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# A preliminary investigation of proximal effects of media multitasking on executive functioning

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**ABSTRACT**

It has been suggested that media-multitasking may be cumulatively harmful to executive functions, but evidence mainly comes from cross-sectional investigations. If media-multitasking does cause harm, we might expect to observe a decline in executive performance in the immediate aftermath of media-multitasking, relative to sequential media engagement. This study examined proximal effects utilising a lab-based experiment where 76 young adults were randomised into either a media-multitasking group or a sequential media engagement group (both consuming media for 20 min). They completed a pre and post battery of executive function tasks measuring working memory, inhibition and cognitive flexibility. However, there were no interactions showing a greater change in performance for the multitasking group at the second time point. Mood became more negative over the study for both groups. Therefore, no evidence was found that executive functions were fatigued by media-multitasking, and the search for mechanisms of harm must continue.

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**KEYWORDS**
Media multitasking; inhibition; working memory; cognitive flexibility

## Introduction

The rise of internet-enabled mobile devices has fuelled a behaviour known as media-multitasking, where people engage with information from multiple media at the same time (Ophir et al., 2009) (or, according to some definitions, where they combine media use with a non-media activity, Van der Schuur et al., 2015). Under this latter definition, media-multitasking would also include behaviours which have been possible for many decades, like reading a newspaper while watching television, or switching between multiple tabs on a PC. Certainly, there is dispute regarding the true meaning of the term "media-multitasking" and a lack of universal understanding (See Aagaard, 2019). Nevertheless, it is widely agreed that media-multitasking is more common in the age of "second screens' held in one's hand (Beuckels et al., 2021). In a recent review and bibliometric analysis, Beuckels et al. (2021) identified that beyond research describing motivations and predictors of the behaviour itself (e.g. Baumgartner & Wiradhany, 2021; Hwang et al., 2014), there were also studies exploring media-multitasking in relation to learning and academic performance (e.g. Uzun & Kilis, 2019; see Zhou & Deng, 2022 for a review), information consumption (e.g. Segijn & Eisend, 2019), socioemotional functioning (e.g. Becker et al., 2013; Xu et al., 2022), and cognitive performance (e.g. Murphy & Creux, 2021). In relation to the latter, much of the research has focussed on higher-order cognitive control, so-called "executive" functioning, and has looked for evidence that habitually "heavy" (i.e. frequent) media multitaskers (HMMs) differ from habitually "light" (i.e. infrequent) media-multitaskers (LMMs) (see Parry & Le Roux, 2021 for a meta-analysis). Cognitive differences identified between these groups can be interpreted as showing that either the difference in cognition caused the difference in behaviour, or more alarmingly, that media-multitasking behaviour might be cumulatively harmful to cognition. However, the cross-sectional methodology employed in most cases makes a definitive conclusion impossible. In the study reported here, we took a different approach, investigating an under-explored question of whether instances of media-multitasking have carry-over effects that affect cognition during subsequent tasks (e.g. Kazakova et al., 2015). We conducted a preliminary investigation of whether such proximal effects might be seen in performance of executive function tasks. Our choice of executive function domains was guided by the theoretical framework presented by

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Diamond (2013), which identifies the core executive functions of inhibitory control, working memory, and cognitive flexibility, that support higher-order executive functions such as planning, reasoning and problem-solving. Accordingly, we chose tasks that would measure the functioning of the core executive functions, as detailed further below.

### *Media-multitasking: associations with executive functions*

There has been a wealth of research into the relationship between multitasking and various aspects of executive functioning. A seminal study by Ophir et al. (2009) found differences between HMMs and LMMs in maintaining attentional control. Specifically, HMMs were more distracted than LMMs by visual distractors during visual attention tasks, had higher switch costs while task-switching, and more false alarms on an n-back task. This study also developed and presented a measure of media-multitasking frequency, the Media Multitasking Index (MMI), which has been adopted by most of the subsequent research. Ophir et al. (2009) proposed that heavy media-multitaskers had a "breadth bias' in attention, finding it more difficult to suppress interference from both external distractors and previously relevant information in working memory. This view was subsequently supported by findings that people classified as HMMs also showed enhanced performance when they needed to divide their spatial attention (Yap & Lim, 2013), benefitted more from multi-sensory cues (Lui & Wong, 2012), and had poor top-down control of visual attention (Cain & Mitroff, 2011). Meanwhile, other studies showed that HMMs had lower working memory capacity than LMMs (Cain et al., 2016; Sanbonmatsu et al., 2013), and greater tendency for attentional lapses (Madore et al., 2020).

However, as research developed the picture became complicated by several failures to replicate some of the original findings regarding task-switching, with some studies showing null effects and others showing an advantage for HMMs (Alzahabi & Becker, 2013; Baumgartner et al., 2014 Elbe et al., 2019; Gorman & Green, 2016; Minear et al., 2013; Murphy & Shin, 2021; Schneider & Chun, 2021). Some studies showed a general performance deficit in attention tasks that was not specifically tied to the processing of distracter stimuli (Cardoso-Leite et al., 2015; Gorman & Green, 2016). Seddon et al. (2018) found no relationships between self-reported media-multitasking frequency (MMI) and the aspects of attention or executive function they examined. Some studies found that people with intermediate levels of media-multitasking performed differently on cognitive tasks to both HMMs and LMMs, suggesting that relationships between the MMI and cognitive functioning may not be linear (Cardoso-Leite et al., 2016; Murphy et al., 2017; Rogobete et al., 2021; Shin et al., 2020), a complication hidden by the tendency for earlier studies to use an extreme-groups design. Wiradhany and Nieuwenstein (2017) conducted a review of the literature and meta-analysis of studies that had looked at media-multitasking and distractor filtering, coming to the overall conclusion that if there is a negative relationship, it is very weak, which is why some smaller studies may fail to detect it. Furthermore, Wiradhany et al. (2021) have recently proposed that the likelihood of a study finding a relationship may depend on the balance of two different types of multitasker in the sample. They draw a distinction between optimal multitaskers (who switch tasks when it is efficient to do so, due to diminishing rewards from their primary task) and distracted multitaskers (who switch more at random to explore opportunities away from their primary task). This proposal will require further investigation, but it could explain some of the inconsistencies present in the literature. This strand of research is also limited by the fact that most of the studies have looked for a cross-sectional relationship between media-multitasking frequency and aspects of executive function, and therefore even where these are found, no determination can be made about cause and effect.

### *Experimental explorations of media-multitasking*

Meanwhile, there is ample evidence from experimental studies exploring its role in learning and retention, that media-multitasking "in-the-moment" is harmful to the learning of new information, in terms of slowing the learning process and making it somewhat less efficient (Conard & Marsh, 2014; Dietz & Henrich, 2014; Gingerich & Lineweaver, 2014; Lin & Parsons, 2018; May & Elder, 2018). Indeed, as Parry et al. (2020) have argued "it could be that, to address the potential interference produced by such behaviour targeting momentary effects holds greater value than targeting trait-level effects" (page 12). Their study tested an intervention targeting students' self-regulation of their media-multitasking behaviour (with the goal of reducing it), but no general improvements in executive functioning were found at the end of a 28-day period. However, participants did report increased awareness of the need to avoid media-related distraction while pursuing their educational goals and felt that they had indeed done so more often. Further testing of interventions to reduce distraction for students would be welcome, especially given the number of studies that have found self-reported increased media-multitasking frequency to be negatively related to grade point averages (Alghamdi et al., 2020; Demirbilek & Talan, 2018; Jamet et al., 2020; Judd, 2014; Junco & Cotten, 2012; Kirschner & Karpinski, 2010; Lau, 2017; le Roux et al., 2021; Marciano & Camerini, 2019).

### *Potential proximal effects of media-multitasking on executive function*

A crucial question is whether instances of media multitasking might have a lingering impact on performance of a subsequent task – i.e. proximal effects, or what Parry et al. (2020) describe as momentary effects in their discussion of how media-multitasking might exert an impact on cognitive control. For example, people could be more orientated towards a "breadth-bias' (Ophir et al., 2009) in the period of time immediately after engaging with multiple-media, leading them to be easily distracted and have slower responses on attentional tasks, as a result of them implementing a broader attentional scope of information when trying to media-multitask and take in information from all media presented. We are aware of only one study to date, Kazakova et al. (2015) that has specifically explored the impact of media-multitasking on subsequent information processing, utilising a media-multitasking versus a sequential media group comparison. Within Kazakova et al.'s (2015) study their media input consisted of two animated Disney films and a website (Experiment 1). Participants in the sequential media group spent 16 minutes engaging with the media, 8 minutes on each medium, whereas the media-multitasking group spent 8 minutes in total with both media. Following the media situation, participants completed a figure comparison task consisting of geometric shapes (either squares or triangles), for which participants had to determine which of two presented shapes was most comparable to a figure presented at the top of the screen. The study found that individuals who had media-multitasked demonstrated a local perceptual processing style whereas individuals who had sequentially engaged with media demonstrated a global processing style. In Experiment 2, participants who had media-multitasked tended to choose more concrete interpretations of a list of everyday behaviours, compared to participants who had engaged with media sequentially, who tended to choose more abstract interpretations. Thus, the study provides evidence of a proximal effect of media-multitasking on information processing style. Kazakova et al. (2015) argue that frequent conceptual switching between media streams depletes self-regulatory resources, and thereby promotes a focus on details, at the expense of more abstract or global processing (which requires greater self-regulatory capacity).

Although focused on concurrent rather than subsequent effects, Srivastava (2013) also used a sequential versus media-multitasking contrast to examine differences in message processing. The media consisted of reading an article and listening to a podcast. They had one group of participants simultaneously engage with the two mediums (media multitask), whilst the other group sequentially engaged. In the sequential group participants were exposed to the article and completed recall tests on that content before being exposed to the podcast and further recall tests on that specific content. They found that media-multitasking (simultaneous consumption) was associated with a decrease in memory performance relative to sequential consumption, specifically free recall, aided recall, and recognition. Proposing that it was due to the greater level of demand placed on cognitive resources. Although, in comparison to Kazakova et al. (2015), Srivastava's focus was on the implications of media consumption on message processing during engagement with media, rather than directly after.

Therefore, the findings of Kazakova et al. (2015) in conjunction with previous research highlighting negative associations between media- multitasking and executive function lead us to research questions regarding the mechanism of putative effects of media-multitasking. One possible explanation is that all executive functions involved during a session of media-multitasking become fatigued. In this general resource-depletion account, we would expect to see weakened performance on a broad spectrum of executive function tasks following a session of media-multitasking. A more specific suggestion made in previous research (Ophir et al., 2009) is that heavy media-multitaskers are more susceptible to distraction from irrelevant stimuli. This would suggest that, if there is a proximal effect of media-multitasking, measures of attentional inhibition might be particularly affected. Kazakova et al.'s proposal about conceptual switching reducing self-regulatory capacity would also be in line with this suggestion. Although the extant literature provides limited discussion of the proximal impact of media-multitasking on executive functions, a logical argument for such an impact can be constructed. Ophir et al.'s suggestion that media-multitasking is associated with increased distractibility and Kazakova et al.'s (2015) report that a short experience of media-multitasking results in subsequent changes in information processing suggests that engaging in MMT *may* impact subsequent executive functioning. Engaging in MMT where there are frequent attentional shifts could fatigue executive functions and therefore impact performance. We therefore in this preliminary study, tackled the research question of whether media-multitasking has greater proximal effects on executive functioning in comparison to sequential media engagement. Furthermore, we investigated whether these effects would be differential for the core aspects of executive functioning outlined by Diamond (2013): inhibitory control, working memory and cognitive flexibility.

Methodologically, it is important to note that in Kazakova et al. (2015) memory performance and processing style were only measured post sequential engagement or media-multitasking (and not beforehand). Thus, there is the possibility that the observed proximal effects media-multitasking were due to pre-existing differences between the groups. One study to-date using a pre and post media exposure design has highlighted that a single medium can improve performance. Rieger et al. (2017) implemented a working memory task and examined the impact of video exposure on involvement, arousal, cognitive performance and relaxation. They found that regardless of video valence the consumption of approximately 1 and a half minutes of a video had restorative effects with both media groups demonstrating fewer errors than the no media group on the working memory task. In addition to finding the negative valence video to increase energetic arousal. Contrastingly, Seddon et al. (2021) showed that a session of media-multitasking led to a fatiguing effect, in terms of decreased levels of arousal and increased levels of depression. These previous studies demonstrate the importance of measuring mood states during media-related studies and considering how they may change over the course of the experimental session in response to tasks completed. Specifically, media exposure and media-multitasking may have differential proximal effects not only on different executive functions but also on mood, for example it is possible that media-multitasking may have a more negative impact on executive functioning and arousal, and sequential media engagement a more positive impact. Therefore, mood measures were also included at key junctures during the experiment.

### *Summary rationale*

Given the limited research into the question of proximal effects in media-multitasking, the present study aimed to explore the proximal effects of media-multitasking on different aspects of executive functioning. It focussed on inhibition, working memory and cognitive flexibility as the three core domains identified by Diamond (2013). We chose tasks that were identified by Diamond as representative for each domain, and that would support a pre-test, post-test design by allowing for parallel forms. This study also incorporates a wider task-battery than has been used in many previous similar investigations thereby affording the opportunity to explore whether there were different impacts of media-multitasking on different executive function domains. Assessments of executive function were made pre and post the completion of a media situation. To explore directly the potential proximal effects on executive functioning of purported attentional bias differences arising from intertwined episodes of engagement with multiple media, two engagement styles were contrasted (similar to Kazakova et al., 2015). One group engaged in media-multitasking where they had to simultaneously engage with media (watch a video and read a piece of text). A second group engaged with one task, then the other in sequence. It was hypothesised that different types of media consumption would result in differential proximal effects on subsequent executive functioning, specifically that media-multitasking would have a greater negative impact on executive function performance than sequential media consumption. Furthermore, mood (arousal, depression and anxiety) was also measured across different time points. Based on the findings of Seddon et al. (2021), it was hypothesised that self-reported levels of arousal would decrease as the study progressed and this would be significantly more pronounced in the media-multitasking group, whereas self-reported rates of depression would increase and also be more pronounced for media-multitaskers compared to individuals in the sequential media group. There was no directional hypothesis for anxiety.

## Method

### *Participants*

Seventy-six participants aged 18–25 (Mean = 21.38, SD = 2.1) were recruited from a university population and the general public, of which there were 51 females (67.10%) and 25 males (32.90%), with 38 participants in each media group (sequential media engagement or simultaneous media multitasking). Study protocols were approved by Liverpool John Moores University research ethics committee (ethical approval number 18/NSP/014), and the study was conducted in accordance, as well as following ethical principles set by the British Psychological Society. Sample size was based on previous research by Kazakova et al. (2015) and the conducting of an a priori power calculation using G*Power, which proposed a minimum sample of 76 for a small effect size of.17 and 36 for a moderate effect size of.25, based on $\alpha = .05$, $\beta = .95$ and correlations of .05 for the within-between interaction effect (Perugini et al., 2018).

### Design

A 2 × 2 mixed design was implemented for the main examination of media-multitasking and executive function, with the within factor of time point (pre- and post-media situation) by between factor of media situation group (sequential media or media-multitasking). Performance on executive function tasks were the dependent measures, with inhibition assessed with a flanker task (congruency conflict) and Go-No go task (number correct inhibitions); working memory assessed with a backwards digit span and backwards Corsi block (mean span), and cognitive flexibility assessed with a Trail making task (B-A difference response times) and both phonetic and semantic fluency tasks (total amount of correct words). A 2 × 4 mixed design was utilised to measure each aspect of state mood (inclusive of arousal, anxiety and depression), with the within-participants factor of time point (baseline, post executive function battery 1, post media situation, and post executive function battery 2) by the between-participants factor of media situation group.

### Procedure

Once participants had consented, they were initially given a mood scale (Matthews et al., 1990) and then completed the first executive function (EF) test battery, consisting of seven tasks. Following the EF task battery, they completed the mood scale for the second time, then a media engagement session termed the "media situation". Participants were randomly allocated to either a sequential media or media-multitasking version of the media situation. For this part of the experiment, instructions to participants in both groups were explicit in stating that both media had to be equally attended to, and that there would be follow up questions about the media content at the end. Participants were not able to speed up or pause the video during either media situation, the researcher set up the media situation for each participant and remained present throughout the testing session. A further mood scale was completed after the media situation, followed by a second battery of executive function tasks and then a further mood scale and media manipulation-check questionnaire. All testing sessions were conducted in person by the same researcher, with each session lasting approximately 90 minutes per participant. Each executive function test battery had a 27 min duration. During the experiment the researcher was unblind to the conditions being administered whilst participants were blind to the condition they were in, until they were explicitly told which media situation they had completed during the debrief. All participants who attended their appointment completed the study.

### Measures

In the present study, a battery of executive function tasks was used, chosen to assess the executive functions of cognitive flexibility, working memory and inhibition (Diamond, 2013) while also balanced with the need to keep the experiment to a feasible running time and general fatigue to a minimum. To assess performance pre- and post-media engagement parallel forms of some tasks were needed, so there were two batteries of seven executive function tasks. In each there were the following tasks; Arrow Flanker, Go No-go, phonetic fluency and semantic fluency, Trail Making, Backwards digit span and Backwards Corsi Blocks.

### Inhibition tasks

*Arrow Flanker:* The version from the Psychological Experiment Building Language (PEBL) test battery (Mueller & Piper, 2014) was used, consisting of an implementation of a flanker task devised by Stins et al. (2007), which was adapted to include 80 trials. Participants had to respond by indicating the direction of a centrally presented arrow, whilst ignoring "flanking" distractor arrows on either side. There were four conditions each with 20 trials; congruent (flanked with the same stimuli), incongruent (flanked with the opposite stimuli, e.g. an arrow pointing right flanked by arrows pointing left (←←→←←)) and vice versa, or, neutral (flanked by "–") and null (not flanked by any stimuli). Attention inhibition performance was indicated by congruency conflict, i.e. the difference between mean response time for congruent and incongruent trials. The order of the trials was randomly generated each time the task was executed. Within PEBL, mean response times are calculated from the total number of trials for each condition (congruent and incongruent), with an output file created automatically. To check for outliers, reaction time data was visually inspected (as is standard practice) for any trials faster than 100- 200 ms (indicative of non-genuine reactions) (Luce, 1986: Whelan, 2008), whilst 800 ms was the maximum time participants had to respond before the trial timed out. The trial data indicated no trials faster than 200 ms, whilst timeouts were very infrequent, and consequently we continued to use the mean response time provided by PEBL.

*Go No-go task*. Moore et al.'s (2012) version of the Go No-go task was implemented. On each trial participants were presented with two horizontal lines on either side of the screen (in peripheral vision – visual angle 14.2°) and a central fixation circle. When either of the lines changed to a vertical position, participants were asked to respond with a key press ("5" for the line on the right and "1" for the line on the left). However, they should only make the response if the central fixation circle was black, and if the fixation circle was red, they should not press either key. This withholding of their response demanded inhibitory control, and therefore performance on this task was indexed by the number of correct inhibitions. The number of no-go trials (30) was less than the number of go trials (120), which increased the inhibitory challenge. Trial order was randomly generated on each execution of the task.

### Cognitive flexibility tasks

*Phonetic and Semantic Fluency*: In phonetic fluency tasks, participants are given an initial letter and have to generate words beginning with this, whilst in semantic fluency tasks they are given a category from which to generate examples. Two parallel forms of each of these tasks were adopted in the current study. For phonetic fluency, one task consisted of the letters F, A, & S while the other used M, C, & L. For semantic fluency, one task used the categories of animals, food, and clothing while the other task used things found in a supermarket, girls names, and furniture. These letters and categories were chosen based on their common use in the literature (e.g. Henry & Crawford, 2004; Troyer, 2000; Nusbaum & Silvia, 2011; Unsworth et al., 2011). The order in which the different versions of both the phonetic and semantic fluency tasks were presented were counterbalanced within each group. Performance was indicated by the number of acceptable words generated within 60 s. Following the scoring procedure of Luo et al. (2010), exclusions were numbers, places, words in different forms, and proper names (except in the girls' names condition). The scores for the phonetic (3 letters) and semantic (3 categories) tasks were each summed, with higher scores indicating greater cognitive flexibility.

*Trail Making Task (TMT)*: The task was the implementation of Reitan's (1958) Trail Making Task devised by Mueller and Piper (2014), and taken from the PEBL computerised test battery. Participants used a mouse to click on a sequence of circles shown on a computer screen, as quickly and accurately as possible. In Trail A, the circles contained a sequence of numbers and in Trail B they contained a sequence of both number and letters. In Trail B cognitive flexibility is required because the participant must switch between clicking on numbers with clicking on letters. There were four practice trials and four test trials for each type of Trail. The arrangement and spacing of the circles was generated randomly each time. Faster response times indicated greater cognitive flexibility, and an overall score was created by summing the mean difference in response times on Trail A trials and Trail B trials. When calculating the mean difference in reaction times, PEBL automatically does this based on the average total length of time for Trail A trials and Trail B trials, with the difference summed by subtracting the A trail average from the B trail average, thereby accounting for processing speed. To check for potential non-genuine responses, reaction time data for clicks on the individual stimuli within each trial were visually examined to determine if any were below 100 ms. There was only one occurrence of a reaction time below 100 ms, that was due to a second click on the same stimuli where the participant may have perceived that they had not registered their response.

### Working memory tasks

*Backwards Digit Span*: The backwards digit span task, based on Woods et al. (2011) was taken from the Millisecond library for Inquisit, and used as an assessment of verbal working memory. In this task the digits are presented auditorily and participants enter the sequence they heard using the keyboard, but in reverse order. The number of digits they are asked to remember (span) increases in length as the task progresses, starting at 2 and going up to a maximum of 9. The programme decides on the next length of span to present based on a 1:2 staircase ratio, that is, a single correct response will increase the length of the span, whilst two incorrect responses are needed to reduce it. Participants had to complete a total of 14 trials. A longer span of digits successfully recalled (and re-ordered) indicates greater working memory capacity, and in this case the mean span attained was used to index performance.

*Backwards Corsi Blocks*: Also taken from the Inquisit test library, a backwards Corsi blocks task was used to assess visuo-spatial working memory. A parallel form of the backwards Corsi blocks was created by the experimenters (still implemented via Inquisit), because the existing task did not randomly generate the patterns. The order in which the two versions were presented (pre- or post- media engagement) was counterbalanced across participants. In each trial, participants have to recall the order in which boxes on the screen "light up" and then use the mouse to click on the same sequence but in reverse. The starting display contained 9 blue boxes. At first only 2 boxes light up, but if the participant responds correctly then the next pattern will show 3 boxes lighting up (and so on). If they make a mistake they are given another sequence of the same length. The task can extend to a maximum of 9, and again mean span was used to index performance (higher spans indicated higher spatial working memory capacity).

***Mood:*** Given that mood may be sensitive to the most recent task, and to allow comparison across groups, these measures were taken at four different experimental timepoints; baseline, following the first executive function battery, after the media situation, and following the second executive function battery, using the UWIST mood adjective checklist by Matthews et al. (1990). Reliability analysis of Cronbach's alpha for each aspect of mood at each timepoint was: arousal – time 1 $\alpha = .63$, time 2 $\alpha = .74$, time 3 $\alpha = .82$ and time 4 $\alpha = .81$. Anxiety – time 1 $\alpha = .77$, time 2 $\alpha = .69$, time 3 $\alpha = .77$ and time 4 $\alpha = .76$, and depression – time 1 $\alpha = .74$, time 2 $\alpha = .75$, time 3 $\alpha = .79$ and time 4 $\alpha = .78$.

***Media situation:*** Participants were randomly allocated to either a media-multitasking situation or a sequential media situation. Both situations consisted of watching a video and reading a piece of text, displayed on a computer screen, using material previously described in Seddon et al. (2021).

*Video*: A 20 min video taken from a series on YouTube® called a "Day in the life of Dan and Phil". The video can be described as light entertainment, produced by professional vloggers, such as a student might watch as a distraction during an independent study session. None of the participants reported having seen the videos before.

*Reading text*: Participants were given two pieces of text on the topic of electronic information cables. One piece was taken from Simmons and Singleton (2000) while the other was a Wikipedia article. This text was chosen to provide contrast with the video, being on a serious topic but also one that was in no way controversial or emotive.

Regarding duration, it was decided that each media condition would take the same length of time, to balance potential fatiguing effects and to minimise the possibility of time as a confounding factor when looking for a media engagement effect. Thus, those in the sequential media situation spent 10 minutes engaging with each medium one after the other, with presentation order randomised across participants. Participants in the media-multitasking situation spent 20 minutes simultaneously engaging with the two mediums. The decision was informed by intricacies about total time spent media-multitasking versus content viewing, when comparing sequential media engagement and media-multitasking conditions, as highlighted by Kazakova et al. (2015). Given that the sequential group had less time with each individual medium, the manipulation check media questionnaire was designed so that it focused on only the specific content that the sequential group were exposed to. That is, questions were taken from the first 10 minutes of the video and opening section of the reading texts.

***Manipulation check media questionnaire***: It was important that participants engaged with the media in the present study, thus, to ensure participants had followed the explicit instructions given and complied in attending to both mediums in the media situation, a manipulation check questionnaire was included. This consisted of 14 multiple-choice questions, with seven referring to each medium (video and text). Example questions were as follows "What do Dan and Phil go on a mission to purchase?" and "Where is the head office of the factory?", a full list can be found in the supplementary material. As previously indicated, due to the duration of the sequential media situation, questions were based on the first parts of the video and text. All participants were found to have adhered to the instructions and passed the manipulation check by performing at above chance levels, the mean score on the manipulation check was 11.51 correct responses.

## Results

A mixed ANOVA analysis was implemented for each of the executive function tasks, with two levels of the between-participants factor media group (multitasking, sequential) and two levels of the within-participants factor of time (pre-media, post-media), with Bonferroni corrections for multiple comparisons applied (the present study implemented a corrected alpha of.005). Prior to analysis, data were examined, which led to the removal of five cases from the executive function tasks and four cases from the mood inventory, due to outliers greater than +/− 3 standard deviations above or below the mean. The specific cases are detailed in the supplementary material and in the open access data file. Additionally, pretest comparisons of performance on the executive function task battery and mood questionnaires were conducted to check for differences at baseline. There were no significant differences between media-multitaskers and sequential media engagers. Please see the supplementary material for the full analysis.

### Inhibition

To assess attentional control and response inhibition, both a flanker task and a Go No-go task were included in the present study. Mixed ANOVAs with Greenhouse-Geisser corrections for both the flanker task and Go No-go task found no significant interaction between time point and media engagement group (flanker- $F(1, 74) = .191$, $p = .663$, $\eta^2 = .002$; Go No-go $F(1, 72) = 1.620$, $p = .207$, $\eta^2 = .021$), no significant effect of time point (flanker- $F(1, 74) = .833$, $p = .364$, $\eta^2 = .011$; Go No-go $F(1, 72) = .942$, $p = .335$, $\eta^2 = .012$), nor a significant effect of media group (flanker-$F(1, 74) = 3.409$, $p = .069$, $\eta^2 = .044$; Go-No go-$F(1, 72) = .015$, $p = .902$, $\eta^2 < .001$). Overall, the results do not support the hypothesis, as they show no evidence that engaging with media (in either condition) has a proximal effect on attentional control and response inhibition. Media-multitasking as a specific media engagement behaviour was not significantly more fatiguing than sequential media consumption.

### Working memory

Assessing working memory, the study used both a backwards Corsi blocks and digit span task. Regarding performance on the Corsi blocks task (see Table 1) the media-multitasking group's performance decreased whilst the sequential group's performance increased. However, a mixed ANOVA with a Greenhouse-Geisser correction, revealed no significant interaction between media group and time point on backwards Corsi blocks performance, $F(1, 74) = 1.642$, $p = .204$, $\eta^2 = .021$, no significant difference between time points on Corsi block performance $F(1, 74) = .411$, $p = .524$, $\eta^2 = .005$, and no significant effect of media group $F(1, 74) = .012$, $p = .914$, $\eta^2 < .001$. Therefore, there were no differential proximal effects of engagement on visual-spatial working memory, and thus the hypothesis of a more pronounced negative impact of media-multitasking was not supported.

Contrary to the hypothesis, there was no significant interaction between the two media groups and across the two experimental time points for the backwards digit span task $F(1, 74) = .073$, $p = .788$, $\eta^2 < .001$. However, there was a significant main effect of time for the backwards digit span task, based on a mixed ANOVA with a Greenhouse-Geisser correction, $F(1, 74) = 24.604$, $p < .001$, $\eta^2 = .24$. Indicating that regardless of media situation exposure, both the sequential media and media-multitasking group performed significantly better the second time they completed the digit span task (for a graphical representation see Figure 1 in the supplementary material). However, there was no main effect for media group performance on this type of verbal working memory task $F(1, 74) = .623$, $p = .433$, $\eta^2 = .008$.

### Cognitive flexibility

Mixed ANOVAs were conducted with Greenhouse-Geisser corrections to determine effects of time, media group and time*media group interactions for cognitive flexibility performance (with the cognitive flexibility measures of a Trail Making Task and phonetic and semantic fluency tasks). There was no significant interaction between the two media groups for Trail Making Task performance across the two experimental time points $F(1,71) = 646$, $p = .424$, $\eta^2 = .005$, nor was there a significant effect of media group $F(1,71)$

**Table 1.** Means and descriptive statistics for executive function tasks pre- and post-media situation.

| | Time 1 | | | | Time 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.D | Skew | Kurtosis | Mean | S.D | Skew | Kurtosis |
| Media Multitasking | | | | | | | | |
| Flanker | 45.18 | 25.22 | −.59 | .78 | 50.67 | 27.19 | .04 | −1.03 |
| Go No-go | 23.13 | 4.98 | −1.24 | 1.05 | 21.28 | 5.87 | −1.09 | .99 |
| Backwards Digit span | 5.362 | 1.12 | .27 | .12 | 5.89 | 1.24 | .15 | −.22 |
| Backwards Corsi Block | 6.39 | 1.10 | .027 | 2.264 | 6.289 | 1.431 | .10 | −.41 |
| Trail Making | 6882.01 | 4105.85 | 1.061 | 1.42 | 4111.43 | 2670.46 | .91 | .61 |
| Phonetic Fluency | 11.82 | 2.92 | .55 | −.26 | 12.75 | 3.25 | .28 | −.61 |
| Semantic Fluency | 18.83 | 4.46 | .15 | −.37 | 18.44 | 4.82 | .89 | 1.13 |
| Sequential Media | | | | | | | | |
| Flanker | 56.84 | 36.91 | .39 | 3.25 | 58.77 | 26.38 | .37 | −.73 |
| Go No-go | 22.46 | 4.18 | −1.07 | 1.47 | 22.45 | 5.54 | −1.21 | 1.55 |
| Backwards Digit span | 5.58 | 1.22 | .05 | −.37 | 6.05 | .95 | −.01 | −.49 |
| Backwards Corsi Block | 6.21 | 1.19 | −.84 | 3.76 | 6.53 | 1.37 | −.52 | .10 |
| Trail Making | 7618.19 | 5273.41 | 1.00 | .72 | 4112.89 | 3277.09 | 1.60 | 3.04 |
| Phonetic Fluency | 11.11 | 2.97 | .68 | .03 | 12.03 | 3.01 | .72 | .55 |
| Semantic Fluency | 18.86 | 3.54 | .02 | −.90 | 18.88 | 5.18 | .44 | −.62 |

The following are the aspects of performance measured for each task and shown above; Flanker (congruency conflict), Go No-go (correct inhibitions), Backwards digit span and Backwards Corsi block (mean span), Trail Making (B-A difference in response times) and Phonetic fluency and semantic fluency (total amount of correct words).

= .237, $p = .628$, $\eta^2 = .003$. Although, for the two experimental time points, performance on the Trail Making Task significantly differed $F(1,71) = 47.115$, $p < .001$, $\eta^2 = .396$. This indicated that both media multitaskers and sequential media engagers performed better on the trail making task post media situation, with faster response times (see Figure 2 in the supplementary material for a graphical representation). Thus, the results contradict the hypothesis that performance would decline post media situation for those in the media-multitasking group (instead, they showed improved performance regardless of the nature of media engagement).

Interestingly, a mixed ANOVA similarly revealed no significant interactions between the two experimental time points and media group $F(1, 72) = .001$, $p = .985$, $\eta^2 = .001$, and no significant effect of media group on overall phonetic fluency performance $F(1, 72) = 1.215$, $p = .274$, $\eta^2 = .016$. But then a significant effect of time point for phonetic fluency performance $F(1, 72) = 15.365$, $p < .001$, $\eta^2 = .174$. More pertinent to this, a parallel version of the phonetic fluency task was included in the present study, with the order of task randomised within each group. To examine the occurrence of order effects, a mixed ANOVA with the addition of phonetic task order was conducted. This revealed that there were no order effects as the timepoint*media group*fluency task version interaction was not significant $F(1,72) = .694$, $p = .407$, $\eta^2 = .007$. Indicating that when either the F, A, S or M, C, L version of the task was completed first, performance increased the second time the task was completed. Overall, the results provide no evidence to support the hypothesis of a fatiguing proximal effect of media-multitasking on cognitive flexibility. Instead highlighting that regardless of the version of the task used and media group, phonetic fluency performance increased post media situation (see Figure 3 in the supplementary material).

For semantic fluency, there was no interaction between pre and post semantic fluency by media group $F(1, 72) = .553$, $p = .460$, $\eta^2 = .002$, no significant main effect across the two experimental time points $F(1, 72) = .462$, $p = .499$, $\eta^2 = .002$, and no significant group differences in overall performance $F(1, 72) = .067$, $p = .796$, $\eta^2 < .001$. This provided no support for the hypothesis of worse semantic fluency performance following media-multitasking. However, order effects of the parallel semantic fluency tasks were uncovered, with a $2 \times 2 \times 2$ mixed ANOVA finding a significant interaction for semantic fluency performance and task version presentation $F(1, 72) = 135.909$, $p < .001$, $\eta^2 = .647$, although there was no significant interaction between media groups for semantic fluency and order of fluency task administered $F(1, 72) = .995$, $p = .322$, $\eta^2 = .004$. Order effects were the same for both media groups, with the furniture, supermarket and girls' names version of the task deemed more difficult. Semantic fluency performance increased over time when the furniture version was completed in the first EF battery as shown in Figure 4 of the supplementary material, and fluency performance decreased when the furniture version was completed in the second EF battery, as shown in Figure 5 of the supplementary material.

## Mood

Mixed measures ($4 \times 2$) ANOVAs were conducted for the three aspects of state mood: anxiety, arousal and depression, with comparisons examined between the two media situation groups and the four time points at which mood was assessed, with Greenhouse-Geisser corrections. Please see supplementary material for tables showing the means and standard deviations for each aspect of mood across all time points: anxiety table 2, arousal table 3 and depression table 4.

### *Anxiety*

No significant difference in self-reported levels of state anxiety between the experimental time points was found $F(2.623, 188.858) = 2.628$, $p = .059 > .01$, $\eta^2 = .035$. There was also no significant difference between the two media groups for overall anxiety $F(1, 72) = 4.719$, $p = .033 > .01$, $\eta^2. = .061$, and no significant interaction between anxiety and media group $F(2.623, 188.858) = .094$, $p = .949$, $\eta^2 = .001$. These are based on Bonferroni corrections to the alpha level, thus the main effect of media consumption group could be said to approach significance and shows a moderate effect size.

### *Arousal*

Self-reported levels of arousal were found to significantly differ across experimental time points, $F(1.966, 145.451) = 36.718$, $p < .001$, $\eta^2 = .329$. However, there were no group differences in overall arousal F(1, 74) = .325, $p = .570$, $\eta^2 = .003$, and no significant interaction based on group $F(1.966, 145.451) = .675$, $p = .508$, $\eta^2 = .006$. Levels of arousal gradually decreased across time points 1–3 for both groups, those in the sequential media group reported an increase at timepoint 4 whilst the media-multitasking group demonstrated a further decrease (this can be seen in Figure 1 below). Post hoc tests revealed that arousal levels did not significantly differ from baseline to after the completion of the first EF battery (time point 2), nor did they significantly differ from time point 3 (after

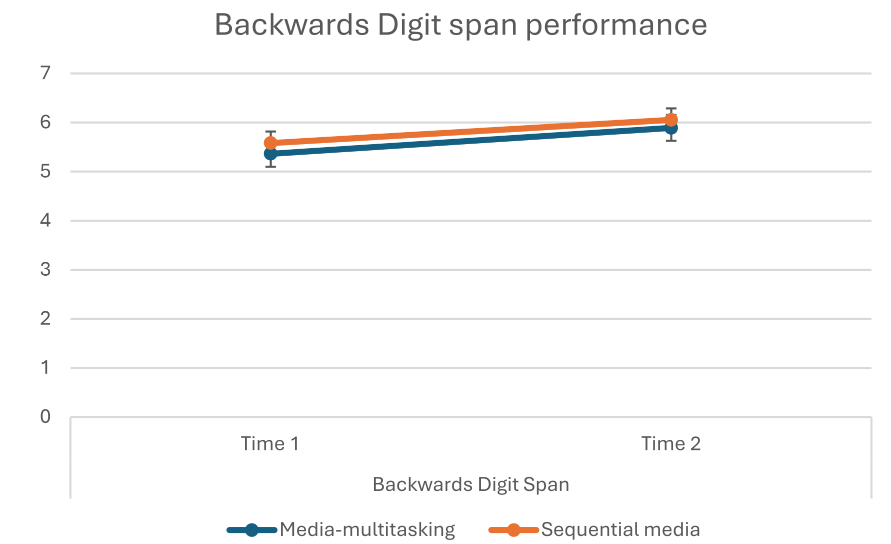


**Figure 1.** Mean level of self-reported arousal across experimental time points by media group, with standard error bars.

completion of the media situation) to time point 4. Interestingly, between time point 2 and time 3 is where they significantly decreased, $p < .01$. Indicating that there is a general fatiguing effect of media engagement, given that both groups demonstrated a significant decrease in arousal following the completion of the media situation. This results in only partial support for the hypothesis as the decrease in arousal was not more pronounced for the media-multitasking group.

### *Depression*

Similar to levels of arousal, self-reported state depression significantly differed across the four experimental time points $F(1.864, 136.067) = 19.041$, $p < .001$, $\eta^2 = .206$, but not by media group, $F(1, 73) = 3.573$, $p = .063$, $\eta^2 = .048$, with no media group *time interaction $F(1.864, 136.067) = .263$, $p = .753$, $\eta^2 = .003$. Depression levels increased linearly from baseline through to time point 4, with post hoc analysis showing depression levels to be significantly higher after completion of the first executive function task battery (time point 2) to after the media situation (time point 3), then levelling off (see Figure 2 below). It is interesting to see this significant increase at time points 2 and 3, which further demonstrates the fatiguing effect of media engagement. Overall, the results support the hypothesis of depression levels increasing over time for both groups, with a large effect size.

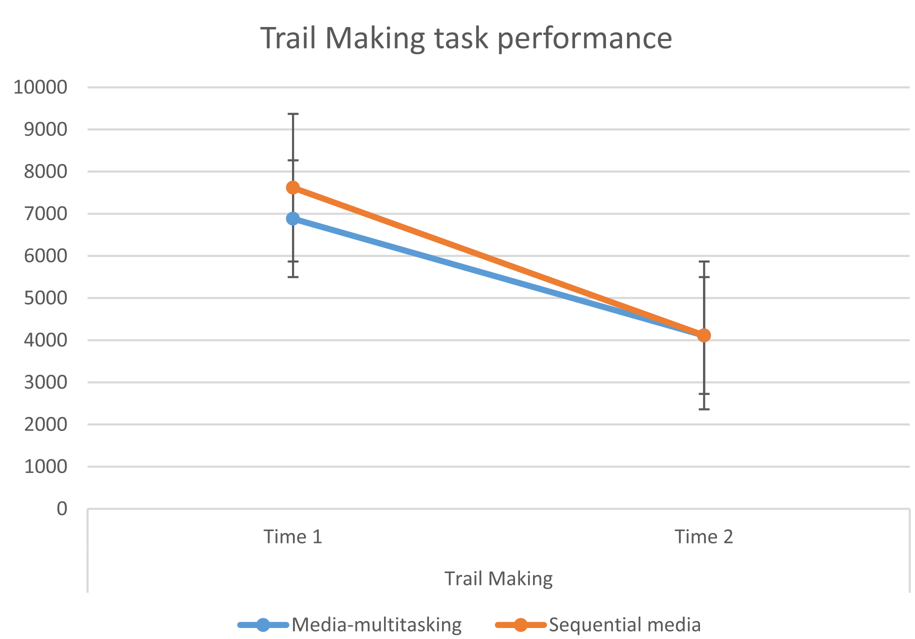


**Figure 2.** Mean self-reported depression at each experimental time point by media group with standard error bars.

## Discussion

The present study aimed to develop a novel experimental paradigm to investigate the proximal effects of media-multitasking on executive function performance. It has been argued that new approaches are needed in this area to understand the mechanisms by which media-multitasking might exert effects "in the moment" (Kazakova et al., 2015; Parry et al., 2020). It was hypothesised that there would be detrimental effects of media-multitasking relative to sequential media engagement, evidenced in a greater decline in performance on a range of executive functioning tasks. However, to sum up our findings, no significant decreases were observed in executive function performance between individuals who had sequentially engaged with media and those who media-multitasked. Effect sizes for the interaction between time point and group ranged from trivial (partial $\eta^2 < .001$) to small (partial $\eta^{2\,=}$ .021) across the battery of executive functioning tasks. We observed that instead of a decline in performance, performance on some of the cognitive flexibility measures (and one working memory measure) increased, regardless of the nature of media consumption.

A comprehensive set of tasks was utilised to assess the different executive function components outlined by Diamond (2013). No significant media group differences or effect of time point was found for inhibition, specifically attentional control and response inhibition (performance on a flanker task and Go-No go task), as well as visuospatial working memory (performance on a backwards Corsi Block task). For cognitive flexibility and verbal working memory, an improvement across the two time points was found, specifically performance on the trail making, phonetic fluency and backwards digit span tasks was enhanced, post completion of the media situation. Furthermore, there was no significant effect of media group, indicating that regardless of the nature of the engagement, both sequential media and media multitasking groups improved. Overall, we found no evidence that media engagement, either sequential or media-multitasking, has a proximal fatiguing effect on inhibition, visuospatial working memory, verbal working memory, or cognitive flexibility. Where differences between time points were identified, these were in the opposite direction, i.e. better performance at Time 2. Although verbal working memory and cognitive flexibility were enhanced at Time 2, it does not necessarily imply that media consumption had a beneficial proximal effect of improving aspects of cognitive flexibility and verbal working memory. The observed improvement might be due to restorative effects of media engagement such as Rieger et al. (2017), or practice effects. Although, there is support for the minimisation of such practice effects when there is an intervention between task completion (Bartels et al., 2010).

Regarding practice effects, parallel versions of tasks were implemented to minimise their occurrence whilst also facilitating a pre- vs post-assessment of executive function (Falleti et al., 2006; Huber et al., 2018). An interesting discovery was made of a difference in difficulty of semantic fluency tasks, with the finding of a significant interaction between semantic fluency performance depending upon which categories were completed first. The categories of furniture, supermarket items and girls' names seem to be more difficult than those of animals, food and clothing. This further highlights discrepancies amongst tasks, whilst also contributing to future research within cognitive psychology, in terms of providing useful information for researchers interested in using a semantic fluency task or implementing a pre- vs post-assessment with such tasks.

### *Relationship to previous research*

#### *Experimental manipulations of media-multitasking*

The effects of concurrent media-multitasking have predominantly been examined in academic contexts, with research finding this type of engagement to impact learning and retention of information (Conard & Marsh, 2014; Dietz & Henrich, 2014; Gingerich & Lineweaver, 2014; Jamet et al., 2020; May & Elder, 2018) and memory for messages (Srivastava, 2013). As for proximal effects in the period immediately following a session of media-multitasking, Kazakova et al. (2015) explored individuals' information processing style, with media-multitasking leading to a more local style of processing. They argued that the shift to a more local processing style was a result of a weakening of inhibitory control during a session of media-multitasking. However, the findings of the present study are not in line with that explanation, because we did not find any post media-multitasking decline in inhibitory control, at least for the tasks we adopted. Therefore, this might suggest that a different explanation is needed for the effect observed by Kazakova et al. (2015). Another key difference to note between the studies is that Kazakova et al. (2015) only assessed processing style after participants had engaged with media, whilst the present study utilised a pre- and post-media engagement design. Therefore, the ability to determine causality is difficult, and it would be interesting to see a replication of the Kazakova et al. (2015) study with the implementation of a pre- and post-assessment of information processing style.

### Media-multitasking associations with executive functioning

Much previous media-multitasking research has centred on determining associations between media-multitasking and executive functioning, using self-report measures and both individual differences and extreme groups approaches (see Wiradhany & Koerts, 2019, or Parry & le Roux, 2019, 2021). The present study can be difficult to place as its novelty lies in the exploration of the proximal impact media-multitasking has on executive functioning during subsequent tasks, with the inclusion of a brief duration of media-multitasking. It is therefore difficult to make direct comparisons between the present findings and previous evidence examining media-multitasking over longer periods of time, and evidence of differences in executive functioning associated with heavy versus light media multitaskers (e.g. Ophir et al., 2009; Shin et al., 2019). Based on these previous findings, the present study hypothesised a potential decline in executive function performance as a result of media-multitasking. Had we found such a decline in executive function, it could have provided support for the idea that media-multitasking is cumulatively harmful to cognition, and that this is why deficits in performance are sometimes found in habitually heavy media-multitaskers. Further experimental studies can help to resolve uncertainly about the direction of causality, and it remains an open question whether pre-existing biases in executive function lead some people to media-multitask more often, or whether media-multitasking behaviour does influence executive function over time. Recent longitudinal studies have tackled this question using a different approach, and as Baumgartner et al. (2018) have observed, these relationships may differ across developmental stages. Their study found evidence that media-multitasking may negatively affect attention in early adolescence but did not observe this in mid adolescence. What we can say based on the results reported here is that we found no evidence of any kind of altered attentional bias or executive function deficit in the immediate aftermath of media-multitasking that could shed light on a mechanism for cumulative damage to cognition. However, it is important to highlight that the present study's manipulation of media-multitasking continued for only a short duration (20 minutes), consistent with similar manipulations (Kazakova et al., 2015) but which may not be long enough to observe the proximal effects that might, over time, lead to a cumulative effect of habitual media-multitasking. It is not straightforward to measure the impacts of these subtle, everyday, media behaviours, but given some of the strong claims made in the popular media about the harmful cognitive impacts of media-multitasking, we argue that it is important for researchers to persist, and to seek new methodological approaches.

### Mood and replication of previous research

Research exploring media-multitasking and mood has previously demonstrated associations between self-reported media-multitasking and anxiety (Becker et al., 2013; Seddon et al., 2018). Seddon et al. (2021) examined state anxiety, arousal and depression following a period of media-multitasking as well as trait anxiety and depression. There was no association between trait anxiety and media-multitasking ability, but an increase in state anxiety after completion of executive function tasks (but not after media-multitasking). Thus, the present study is generally in line with their findings, as there was a general though non-significant trend of increased self-reported anxiety as the experiment progressed.

More interestingly, Seddon et al. (2021) found levels of state arousal decreased whilst levels of state depression increased after a period of media-multitasking. Thus, the present study can be said to replicate this study, as levels of arousal and depression were found to significantly differ across experimental time points. Specifically, the difference in self-reported levels of arousal and depression can be pin-pointed as occurring after completion of the first executive function battery and after completion of the media situation. Levels of depression increased and levels of arousal decreased significantly for both media groups. There was no significant difference in levels of arousal or depression from after the media situation to after the second EF battery, clearly demonstrating that engagement with media, whether sequentially or simultaneous, increased feelings of depression and reduced arousal. Although there was no significant interaction based on the media engagement group, this may be due to length of the manipulation of the media situation which can be considered short at 20 minutes.

## Limitations and future directions

### Methodological intricacies of executive function assessment

Our findings show no evidence that brief sequential media use and media-multitasking have a differential impact on inhibition, working memory or cognitive flexibility. However, we cannot determine whether the stronger performance on some of the tasks at the second time point reflects a facilitative impact of media use (consistent with Rieger et al., 2017) or a practice effect. Testing executive functioning at multiple time points in the study was crucial in being able to determine the proximal effect of media-multitasking, whilst simultaneously increasing susceptibility to practice effects. Practice effects arise from the loss of novelty, certainly something can only be novel once (Chan et al., 2008). Novelty is fundamental to the types of real-life situation that require executive function (Burgess, 1997). When novelty is lost, the main target of the executive function is said to be no longer assessed, with memory and lower order processes measured instead (Suchy et al., 2017). Practice effects can occur with just one repetition of a task (Bartels et al., 2010), with learning and reaction key elements of the process (Suchy et al., 2017), which may imply that they are an inevitability. To minimise practice effects, we utilised parallel versions of the same tasks with altered stimuli, which are another acceptable option (Falleti et al., 2006), although for some tasks this is not possible e.g. the Wisconsin Card Sorting Task (Suchy et al., 2017). Further factors are the specific executive function being assessed; some may be more vulnerable to practice effects than others, such as working memory (Bartels et al., 2010; Falleti et al., 2006), and the time interval between assessment also becomes a relevant consideration (Burke et al., 2015).

In line with practice effects, executive function tasks are also renowned to have further psychometric issues such as variability in test re-test reliability (Soveri et al., 2018), arising from the issue of novelty (Chan et al., 2008). This is especially the case for those utilising reaction time data such as the trail making task (Arán Filippetti & Gutierrez, 2024) and flanker task. For example, when using the difference between congruent and incongruent trials as the outcome variable for the flanker task, this is said to tap into greater task purity but have lower reliability in comparison to single mean measures, with the test re-test reliability affected by the number of trials completed and the correlation between congruent and incongruent means (Paap & Sawi, 2016; see also Kucina et al., 2023). A further element relating to reaction time performance is that reaction time data distributions are not normal and tend to be skewed, upon which the number of trials may impact (Whelan, 2008). In teasing out the potential issue of practice effects there is also the need for the inclusion of a non-media engagement group to make further comparisons with various media engagement conditions. These are all issues that need careful consideration in future similar research.

### *Consideration of a replenishing effect of media engagement*

If we were to consider the possibility that general media engagement improved executive function over and above practice effects, it is important to consider why this might occur, what it means and how future research could examine this. It is possible that engagement with media has a replenishing effect on depleted resources (Reinecke et al., 2011), leading to enhanced working memory (See also Rieger et al., 2017) and cognitive flexibility performance, especially when using a combination of media with different valences. The present study utilised a hedonically pleasing and positive video and a neutral text, whilst Rieger et al. (2017) found both positive and negative valence media to have recovery effects, thus the valence of media may or may not play a role in potential restorative effects. In addition to valence, the length of exposure/engagement with each type of valanced media is an important aspect to consider in relation to recovery effects, which was controlled for in the present study. Nonetheless, a "recovery" effect seems less likely given the deleterious effect on mood, which may further support the interpretation that we observed practice effects in the present study. Rieger et al. (2017) also found that media with negative valence leads to greater levels of arousal, and positive with reduced arousal. It would be interesting for future research to compare proximal effects across a range of media situation set ups, comparing media-multitasking to sequential engagement, focusing on the motivations behind different types of media used to media-multitask and their affective valence. Further assessments of media-induced recovery should also be considered for future research.

### *Media-multitasking experimental paradigms-factors to consider*

Additionally, future research should ensure it objectively captures and compares the diverse and complex nature of media-multitasking through novel experimental paradigms, such as the variation in the duration of periods of media-multitasking, the number of periods of media-multitasking and the type of media activities (Van Cauwenberge et al., 2014). Eye-tracking methodology could also provide insights into the frequency and type of attention switching when media-multitasking. The media scenario used in the present study could be said to be limited in determining a cumulative fatiguing effect due to its simplicity and duration. The observed improvement at Time 2 in working memory and cognitive flexibility may have only been highlighted due to the short period of media engagement (20 minutes) and may not be observed with longer or more frequent sessions of media-multitasking. Not only should research focus on novel experimental designs but also on longitudinal designs which have so far examined media- multitasking and attentional problems (Baumgartner et al., 2018), sleep problems (van der Schuur et al., 2018), motivational systems (Xu et al., 2019), academic achievement (van der Schuur et al., 2020), as well executive functioning (Luo et al., 2021).

## Conclusion

To summarise, the present study found no evidence that a short period of media-multitasking had a differential immediate impact on executive functions when compared to sequential engagement with media. Very small effect sizes were observed. However, the study did demonstrate an overall negative effect on state mood, regardless of how media was engaged with. Future research should search for new methods to determine cause and effect for the associations previously found between executive functioning and media-multitasking, by utilising both longitudinal studies and novel experimental designs.

## Disclosure statement

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## Data availability statement

The data that support the findings of this study are openly available in the Liverpool John Moores University data repository at https://doi.org/10.24377/LJMU.d.00000193

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## References

Aagaard, J. (2019). Multitasking as distraction: A conceptual analysis of media multitasking research. *Theory & Psychology*, *29*(1), 87–99. https://doi.org/10.1177/0959354318815766

Alghamdi, A., Karpinski, A. C., Lepp, A., & Barkley, J. (2020). Online and face-to-face classroom multitasking and academic performance: Moderated mediation with self-efficacy for self-regulated learning and gender. *Computers in Human Behavior*, *102*, 214–222. https://doi.org/10.1016/j.chb.2019.08.018

Alzahabi, R., & Becker, M. W. (2013). The association between media multitasking, task-switching,and dual-task performance. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(5), 1485–1495. https://psycnet.apa.org/doi/10.1037a0031208

Arán Filippetti, V., & Gutierrez, M. (2024). Interpreting the direct- and derived-Trail Making Test scores in Argentinian children: Regression-based norms, convergent validity, test-retest reliability, and practice effects. *The Clinical Neuropsychologist*, 1–26. https://doi.org/10.1080/13854046.2024.2423414

Bartels, C., Wegrzyn, M., Wiedl, A., Ackermann, V., & Ehrenreich, H. (2010). Practice effects in healthy adults: A longitudinal study on frequent repetitive cognitive testing. *BMC Neuroscience*, *11*(1), 118. https://doi.org/10.1186/1471-2202-11-118

Baumgartner, S. E., van der Schuur, W. A., Lemmens, J. S., & te Poel, F. (2018). The relationship between media multitasking and attention problems in adolescents: Results of two longitudinal studies. *Human Communication Research*, *44*(1), 3–30. https://doi.org/10.1093/hcre.12111

Baumgartner, S. E., Weeda, W. D., Van der Heijden, L. L., & Huizinga, M. (2014). The relationship between media multitasking and executive function in early adolescents. *Journal of Early Adolescents*, *34*(8), 1120–1144. https://doi.org/10.1177/0272431614523133

Baumgartner, S. E., & Wiradhany, W. (2021). Not all media multitasking is the same: The frequency of media multitasking depends on cognitive and affective characteristics of media combinations. *Psychology of Popular Media*, *11*(1), 1–12. https://doi.org/10.1037/ppm0000338

Becker, M. W., Alzahabi, R., & Hopwood, C. J. (2013). Media multitasking is associated with symptoms of depression and social anxiety. *Cyberpsychology, Behavior, and Social Networking*, *16*(2), 132–135. https://doi.org/10.1089/cyber.2012.0291

Beuckels, E., Ye, G., Hudders, L., & Cauberghe, V. (2021). Media multitasking: A bibliometric approach and literature review. *Frontiers in Psychology*, *12*, 2322. https://doi.org/10.3389/fpsyg.2021.623643

Burgess, P. W. (1997). Theory and methodology in executive function research. In P. Rabbitt (Ed.), *Theory and methodology of frontal and executive function* (pp. 81–116). Psychology press.

Burke, T. M., Scheer, F. A., Ronda, J. M., Czeisler, C. A., Wright, K. P. Jr. (2015). Sleep inertia, sleep homeostatic and circadian influences on higher-order cognitive functions. *Journal of sleep research*, *24*(4), 364–371. https://doi.org/10.1111/jsr.12291

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

Cain, M. S., & Mitroff, S. (2011). Distractor filtering in media multitaskers. *Perception*, *40*, 1183–1192. https://doi.org/10.1068/p7017

Cardoso-Leite, P., Green, C. S., & Bavelier, D. (2015). On the impact of new technologies on multitasking. *Developmental Review*, *35*, 98–112. https://doi.org/10.1016/j.dr.2014.12.001

Cardoso-Leite, P., Kludt, R., Vignola, G., Ma, W. J., Green, C. S., & Bavelier, D. (2016). Technology consumption and cognitive control: Contrasting action video game experience with media multitasking. *Attention, Perception, & Psychophysics*, *78*(1), 218–241. https://doi.org/10.3758/s13414-015-1014-2

Chan, R. C., Shum, D., Toulopoulou, T., & Chen, E. Y. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of Clinical Neuropsychology*, *23*(2), 201–216. https://doi.org/10.1016/j.acn.2007.08.010

Conard, M. A., & Marsh, R. F. (2014). Interest level improves learning but does not moderate the effects of interruptions: An experiment using simultaneous multitasking. *Learning and Individual Differences*, *30*, 112–117. https://doi.org/10.1016/j.lindif.2013.11.004

Demirbilek, M., & Talan, T. (2018). The effect of social media multitasking on classroom performance. *Active Learning in Higher Education*, *19*(2), 117–129. https://doi.org/10.1177/1469787417721382

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dietz, S., & Henrich, C. (2014). Texting as a distraction to learning in college students. *Computers in Human Behavior*, *36*, 163–167. https://doi.org/10.1016/j.chb.2014.03.045

Elbe, P., Sörman, D. E., Mellqvist, E., Brändström, J., & Ljungberg, J. K. (2019). Predicting attention shifting abilities from self-reported media multitasking. *Psychonomic Bulletin & Review*, *26*(4), 1257–1265. https://doi.org/10.3758/s13423-018-01566-6

Falleti, M. G., Maruff, P., Collie, A., & Darby, D. G. (2006). Practice effects associated with the repeated assessment of cognitive function using the CogState battery at 10-minute, one week and one month test-retest intervals. *Journal of Clinical and Experimental Neuropsychology*, *28*(7), 1095–1112. https://doi.org/10.1080/13803390500205718

Gingerich, A. C., & Lineweaver, T. T. (2014). OMG! Texting in class=U Fail:(Empirical evidence that text messaging during class disrupts comprehension. *Teaching of Psychology*, *41*(1), 44–51. https://doi.org/10.1177/0098628313514177

Gorman, T. E., & Green, C. S. (2016). Short-term mindfulness intervention reduces the negative attentional effects associated with heavy media multitasking. *Scientific Reports*, *6*, 24542. https://doi.org/10.1038/srep24542

Henry, J. D., & Crawford, J. R. (2004). Verbal fluency deficits in Parkinson's disease: A meta-analysis. *Journal of the International Neuropsychological Society*, *10*(4), 608–622. https://doi.org/10.1017/S1355617704104141

Huber, B., Yeates, M., Meyer, D., Fleckhammer, L., & Kaufman, J. (2018). The effects of screen media content on young children's executive functioning. *Journal of Experimental Child Psychology*, *170*, 72–85. https://doi.org/10.1016/j.jecp.2018.01.006

Hwang, Y., Kim, H., & Jeong, S. H. (2014). Why do media users multitask?: Motives for general, medium-specific, and content-specific types of multitasking. *Computers in Human Behavior*, *36*, 542–548. https://doi.org/10.1016/S0361-9230(03)00066-2

Jamet, E., Gonthier, C., Cojean, S., Colliot, T., & Erhel, S. (2020). Does multitasking in the classroom affect learning outcomes? A naturalistic study. *Computers in Human Behavior*, *106*, 106264. https://doi.org/10.1016/j.chb.2020.106264

Judd, T. (2014). Making sense of multitasking: The role of Facebook. *Computers & Education*, *70*, 194–202. https://doi.org/10.1016/j.compedu.2013.08.013

Junco, R., & Cotten, S. R. (2012). No A 4 U: The relationship between multitasking and academic performance. *Computers & Education*, *59*(2), 505–514. https://doi.org/10.1016/j.compedu.2011.12.023

Kazakova, S., Cauberghe, V., Pandelaere, M., & De Pelsmacker, P. (2015). Can't see the forest for the trees? The effect of media multitasking on cognitive processing style. *Media Psychology*, *18*(4), 425–450. https://doi.org/10.1080/15213269.2015.1006789

Kirschner, P. A., & Karpinski, A. C. (2010). Facebook® and academic performance. *Computers in Human Behavior*, *26*(6), 1237–1245. https://doi.org/10.1016/j.chb.2010.03.024

Kucina, T., Wells, L., Lewis, I., de Salas, K., Kohl, A., Palmer, M. A., Sauer, J. D., Matzke, D., Aidman, E., & Heathcote, A. (2023). Calibration of cognitive tests to address the reliability paradox for decision-conflict tasks. *Nature Communications*, *14*(1), 2234. https://doi.org/10.1038/s41467-023-37777-2

Lau, W. W. (2017). Effects of social media usage and social media multitasking on the academic performance of university students. *Computers in Human Behavior*, *68*, 286–291. https://doi.org/10.1016/j.chb.2016.11.043

le Roux, D. B., Parry, D. A., Totolo, A., Iyawa, G., Holloway, J., Prenter, A., & Botha, L. (2021). Media multitasking, online vigilance and academic performance among students in three Southern African countries. *Computers & Education*, *160*, 104056. https://doi.org/10.1016/j.compedu.2020.104056

Lin, L., & Parsons, T. D. (2018). Ecologically valid assessments of attention and learning engagement in media multitaskers. *TechTrends*, *62*(5), 518–524. https://doi.org/10.1007/s11528-018-0311-8

Luce, R. D. (1986). *Response times: Their role in inferring elementary mental organization*. Oxford University Press.

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

Luo, L., Luk, G., & Bialystok, E. (2010). Effect of language proficiency and executive control on verbal fluency performance in bilinguals. *Cognition*, *114*(1), 29–41. https://doi.org/10.1016/j.cognition.2009.08.014

Luo, J., Yeung, P. S., & Li, H. (2021). Impact of media multitasking on executive function in adolescents: Behavioral and self-reported evidence from a one-year longitudinal study. *Internet Research*, *32*(4), 1310–1328. https://doi.org/10.1108/INTR-01-2021-0078

Madore, K. P., Khazenzon, A. M., Backes, C. W., Jiang, J., Uncapher, M. R., Norcia, A. M., & Wagner, A. D. (2020). Memory failure predicted by attention lapsing and media multitasking. *Nature*, *587*(7832), 87–91. https://doi.org/10.1038/s41586-020-2870-z

Marciano, L., & Camerini, A. L. (2019). Smartphone overuse, attention problems, and media multitasking: Their associations with academic achievement in Swiss students. *Well-being in Education Systems*, *1*, 268–272. http://www2.supsi.ch/cms/wellbeing/it/

Matthews, G., Jones, D. M., & Chamberlain, A. G. (1990). Refining the measurement of mood: The UWIST mood adjective checklist. *British Journal of Psychology*, *81*(1), 17–42. https://doi.org/10.1111/j.2044-8295.1990.tb02343.x

May, K. E., & Elder, A. D. (2018). Efficient, helpful, or distracting? A literature review of media multitasking in relation to academic performance. *International Journal of Educational Technology in Higher Education*, *15*(1), 13. https://doi.org/10.1186/s41239-018-0096-z

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

Moore, D. J., Keogh, E., & Eccleston, C. (2012). The interruptive effect of pain on attention. *The Quarterly Journal of Experimental Psychology*, *65*(3), 565–586. https://doi.org/10.1080/17470218.2011.626865

Mueller, S. T., & Piper, B. J. (2014). The Psychology Experiment Building Language (PEBL) and PEBL test battery. *Journal of Neuroscience Methods*, *222*, 250–259. https://doi.org/10.1016/j.jneumeth.2013.10.024

Murphy, K., & Creux, O. (2021). Examining the association between media multitasking, and performance on working memory and inhibition tasks. *Computers in Human Behavior*, *114*, 106532. https://doi.org/10.1016/j.chb.2020.106532

Murphy, K., McLauchlan, S., & Lee, M. (2017). Is there a link between media-multitasking and the executive functions of filtering and response inhibition? *Computers in Human Behaviour*, *75*, 667–677. https://doi.org/10.1016/j.chb.2017.06.001

Murphy, K., & Shin, M. (2021). Frequent media multitasking is not associated with better cognitive flexibility. *Journal of Cognitive Psychology*, *34*(4), 516–528. https://doi.org/10.1080/20445911.2021.2002876

Nusbaum, E. C., & Silvia, P. J. (2011). Are intelligence and creativity really so different?: Fluid intelligence, executive processes, and strategy use in divergent thinking. *Intelligence*, *39*(1), 36–45. https://doi.org/10.1016/j.intell.2010.11.002

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multi-taskers. *Proceedings of the National Academy of Sciences*, *106*(37), 15538–15587. https://doi.org/10.1073/pnas.0903620106

Paap, K. R., & Sawi, O. (2016). The role of test-retest reliability in measuring individual and group differences in executive functioning. *Journal of Neuroscience Methods*, *274*, 81–93. https://doi.org/10.1016/j.jneumeth.2016.10.002

Parry, D. A., & Le Roux, D. B. (2019). Media multitasking and cognitive control: A systematic review of interventions. *Computers in Human Behavior*, *92*, 316–327. https://doi.org/10.1016/j.chb.2018.11.031

Parry, D. A., & Le Roux, D. B. (2021). Cognitive control in media multitaskers" ten years on: A meta-analysis. *Cyberpsychology: Journal of Psychosocial Research on Cyberspace*, *15*(2), 7. https://doi.org/10.5817/CP2021-2-7

Parry, D. A., le Roux, D. B., & Bantjes, J. R. (2020). Testing the feasibility of a media multitasking self-regulation intervention for students: Behaviour change, attention, and self-perception. *Computers in Human Behavior*, *104*, 106182. https://doi.org/10.1016/j.chb.2019.106182

Perugini, M., Gallucci, M., & Costantini, G. (2018). A practical primer to power analysis for simple experimental designs. *International Review of Social Psychology*, *31*(1), 20. https://doi.org/10.5334/irsp.181

Reinecke, L., Klatt, J., & Krämer, N. C. (2011). Entertaining media use and the satisfaction of recovery needs: Recovery outcomes associated with the use of interactive and noninteractive entertaining media. *Media Psychology*, *14*(2), 192–215. https://doi.org/10.1080/15213269.2011.573466

Reitan, R. M. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and Motor Skills*, *8*(3), 271–276. https://journals.sagepub.com/doi/pdf/10.2466pms.1958.8.3.271?casa_token=tZTakqJgWD0AAAAA:1DmkVvskvAA9LH4vasbErVyhwXFsK2jAW4ki6fPSwB81wPKBZwpkXEZzgSZq_pNAFny_zup-d6N5

Rieger, D., Reinecke, L., & Bente, G. (2017). Media-induced recovery: The effects of positive versus negative media stimuli on recovery experience, cognitive performance, and energetic arousal. *Psychology of Popular Media Culture*, *6*(2), 174–191. https://doi.org/10.1037/ppm0000075

Rogobete, D. A., Ionescu, T., & Miclea, M. (2021). The relationship between media multitasking behavior and executive function in adolescence: A replication study. *The Journal of Early Adolescence*, *41*(5), 725–753. https://doi.org/10.1177/0272431620950478

Sanbonmatsu, D. M., Strayer, D. L., Medeiros-Ward, N., & Watson, J. M. (2013). Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking. *PLoS One*, *8*(1), e54402. https://doi.org/10.1371/journal.pone.0054402

Schneider, D. W., & Chun, H. (2021). Partitioning switch costs when investigating task switching in relation to media multitasking. *Psychonomic Bulletin & Review*, *28*(3), 910–917. https://doi.org/10.3758/s13423-021-01895-z

Seddon, A. L., Law, A. S., Adams, A. M., & Simmons, F. R. (2018). Exploring the relationship between executive functions and self-reported media-multitasking in young adults. *Journal of Cognitive Psychology*, 1–15. https://doi.org/10.1080/20445911.2018.1525387

Seddon, A. L., Law, A. S., Adams, A. M., & Simmons, F. R. (2021). Individual differences in media multitasking ability: The importance of cognitive flexibility. *Computers in Human Behavior Reports*, *3*, 100068. https://doi.org/10.1016/j.chbr.2021.100068

Segijn, C. M., & Eisend, M. (2019). A meta-analysis into multiscreening and advertising effectiveness: Direct effects, moderators, and underlying mechanisms. *Journal of Advertising*, *48*(3), 313–332. https://doi.org/10.1080/00913367.2019.1604009

Shin, M., Linke, A., & Kemps, E. (2020). Moderate amounts of media multitasking are associated with optimal task performance and minimal mind wandering. *Computers in Human Behavior*, *111*, 106422. https://doi.org/10.1016/j.chb.2020.106422

Shin, M., Webb, A., & Kemps, E. (2019). Media multitasking, impulsivity and dual task ability. *Computers in Human Behavior*, *92*, 160–168. https://doi.org/10.1016/j.chb.2018.11.018

Simmons, F., & Singleton, C. (2000). The reading comprehension abilities of dyslexic students in higher education. *Dyslexia*, *6*(3), 178–192. https://doi.org/10.1002/1099-0909(200007/09)6:3%3C178::AID-DYS171%3E3.0.CO;2-9

Soveri, A., Lehtonen, M., Karlsson, L. C., Lukasik, K., Antfolk, J., & Laine, M. (2018). Test–retest reliability of five frequently used executive tasks in healthy adults. *Applied Neuropsychology: Adult*, *25*(2), 155–165. https://doi.org/10.1080/23279095.2016.1263795

Srivastava, J. (2013). Media multitasking performance: Role of message relevance and formatting cues in online environments. *Computers in Human Behavior*, *29*(3), 888–895. https://doi.org/10.1016/j.chb.2012.12.023

Stins, J. F., Polderman, T. J. C., Boomsma, D. I., & de Geus, E. J. C. (2007). Conditional accuracy in response interference tasks:

Evidence form the Eriksen flanker task and the spatial conflict task. *Advances in Cognitive Psychology*, *3*(3), 409–417. https://doi.org/10.2478/v10053-008-0005-4

Suchy, Y., Niermeyer, M. A., & Ziemnik, R. E. (2017). Assessment of executive functions in research. In E. Goldberg (Ed.), *Executive functions in health and disease* (pp. 197–216). Academic Press. https://doi.org/10.1016/B978-0-12-803676-1.00009-X

Troyer, A. K. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology*, *22*(3), 370–378. doi.org/10.10761380-3395(200006)22:3;1-V;FT370

Unsworth, N., Spillers, G. J., & Brewer, G. A.. (2011). Variation in verbal fluency: A latent variable analysis of clustering, switching, and overall performance. *Quarterly Journal of Experimental Psychology*, *64*(3), 447–466. https://doi.org/10.1080/17470218.2010.505292

Uzun, A. M., & Kilis, S. (2019). Does persistent involvement in media and technology lead to lower academic performance? Evaluating media and technology use in relation to multitasking, self-regulation and academic performance. *Computers in Human Behavior*, *90*, 196–203. https://doi.org/10.1016/j.chb.2018.08.045

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

Van der Schuur, W. A., Baumgartner, S. E., Sumter, S. R., & Valkenburg, P. M. (2015). The consequences of media multitasking for youth: A review. *Computers in Human Behavior*, *53*, 204–215. https://doi.org/10.1016/j.chb.2015.06.035

van der Schuur, W. A., Baumgartner, S. E., Sumter, S. R., & Valkenburg, P. M. (2018). Media multitasking and sleep problems: A longitudinal study among adolescents. *Computers in Human Behavior*, *81*, 316–324. https://doi.org/10.1016/j.chb.2017.12.024

van der Schuur, W. A., Baumgartner, S. E., Sumter, S. R., & Valkenburg, P. M. (2020). Exploring the long-term relationship between academic-media multitasking and adolescents' academic achievement. *New Media & Society*, *22*(1), 140–158. https://doi.org/10.1177/1461444819861956

Whelan, R. (2008). Effective analysis of reaction time data. *The Psychological Record*, *58*, 475–482. https://doi.org/10.1007/BF03395630

Wiradhany, W., Baumgartner, S., & de Bruin, A. (2021). Exploitation–exploration model of media multitasking. *Journal of Media Psychology: Theories, Methods, and Applications*, *33*(4), 169. https://doi.org/10.1027/1864-1105/a000303

Wiradhany, W., & Koerts, J. (2019). Everyday functioning-related cognitive correlates of media multitasking: A mini meta-analysis. *Media Psychology*, 1–28. https://doi.org/10.1080/15213269.2019.1685393

Wiradhany, W., & Nieuwenstein, M. R. (2017). Cognitive control in media multitaskers: Two replication studies and a meta-analysis. *Attention, Perception, & Psychophysics*, *79*(8), 2620–2641. https://doi.org/10.3758/s13414-017-1408-4

Woods, D. L., Kishiyama, M. M., Yund, E. W., Herron, T. J., Edwards, B., Poliva, O., Hink, R. F., & Reed, B. (2011). Improving digit span assessment of short-term verbal memory. *Journal of Clinical and Experimental Neuropsychology*, *33*(1), 101–111. https://doi.org/10.1080/13803395.2010.493149

Xu, S., Wang, Z., & David, P. (2022). Social Media Multitasking (SMM) and well-being: Existing evidence and future directions. *Current Opinion in Psychology*, 101345. https://doi.org/10.1016/j.copsyc.2022.101345

Xu, S., Wang, Z., & Woods, K. (2019). Multitasking and dual motivational systems: A dynamic longitudinal study. *Human Communication Research*, *45*(4), 371–394. https://doi.org/10.1093/hcr/hqz009

Yap, J. Y., & Lim, S. W. H. (2013). Media multitasking predicts unitary versus splitting visual focal attention. *Journal of Cognitive Psychology*, *25*(7), 889–890. https://doi.org/10.1080/20445911.2013.835315

Zhou, Y., & Deng, L. (2022). A systematic review of media multitasking in educational contexts: Trends, gaps, and antecedents. *Interactive Learning Environments*, *31*(10), 6279–6294. https://doi.org/10.1080/10494820.2022.2032760