where participants had to retain multiple task rules to differentiate between go and no-go response trials (high load condition). This enabled the assessment of the link between media multitasking and response inhibition and the combination of WM and response inhibition processes.

1.4. The Current Study

While numerous media multitasking studies have used an extreme groups approach to examine LMM and HMM differences on EF measures, it has been argued that this is problematic as it ignores the performance of the middle portion of media multitaskers, typically results in small sample sizes for each group (Ralph & Smilek, 2016) and tends to overestimate effect sizes (Wilhelm et al., 2013). To avoid these issues this study used MMI scores as a continuous variable to examine the link between media multitasking and performance on measures of WM (DOT), Response Inhibition (Spatial Stroop task) and both WM and Response Inhibition (Go/No-Go task with low and high cognitive load conditions).

Research has shown a link between age, fluid intelligence and EFs (e.g., Diamond, 2013; Salthouse, Atkinson, & Berish, 2003) and EFs and measures of impulsivity (Sanbonmatsu et al., 2013; Uncapher et al., 2016). Therefore, age, IQ and self-report impulsivity were included as control variables in the regression analysis to ensure that the unique contribution of media multitasking could be examined in relation to the WM and Inhibition task outcomes. Media multitasking was used as a predictor of EFs task performance, to allow direct comparison with the results of the other studies that have also examined the link between media multitasking and performance on EF measures as the dependent variable (e.g., Minear et al., 2013; Ophir et al., 2009; Shin et al., 2020; Shin et al., 2019; Wiradhany & Nieuwenstein, 2017).

Thus, the current study sought to further our understanding of the link between media multitasking and the EFs of WM and Response Inhibition. Although the studies of WM and media multitasking have produced mixed outcomes to date, it appears that when WM is measured via a task largely reliant on updating (e.g., *n*-back task), HMM tend to perform more poorly than LMM. Given the DOT relies heavily on updating, it was predicted that higher MMI scores would be associated with poorer WM capacity. Further, from the review of literature presented above it appears that those who engage in greater amounts of media multitasking demonstrate poorer filtering and response inhibition task performance. Thus, it was predicted that higher MMI scores would be associated with poorer performance in the Spatial Stroop and Go/No-Go tasks.

2. Method

2.1. Participants

One hundred first year university students (28 males and 72 females) aged between 17 and 70 years (*M* = 25.14, *SD* = 10.78) completed the study in return for partial course credits. All participants had normal colour vision (Ishihara, 1994) and normal or corrected to normal vision. The data from three participants were excluded from the analysis as their performance on the computer tasks and/or the measure of WM were at least three SDs below the sample mean suggesting a failure to follow task instructions. As Cardoso-Leite et al. (2016) has demonstrated an interaction between gaming experience and media multitasking such that video game playing influences extreme media multitasking groups' attentional performance, the data from six expert first person shooter video game players were also excluded from the analysis. Thus the data analysis for this study was based on a final sample of 91 participants (70 females and 21 males) with ages ranging from 17 to 61 years (M =24.41, SD = 9.39). G*Power analysis determined the sample size sufficient to detect an effect size f^2 of 0.12 (significance level 5% and 80% power).

2.2. Media Multitasking Index (MMI). The MMI was a modification of that used by Ophir et al. (2009) (Author, 2017). Participants noted the number of hours they spent weekly using different media (reading print, listening to non-musical audio, using social media, listening to music, instant message text or email, phone or video chat, viewing video/TV content, using non-social media web-sites, playing video/computer/phone games and completing offline computer tasks such as word processing). For each primary media, participants also indicated the extent to which they used all 10 media simultaneously (*0 – Never, .33 – Some of the time, .67 – A little of the time* and *1 – Most of the time).* A MMI score was computed for each participant using the formula from Ophir et al. (2009) and higher scores indicate a greater proportion of media use time is spent undertaking media multitasking.

2.3. Executive Function Tasks

2.3.1. Working Memory Task. The Digit Ordering task (DOT) (Cooper et al., 1991) was used to measure WM capacity. It has ecological validity, high internal consistency and good reliability (Cronbach's alpha > .80) (Hoppe, Müller, Werheid, Thöne, & von Cramon, 2000). The DOT auditorily presented participants with sequences of seven randomly presented digits from the set of numbers 0 to 9, presented at the rate of one per second.[1] At the end of the digit sequence, a tone indicated that participants should write down (recall) the digits in ascending numerical order. The DOT consisted of five practice trials and 15 experimental trials. Position-related scoring was used, requiring digits to be correctly identified and noted in the right order for a trial to be correct (Cooper et al., 1991). The maximum possible score was 15 and higher scores indicate better WM capacity.

2.3.2. Inhibition Task. The Spatial Stroop task was used as a measure of inhibition to examine the influence of irrelevant spatial information on responses (Lu & Proctor, 1995). On each trial a centrally presented fixation cross appeared for 500 ms, after which time the cross remained on the screen and was accompanied by an arrow pointing to the left or the right. The cross and arrow remained on the screen until a response was made or for a maximum time of 1000 ms. Participants were instructed to respond as soon as the arrow was presented and to press the left or right shift key to indicate the arrow pointing direction. The arrow either appeared with the pointing direction and location congruent (e.g., left pointing arrow appeared on the left of fixation) or the arrow pointing direction and screen location were incongruent (e.g., left pointing arrow presented to the right of fixation). Arrow direction and location were congruent on 75% of the trials. This ratio of congruent to incongruent trials was selected to ensure participants were primed to expect consistency between the arrow direction and location, thereby truly capture inhibition processes on the less frequent incongruent trials. Before starting the 80 experimental trials, participants completed 10 practice trials. The experimental trials comprised 20 incongruent and 20 congruent condition trials that were used for the data analysis. The task also included 40 fillers trials (arrow direction and location congruent) to meet the 75% congruent trials criteria noted above. Responses to these trials were excluded from the analysis and filler trial data were not

[1] The numbers were spoken by a native English speaker and recorded onto computer and presented using the DMDX computer program (Forster & Forster, 2003) to ensure standardised task presentation.

examined prior to exclusion. The filler trials appeared randomly throughout the task as part of the computer program trial randomization for each participant, and the same filler trials were presented to all participants.

2.3.3. Inhibition Task with Working Memory Load. The Go/No-Go task (Lavie, 1995; Author, 2017) assessed response inhibition in the low load condition and both response inhibition and WM in the high load condition. On each trial, a fixation cross appeared for 500 ms followed by the simultaneous presentation of a target letter (X or N in white font), a coloured shape (red or blue circle or square) and a distractor letter (X or N in white font) for 100 ms on a black background. The target letter appeared left or right of the coloured shape, while the distractor appeared above or below these two stimulus elements. There were two distractor letter conditions; the distractor and target letter were the same (X target, X distractor both responses the same key – congruent condition) or the distractor was the other target letter (X target, N distractor, responses mapped to two different keys – incongruent condition). The target letter and shape subtended a visual angle of 0.80° horizontally and 1.0° vertically and were separated by 1.5° of visual angle. The distractor letter was presented 1.5° of visual angle above or below the target and shape display. Participants were instructed to identify the target letter (X or N by pressing the x-key or n-key respectively) when the figure was a certain colour and/or shape (go trials) and otherwise withhold responses (no-go trials). For no-go trials, where no response was correct response, the program allowed 2000 ms before progressing to the next trial. If a response occurred, this error and RT was recorded for the go trials.

Participants completed two versions of the Go/No-Go task. In the low load condition, responses were required for a blue shape shown with the target letter (blue circle or blue square) (go trials) and no response was required for a red shape (red circle or red square) (no-go trials). In the high load condition, a response was required when a blue circle or red square was presented with the target letter (go trials). Participants were instructed to withhold their responses if a blue square or a red circle accompanied the target letter (no-go trials). There were 12 practice trials for the low load and 24 practice trials for the high load condition. Both load conditions had 128 experimental trials (2 blocks of 64 trials with rest break between). In both task loads, 75% of the trials were go trials, with 48 blue circle and 48 blue square trials in the low load condition and 48 red square and 48 blue circle target trials in the high load condition. Within the experimental trials the target was presented to the left of fixation for half the trials and the right of fixation for the other half of the trials. The target letter identity was X for half of the trials and N for the other half the trials and the distractor presentation occurred above or below the stimulus display an equal number of times within the trials. The target letter appeared with a response congruent distractor on 50% of the trials and with a response incongruent distractor on the other 50% of trials.

2.4. Control Measures

2.4.1. Demographics Questionnaire. Participants completed a demographic questionnaire which asked about their age, gender, physical activity levels (frequency and duration of weekly exercise sessions) and video gaming behaviours (duration of game sessions and games genres played within the last 6 months). This information was used as participant inclusion criteria as these factors have been linked to performance on EF tasks in previous research. For example, higher levels of physical activity have been associated with better cognitive control and working memory processes (Chen, Ringenbach, Crews, Kulinna, & Amazeen, 2015; Cox et al., 2016). As no participant was an elite athlete or exercised beyond reasonable daily levels no participant data were excluded on this basis.

2.4.2. Ishihara Colour Vision Test. Participants were screened for colour blindness using the Ishihara (1994) colour vision test as decisions in the Go/No-Go task were reliant on colour cues.

2.4.3. Culture Fair Intelligence Test (CFIT). Previous research shows that individuals with higher level of fluid intelligence perform better on measures of WM capacity and inhibition (Barbey, Colom, Paul, & Grafman, 2014; Diamond, 2013; Ropovik et al., 2016). Therefore, participants' CFIT (Cattell & Cattell, 1973) scores were used as a control variable in the regression analysis. The CFIT is a nonverbal measure of fluid intelligence. Scale 3 Form A was used in this study and it comprises four time limited subtests: series, classification, matrices, and conditions, requiring participants solve different problems by identifying the relationship between shapes and figures. Higher scores indicate higher levels of fluid intelligence.

2.4.4. Barratt Impulsiveness Scale (BIS-11). Studies have shown that higher levels of impulsiveness are related to poorer performance on tasks assessing inhibition (Enticott, Ogloff, & Bradshaw, 2006; Pietrzak, Sprague, & Snyder, 2008) and WM capacity (Uncapher et al., 2016). Therefore this study used the 30 item BIS-11 (Patton, Stanford, & Barratt, 1995) as a control measure of impulsivity. Participants rate how often each statement applies to them on a four-point scale (1 = Rarely/Never to 4 = Almost Always/Always). Sample items include statements such as "I do things without thinking" and "I buy things on impulse". The BIS-11 comprises three second order factors, attention (8 items), motor (11 items) and non-planning (11 items). Higher scores on each subscale indicate poorer outcomes. In the current study the attention and non-planning subscales showed acceptable reliability (Cronbach's alpha = .713 and = .690 respectively). The motor sub-scale showed marginal reliability (Cronbach's alpha = .555).

2.5. Procedure

The research received ethics approval from the University Research Ethics committee and prior to completing the study participants provided written informed consent. Volunteers were recruited via the Department online research participation system and the study took approximately one and a half hours per participant to complete. Participants completed the study individually or in pairs and the computer tasks and online questionnaire measures were completed in small individual computer rooms with low illumination. The pen and paper measures of the CFIT (Cattell & Cattell, 1973) and DOT (Cooper et al., 1991) tasks were completed at writing desks. To reduce the potential for fatigue to affect task performance, eight different task orders were used for the participants. Participants first completed the demographic questionnaire. This was followed by the CFIT (Cattell & Cattell, 1973) and then the DOT (Cooper et al., 1991) for half of the participants while the other half of the participants completed the DOT and then the CFIT (Cattell & Cattell, 1973).[2] Completion of the computer tasks then followed and half the participants completed the Go/No-Go task (Lavie, 2005, Author, 2017) first then the Spatial Stroop task (Lu & Proctor, 1995) and the other half completed the Spatial Stroop task first. For the Go/No-Go task, 50% of the participants were assigned to the low load condition first and 50% to the high load first. The computer tasks were run on a Dell Optiplex MT PCs with a BenQ 144Hz 24-inch monitor using the DMDX software (Forster & Forster, 2003). The DMDX program recorded the RT and accuracy for each trial within the tasks. Participants were seated approximately 60 cm away from the computer. Following the computer tasks participants completed online versions of the MMI (Author, 2017; Ophir et al., 2009) and BIS-11 (Patton et al., 1995).

3. Results

3.1. Data Preparation and Analyses

For the DOT (WM task) the dependent variable was number of correct trials (maximum 15) where the digits were recalled correctly and in the correct order (Cooper et al., 1991). RT data were only for correct responses for the Spatial Stroop and go trials of the Go/No-Go

[2] The DOT and CFIT were always completed prior to the computer tasks. This was because both tests were group administered and used auditory presentation of stimuli or instructions. If these tasks were scheduled last then participants would have been required to wait for the other in their group of 2 to complete all other measures first. This would have placed an unnecessary burden on participant's time.

task. To control for the impact of outlying RTs on any individual trial, for each participant, any RT more than two standard deviations outside the participant's mean RT were excluded from the analysis. Accuracy was also used as an outcome measure for the Spatial Stroop task and both the go and no-go trials of the Go/No-Go task. [3]

Hierarchical multiple regression analyses were run to examine if WM and inhibition task performance could be explained by media multitasking (MMI scores). Age, IQ and BIS attention score [4] were used as control variables (Step 1 of the regression). MMI score was the IV entered at step 2. Table 1 shows the zero-order correlations among the control measures (age, IQ and BIS attention score), MMI scores and the WM and Inhibition task outcomes measures (DOT and Spatial Stroop) and the mean and standard deviation for these variables.

For the Spatial Stroop task performance was examined separately for the incongruent and congruent conditions to ensure any relationship with MMI score was evident in the analysis. If a Stroop Congruency (incongruent vs. congruent condition difference score) was used as the dependent variable, this would not determine if any relationship between MMI scores and performance (RT or accuracy) was due to poorer performance in the incongruent condition or better performance in the congruent condition as either condition could contribute to MMI scores being related with a Stroop Congruency (difference score) effect. The same approach was also used for the Go/No-Go task to ensure the link between MMI score and performance within each task condition (congruent and incongruent target-distractors under low and high WM load conditions) was examined in detail.

[3] Inverse efficiency scores (RT/ proportion correct) were not used as a dependent variable as it has been shown to produce unreliable data when the proportion of correct responses is below 90% (Bruyer & Brysbaert, 2011)and in the high load condition of the Go/No-Go task many participants' accuracy fell below this level.

[4] Only the BIS attention score was correlated with outcome measures and therefore was used as a control measure in the regression analysis. This association was also reported by Uncapher et al. (2016).

Table 1

Descriptive Statistics and Pearson correlations for Age, IQ, BIS Attention and MMI scores and the WM (DOT) and Inhibition (Spatial Stroop task) Outcome Measures

	Age	IQ score	BIS-A	MMI	*Mean*	*SD*
Age					24.41	9.40
IQ score	-.097				110.02	12.08
BIS-A	-.039	.049			17.69	3.88
MMI score	-.258*	.024	.299*		4.06	1.48
DOT correct	.099	.298*	.216	.200*	6.51	3.58
Spatial Stroop RT (ms) Incongruent cond.	.334*	-.199*	.044	-.065	536	88
Spatial Stroop RT (ms) Congruent cond.	.358*	-.059	-.001	-.186	429	57
Spatial Stroop Accuracy (%) Incongruent cond.	.184*	.173*	-.099	-.246**	74.51	17.73
Spatial Stroop Accuracy (%) Congruent cond.	.100	.076	-.008	-.081	96.91	6.66

Note: BIS-A = BIS-Attention subscale score; MMI score = Media Multitasking Index score; DOT correct = number trials out of 15 correct in DOT;

3.2. Working Memory Task (DOT) Results

The hierarchical regression analysis revealed that at step 1 the control measures of age, IQ and BIS attention score, together accounted for 14.7% of the variance in DOT scores, $F(3, 87) = 4.99$, $p = .003$. Adding MMI scores at step 2 accounted for a marginally significant 3.3% of the variance in DOT scores, $F_{change}(1, 86) = 3.24$, $p = .067$. At step 2 the unique contribution of IQ (9.1%) was significant and MMI scores showed a trend towards significance (3.28 %), Multiple $R = 0.18$, $F(4, 86) = 4.72$, $p = .002$. Thus, independent of the control measures, there was a marginally significant association between higher MMI scores and greater WM capacity (higher DOT scores). Table 2 provides a summary of this analysis.[5]

[5] The DOT data was also rescored for listing the correct digits on each trial regardless of the correct ordering of the numbers. These data were analysed using the same hierarchical regression as noted above and the outcomes of the analysis were the same as reported for DOT scores based on listing correct digits in correct order.

Table 2

Hierarchical Multiple Regression Analysis for the Control Variables, MMI scores on DOT Performance (WM capacity measure)

	DOT score		
Step	Variables	β	Part correlation
1	Age	.136	.135
	IQ	.301	.299**
	BIS attention	.206	.206*
2	Age	.185	.178
	IQ	.303	.302**
	BIS attention	.149	.142
	MMI score	.196	.181

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

3.3. Inhibition Task (Spatial Stroop Task) Results

3.3.1. Spatial Stroop Task t-test Results. To verify a congruency effect within the Spatial Stroop task, repeated measures t-tests were run comparing RT (ms) and accuracy (%) in the incongruent and congruent conditions. Table 1 presents the correlations and descriptive statistics for this task. Correctly identifying the arrow direction within the incongruent condition took longer, $t(90) = 16.67$, $p < .001$ and accuracy was poorer, $t(90) = -13.65$, $p < .001$, than when the arrow location and direction were congruent. Thus standard results were replicated within the Spatial Stroop task.

3.3.2. Spatial Stroop Task Response Time Data Regression Results. Table 3 presents the relevant statistics for the hierarchical regression for RTs in the incongruent and congruent conditions of the Spatial Stroop task. At step 1, the control variables (age, IQ and BIS attention score) together accounted for 14.4% of the variance in RTs in the incongruent condition, $F(3, 87) = 4.88$, $p = .003$. Entering MMI scores at step 2 did not account for any additional variance, $F_{change}(1, 86) = .001$, $p = .978$, and age remained as a significant unique predictor of RT for the incongruent condition (9.99%), Multiple $R = 0.14$, $F(4, 86) = 3.62$, $p = .009$.

For the congruent condition, 12.9 % of the variance in RT was explained by the control variables (step 1), $F(3, 87) = 4.29$, $p = .007$. At Step 2, MMI scores (1.1%) did not account for any additional variance, $F_{change}(1, 86) = 1.11$, $p = .294$, and the unique contribution of age remained significant (10.3%), Multiple $R = 0.14$, $F(4, 86) = 3.50$, $p = .011$. Thus, for both the incongruent and congruent conditions of the Spatial Stroop task older participants produced longer RTs.

3.3.3. Spatial Stroop Task Accuracy Data Regression Results. Table 3 presents the results of the hierarchical regression analysis for the Spatial Stroop task accuracy data. At Step 1, the control variables accounted for 8.1% of the variance in accuracy within the incongruent condition, $F(3, 87) = 2.54$, $p = .061$. At step 2, MMI scores explained a further 3.3 % of the variance, $F_{change}(1, 86) = 3.24$, $p = .075$. Although marginally significant, the unique contributions of IQ (3.72%) and MMI (3.35%) scores accounted for variance in accuracy. Lower IQ scores and higher MMI scores were associated with poorer accuracy in the incongruent condition of the Spatial Stroop task, Multiple $R = 0.11$, $F(4, 86) = 2.77$, $p = .032$.

For the congruent condition, at Step 1 the control variables explained a non-significant 1.79% of the variance in accuracy, $F(3, 87) = .52$, $p = .673$. At Step 2, MMI scores did not account for additional variance, $F_{change}(1, 86) = .29$, $p = .593$ and no other variables were significant in the model, Multiple $R = 0.02$, $F(4, 86) = 0.46$, $p = .768$.

Table 3

Hierarchical Multiple Regression Analysis of Control Variables, MMI scores for RT and Accuracy Data within the Incongruent and Congruent Conditions of the Spatial Stroop task

		RT Data			
		Arrow Direction and Location Incongruent		Arrow Direction and Location Congruent	
Step	Variables	β	Partial correlations	β	Partial correlations
1	Age	.320	.319**	.356	.354**
	IQ	-.172	-.171	-.025	-.025
	BIS attention	.065	.065	.014	.014
2	Age	.321	.309**	.327	.315**
	IQ	-.172	-.171	-.027	.027
	BIS attention	.064	.061	.047	.045
	MMI score	.003	.003	-.115	-.106
		Accuracy Data			
		Arrow Direction and Location Incongruent		Arrow Direction and Location Congruent	
Step	Variables	β	Partial correlations	β	Partial correlations
1	Age	.199	.198	.108	.108
	IQ	.197	.196	.086	.086
	BIS attention	-.101	-.101	-.008	-.008
2	Age	.150	.144	.093	.089
	IQ	.194	.193	.086	.085
	BIS attention	-.044	-.042	.010	.009
	MMI score	-.198	-.183	-.062	-.057

*Note: * p < .05, **p < .01*

3.4. Inhibition Task with Working Memory Load (Go/No-Go Task) Results

3.4.1. Go/No-Go Task ANOVA Results

To examine overall performance in the Go/No-Go task, a series of 2 (load: low load, high load) $\times$ 2 (target-distractor congruency: incongruent, congruent) fully repeated measures factorial ANOVAs were run for the accuracy data for the no-go trials and for the RT and accuracy data for the go trials. Table 4 presents the relevant descriptive statistics.

Performance for the no-go trials was more accurate in the low than high load conditions, $F(1,90) = 230.39$, $p < .001$, $\eta_p^2 = 0.72$. There was no main effect for target-distractor congruency, $F(1,90) = 0.39$, $p = .535$, $\eta_p^2 = 0.004$, and the interaction between load and target distractor congruency was not significant, $F(1,90) = 0.47$, $p = .493$, $\eta_p^2 = 0.005$.

For the go trials, RTs were shorter for targets presented in the low than high load conditions, $F(1,90) = 343.37$, $p < .001$, $\eta_p^2 = 0.79$, and when the target and distractor were congruent compared to when they were incongruent, $F(1,90) = 21.60$, $p < .001$, $\eta_p^2 = 0.19$. The interaction between load and target-distractor congruency was not significant, $F(1,90) = 1.09$, $p = .300$, $\eta_p^2 = 0.012$.

Go trial accuracy was higher for the low than high load conditions, $F(1,90) = 132.52$, $p < .001$, $\eta_p^2 = 0.60$, and the main effect of target-distractor congruency was not significant, $F(1,90) = 0.70$, $p = .402$, $\eta_p^2 = 0.007$. The interaction between load and target-distractor congruency was significant, $F(1,90) = 12.42$, $p = .001$ $\eta_p^2 = 0.12$, with a congruency effect in accuracy only evident in the low load condition ($p < .05$). Thus the overall results for the outcome measures of the Go/No-Go task are consistent with standard effects observed in prior studies (e.g., Author, 2017).

Table 4

Descriptive Statistics and Pearson correlations for Age, IQ, BIS Attention and MMI scores and Performance on the Go/No-Go Task for Low and High Load Conditions with Incongruent and Congruent Distractors.

No-Go Trials	Age	IQ	BIS attention	MMI score	*Mean*	*SD*
Low load accuracy incongruent	.11	-.05	-.12	-.06	98.61%	3.07
Low load accuracy congruent	.01	-.16	-.003	-.03	98.55%	3.38
High load accuracy incongruent	.21	-.06	-.22*	-.29**	64.12%	24.15
High load accuracy congruent	.26*	.02	-.26**	-.27**	65.22%	22.88
Go Trials						
Low load RT incongruent	.26*	-.05	.11	-.22*	558 ms	76
Low load RT congruent	.28*	-.08	.09	-.23*	546 ms	75
High load RT incongruent	.32**	.003	-.01	-.28**	742 ms	137
High load RT congruent	.29**	.05	-.02	-.32**	734 ms	133
Low load accuracy incongruent	.26*	-.08	-.09	-.11	92.55%	6.74
Low load accuracy congruent	.20	.09	-.11	-.27**	94.49%	4.82
High load accuracy incongruent	.10	-.03	-.25*	-.07	82.05%	11.37
High load accuracy congruent	.08	.15	-.17	.04	80.94%	12.02

3.4.2. No-Go Trial Accuracy Data Regression Results. Table 5 presents the hierarchical regression analysis for no-go trial accuracy data for the incongruent and congruent conditions under low and high task loads.

Low Load Condition. At step 1, 2.6% of the variance for the incongruent no-go trial accuracy was accounted for by the control variables, $F(3, 87) = .77$, $p = .513$. Entering MMI scores at Step 2 did not explain further variance, $F_{change}(1, 86) = .00$, $p = .974$, and no individual variable was significant, Multiple $R = 0.16$, $F(4, 86) = 0.57$, $p = .684$.

Similarly, for the low load congruent condition, the control variables only explained 2.6% of the variance in accuracy, $F(3,87) = .78$, $p = .506$. The contribution of MMI scores at Step 2 did not account for additional variance in accuracy, $F_{change}(1, 86) = .11$, $p = .742$, and no individual variable was significant, Multiple $R = 0.17$, $F(4, 86) = 0.61$, $p = .657$. Thus there was no link between MMI score and no-go trial accuracy within the low load condition.

High Load Condition. Under the high load, 9% of the variance in no-go trial accuracy for the incongruent condition was accounted for by the control variables, $F(3, 87) = 2.86$, $p = .042$. At step 2, the addition of MMI scores explained a further 3.4% of the variance in no-go trial accuracy, $F_{change}(1, 86) = 2.85$, $p = .071$. The marginally significant result showed a trend for higher MMI scores to be associated with lower accuracy for the no-go trials in the high load incongruent condition, Multiple $R = 0.35$, $F(4, 86) = 3.03$, $p = .022$.

For the no-go trials in the congruent high load condition, 13.3% of the variance in accuracy was explained by the control variables, $F(3, 87) = 4.46$, $p = .004$. Entering MMI scores at Step 2 was not significant, $F_{change}(1, 86) = 1.92$, $p = .169$. The unique contributions of age (4.24%) and BIS attention scores (4.12%) were significant, Multiple $R = 0.39$, $F(4, 86) = 3.80$, $p = .006$.

Table 5

Hierarchical Multiple Regression Analysis of Control Variables and MMI scores for the No-Go Trial Accuracy Data for the Low and High Load Conditions with Distractors Incongruent and Congruent with the Target

Low Load Condition		Target-Distractor Incongruent		Target-Distractor Congruent	
Step	Variables	β	Partial correlations	β	Partial correlations
1	Age	.104	.103	-.008	-.008
	IQ	-.029	-.029	-.163	-.162
	BIS attention	.-.111	-.111	.005	.005
2	Age	.103	.099	-.018	-.017
	IQ	-.029	-.029	-.164	-.163
	BIS attention	-.110	-.105	.016	.015
	MMI score	-.004	-.003	-.038	-.035
High Load Condition		Target-Distractor Incongruent		Target-Distractor Congruent	
Step	Variables	β	Partial correlations	β	Partial correlations
1	Age	.200	.199	.252	.250**
	IQ	-.025	-.028	.053	.052
	BIS attention	-.210	-.209	-.257	-.256**
2	Age	.150	.144	.212	.206
	IQ	-.031	-.031	.050	.050
	BIS attention	-.152	-.144	-.213	-.203
	MMI score	-.200	-.185	-.149	-.138

*Note: * p < .05, **p < .01*

3.4.3. Go Trial Response Time Data Regression Results. Refer to Table 6 for a summary of the regression analysis for the go trial RT data for the incongruent and congruent conditions under low and high task loads.

Low Load Condition. At step 1, 8.4% of the variance in go trial RTs within the incongruent condition, was explained by the control variables, $F(3, 87) = 2.66$, $p = .053$, (age explaining a significant 6.92% of the variance). Entering MMI scores at Step 2, explained an additional and significant 4.2% of the variance, $F_{change}(1, 86) = 4.14$, $p = .045$ (age remained as a significant predictor, 4.04%). Therefore beyond the age effect, higher MMI scores were associated with shorter RTs to target letters presented with an incongruent distractor in the low load condition, Multiple $R = 0.36$, $F(4, 86) = 3.01$, $p = .020$.

A significant 9.3% of the variance in RTs for the go trials within the congruent condition was explained by the control variables, $F(3, 87) = 2.98$, $p = .036$, and age was a significant predictor (7.84%). At step 2, MMI scores explained a further 4.2% of the variance, $F_{change}(1, 86) = 4.16$, $p = .044$, and higher MMI scores were linked with shorter RTs to targets presented with congruent distractors, Multiple $R = 0.37$, $F(4, 86) = 3.36$, $p = .013$.

High Load Condition. The regression for RTs to targets presented with incongruent distractors revealed that the control variables accounted for 10 % of the variance, $F(3, 87) = 3.36$, $p = .022$, with age as the only significant predictor (10.37%). At step 2 an additional significant 4.58% of the variance was explained by MMI scores, $F_{change}(1, 86) = 4.64$, $p = .034$, and age remained a significant predictor (6.50%). Thus, beyond the age related effect, higher MMI scores were associated with shorter RTs to targets presented with incongruent distractors in the high load condition, Multiple $R = 0.39$, $F(4, 86) = 3.78$, $p = .007$.

The analysis of RTs for the go trials in the congruent condition, showed that at step 1, 9% of the variance was explained by the control variables, $F(3,87) = 2.81$, $p = .044$. However age was the only significant variable (8.94%). At step 2, MMI scores explained an additional

6.55% of the variance in go trial RTs within the target-distractor congruent condition, $F_{change}(1,86) = 6.71$, $p = .011$ and age (4.97%) remained significant, Multiple $R = 0.37$, $F(4, 86) = 4.03$, $p = .005$. Thus higher MMI scores were associated with shorter RTs to targets presented with a congruent distractor.

Table 6

Hierarchical Multiple Regression Analysis of Control Variables and MMI scores for Go Trial RT Data for the Low and High Load Conditions for Distractors Incongruent and Congruent with the Target.

Low Load Condition		Target-Distractor Incongruent		Target-Distractor Congruent	
Step	Variables	β	Partial correlations	β	Partial correlations
1	Age	.264	.263*	.282	.280**
	IQ	-.027	-.027	-.057	-.057
	BIS attention	.122	.122	.101	.101
2	Age	.209	.201*	.227	.218*
	IQ	-.030	-.030	-.060	-.060
	BIS attention	.187	.178	.166	.158
	MMI score	-.227	-.205*	-.222	-.205*
High Load Condition		**Target-Distractor Incongruent**		**Target-Distractor Congruent**	
Step	Variables	β	Partial correlations	β	Partial correlations
1	Age	.324	.322**	.301	.299**
	IQ	.0434	.034	.077	.077
	BIS attention	-.000	-.000	-.010	-.010
2	Age	.266	.255*	.232	.223*
	IQ	.031	.031	.073	.073
	BIS attention	.067	.064	.070	.067
	MMI score	-.233	-.214*	-.275	-.256*

*Note: * p < .05, **p < .01*

3.4.4. Go Trial Accuracy Data Regression Results. Table 7 presents the results of the regression analysis for go trial accuracy in the low and high load conditions for the two target-distractor congruency conditions.

Low Load Condition. Although collectively the control variables accounted for 7.6% of the variance in accuracy for the go trial responses when targets were presented with an incongruent distractor, the effect was marginally significant, $F(3,87) = 2.37$, $p = .076$. At Step 2, no additional variance was explained by MMI scores, $F_{change}(1,86) = .07$, $p = .798$, and age remained as a significant predictor (5.43%), Multiple $R = 0.28$, $F(4, 86) = 1.78$, $p = .141$.

When targets were presented with a congruent distractor, a non-significant 6.3% of the variance in accuracy was attributed to the control variables, $F(3,87) = 1.96$, $p = .125$, and age explained a marginal amount of variance (4.34%). At step 2, MMI scores accounted for additional and marginally significant 4% of the variance 2, $F_{change}(1,86) = 3.18$, $p = .054$, and age was no longer significant, Multiple $R = 0.32$, $F(4, 86) = 2.47$, $p = .050$. Higher MMI scores were associated with (trend towards significance) poorer target accuracy when the distractors were congruent with the target.

High Load Condition. For the go trials with incongruent distractors, 6.9% of the variance in accuracy was explained by the control variables, F (3,87) = 2.16, $p = .099$. Entering MMI scores at step 2 did not explain further variance, $F_{change}(1,86) = .101$, $p = .751$ and only BIS-Attention scores were significant (5.86%), Multiple $R = 0.27$, $F(4, 86) = 1.63$, $p = .175$.

When the distractors were congruent, the control variables accounted for 6% of the variance of the go trial accuracy, $F(3,87) = 1.88$, $p = .140$. At step 2, only a further 1.39% of the variance was accounted for by media multitasking, $F_{change}(1,86) = 1.29$, $p = .260$ and no individual variable was a significant predictor, Multiple $R = 0.27$, $F(4, 86) = 1.73$, $p = .150$.

Table 7

Hierarchical Multiple Regression Analysis of Control Variables and MMI scores for Go Trial Accuracy Data for the Low and High Load Condition with Distractors Incongruent and Congruent with the Target.

Low Load Condition		Target-Distractor Incongruent		Target-Distractor Congruent	
Step	Variables	β	Partial correlations	β	Partial correlations
1	Age	.249	.248*	.208	.207*
	IQ	-.055	-.054	.119	.118
	BIS attention	-.077	-.077	-.102	-.102
2	Age	.242	.233*	.154	.148
	IQ	-.055	-.055	.116	.115
	BIS attention	-.069	-.065	-.040	-.038
	MMI score	-.029	-.027	-.216	-.199*
High Load Condition		**Target-Distractor Incongruent**		**Target-Distractor Congruent**	
Step	Variables	β	Partial correlations	β	Partial correlations
1	Age	.087	.087	.091	.091
	IQ	-.009	-.009	.163	.162
	BIS attention	-.2434	-.243*	-.174	-.173
2	Age	.096	.092	.123	.118
	IQ	-.009	-.010	.165	.164
	BIS attention	-.254*	-.242*	-.211	-.201
	MMI score	.036	.033	.128	.118

*Note: * p < .05, **p < .01*

4. Discussion

The previous research that has examined the link between media multitasking and the EFs of WM and Inhibition has produced mixed results. Possible reasons for these varied results were identified including tasks employing more than one EF (task impurity), tasks engaging different sub-processes within the one EF (e.g., different WM processes) and the use of an extreme groups approach to select samples within the studies. To address these issues, in this study MMI scores were used as a continuous variable to allow for understanding of the full range of participants' performance on EF measures. Further the WM and Inhibition tasks used were specifically selected as they allowed for either WM or Inhibition or a combination of these EFs to be assessed. Therefore, by overcoming some of the limitations of prior research within the area, this study sought to increase understanding of the relationship between media multitasking, WM and Inhibition.

4.1. Media Multitasking and Working Memory

As expected fluid intelligence scores were positively related to DOT scores, replicating the standard effect (e.g., Colom et al., 2015; Diamond, 2013; Shipstead, Harrison, & Engle, 2016). However, contrary to the predicted outcome, higher levels of media multitasking showed a marginally significant association with greater WM capacity (better DOT performance). This finding contrasts with the outcomes of previous research, with most studies noting higher levels of media multitasking being related with poorer WM (e.g., Cain et al., 2016; Ophir et al., 2009; Ralph & Smilek, 2016; Uncapher et al., 2016) or no association between these variables (Baumgartner et al., 2014; Minear et al., 2013; Seddon et al., 2018). While all of these studies have used standard WM tasks, the different outcomes may be explained by the measures emphasizing different elements of WM. For example, the *n*-back requires updating, filtering and inhibition. In contrast, the DOT uses predominately updating processes with a constant memory load (Werheid et al., 2002). Thus, the marginal trend towards higher MMI scores being associated with greater WM capacity (better DOT performance) suggests that updating might be one aspect of WM that is related to media multitasking behavior. However, further research is required to replicate this marginally significant effect and it should also employ measures to assess different WM processes (e.g., updating information, maintaining a memory load and temporal ordering of information) within the same set of participants. This would further our understanding of how the different sub-processes of WM might be linked with MMI scores.

4.2. Media Multitasking and Inhibition

The Spatial Stroop task (Lu & Proctor, 1995) was used as a measure of inhibition and due to the task's low WM demands (Diamond, 2013), provides a pure measure of participant's abilities to filter out irrelevant location information. The regression analysis showed that while age was positively related to RTs (for congruent and incongruent trials), there was no relationship between MMI scores and RTs within the Spatial Stroop task. For the congruent trials, MMI scores were not related to accuracy. However, in the incongruent condition, there was a marginally significant trend for those with higher MMI scores to be less accurate, suggesting poorer ability to ignore the irrelevant arrow location information. While only marginally significant this result is consistent with the hypothesis and the results of several other studies reporting poorer filtering task performance for HMM relative to LMM (Cain & Mitroff, 2011; Cardoso-Leite et al., 2016; Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017). Thus this result suggests that those who engage in more media multitasking might be less able to ignore task irrelevant information. However, given the marginal significance of this finding, replication of this outcome is required in future research.

4.3. Media Multitasking, Inhibition and Working Memory

The Go/No-Go task used in this study presented targets with response congruent and incongruent distractors under low and high task load conditions. MMI scores were not associated with no-go trial accuracy in either the congruent or incongruent conditions in the low load or the high load congruent condition. In the high load condition for targets presented with incongruent distractors, higher MMI scores were marginally associated with poorer no-go trial accuracy. This marginally significant trend is consistent with the correlation reported by Ralph et al. (2015) but not the results reported by Author (2017) who used the same Go/No-Go task and found that IMM (intermediate media multitaskers) had poorer response inhibition compared to LMM and HMM. However, that study had a smaller sample size and did not use MMI scores as a continuous variable and thus this may have been a contributing factor to the different results reported here. This result provides some tentative evidence that those who undertake more media multitasking might have greater problems with response inhibition but only when the cognitive load is high and incongruent distracting information is presented.

Within the Go/No-Go task higher MMI scores were marginally associated with poorer accuracy for the go trials in the congruent low load condition. For the low and high load conditions for both the congruent and incongruent distractors, shorter RTs for go trials were associated with higher MMI scores. While the RT results might suggest higher levels of media multitasking are related to more efficient task performance, prior studies have shown a link between shorter RTs for go trials and poorer accuracy for no-go trials (Ralph et al., 2015). Thus, shorter RTs for go trials might be the result of poorer inhibition (lower no-go trial accuracy) rather than processing efficiency. To examine this issue, a series of hierarchical regression analyses were conducted with accuracy for each no-go trial condition entered as a control variable (along with age and IQ) and MMI scores were used as a predictor of go trial RT for each of the conditions. After controlling for age, IQ and no-go trial accuracy within the relevant condition, higher MMI scores were significantly associated with shorter RTs for each condition (all *ps* < .05) except for the high load condition with the incongruent distractors. Thus, the RT results support greater processing efficiency being linked with higher MMI scores in all but the high load incongruent distractor condition. Given that the go trial RT-no-go trial accuracy trade-off was only evident for incongruent distractors under the high load this does not provide strong evidence of poorer response inhibition for those with higher MMI scores. Instead it might be that participants with higher MMI scores are less able to filter out the incongruent distractor information under a high cognitive load, which could be interpreted as poorer filtering skills. However, Green and Bavelier (2003) demonstrated that action video game players were more affected by irrelevant incongruent distractors than non-video game players in a flanker task with a high cognitive load. They interpreted this result as reflecting the greater attentional capacity of video game players processing the distractors that did not occur in non-video game players with less attentional capacity. Thus, the poorer accuracy on no-go trials in the high load incongruent condition for those with higher MMI scores may reflect greater attentional capacity or a wider breadth of attention. This is consistent with the suggestion that HMM have a more ‘breadth-biased’ cognitive control (Ophir et al., 2009) or more scattered attention (van der Schuur et al., 2015). Therefore, while the go trial RT results indicate that those who engage in more media multitasking are able to perform the task more efficiently, the locus of the no-go trial accuracy result requires further investigation.

Given that higher MMI scores were marginally related to better DOT performance, the role of WM in relation to the Go/No-Go task RT data also requires consideration. If the shorter go trial RTs were a function of greater WM capacity, then this result would have only occurred for the high load condition where multiple the response criteria (blue circle and red square go otherwise no response) would have been retained in memory during the task. It may therefore be the case that higher levels of media multitasking are in fact associated with increased general processing speed, which in turn allows high MMI scorers to be more efficient in stimulus processing (Salthouse et al., 2003) during the 100ms stimulus display time in the Go/No-Go task.

Event-related potentials (ERPs) provide precise temporal measurement of neural activation and are able to elucidate the operation of cognitive processes during task performance (Luck, 2012). To further understand inhibitory processes, ERPs have been used to measure neural activity during response conflict tasks such as Flanker and Go/No-Go tasks (e.g., Aasen & Brunner, 2016; Ribes-Guardiola, Poy, Patrick, & Moltó, 2020; Zordan, Sarlo, & Stablum, 2008) and would therefore provide a potential avenue for further investigation of the Go/No-Go task results. Of particular relevance for the Go/No-Go task is the N2/P3 ERP complex, a fronto-central negative deflection occurring 250-350 after stimulus onset (N2) followed by a positive centro-parietal component (P3) 300-600 ms after stimulus onset (Huster, Enriquez-Geppert, Lavallee, Falkenstein, & Herrmann, 2013; Ribes-Guardiola et al., 2020). Within the Go/No-Go paradigm, greater N2 negativity has been found for no-go trials compared to go trials (Huster et al., 2013), which is thought to reflect inhibition monitoring processes (Ribes-Guardiola et al., 2020). The P3 component, a measure of the cognitive processes supporting inhibition or the evaluation of response inhibition has also been shown to be enhanced for no-go compared to go trials (Albert, López-Martín, Hinojosa, & Carretié, 2013; Huster et al., 2013; Ribes-Guardiola et al., 2020). Thus, if higher levels of media multitasking are associated with greater processing efficiency then it would be expected that this would be reflected in N2/P3 amplitude or latency differences for the go and no-go trials. This would help determine if inhibition monitoring and/or the support or evaluation of response inhibition are related to the greater response efficiency demonstrated by those with high MMI scores.

4.4. Limitations of the Current Study

The current sample of 91 participants is smaller than that reported in several other media multitasking studies (Minear et al., 2013; Sanbonmatsu et al., 2013), however the power analysis revealed this was sufficient sample size to detect moderate effect sizes. Given the small effect sizes evident in the current study it would be advisable for future studies to utilize larger sample sizes to investigate the link between media multitasking and EFs. However, even when much larger sample sizes (e.g., Baumgartner et al., 2014 N = 523, Ralph et al, 2015, N = 174) have been employed in studies examining the link between media multitasking and EFs, the results have been shown to be marginally significant. Therefore it may be the case that the effect size for relationship between EFs and media multitasking is small or it is mediated by numerous other variables. These issues should be considered in future research studies.

The cross-sectional nature of the design of this study does not provide clarity about the causal link, if any, between media multitasking and EF task performance. Further research measuring actual media multitasking behaviours and EF performance across time is required to establish if more frequent media multitasking might result in cognitive changes.

4.5. Summary and Conclusion

The results of this study showed a marginal association between higher MMI scores and greater WM capacity. Higher MMI scores were related to more efficient performance on the go trials of the Go/No-Go task. Within the incongruent trials of the Spatial Stroop task and no-go trials incongruent distractors with a high load and the go trials low load congruent condition of the Go/No-Go task, there was a marginally significant trend for higher MMI scores to be linked within poorer task accuracy. These results suggest that the links between media multitasking and task performance differ across EFs. Thus, it appears that the link between media multitasking and the different EFs is complex and requires further research to gain a complete understanding in this area.

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Article Highlights

- Higher MMI scores were marginally associated with Digit Ordering Task performance
- Higher MMI scores were marginally associated with lower Spatial Stroop task accuracy
- Higher MMI scores were marginally associated with more errors on the no-go trials
- Higher MMI scores were associated with shorter go trial RTs in the Go/No-Go task