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# Exploring the relationship between executive functions and self-reported media-multitasking in young adults

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# Exploring the relationship between executive functions and self-reported media-multitasking in young adults

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**ABSTRACT**

Media-multitasking involves simultaneous engagement with information streams from multiple media sources, and is most prevalent in young adults. Heavy media-multitasking has been associated with differential performance on tasks involving attentional control and working memory relative to light media-multitasking. The aim of the present study was to systematically investigate relationships between executive functions and self-reported media-multitasking. Healthy participants ($N = 112$, aged 18–25, male $N = 36$) completed a battery of 10 traditional executive function tasks, that included assessments of attentional inhibition, response inhibition, working memory, and cognitive flexibility. Scores on the individual executive function tasks were correlated against frequency of self-reported media-multitasking, but no significant relationships were found. Trait anxiety, however, was found to be significantly associated with greater frequency of self-reported media-multitasking. The present study found no evidence of a relationship between the frequency of self-reported media-multitasking and executive functioning. The possible reasons for this are discussed.

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Media-multitasking; attentional inhibition; working memory; cognitive flexibility; trait anxiety

## Introduction

The way in which individuals engage with media has dramatically altered since the digital media revolution. Digital media has become a major part of daily life, enabling and driving individuals to be constantly connected and to communicate via technology (Russo, Fallon, Zhang, & Acevedo, 2014). The importance of the role of digital media corresponds with the exponential growth in accessibility and usage of media devices (Baumgartner, Weeda, van der Heijden, & Huizinga, 2014). Individuals simultaneously engage with multiple forms of media within either a single device or by employing multiple devices (Ziegler, Mishra, & Gazzaley, 2015). Using an experience sampling method, Moreno et al. (2012) found that for 190 students "media-multitasking" was the most prevalent way in which media was consumed, with 56.6% of individuals' time on the internet spent multitasking. The combination most frequently engaged in is watching T.V. whilst social networking on a smart phone, tablet or laptop (Baumgartner et al., 2014; Van Cauwenberge, Schaap, & Van Roy, 2014). This type of media consumption is widespread, and has been found to associate negatively with individuals' academic performance (e.g. Bellur, Nowak, & Hull, 2015; Junco & Cotten, 2012); mental health and well-being (e.g. Becker, Alzahabi, & Hopwood, 2013; Xu, Wang, & David, 2016) and cognitive functioning (e.g. Ophir, Nass, & Wagner, 2009; Uncapher, Thieu, & Wagner, 2016). However, there is also evidence demonstrating no relationship between media-multitasking and cognitive functioning (Minear, Brasher, McCurdy, Lewis, & Younggren, 2013; Murphy, McLauchlan, & Lee, 2017). The aim of the present study was to explore systematically the relationships between executive functions and self-reported media-multitasking.

### *Media-multitasking and cognitive functioning*

#### *Attentional control*

In a pioneering study, Ophir et al. (2009) explored the relationship between self-reported media-multitasking and cognitive function, comparing the per-

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formance of heavy media-multitaskers (HMMs) with light media-multitaskers (LMMs) on a range of cognitive tasks. To investigate sustained attention, they required participants to complete an AX- continuous performance task (AX-CPT) and found no significant differences between the performance of heavy and light media-multitaskers, in terms of response times or accuracy. Whereas Ralph, Thomson, Seli, Carriere, and Smilek (2015) utilised a metronome task to assess sustained attention (experiment 1 and 3a) and found a significant positive correlation for HMMs and greater response variability, indicating that HMMs sustained attention is poor in comparison to that of LMMs.

However, Ophir et al. (2009) also included an altered version of the AX-CPT task that featured distractors. They found that on the distractor version of the task HMMs- performed worse (with slower response times) than LMMs. Therefore, the authors concluded that HMMs struggle to disregard irrelevant stimuli, leading the authors to suggest that HMMs display a breadth-based bias in attentional processing. Further studies have also demonstrated such bias (Cain & Mitroff, 2011; Cardoso-Leite et al., 2016; Gorman & Green, 2016; Wiradhany & Nieuwenstein, 2017) including research using tasks higher in ecological validity (see Moisala et al., 2016).

It is important to highlight that a broader scope of attention is not inherently unfavourable. Heavy media-multitaskers' distributed mode of attention could be advantageous in terms of faster response times to stimuli presented simultaneously at different locations (Yap & Lim, 2013) or in facilitating a multi-sensory integration of information (Lui & Wong, 2012).

In contrast, there is some evidence opposing the media-multitasking breadth-based bias in attention, with other authors suggesting that frequent media-multitaskers do not differ from light media-multitaskers in terms of their attentional control. Minear et al. (2013) used the attention network task (ANT) and found no difference in LMM's and HMM's executive attention, alerting attention and orientation of attention performance.

Similarly, when implementing a flanker task Murphy et al. (2017) found no significant difference in HMM's and LMM's performance, suggesting that their ability to focus attention to stimuli and process information is no different. However, other research utilising flanker tasks has found HMMs to perform significantly worse than LMMs (Gorman & Green, 2016) or the opposite, with HMMs performing better (faster on incongruent trials) than LMMs (Baumgartner et al., 2014). However, the difference in performance was only marginally significant in this latter study. In a recent review, Uncapher et al. (2017) suggest that the majority of the research indicates a negative relationship between more frequent media-multitasking and attentional control.

### Response inhibition

Media multitasking has also been explored in relation to behavioural control of responses. Ophir et al. (2009) used Verbruggen, Logan, and Stevens (2008) stop signal task, Ralph et al. (2015) and Gorman and Green (2016) both used the Sustained Attention to Response Task (SART) (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), whereas Murphy et al. (2017) used a Go- No go task. Ophir et al. (2009) found no significant difference in LMM's and HMM's performance on the stop signal task. Similarly, using the SART, Ralph et al. (2015) found no significant correlation between self-reported media-multitasking and no-go errors (experiment 2, 83 participants). However, when they replicated the study (experiment 3b) using a larger sample of 152 participants they found a correlation between MMI and SART that bordered significance, which is further supported by Gorman and Green (2016) who also found a significant main effect, with HMMs demonstrating poorer performance on the SART. However, in a further experiment (experiment 4) Ralph et al. (2015) used a vigilance task, a type of Go-No go task, similar to SART but different in terms of the amount of trials the participant is required to be non-responsive for. They found a negative, significant but weak correlation with MMI and overall sensitivity, and no association between MMI and response time. The authors suggest that one's ability to remain vigilant is not associated with media-multitasking. In contrast, Murphy et al. (2017) compared light, average and high media-multitaskers and, surprisingly, average media-multitaskers (AMMs) were found to make significantly more errors than LMMs and HMMs on the Go- No Go task. Overall, where relationships between media-multitasking and response inhibition have been found, they have tended to be weak.

### Working memory

Research has also explored the relationship between media-multitasking and working memory. However, the evidence is pervasively inconsistent (Uncapher et al., 2017) with some research finding differences between HMMs and LMMs on working memory tasks (e.g. Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013; Uncapher et al., 2016) and other research demonstrating no differences (e.g. Baumgartner et al., 2014; Cardoso-Leite et al., 2016; Minear et al., 2013; Ophir et al., 2009). Critically the disparities in results cannot be explained by the use of different tasks, since similar tasks are not associated with consistent patterns of results, even within single research studies authors have found differences in performance on some tasks and not for others (e.g. Cain, Leonard, Gabrieli, & Finn, 2016). For example, when using complex span tasks that involve the simultaneous processing and storage of information, Baumgartner et al. (2014), Minear et al. (2013), and Gorman and Green (2016) found no difference in media-multitaskers' performance, whilst Cain et al. (2016) found more frequent media-multitasking to predict worse performance, in terms of reduced working memory capacity.

When using n-back tasks, that require continuous recognition based discrimination of stimuli (Chen, Mitra, & Schlaghecken, 2008), Cardoso-Leite et al. (2016), Ophir et al. (2009), and Wiradhany and Nieuwenstein (2017) (experiments 1 and 2) found no significant difference in performance: whereas Cain et al. (2016) and Ralph and Smilek (2017) found more frequent media-multitasking to be associated with poorer performance, in terms of averaged "hits" minus "false alarms".

When using filter tasks, a type of task that also involves discrimination between changing stimuli (sometimes also classed as an attention task), Ophir et al. (2009) found HMMs to be linearly negatively affected by distractors, whereas LMMs were not affected by distractors, which is further supported by Uncapher et al. (2016). In this latter study, HMMs were less able to differentiate between the absence and presence of a change, thus they displayed poorer working memory discriminability. This has been further demonstrated by Gorman and Green (2016) who used the same filter (change detection) task as Ophir et al. (2009) and found HMMs to perform significantly worse than LMMs. In addition to Cardoso-Leite et al. (2016) who also used the same filter task as Ophir et al. (2009) and found heavy media multitaskers to perform worse than light media multitaskers and intermediate media multitaskers. However, they did not fully replicate the results, as when contrasting heavy and light media multitaskers filter task performance they found no reliable difference in distractor effects. Furthermore, some studies such as Cain et al. (2016) have found no significant difference.

In summary then, no type of working memory task has demonstrated an entirely consistent relationship with self-reported media-multitasking, but most of the published studies have found a relationship with at least one of the tasks they used.

### *Task switching (cognitive flexibility)*

The issue of inconsistent evidence is also prevalent in the few studies exploring media-multitasking and task switching (Uncapher et al., 2017; Van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015). HMMs have been found to be significantly slower in switch trials (Wiradhany & Nieuwenstein, 2017), and slower in both switch and non-switch trials in terms of switch cost (Ophir et al., 2009), indicating a higher switch cost and poor task-switching ability. However, subsequent studies have not replicated this finding (e.g. Baumgartner et al., 2014; Cardoso-Leite et al., 2016; Minear et al., 2013). Two studies have even found the opposite, with HMMs displaying a lower switch-cost, indicating better task switching ability (Alzahabi & Becker, 2013), and an association of media-multitasking with faster task switching, due to a faster ability to prepare in advance (Alzahabi, Becker, & Hambrick, 2017). These inconsistent findings suggest that it may be beneficial to use other measures besides task-switching to explore the relationship between media-multitasking and cognitive flexibility.

### *Theoretical background on executive function*

Multiple definitions and frameworks of executive function have been proposed, with prominent models put forward by Miyake et al. (2000) and Diamond (2013). Diamond's (2013) theoretical framework proposes that there are three core facets of executive function; inhibition, working memory and cognitive flexibility. The theory postulates that inhibition is further split into inhibitory control of attention, cognitive inhibition and self-control, where attentional inhibition is the way in which one is able to selectively focus one's attention, cognitive inhibition is the way in which one can supress unwanted thought, prepotent mental representations and resist both proactive and retroactive interference, and self-control is the way in which one is able to supress habitual or impulsive behaviour. Working memory is the process involved in the manipulation of information that is held currently in mind, it is the way in which mental representations of information are "worked with". Lastly, cognitive flexibility is the ability to adapt effortlessly one's way of thinking, switching between mental sets and changing perspective. However, it also encompasses sinuous generation of abstract thought.

A key concern within executive function research is "impurity" of the assessment tasks available (Miyake et al., 2000; Snyder, Miyake, & Hankin, 2015), in the sense that a task does not measure one executive function, rather the tasks used often place demands on more than one function (Rabbitt, 1997) as well as domain-specific functions (Phillips, 1997; Miyake et al., 2000). A way to address the issue of task impurity is to use more than one task to measure the executive function of interest (Snyder et al., 2015), which facilitates the utilisation of the shared variance of the multiple tasks to be used as a latent variable of the underlying construct. For example, this type of approach was previously used by Alzahabi et al. (2017), who examined task switching in relation to media-multitasking. A latent variable approach was also explored in the current study, with the application of confirmatory factor analysis on data from a battery of executive function tasks, within a single sample.

### Assessing media-multitasking

The Media Multitasking Index (MMI) developed by Ophir et al. (2009) is a self-report measure designed to determine individuals' frequency of media-multitasking. It has been widely used within the literature with researchers using the MMI to distinguish media-multitaskers by frequency, with some studies grouping them into light media-multitaskers and heavy media-multitaskers. Referred to as extreme grouping, this presents two key methodological issues. First, the use of extreme groups introduces the risk of bias through the implication of possibly missing vital data that is simply ignored (Preacher, Rucker, MacCallum, & Nicewander, 2005). Second, there is no standardised way of determining light and heavy media-multitaskers. Research has used both standard deviation (e.g. Ophir et al., 2009) and quartiles (e.g. Cain & Mitroff, 2011) to define the two groups making it difficult to compare results across studies. It has been proposed that a full continuum of MMI scores should be included, and then correlated with executive function performance (Van der Schuur et al., 2015). This approach has increasingly been adopted, with the use of a full continuum of MMI scores in over half of the literature exploring media-multitasking and cognitive function, (e.g. Cain et al., 2016; Moisala et al., 2016; Ralph & Smilek, 2017), including the research reported here.

### Rationale for the present study

To summarise, previous findings investigating the relationship between cognitive performance and frequency of media-multitasking have been mixed and further research is needed.

The main objective of the current study was to examine the relationships between executive function components (inhibition, working memory and cognitive flexibility) and media-multitasking frequency as measured by the Media-multitasking Index (Ophir et al., 2009) utilising the full continuum of scores. A data reduction approach of the battery of executive function tasks was conducted to explore components reflecting the functioning of these theoretical constructs.

It was hypothesised that self-reported frequency of media-multitasking would be negatively correlated with inhibition and working memory, with poorer inhibitory control and working memory associated with a higher media-multitasking score. The relationship between cognitive flexibility and self-reported media-multitasking was also explored, with no directional prediction. In addition to executive functioning we measured mood, anxiety and depression, with the inclusion of a mood questionnaire and the Hospital Anxiety and Depression scale (Bjelland, Dahl, Haug, & Neckelmann, 2002; Zigmond & Snaith, 1983), in an attempt to replicate previous research by Becker et al. (2013) that found symptoms of anxiety and depression to be associated with MMI score.

## Method

### Participants

A total of 112 participants, 76 females (67.9%), 18–25 years old (mean = 20.83, SD = 2.12) were recruited from the university student population and members of the public. Complete data were collected for all participants. The sample size was chosen based on Tabachnick and Fidel (2001), and the stopping rule used was based on a deadline for data collection, provided that a minimum goal of 107 participants had been reached. Data were not analysed until the final sample of 112 was achieved. The experiment was performed in accordance with a protocol approved by the university research ethics committee and in accordance with the principles laid out by the British Psychological Society.

### *Procedure*

After informed consent was obtained, participants completed three questionnaires and ten executive function tasks (described below). The questionnaires included an adapted version of the Media-Multitasking Index (MMI) (Ophir et al., 2009), a mood inventory (Matthews, Jones, & Chamberlain, 1990) and an anxiety and depression inventory (Zigmond & Snaith, 1983). All Stimuli for computer tasks were presented on an Ilyama prolite B1980SD monitor, powered by a Viglen desktop computer with a 3.20 GHz Intel® Core™ I5-6500 processor. No tasks other than the ones reported below were completed by the participants.

## Measures

### *Media-multitasking*

Media multitasking was assessed using a modified version of the Media Multitasking Index (MMI) designed by Ophir et al. (2009). The aspects of the MMI that were modified were the types of media used; media that was deemed more appropriate to the current technological and media-multitasking behavioural environment was included. The present study used the following 12 categories of media; print/ text media (magazines, text books, e-readers), video (TV or computer based), music, non-music audio, video/computer games, phone calls, browsing and posting on social media, instant messaging, e-mail, web surfing and other computer applications (e.g. Microsoft Word). Similar to Ophir et al. (2009) texting was only included in the matrix, and not in the first section where participants had to indicate how many hours a week they used each form of media. A matrix was used to assess how often each type of media was simultaneously used with another. MMI score was calculated in the same way as Ophir et al. (2009), using the following formula:

$$\mathrm{MMI} = \sum_{i=1}^{11} \frac{m_i \times h_i}{h_{\mathrm{total}}}$$

For each of the 11 primary media (except texting) the ratings for all possible combinations with the other media were summed. The resulting score (mi) was multiplied by the number of hours spent using that primary medium (hi), and then divided by htotal (total number of hours using all media). A higher MMI score indicates more frequent media-multitasking within a typical media consumption hour (Ophir et al., 2009).

### *Mood*

State mood was measured using the UWIST (University of Wales Institute of Science and Technology) mood adjective checklist (UMACL; Matthews et al., 1990). The checklist consists of 18 items (adjectives), to which participants have to rate how they are feeling at that specific time. Each item is rated using a five-point Likert scale ranging from "not at all, slightly, moderately, very or extremely". The adjectives load onto three constructs of mood (arousal, anxiety and depression) which can also be totalled to give an overall score. The mood inventory was found to have acceptable reliability with the following cronbach's alphas for each subscale; anxiety ($\alpha = .70$), arousal ($\alpha = .74$) and depression ($\alpha = .60$).

Trait Anxiety and depression were also assessed with the use of the Hospital Anxiety and Depression scale (HADS) (Zigmond & Snaith, 1983). This features 14 questions with seven questions relating to depression (and seven relating to anxiety), each response is scored on a 4 point Likert scale, 0–3. Cronbach's alphas for the 7 anxiety items and the 7 depression items were .75 and .67.

### *Tasks intended to measure inhibition*

### *Attentional inhibition*

Attentional inhibition was assessed using two flanker tasks. The principle basis of a flanker task is that it requires the individual to "zoom in" their attentional focus to specific stimuli, and process the stimuli in focus to facilitate a specific response, whilst ignoring other stimuli that are not in the focus, that could interfere (Stins, Polderman, Boomsma, & de Geus, 2007). The first flanker task used was the same implementation as Moore, Keogh, and Eccleston (2012) and consisted of numerical stimuli and a total of 160 trials, with 40 trials per each flanker condition. The second flanker task features arrow stimuli, and is part of the Psychological Experiment Building Language (PEBL) test battery designed by Mueller and Piper (2014). The only adaption made to the task was the amount of trials it consisted of; it was modified to include 80 trials, with 20 trials per each flanker condition. Each task required the participant to respond to the central target stimuli (number/arrow) with the press of a button. There were four flanker conditions in each task; congruent (flanked with the same stimuli), incongruent (flanked with the opposite stimuli, e.g. a 2 flanked by a 4 (44244), or an arrow pointing right flanked by arrows pointing left (←←→←←) and vice versa), neutral (flanked by "h" in number task and dashed lines in the arrow task) and null (not flanked by any stimuli). The main outcome measure for the flanker tasks was congruency conflict, which is the difference between mean response time for congruent and incongruent trials.

### Response inhibition

Response inhibition was measured using a stop-signal and a go/no-go task. The study implemented the Stop-it programme by Verbruggen et al. (2008). In the Stop-it task, participants were presented with different shapes on the screen, either a square or a circle. Shapes were shown one at a time to which participants had to respond by pressing "Z" for square and "/" for circle. Whilst responding to the shapes they also had to listen out for a beep. If a beep occurred when the shape appeared, the participant had to withhold their response (not press the button). The main outcome measure of the task is stop signal response time (SSRT) that equates to the covert latency of the internal stop process reflecting inhibition. The SSRT is calculated using a horse race model, which states the success of response inhibition depends on the race between the finishing times of a go process (pressing a button) and stop process (withholding a response) (Verbruggen et al., 2008).

The go/no-go task used was the same featured in Moore et al. (2012), in which participants are presented with a central fixation circle and two horizontal lines, one on either side of the screen in the periphery, the angle of vision was 14.2°. Participants had to respond when either of the lines turned vertical in the trial (pressing "1" for the line on the left and "5" for the right), but only when the central fixation circle was black, when the circle was red participants had to withhold their response. Performance was indexed by number of correct inhibitions, with a higher number indicating greater inhibitory control. There were a total of 120 go trials and 30 no-go trials.

### Tasks intended to measure cognitive flexibility

Cognitive flexibility was assessed using four separate tasks. The first task was the computerised short version of the Wisconsin Card Sorting (64-card version) from the (PEBL) psychological test battery (Piper et al., 2012), no adaptations to the task were made. Participants are presented with four cards on the screen featuring different shapes, in different colours and different numbers of shapes. These four cards stay on the screen constantly and underneath them are corresponding card-shaped spaces. A card then appears on the right side of the screen that has to be sorted into one of the four piles. Each time a card is sorted the participant is given feedback on the screen saying "correct" or "incorrect". The rule of sorting (shape, colour, number of items) changes throughout the task as the cards are sorted, which participants have to recognise based on the feedback they receive. Percentage of perseverative errors (trials where participants fail to change to a new sorting rule) was used as the main outcome, with higher scores reflecting poorer cognitive flexibility.

A computerised version of the Trail Making Task (TMT) Reitan (1958) from the PEBL battery (Mueller, 2014) was implemented, the only adaptions made to the task were the specifics of the screen size for the size of the monitor used. The task requires participants to click on the computer screen using the mouse. They have to click on circles containing a sequence of numbers for trail A and on trail B switch between clicking a number sequence and a letter sequence. The circles have to be clicked in order in as fast a time as possible. Each condition consisted of four practice trials and four test trials, with participants completing a practice each time before a trial. On each trial, the arrangement of circles was randomly re-arranged to create different orders for each trial. Calculation of the mean difference in response times on trail A and trail B conditions was used as an indicator of cognitive flexibility with faster times equal to greater cognitive flexibility.

The phonetic fluency task involved the participant being presented with a letter to which they have to respond by saying as many words as possible that start with that letter, in 60 seconds. The present study used the letters; F, A, S as these are the most frequently used within the literature (Herrmann, Ehlis, & Fallgatter, 2003; Laws, Duncan, & Gale, 2010). In the semantic fluency task, participants were given three different categories; Animals, clothing and food as these are the most commonly used (Luo, Luk, & Bialystok, 2010; Nusbaum & Silvia, 2011). The task involved participants stating as many words as possible for each category in 60 seconds. The mean total scores across the three letters (phonetic) and categories (semantic) were summed, with higher scores representing greater cognitive flexibility. Scoring for both fluency tasks followed that of Luo et al. (2010) where proper names, numbers, places and words in different forms were excluded. Reske, Delis, and Paulus (2011) have previously used fluency tasks to assess cognitive flexibility.

### *Tasks intended to measure working memory*

A computerised backwards Corsi block task from the Millisecond library for Inquisit was implemented as a measure of visuo-spatial working memory. This task features 9 blue boxes displayed on a screen that light up. The pattern in which the boxes light up has to be replicated in reverse order to that observed. If the pattern is replicated correctly, then the next pattern increases by one box. However, if the pattern is repeated incorrectly the same number of boxes appears in a different pattern again. If two patterns are consecutively repeated incorrectly then the task stops. The mean span was recorded with a longer span indicating a greater working memory capacity.

A computerised backwards digit span task from the Millisecond library for Inquisit was used as an assessment of verbal working memory (Woods et al., 2011). The span starts with 2 digits and increases as the task progresses to a maximum of 9 digits. Trials fluctuate in length of span based on a 1:2 staircase ratio; a single correct response increases the length of the span, whilst two incorrect responses are needed to reduce span length. Participants complete 14 trials. Mean span was used, with a longer span indicative of a greater working memory capacity. Forwards versions of the Corsi block and digit span task were also completed by participants. However, they were not included in the analysis as they do not require manipulation of stored information.

## Results

Data were explored and outliers with performance scores further than 3 standard deviations from the mean (indicating non-compliance with instructions) were removed from the data set. This resulted in the removal of 7 participants leaving a final sample of 105 for the analysis of executive function data. The mean scores for all study variables are shown in Table 1.

### *Executive function factor analysis*

We explored whether data reduction of the 10 individual executive function tasks into the three latent executive function constructs specified in Diamond's

**Table 1.** Mean scores for MMI, mood measures and executive function tasks.

| | Mean | S.D | Skew | Kurtosis |
|---|---|---|---|---|
| MMI (Media-multitasking) | 4.751 | 1.337 | .310 | −.189 |
| **Mood measures** | | | | |
| HADS Anxiety | 6.261 | 3.329 | .479 | .036 |
| HADS Depression | 3.118 | 2.289 | .889 | 1.066 |
| State Arousal | 20.134 | 3.491 | −.417 | .211 |
| State Anxiety | 11.198 | 2.607 | .352 | −.010 |
| State Depression | 11.339 | 2.162 | −.155 | −.288 |
| **Executive Function Tasks** | | | | |
| Stop-it (SSRT) | 248.578 | 54.825 | −.552 | 2.447 |
| Go/No-go (Correct inhibitions) | 20.598 | 6.572 | −.450 | −.770 |
| Number Flanker (Congruency conflict) | 39.558 | 27.662 | −.456 | .804 |
| Arrow Flanker (Congruency conflict) | 55.138 | 24.703 | −.123 | .096 |
| Phonetic fluency (Total words correct) | 12.035 | 3.276 | .502 | −.069 |
| Semantic fluency (Total words correct) | 20.413 | 4.664 | .160 | −.072 |
| WCST (% Perseverative Error) | 13.895 | 6.464 | .877 | .822 |
| Trail making (B-A Difference) | 5046.076 | 2739.315 | .701 | .560 |
| Backwards digit span (Mean span) | 5.606 | 1.010 | .367 | .487 |
| Backwards Corsi block (Block span) | 6.366 | .890 | .687 | .743 |

Note: High scores on Go-No go, Backwards digit span, Backwards Corsi block, Phonetic fluency and Semantic fluency indicate better performance, whereas high scores on Stop-it, WCST, TMT, Number flanker and Arrow flanker indicate worse performance.

(2013) model was viable. Two models were tested via Confirmatory Factor Analysis. Model 1 included Diamond's three hypothesised executive function factors (i.e. inhibition, working memory and cognitive flexibility). The inhibition construct consisted of four indicators (Arrow Flanker task, Number Flanker task, Go-No go and the Stop Signal Task), working memory consisted of two indicators (Backwards digit span and Backwards Corsi block) and cognitive flexibility consisted of four indicators (Wisconsin Card Sorting Task (WCST), Trail Making Task (TMT), Phonetic fluency and Semantic fluency). Please see supplementary material for the graphical representation. This model was a poor fit (see Table 2) and inadmissible due the iteration limit being reached and negative error variance for the Backwards digit span task. Thus modification indices were inspected which indicated correlations between the error variances of the Go No-go and Backwards Corsi, Arrow Flanker and Number Flanker tasks both with the TMT, as well as change in regression weights for TMT and both Backwards Corsi and Backwards digit span.

Thus, a post hoc model utilising exploratory factor analysis was then conducted, which had the same structure as Model 1 but with the error variances correlated and TMT moved to the working memory latent factor. (In keeping with the theory that cognitive flexibility is underpinned by working memory (Diamond, 2013), the TMT may have placed a higher demand on working memory). This resulted in model 2, a better fitting model, although still inadmissible due to negative error variance for the Backwards digit span (see Table 2 for model fit indices). Furthermore, the model also demonstrated poor reliability of some of the indicators for all of the latent variables (see supplementary materials for graphical representation of Model 2), which would indicate removal of these tasks from the model. However, if all of these tasks were removed it would result in a model with a single indicator for working memory (Backwards digit span), and two indicators for inhibition (Stop-signal and Go No-go) and two for cognitive flexibility (Phonetic fluency and Semantic fluency). In regards to the latter mentioned latent variables, there is a possibility that shared method variance may be driving the models.

Thus to summarise, we were not able to produce a reliable model with single factors accounting for performance on multiple tasks. Therefore, structural equation modelling was not conducted and the relationship between executive function and media-multitasking was explored through the relationships with the individual executive function tasks.

**Table 2.** Models examining best fit for executive function factors.

| Model | $\chi^2$ | df | CFI | NFI | RMSEA |
|---|---|---|---|---|---|
| Model 1; 3 Factors | 54.204 | 32 | .755 | .601 | .082 |
| **Inhibition** (4 indicators) | | | | | |
| **Working memory** (2 indicators) | | | | | |
| **Cognitive Flexibility** (4 indicators) | | | | | |
| N.B Inadmissible solution, iteration limit reached and negative error variance | | | | | |
| Model 2; 3 factors | 30.677 | 29 | .982 | .774 | .024 |
| **Inhibition** (4 indicators) | | | | | |
| **Working Memory** (3 indicators) | | | | | |
| **Cognitive Flexibility** (3 indicators) | | | | | |
| N.B Inadmissible solution, negative error variance | | | | | |

### *Executive function correlational analysis*

A correlational analysis of the 10 individual executive function tasks and MMI scores was carried out. No significant correlations between media-multitasking and performance on each of the executive function tasks were found (see Table 3), all *p*s > .05, based on Bonferroni correction to the $\alpha$-value. Therefore, the hypothesis that MMI would be negatively related to working memory and inhibition was not supported, and no relationships were found between MMI and cognitive flexibility as assessed by the tasks in the battery.

### *Mood*

A significant positive correlation was found for MMI score and trait anxiety ($r = .267$, $p < .05$, see Table 4), indicating that individuals who more frequently media-multitask have higher levels of trait anxiety. No significant correlations were apparent for MMI score and state measures of: anxiety, depression and arousal, or trait depression. A Bonferroni adjustment to the $\alpha$-value was made.

## Discussion

The findings of this study were clear, in that no relationship was observed between self-reported

**Table 3.** Correlation co-efficients for all executive function tasks and media-multitasking.

| | Stop-it (SSRT) | Go/No-go (Correct Inhibitions) | Number Flanker (Congruency conflict) | Arrow Flanker (Congruency conflict) | Phonetic Fluency (Total correct words) | Semantic Fluency (Total correct words) | WCST (% Perseverative Errors) | TMT (B-A Difference) | Backwards Digit Span (Mean span) | Backwards Corsi Block (Block span) |
|---|---|---|---|---|---|---|---|---|---|---|
| Media-multitasking | .176 | .039 | .010 | −.074 | −.039 | −.113 | .091 | .087 | .014 | −.179 |
| Stop-it (SSRT) | | −.368** | −.064 | .031 | −.238 | −.146 | .084 | −.107 | −.221 | .018 |
| Go/No-go (Correct Inhibitions) | | | .057 | .005 | .123 | .034 | −.104 | .095 | .206 | .235 |
| Number Flanker (Congruency conflict) | | | | .130 | .024 | .066 | .150 | −.227 | .069 | .115 |
| Arrow Flanker (Congruency conflict) | | | | | .049 | .118 | .068 | −.289* | .101 | .060 |
| Phonetic Fluency (Total correct words) | | | | | | .451** | .067 | −.059 | .265 | −.042 |
| Semantic Fluency (Total correct words) | | | | | | | .041 | −.173 | .170 | .032 |
| WCST (% Perseverative Errors) | | | | | | | | .113 | −.160 | −.232 |
| TMT (B-A Difference) | | | | | | | | | −.245 | −.216 |
| Backwards Digit Span (Mean span) | | | | | | | | | | .419** |

*Significant at $p < .05$, **Significant at $p < .01$, $N = 105$, adjusted based on a Bonferroni correction.

**Table 4.** Correlation co-efficients for media-multitasking, anxiety, depression and state mood measures.

| | Mood, Anxiety and Depression measures | | | | |
|---|---|---|---|---|---|
| | HADs Anxiety | HADs Depression | State Arousal | State Anxiety | State Depression |
| Media-multitasking (MMI) | .267* | .068 | −.052 | −.069 | .061 |

*Significant at $p < .05$, $N = 107$, adjusted based on a Bonferroni correction.

frequency of media-multitasking and measures of executive function. The relationships between the individual task performance scores and MMI scores were explored, due to the planned modelling of the relationships resulting in a non-substantive model. Self-reported frequency of media-multitasking was not found to relate to any executive functioning task within a battery of 10 tasks designed to measure inhibition, working memory and cognitive flexibility. No significant relationships were found between media-multitasking and the battery of executive function tasks. However, a significant correlation did emerge for the relationship between MMI and a trait anxiety measure, even when a Bonferroni correction for multiple comparisons was applied.

It was disappointing that within the present study we were unable to produce a reliable model of latent constructs underpinning the executive function tasks, unlike previous research such as Miyake et al. (2000) or Fisk and Sharp (2004). This may be due to idiosyncrasies in our data set, including the possibility that in the present study some of the tasks were not sufficiently distinct from each other, creating a high level of shared method variance, a limitation which is discussed further below.

### *Previous media-multitasking research*

The findings of the current study are not consistent with the research that demonstrates a breadth-based bias associated with more frequent media-multitasking (e.g. Cain & Mitroff, 2011; Cardoso-Leite et al., 2016; Ophir et al., 2009; Yap & Lim, 2013), given that no associations were found with performance on the two flanker tasks. However, the present study does support previous research by Minear et al. (2013) who found no significant difference between HMMs and LMMs in terms of performance on attentional tasks. However, if we focus on comparing previous research that has specifically utilised flanker tasks to assess attentional control, then the present study is inconsistent with Baumgartner et al. (2014) who found a trend of HMMs performing better than LMMs and Gorman and Green (2016) who found HMMs to perform worse than LMMs. It is consistent with Murphy et al. (2017) who found no difference in performance on a flanker task. It also extends these findings by replicating these non-significant results in an individual differences design.

In relation to response inhibition, neither Ophir et al. (2009) nor Ralph et al. (2015) found any association with media-multitasking, replicated in the current study, with performance on both a Go No-go task and the Stop Signal Task. However, the present study is inconsistent with Murphy et al. (2017), who did find that AMMs make more errors than HMMs and LMMs on a go-no go task. The concept of behavioural inhibition has also been examined in terms of trait impulsivity, with evidence associating higher levels of impulsivity with greater levels of self-reported frequency of media-multitasking (Sanbonmatsu et al., 2013; Wilmer & Chein, 2016).

Within the study, both a backwards digit span and a backwards corsi block task were included to assess verbal and visual working memory. However, no significant relationship with media-multitasking was found for either task. More specifically, the present study supports previous research that has found no difference in media-multitaskers' performance on span tasks (Baumgartner et al., 2014; Minear et al., 2013; Gorman & Green, 2016). However, the results of the present study are inconsistent with research by Uncapher et al. (2016) who found heavy media-multitaskers to perform worse on a filter task than light media-multitaskers, and with both Cain et al. (2016) and Ralph & Smilek (2016) who found poor working memory performance on an n-back task to be associated with more frequent media-multitasking. Therefore, further data will be needed to establish a clear picture of the relationship between working memory and media-multitasking.

The verbal fluency tasks were a novel inclusion in this study as a measure of cognitive flexibility, as supported by Diamond (2013) and Reske et al.

(2011). No previous research had investigated this type of task in relation to MMI. However, no significant relationships were found, suggesting that media-multitasking is not associated with verbal fluency, which has also been characterised as access to semantic memory (Fisk & Sharp, 2004).

Similarly, the Wisconsin Card Sorting Task and the Trail Making Task are traditionally viewed as task-switching tasks and were included as measures of cognitive flexibility. However, the present study found no significant relationship between performance on these two tasks and frequency of media-multitasking. Thus the present study adds to the literature suggesting that media-multitasking is not associated with cognitive flexibility (Baumgartner et al., 2014; Cardoso-Leite et al., 2016; Gorman & Green, 2016; Minear et al., 2013), adding novelty with the use of specific tasks that have not previously been explored in relation to media-multitasking. Although, the findings are inconsistent with Ophir et al. (2009) and Wiradhany and Nieuwenstein (2017) who found HMMs to be worse at task switching and, contrastingly, Alzahabi and Becker (2013) who found heavy media-multitaskers to be more resistant to switch costs; and Alzahabi et al. (2017) who found media-multitasking to be associated with faster task switching. Thus, while there seems to be some evidence that media-multitasking is associated with performance in simple task-switching paradigms, these effects may be too small to be detectable in more complex tasks that involve switching, limiting real-world implications.

### *Media multitasking and mood*

In the present study a significant relationship was found for media-multitasking and anxiety as measured using the HADs, with more frequent media-multitasking associated with higher levels of anxiety. Thus, the findings support previous research by Becker et al. (2013) who found media-multitasking to be a specific distinctive risk factor for mood and anxiety-related mental health issues. However, it is noteworthy that there are only two studies exploring mood and the specific measure of MMI, and the other of those, Shih and Gray (2013), has found no significant correlation between MMI and well-being. In regards to this sparse and opposing evidence, our findings expand and reveal evidence of a relationship between media-multitasking and mood. However, it is not known whether more anxious individuals seek out media-multitasking behaviour more frequently or if more frequent media-multitasking leads to higher levels of anxiety – the direction of causality still needs to be established (van der Schuur et al., 2015). Although the study found a significant correlation for trait anxiety and media-multitasking, no correlation was found for the state measure of anxiety. In this regard, it is important to highlight the difference in response timescales each measure requires. The HADs questionnaire requires the participant to think about how they have felt for the previous week, thus a longer timescale of feelings, whereas the mood measure of anxiety asks participants to indicate how they are feeling at the current moment in time. In comparison, the timescale of the MMI covers aspects of individual’s weekly hourly use of varying media, with the MMI score reflective of a typical hour spent media-multitasking.

### *Implications*

The present study adds to the other null findings reported within the literature. Thus, unfortunately a clear conclusion about the association between media-multitasking and executive functions must await further research evidence. Some articles in the popular media have made bold claims that media-multitasking is cumulatively harmful to cognitive ability, but it is important to recognise that concurrent relationships are not always demonstrated in the literature, and that there is a lack of evidence for cause and effect.

A relationship between media-multitasking and trait anxiety was found in the current study (although again, it is important to recognise that cause and effect could not be established). This association raises a particular issue concerning young adults’ mental health. As previously stated, individuals’ may media-multitask more frequently due to anxiety issues, or their media- multitasking may be a way of coping with their anxiety. If this is the case, given that media-multitasking seems to have more of a negative association with attentional control (despite the null findings of the present study), highly anxious individuals may be more susceptible to have issues controlling attention. For example, Eysenck, Derakshan, Santos, and Calvo (2007) proposed attention control theory, postulating that the goal-directed attentional system is impaired by anxiety, in terms of efficient functionality.

### *Methodological limitations*

A key limitation of the present study is the reliance on self-reported media-multitasking. The MMI requires people to estimate the number of hours spent on different types of media and how often time is spent on two types of media, which is then calculated to create an overall representative score. Individuals may not have accurately introspected on how often they media multitask.

In this regard, it is important to highlight that Ophir, Nass & Wagner first developed the MMI in 2009, since then technologies have advanced dramatically. This is especially applicable to smartphone technology and the invention of various social media and instant messaging apps such as; Instagram® which launched in 2010 (Instagram Press, 2017) and Facebook® messenger, which launched in 2011 (Facebook.com, 2017). Indeed, it is commonplace for individuals to compulsively use social media through their smart phones (Lee, Chang, Lin, & Cheng, 2014). The smartphone technological expansion has fundamentally changed individuals' media-multitasking behaviour. Individuals simply have access to technology that previously did not exist, which has created the current environment of easily and abundantly available technology, which in turn has generated an environment that is conducive of increasing individuals' susceptibility to becoming "addicted" to technology (Schou et al., 2016). This change in behaviour induced by technological advancement in turn possibly impacts how accurately individuals are able to report their media usage, especially when they are accessing media through their smartphone. Authors have suggested that individuals struggle to remember and accurately report actual phone use (Boase & Ling, 2013), which could be exacerbated if individuals are using smartphones differently and more frequently, possibly compulsively, than individuals did in 2009. Therefore, it brings the reliability of self-report measures of media-multitasking further into question. The study attempted to make comparisons between objective measures of executive function and a subjective measure of media-multitasking (in a similar vein to previous studies utilising the MMI). Future research could benefit from utilising a performance-based method to assess media-multitasking, or a different way of estimating frequency, such as experience sampling. A further issue with the Media Multitasking index, as highlighted by Wilmer, Sherman, and Chein (2017) is the way in which the media-multitasking score is constructed. Wilmer et al. (2017) suggest that the MMI is not sensitive to particular types of multitasking nor is it sensitive to the varying attentional demands of different media activities and combined media activities. They go on to suggest that by treating the various forms of multitasking as the same, in terms of mathematical weighting; the MMI does not allow for distinctions to be made between individuals who distract themselves with a second media and those who combine complex media activities. They also state this as a possible contributor for mixed results in individual difference samples, particularly in the attentional control and media-multitasking literature (see Wilmer et al., 2017 for a full review).

Another limitation of the study is the lack of a reliable model reflecting theoretical constructs of executive function from the shared variance of the executive function tasks. In this regard, future research could utilise a larger battery of tasks, which are more distinctly different from one another (reducing variance that can be attributed to shared method), in order to create a model of all three executive functions. However, this does bring about practical issues in terms of the time commitment of individual participants. It may be more practical to take a similar approach to Alzahabi et al. (2017), and focus on a single executive function and have multiple tasks for that function. It would be particularly interesting to see this for working memory in relation to media-multitasking, with a study utilising a number of tasks assessing different aspects of working memory, tasks such as; span tasks, filter tasks, and n-back tasks, within a single sample.

## Conclusion

In sum, the present study found no evidence of an association between frequency of self-reported media-multitasking, and measures of executive function. Along with other null findings in the literature, this suggests that these relationships may tend to be weak, or inconsistent across different populations studied. A significant relationship between anxiety and media-multitasking did emerge from the data, suggesting that it would be useful to include this variable in future research.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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The data that supports the findings of this study will be made publicly available through the Liverpool John Moores University data repository, LJMU Research Online http://researchonline.ljmu.ac.uk/

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