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Individual differences in media multitasking ability: The importance of cognitive flexibility

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ABSTRACT

Previous research on media multitasking has often focussed on the frequency with which people perform this type of behaviour. Heavy media multitaskers have been found to differ from light media multitaskers in their performance of tasks involving executive functioning (although these differences have not always been found consistently). The aim of the present study was to explore individuals' executive functioning in relation to their ability to media multitask (i.e., their ability to retain information presented during the session), rather than their propensity to media multitask. Participants ($N = 116$, aged 18–25, male $N = 32$) completed an executive function task battery, inclusive of working memory, inhibition and cognitive flexibility tasks, followed by a studious media multitasking situation. Individual executive function task performance scores were correlated with media multitasking ability scores. Greater cognitive flexibility was significantly associated with greater ability to media multitask, in terms of retention of information from a media multitasking situation. Furthermore, media multitasking influenced mood, reducing levels of self-reported arousal. Thus, the present study provides some elucidation as to what cognitive characteristics are involved in being able to media multitask, whilst also indicating a possible cognitive mechanism for negative associations found between media multitasking and academic performance.

1. Introduction

1.1. Media multitasking and executive functioning

The exploration of technology in relation to human cognition is continually expanding, in line with the way that mobile technologies have become an integral part of modern life (Pink et al., 2018). One aspect of cognition often explored is that of executive functioning. Executive functioning is an umbrella term given to a specific set of higher order cognitive processes that are involved in planning, problem solving, co-ordination, adaptation and concentration (Diamond, 2013; Miyake et al., 2000). Various theories have been proposed; however, three key executive functions are often cited: inhibition, working memory and cognitive flexibility (Diamond, 2006, 2013). Inhibition is the way in which we are able to control our attention and impulses, preventing us from being distracted and enabling us to remain goal oriented. Working memory is the way in which we retain information over short periods simultaneously manipulating it, whilst cognitive flexibility builds upon these two functions, enabling us to switch between two differing mental sets, generate abstract thought and see things from other perspectives (Diamond, 2013, 2016).

The rise in ownership of internet enabled mobile devices has produced the current milieu, in which there is a specific technological engagement behaviour that is ubiquitous across varying generations. That behaviour is known as media multitasking and is the term given to the simultaneous consumption of multiple streams of media-based technology (Baumgartner et al., 2014; Ophir et al., 2009), for example watching T.V. whilst scrolling through or posting on social media sites. It is most prevalent in young adults (Voorveld & Van Der Groot, 2013), with a recent Ofcom report finding that 16–24 year olds spend 35% of their media time specifically media multitasking, this percentage decreased as age increased (Ofcom, 2015). Considering the prevalence of media multitasking, many commentators and researchers considered how such behaviour may impact upon everyday functioning, inclusive of executive functioning.

In this regard, self-reported frequency of media multitasking has been associated negatively with biases in executive function, inclusive of attentional control (Cain & Mitroff, 2011; Cardoso-Leite et al., 2016;

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Gorman & Green, 2016; Moisala et al., 2016; Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017), working memory (Ralph & Smilek, 2017; Sanbonmatsu et al., 2013; Uncapher et al., 2016), and cognitive flexibility (Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017). However, other studies have failed to find evidence of associations (Minear et al., 2013; Murphy et al., 2017; Ralph et al., 2015; experiments 2 and 3b; Seddon et al., 2018). Some studies have explored multiple executive functions in relation to media multitasking, finding biases associated with some functions and not for others. For example, Ophir et al. (2009) found no difference in the performance of heavy and light media multitaskers on measures of inhibition such as the Stop-signal task but did find a difference for a measure of attentional control that included distractors (the AX continuous performance task). For a full review of the literature on the relationships between media multitasking and executive function, see Wiradhany and Koerts (2019).

Studies investigating media multitasking in relation to executive functioning have predominantly examined how often individuals media multitask, with much research utilising the Media Multitasking Index (MMI) by Ophir et al. (2009). In contrast, research exploring media use and media multitasking in applied or more naturalistic settings has utilised distinctly different methodology, where participants actively engage in media multitasking rather than passively reporting how frequently they media multitask, as highlighted in a review by Van Der Schuur et al. (2015). Many studies conducted within an academic context and have found negative relationships between media multitasking and academic performance (May & Elder, 2018), with media multitasking relating to grade performance (Demirbilek & Talan, 2018), exam performance (Patterson, 2017), and learning, more so than mind wandering during lectures (Wammes et al., 2019). Other research has adopted an experimental approach to investigating how well participants learn new information while media multitasking.

1.2. Media multitasking and academic performance: the use of naturalistic methods

The research exploring academic performance in relation to media use, inclusive of media multitasking, has often implemented naturalistic tasks and experimental designs. Methods that are higher in ecological validity (Lin, 2009) often involve participants engaging in media multitasking within simulated or real-world academic situations. They have investigated behaviours such as instant messaging whilst watching an academic presentation (Waite et al., 2018) or a video lecture (Kuznekoff & Titsworth, 2013; Rosen et al., 2011), reading a text whilst watching a video (Lee et al., 2012), and instant messaging whilst reading (Bowman et al., 2010; Fox et al., 2009). One study examined engagement with texting, email, MSN and Facebook® during the completion of a learning task (Wood et al., 2012), with the intention of examining the impacts of media multitasking on academic performance. The studies mentioned generally found that media-multitasking caused the academic task to take longer or impacted negatively on the information retained from the session. Within these various studies, the media multitasking set-ups have been specific to academic scenarios and representative of real-world media multitasking in relation to study. Thus, these elements are fundamental and need to be considered in further naturalistic experimental explorations (Kononova & Chiang, 2015). The advantages of utilising naturalistic media multitasking experiments lie in their ability to directly measure media multitasking behaviour, overcome the biases present in self-report measures, and provide findings that are more generalisable with real-world implications.

1.3. Possible role of executive function in media multitasking

Considering the methodological differences, to the best of our knowledge there is little research examining the relationship between executive function and media multitasking ability (as opposed to frequency). It is thus important to explore the possible involvement of executive function in media multitasking, given the amount we engage in this behaviour and the evidence to date demonstrating possible biases in executive functioning related to level of engagement (self-reported frequency) (Fisher & Keene, 2020; Murphy & Creux, 2021). It is not only important to determine the factors that influence effective media multitasking, but also those regarding efficiency and that reflect real-world media multitasking behaviours, such as the way in which media multitasking is carried out both between multiple devices and within a single device (Voorveld & Van Der Groot, 2013; Ziegler et al., 2015, pp. 1–19).

Diamond's (2013) theory of executive function proposes that inhibition allows us to control our attention and motor actions, working memory enables us to hold information in our minds and work with it, whilst cognitive flexibility enables us to change our perspective, adapt our way of thinking and generate abstract thought. It is logical to perceive the following roles for executive function in one's ability to media multitask, dependent on the type of media included. Reading a piece of text, whilst watching a video and responding to instant messages (the media situation used within the present study), places demand on working memory in that it requires the retention and manipulation of information from multiple media streams. Participants need to respond to anticipated instant messages whilst remembering to focus equally between these streams. The perceived demand on inhibitory processes is that the media situation taxes both the ability to control behavioural responses and to control attention. Attention needs to be split between multiple media streams, as well as ignoring no-longer-relevant information and controlling behavioural responses to environmental cues. In terms of cognitive flexibility, participants need to change between reading a piece of text and watching a video, which is facilitated by switching between mental sets. Furthermore, whilst switching between these two media participants are also required to respond to instant messages, thus requiring them to disengage from ongoing task performance (retention of information from the video and text), in order to respond to the instant messages received. Given these media multitasking 'requirements', it would be expected that greater capacity of these functions would equate to more effective media multitasking with greater retention of information encountered during the session.

Previous research exploring multitasking has traditionally used two distinct laboratory paradigms: dual-tasking and task switching. Conventionally, dual-task experiments require participants to complete tasks concurrently, whilst task switching requires switching or alternating between tasks in quick succession. In dual task experiments the stimuli that are presented to participants overlap in time (e.g., concurrent presentation of visual and auditory streams of information), or else participants have to maintain a stream of responses in one modality while responding to stimuli presented in another (e.g., responding to images while vocalising a stream of random numbers). In traditional task-switching experiments stimuli are presented sequentially but require different responses (e.g., numbers that need to be added or subtracted) (Koch et al., 2018). Findings from both paradigms have indicated the involvement of executive function (Strobach et al., 2018). There has been much theoretical debate about the extent to which bottlenecks occur when two tasks are performed concurrently, and whether processing can only be done serially or if resources can be shared to allow processing in parallel (Fischer & Plessow, 2015; Meyer et al., 1995; Salvucci & Taatgen, 2011). In everyday, real-world multitasking, the stimuli that people encounter, and their own shifting priorities, are unlikely to align with the rigid structure of either a dual-task or task-switching laboratory experiment, which has led some researchers to attempt to create more ecologically valid tests of multitasking (Jansari et al., 2004; Lamberts et al., 2010; Logie et al., 2011) and media-multitasking (Kazakova et al., 2016; Segijn et al., 2017). The media-multitasking situation used in the present study follows this more naturalistic approach and does not neatly fall into either traditional dual-task or task-switching paradigm, given that there are three mediums (tasks) to be engaged with within a set time period, that also have elements of temporal overlap. This type of naturalistic studious set up is essentially examining distraction from an academic task (Aagaard, 2019), in terms of switching between on-task and off-task activity. Indeed, in such complex cognitive environments participants will need to draw on a wide range of different cognitive functions acting in concert (Logie et al., 2011) and their priorities and motivations are likely to fluctuate over the session. Ralph et al. (2020) highlighted that individuals choose specific modalities to engage with simultaneously based on their processing requirements and are aware of possible difficulties in combining information from different media. Thus, as previously highlighted executive functioning is posited as enabling the attention to, and retention of, information from the different modalities, by managing processing resources.

Thus, the combination of the three executive functions could be said to be vital in facilitating media multitasking in this context, enabling more information from a media multitasking situation to be retained. Positive associations between media multitasking ability and executive function performance would be expected, due to the facilitative role of executive function in the simultaneous engagement with and processing of information from multiple streams of media. Only one study to date, that we are aware of, Kazakova et al. (2015), has explored cognitive control in relation to media multitasking using a naturalistic approach.

1.4. Rationale

In sum, self-report measures of frequency of media multitasking have dominated previous research. Specifically, most studies have implemented the Media Multitasking Index (MMI) (Ophir et al., 2009) to explore associations between frequency of media multitasking and executive functioning. In contrast, the present study aimed to implement a performance-based measure of media multitasking in a naturalistic studious setting, to examine which executive functions are most strongly associated. From reviewing the literature, the primarily used method of assessment was multiple choice comprehension tests of retention of information from the media that was presented/viewed (e.g. Bowman et al., 2010; Kuznekoff & Titsworth, 2013; Lee et al., 2012; Waite et al., 2018; Wood et al., 2012). The present study used a specific media multitasking scenario similar to a situation where a student might study text-based material whilst watching T.V and communicating with friends via instant messaging. Executive functioning was assessed using a battery of 10 tasks, intended to measure working memory, inhibition and cognitive flexibility. Multiple tasks were chosen to measure each executive function as a means to overcome the issue of task impurity (Snyder et al., 2015), a fundamental limitation within executive function assessment (see Rabbitt, 1997). They were also chosen as varying associations between self-reported media multitasking and executive functioning have been found when different executive function tasks have been implemented. A correlation analysis of the individual executive function task scores and the media multitasking ability scores was implemented. For H1-It was hypothesised that enhanced performance on working memory, inhibition and cognitive flexibility tasks, would be associated with greater media multitasking ability. This was based on the perceived involvement of executive function processes (previously stated in section 1.3), as detailed in Diamond's (2016) theory of executive functioning, in the specific media multitasking situation implemented in this study. State mood, trait anxiety and depression were also explored considering the associations between executive function performance and mood (Shields et al., 2016; Ursache & Raver, 2014), and previous findings of associations between high trait anxiety and self-reported media multitasking (Becker et al., 2013; Seddon et al., 2018). Additionally, there is a need to examine state and trait variables that can impact performance stability when undertaking an individual differences approach (Goodhew & Edwards, 2019). A negative association between media multitasking ability and trait anxiety was hypothesised (H2). In terms of mood, it was hypothesised that arousal would decrease linearly after the completion of executive function tasks, with a further decrease following completion of the media multitasking situation (H3). Although anxiety and depression were expected to change across the experimental session, there was no hypothesis about the direction(H4/H5). Trait depression was predicted to relate to media multitasking score (H6).

A further inclusion to the study was to explore media multitasking between multiple devices in comparison to media multitasking within a single device, to determine whether there were associated differences in media multitasking ability. In regards to the device manipulation, media multitasking between devices was perceived to be more demanding than media multitasking within a single device, given the previously mentioned media multitasking demands and the larger visual field and decreased proximity of the three information streams to be engaged with in this condition. Thus, it was hypothesised that those in the media multitasking between-devices condition would score lower in media multitasking ability, compared to those in the within-device condition (H7), and would take longer to respond to instant messages (H8).

2. Method

2.1. Participants

Participants were young adults from an undergraduate student population and the general public, ($N = 116$, 84 females (72.4%), 18–25 years old ($mean = 20.47$, $SD = 2.04$)), recruited via email, poster, Facebook® and Twitter® advertisements, as well as the SONA research management system. The University Research Ethics committee granted ethical approval, and the experiment was conducted in accordance with the approved protocol and ethical principles set out by the British Psychological Society.

2.2. Design and procedure

Participants' ability to media multitask was indexed by their retention of information presented during a media multitasking session in which they had to read a passage of text, watch a video and respond to instant messages. Scores on the multiple-choice test were correlated against the measures of executive function detailed below. Scores were also examined for any differences according to whether participants multitasked within the same device or between devices.

Once informed consent had been obtained, participants completed both a trait and state mood inventory, followed by a battery of ten executive function tasks and then a media multitasking situation (described below). All participants completed the tasks in the same order, in line with individual difference experimental research recommendations (See Goodhew & Edwards, 2019). The order of which was: Stop-Signal task, Go No-go, number flanker, arrow flanker, phonetic fluency, semantic fluency, Wisconsin card sorting task, trail making, backwards digit span and backwards Corsi block. State mood was assessed at three different time points: at the beginning of the experiment, after the executive function tasks and after the media multitasking situation. The total time taken to complete the experiment was 120 min and participants received a nominal financial incentive.

Within the study, participants were allocated into different device conditions to complete the same media multitasking situation. Allocation was random and those in the within-device group were instructed to watch the video on the top left half of the screen, whilst the instant messages would appear in the bottom left half of the screen, and to read the text on the right side of the screen. Whereas individuals in the between-device group were instructed to watch the video on the left side of the screen, whilst the messages would be on the right hand side of the screen, and to read the piece of text on the tablet pc, which could be held up and moved about. Regardless of device condition, participants were informed to pay equal attention to the video, text and instant messages. They were explicitly instructed that instant messages had to be responded to as soon as they were received and that their recall of content of the video and text would be tested. For the final part, participants were given two multiple-choice tests, one relating to the text and one to the video. Presentation of these tests was counterbalanced for each device condition.[1]

3. Measures

All stimuli were presented on an Ilyama prolite B1980SD monitor, powered by a Viglen desktop computer with a 3.20 GHz Intel® Core™ I5-6500 processor. Participants who multitasked between devices read the text for the article on a 9.7" LCD 16 GB Samsung Galaxy Tab A.

3.1. Executive functioning performance

3.1.1. Working memory tasks

Two types of span tasks were used to measure working memory, one specific to visual-spatial working memory and the other to verbal working memory. Inquisit software was used to run both tasks, with implementations taken from the Millisecond Test Library. The task used to assess visual spatial working memory was a backwards Corsi block task. This involves participants viewing a screen featuring nine blue boxes. The different boxes light up throughout the task creating a pattern, which must be repeated by the participant, in reverse order, to what they are originally shown. The task starts with two boxes lighting up and increases as the task progresses. The maximum pattern length is nine boxes. If a pattern is correctly repeated, then the next pattern increases by one box. However, if the pattern is incorrectly repeated then the same number of boxes lights up as the last time, but in a different order. Visual-spatial working memory performance was indicated by mean span of the length of the pattern recalled correctly.

Verbal working memory was assessed with a backwards digit span task, specifically an implementation of Woods et al. (2011). The task involves participants being presented auditorily with digits, which they are required to repeat in a reversal of the presentation order, entering their responses on the keyboard. The length of digits, also known as span, begins with just two digits being presented. This span increases as the task progresses, going up to a maximum of nine digits, with 14 trials to be completed. The length of span is determined on the participant's performance, with changes to length based on a 1:2 staircase ratio: meaning that a single correct response will increase the span whereas two incorrect responses are required to reduce span length. Performance was indicated by mean span, with greater working memory capacity reflected by a longer span.

3.1.2. Inhibition tasks- attentional inhibition and response inhibition

Attentional inhibition was assessed using two versions of a flanker task. A flanker task is an assessment that captures an individuals' ability to focus, or "zoom in" their attention. It requires individuals to "zoom in" to a specific stimulus, whilst ignoring others outside their attentional focus, to which a response (specific to the stimulus of the attentional focus) is carried out, such as a button press (Stins et al., 2007).The first flanker task was taken from the Psychological Experiment Building Language (PEBL) test battery by Mueller and Piper (2014). It consisted of arrow (←/→) stimuli and was adapted to include 80 trials. The second flanker task was an implementation of the flanker task used by Moore et al. (2012). It featured numerical stimuli (2/4) and consisted of 160 trials. For both tasks there were four conditions, congruent, incongruent, neutral and null. In the null condition the central stimulus of the attentional focus was not flanked by any other stimuli, whereas in the neutral condition the stimulus was flanked by "_" in the arrow version and "h" in the numerical version. While the congruent trials consisted of the stimulus being flanked by the same stimuli e.g. (22222 or →→→→→), and the incongruent trials consisted of the stimulus being flanked by the opposite stimuli e.g. a 2 flanked by a 4 in the numerical version (44244) or a left arrow flanked by a right arrow (→←←→←) and vice versa. Attentional inhibition performance was indicated by congruency conflict, which is the difference between mean response time for the congruent trials and mean response time for the incongruent trials.

In terms of response inhibition, two tasks were utilised. The first was the Stop-Signal task, an implementation of the Verbruggen et al. (2008) Stop-it programme. The programme is a type of Go-No-go task where participants are shown different stimulus on a screen, consisting of single shapes of either a circle or a square. The shapes are shown one at a time with participants informed to press a specific button on the keyboard when they see the shape (/for circle, z for square). At the same time as watching for these shapes and responding via button presses, participants also have to listen out for a beep. If a beep occurs at the same time as a shape is presented then the participant has to not press the button (withhold their response). The main performance indicator for this task is stop-signal response time (SSRT). SSRT is essentially the latency of the internal stop process and is calculated based on the finishing time of a go process (button press) and stop process (withholding button press), using a horse race model (Verbruggen et al., 2008). The second task was an implementation of Moore et al. (2012) Go No-go task, which consisted of two lines presented horizontally, with a fixation circle centred in the middle of the two lines. Participants were required to respond, with a button press, when either of the lines turned vertical and only when the central fixation circle was black. If the fixation circle was red, they had to withhold their response and not press either key. The lines were presented on either side of the screen in the participants' periphery field of vison (angle of vision 14.2°). There were 30 No-go trials and 120 Go trials, with performance indicated by the number of correct inhibitions.

3.1.3. Cognitive flexibility

There were four tasks used to assess cognitive flexibility. One of these tasks was a computerised version of the trail making task (TMT, Reitan, 1958). This task was the version taken from the PEBL battery, devised by Mueller and Piper (2014). The task consists of circles on a screen that are presented to a participant, within the circles are a sequence of numbers (trail A) or a sequence of numbers and letters (trail B). As quickly as possible, the participant has to click on the circles in sequence order. On trail B trials, the participant is required to switch between clicking on numbers and letters (1-A-2-B-3-C). Sequences were randomly generated by the computer for each trial, with four trials for each trail condition, with a practice trial completed before each trial. The performance indicator for cognitive flexibility was the difference in mean response times, calculated by taking the mean response time for trials following trail B from the mean response time for trail A trials. Thus, faster response times indicated greater cognitive flexibility.

Another task utilised was a computerised short version (64 cards) of the Wisconsin Card Sorting Task (WCST). This was the implementation available in PEBL (see Piper et al., 2011). The task features four cards on a computer screen, on which there are different shapes in different amounts and colours. Within the task the cards are shown at the top of the screen, below them are card-shaped spaces. A new card appears on the right-hand side of the screen, which then has to be sorted into one of the four card-shaped spaces. The task proceeds through all of the 64 cards, with participants sorting through them based on colour, amount of shapes or shape. Each time a sort is completed; feedback is shown on the screen indicating whether the sort was "correct" or "incorrect". The rule of sorting changes as the participants proceed through the cards and the feedback is intended to be used to recognise when the sorting rule has changed. Performance on this task is indicated by the percentage of perseverative errors. That being the percentage of trials in which the participants carried on sorting cards using the previous (incorrect) sorting rule and neglected to recognise the changed (new) sorting rule.

The other two cognitive flexibility tasks were a phonetic fluency task and a semantic fluency task. In the phonetic fluency task, participants were given a letter and instructed to generate words beginning with said

[1] no effect of presentation order in relation to media multitasking ability was found.

letter, as many as possible, within 60 s. Three different letters were used in the task, specifically F, A and S, considering that these are the most widely used within the literature (Herrmann et al., 2003; Laws et al., 2010). For the semantic fluency task participants were given categories, rather than letters and asked to generate as many words as possible fitting to the category, again within 60 s. The specific categories used were animals, clothing and food, these are the ones most commonly used within the literature (Luo et al., 2010; Nusbaum & Silvia, 2011). The rules used for scoring the fluency task were that of excluding proper names, numbers, places and words in different forms, in line with Luo et al. (2010). Mean total scores for each fluency task were calculated (mean of total score of three letters/categories), with higher scores indicative of greater cognitive flexibility.

3.2. Media multitasking

3.2.1. Media multitasking situation

A media multitasking situation was used to assess media multitasking ability. The situation consisted of participants responding to instant messages on Facebook Messenger®, whilst reading a piece of text and watching a video. An addition to the situation was the inclusion of two different device conditions, a within-device media multitasking set up and a between device set up (previously described in section 2.2).

3.2.1.1. Instant messages. During the media multitasking situation, instant messages were sent using Facebook messenger, with 10 messages sent by the experimenter to the participant. Throughout the 20-min media multitasking situation, instant messages were sent at pseudo-random time intervals with a message being received within every 2 min window. The time intervals were carefully constructed to ensure none of the messages interrupted auditory information from the video that was to be assessed in the multiple-choice test. Participants were explicitly instructed to respond to messages instantaneously, as soon as they received them, responding with simple yes or no answers. Questions such as “Are you in the library at the moment?” “Did I leave the oven on?” were included in the messages, with four of the ten requiring truthful responses. This finer detail was included as a means to monitor participant engagement, with only 5 participants being found to have given a false response to one or more instant message. A stopwatch was used to record instant message response times, with the stopwatch started as soon as the message was sent and stopped as soon a response was received. Instant message details (specific messages and time sent) can be found in supplementary materials.

3.2.1.2. Video. The present study utilised a video that consisted of a combination of two YouTube® videos. The videos were taken from the series a “Day in the life of Dan and Phil”, a pair of professional vloggers. The videos were chosen based on the suitability of their content in terms of appropriateness and depth, their accessibility, and their potential for question derivation. The age of the videos meant that they were also deemed to not be extensively viewed by our target audience. Potential previous viewings were screened at the start of the experiment, with none declared. The videos lasted 20 min and can be found by following the links available in the supplementary materials.

3.2.1.3. Reading text. The reading text part of the situation consisted of two pieces of text, which covered the topic of electronic information cables. One text was taken from Wikipedia and the other from Simmons and Singleton (2000) (see supplementary materials for both pieces of text). The specific pieces of text were selected to differ from the videos in context with a non-emotive topic focus.

3.2.2. 2. multiple-choice tests

Media multitasking ability was assessed in terms of memory for the content presented in each medium, thus two multiple-choice tests were included: with one test on the content of the video and the other on the content of the reading text. The video multiple-choice test included questions such as “What celebrity do they point out from the view?” and “What are Dan and Phil on the search for?”, whereas the reading text multiple-choice test included questions such as “Who has received additional training?” and “What is the most important market for the copper industry?”. Material required for the completion of both multiple-choice tests did not require inference and was directly retrievable from the presentation. The multiple-choice tests were piloted beforehand to ensure that they produced variable responses that were better than chance but away from ceiling. The final versions used in the present study consisted of 42 questions each (see supplementary materials). Media multitasking ability was indexed by the total number of questions answered correctly, combined from both multiple-choice tests (maximum = 84).

3.3. Mood

The Hospital Anxiety and Depression scale (HADS) (Zigmond & Snaith, 1983) was used to assess trait mood, inclusive of anxiety and depression. The scale consists of 14 questions, with seven questions relating to anxiety and the other 7 to depression. For each question, participants responded using a 4-point Likert scale, scored 0–3, thus the highest score that can be obtained is 21. In the present study, the reliability scores for HADS Anxiety and Depression were $\alpha = 0.698$ and $\alpha = 0.732$, respectively.

In addition to trait mood, state mood was also explored. This was assessed using the University of Wales Institute of Science and Technology (UWIST) mood adjective checklist (UMACL) (Matthews et al., 1990). The checklist comprises a list of 18 adjectives that underpin 3 factors; depression, anxiety and arousal, for which there are 6 corresponding adjectives. Participants have to consider how they feel at that particular moment in time and rate each adjective, accordingly, using a 5 point Likert scale that ranges from “not at all” to “extremely”. Thus, a higher score on each of the factors indicates a higher self-reported level of that state mood, possible scores range from 6 to 30. The reliability of the mood inventory for the present study is as follows; Arousal (time 1 $\alpha = 0.713$, time 2 $\alpha = 0.762$, time 3 $\alpha = 0.818$), Anxiety (time 1 $\alpha = 0.714$, time 2 $\alpha = 0.739$, time 3 $\alpha = 0.811$) and Depression (time 1 $\alpha = 0.813$, time 2 $\alpha = 0.733$, time 3 $\alpha = 0.787$).

4. Results

Data were explored and performance scores with outliers greater than three standard deviations were removed which led to the removal of 5 participants. A further 3 participants were removed under multiple-choice test non-compliance protocols, leaving a total of 108 for executive function analysis. Media multitasking ability did not significantly differ based on device group (MD = 1.261, CI [-1.639, 4.161], $t = (111) = 0.861$, $p = .391$), with a small effect size ($\eta^2 < 0.01$). Therefore, H7, the hypothesis of individuals in the between-device group performing worse in terms of lower media multitasking ability score was not supported, and the data were collapsed across device group for the analyses below. The mean scores and descriptive statistics for media multitasking ability and the principal outcome measure from all executive function tasks are shown in Table 1.

4.1. Planned analysis of relationships with individual executive function tasks

In regards to media multitasking and executive functioning, a correlational analysis of media multitasking ability and the 10 executive function tasks was conducted. No significant correlations between media multitasking ability and the four inhibition tasks were found: Number Flanker $r = -0.101$, $p = .298$, Arrow Flanker $r = -0.012$, $p = .899$, Stop-Signal task $r = 0.095$, $p = .330$ and the Go No-go $r = -0.072$, $p = .462$.

Table 1
Mean scores for media multitasking ability and executive function tasks.

	Mean	S. D	Range
Media multitasking Ability (Combined multiple-choice score)	42.06	7.77	32.00
Executive Function Task			
Stop-Signal (SSRT- Stop-Signal response time ms)	248.54	41.26	243.50
Go-No go (Number of correct inhibitions-accuracy)	21.73	6.12	27.00
Number Flanker (Congruency conflict-difference in response time ms)	40.67	27.19	127.19
Arrow Flanker (Congruency conflict- difference in response time-ms)	53.57	26.70	151.90
Phonetic fluency (Total words correct)	11.80	3.09	13.67
Semantic fluency (Total words correct)	19.26	4.77	26.67
WCST (% Perseverative Error)	13.11	6.95	34.38
Trail making (B-A Difference in mean response times- ms)	7207.07	4225.60	19274.50
Backwards digit span (Mean span)	5.70	1.01	4.75
Backwards Corsi block (Block span)	6.25	1.10	6.00

Thus, H1, the hypothesis of a relationship between enhanced executive function performance and media multitasking ability is not fully supported in terms of the inhibition tasks.

Media multitasking ability was found to be significantly associated with the two working memory tasks: backwards Corsi block, $r = .198$, $p = .040$ and backwards digit span, $r = 0.226$, $p = .019$. Significant relationships were also found for the four cognitive flexibility tasks, Wisconsin Card Sorting Task $r = -0.323$, $p = .001$, Trail Making Task $r = -0.237$, $p = .013$, Phonetic fluency $r = 0.282$, $p = .003$ and Semantic fluency $r = 0.335$, $p = .001$. In all cases these correlations demonstrate that greater cognitive flexibility is related to better media multitasking ability (higher score on the test). However, considering the multiple comparisons undertaken, it was necessary to apply a Bonferroni correction to the α level. This subsequently resulted in the reduction of six significant correlations down to three, with only measures of cognitive flexibility (Wisconsin Card Sorting Task, Phonetic and Semantic fluency) associated with media multitasking ability, $p < .004$ in all cases. Thus, H1, the hypothesis of enhanced executive function performance is supported for cognitive flexibility but not supported for working memory. For the matrices of all correlations, please see Table 4 of the supplementary material.

4.2. Supplementary analysis of relationships with inhibition tasks

In a supplementary analysis as suggested by reviewers, performance on the inhibition tasks was explored in more detail in relation to media multitasking ability. For the arrow flanker task, there were no significant associations with response times on the congruent (M = 491.14, SD = 50.67) and incongruent trials (M = 544.57, SD = 51.85) and media multitasking, with $r = -0.135$, $p = .158$ and $r = -0.138$, $p = .151$, respectively. Nor were there any significant associations between response times on the null (M = 463.33, SD = 46.21) and neutral trials (M = 481.86, SD = 47.53) of the arrow flanker tasks and media multitasking, with $r = -0.138$, $p = .148$ and $r = -0.103$, $p = .284$, respectively. In terms of the number flanker task, there was no significant association between performance on congruent trials (M = 516, SD = 59.77) and media multitasking ability, $r = -0.174$, $p = .069$. However, performance on incongruent trials (M = 557.21, SD = 64.99), null trials (M = 504.63, SD = 61.98) and neutral trials (M = 534.35, SD = 64.32), was significantly associated with media multitasking ability, with $r = -0.197$, $p = .039$, $r = -0.213$, $p = .024$ and $r = -0.189$, $p = .047$. The direction of these correlations indicates that those who performed better on these trials, in terms of shorter response times, had better media multitasking ability in terms of higher scores on the multiple-choice test. However, taking into account the number of comparisons within these supplementary analyses, it should be noted that these correlations would not withstand a Bonferroni correction to the alpha level (p <. 004).

Additionally, we examined the speed-accuracy trade-offs for the go no-go and stop signal tasks. As found in Ralph et al. (2015), there was a speed-accuracy trade off with the number of incorrect inhibitions (M = 8.37, SD = 5.60) associated with mean reaction time on go trials (M = 416.60, SD = 74.63), $r_s = -0.497$, $p < .001$. However, neither the number of incorrect inhibitions, $r_s = -0.017$, $p = .860$ or mean response time on go trials, $r = -0.104$, $p = .272$, were associated with media multitasking ability. Similarly, the probability of reacting to a stop signal trial (M = 45.32, SD = 4.82) was negatively associated with mean response times on no signal trials (M = 795.57, SD = 146.69), $r = -0.513$, $p < .001$. Although, neither probability of reacting to a stop signal trial, $r = -0.032$, $p = .739$ or mean response times on no signal trials, $r = -0.145$, $p = .127$ were significantly associated with media multitasking ability. Following this, in line with the procedure used by Ralph et al. (2015) regression analyses were conducted to determine whether either RTs and/or errors in the go no-go and stop signal tasks predicted media multitasking ability, whilst controlling for the other factor. Table 5 indicates that media multitasking ability was not significantly predicted by either RTs or errors on the go no-go task. Table 6 indicates that when controlling for the probability of responses on stop signal trials, RTs on no signal trials weakly predicted media multitasking ability, but the overall regression model did not predict a significant amount of variance.

4.3. Relationships between media multitasking and mood

4.3.1. Trait mood, state mood and media multitasking ability

Media multitasking ability was not associated with either trait

Table 2
Mean scores and descriptive statistics for trait mood measures.

Mood Measure	Mean	S.D.	Range
Trait			
HADs Anxiety	6.63	3.05	11
HADs Depression	2.92	2.41	16

Table 5
Regression of no-go incorrect inhibitions (errors) and RT predicting media multitasking ability.

	β	t	p	Partial correlation
RTs	-.078	-.699	.486	-.067
No-go incorrect inhibitons	.040	.359	.720	.034

$r = 0.11$, $F(2, 109) = 0.608$, $p = .546$.

Table 3
Mean scores and descriptive statistics for state mood (arousal, anxiety, depression) by experimental time point.

	Experimental Time Point								
	1 Mean	S.D.	Range	2 Mean	S.D.	Range	3 Mean	S.D.	Range
State Arousal	20.41	3.73	18.00	20.02	3.70	17.00	18.61	4.38	25.00
State Anxiety	11.54	2.61	13	13.03	3.27	17.00	12.68	3.61	18.00
State Depression	11.63	3.18	15	12.14	2.82	1400	12.75	3.10	16.00

Table 6
Regression of probability of responding on a signal trial and no signal trial RT predicting media multitasking ability.

	β	t	p	Partial Correlation
Probability of response on signal trial	-.144	−1.316	.191	-.125
No signal RTs	-.219	−1.999	.048	-.188

$r = 0.19$, $F(2, 109) = 2.06$, $p = .133$.

depression or anxiety (trait depression $r = -0.014$, $p = .887$, trait anxiety $r = 0.122$, $p = .201$), see Table 2 for means and standard deviations. Thus, H2 which predicted a negative association with trait anxiety and media multitasking ability, and H6 which predicted an association for trait depression and media multitasking ability were both not supported. Nor were there any associations between trait anxiety and executive task performance, all $rs < 0.069$, all p's > 0.004 and trait depression, all $rs < 0.152$, $ps > .004$, following Bonferroni correction for multiple comparisons, which were examined to check for relationships between trait mood and executive function performance. However, statistically significant changes in state mood (arousal, anxiety and depression) over the experimental time period were found. Table 3 below indicates the mean changes for each.

4.3.1.1. State arousal. Mean scores for arousal differed significantly between time points, as determined by a repeated measures ANOVA with a Greenhouse-Geisser correction (F (1.835, 211.002) = 17.193, $p < .001$, with a large effect size, partial $\eta^2 = 0.130$). Self-reported levels of arousal did not significantly change from baseline after completion of the executive function tasks, but did significantly decrease after completion of the media multitasking situation ($p < .001$) and were significantly lower than baseline ($p < .01$), as revealed by post-hoc Bonferroni corrections. Thus, the hypothesis (H3) was only partially supported, in that a significant linear decrease in arousal after the completion of the executive function battery and further decrease after the media multitasking situation was predicted. With arousal only significantly decreasing following the completion of the media multitasking situation, the findings seem to indicate an effect of media multitasking on mood in terms of reducing arousal.

4.3.1.2. State anxiety. Self-reported levels of anxiety significantly differed between time points, as determined by a repeated measures ANOVA with a Greenhouse-Geisser correction, F (1.819, 207.346) = 16.226, $p < .001$, partial $\eta^2 = 0.125$. Specifically, self-reported levels of anxiety significantly increased after completion of executive function tasks ($p < .001$). However, they did not significantly change further after completion of the media multitasking situation, although they remained higher than baseline ($p < .01$), as revealed by post-hoc Bonferroni tests. Thus, the findings indicate that completion of executive function tasks had an anxiety inducing effect, partially supporting H4.

4.3.1.3. State depression. Self-reported levels of depression differed significantly between time points, as determined by a repeated measures ANOVA, F (2, 226) = 17.554, $p < .001$, partial $\eta^2 = 0.134$. Self-reported levels of depression significantly increased after completion of the executive function tasks ($p = .016$) and again after completion of the media multitasking situation ($p = .004$). This indicates that executive function task completion had a depressive effect on mood that was further exacerbated by media multitasking. Thus, H5 was supported.

4.4. Responses to instant messages

An extra inclusion within the study was an exploration into media multitasking within a single device and media multitasking across multiple devices. In this regard, the only significant difference found was that of time to respond to instant messages (MD = −1.874, CI [-3.110, −0.637], t (114) = −3.003, $p = .003$). Individuals in the between-device group took longer to respond to instant messages (M = 10.33 s, SE = 0.456), than those in the within-device group (M = 8.45 s, SE = 0.426), as predicted (H8), with a medium effect size ($\eta^2 = 0.07$).

5. Discussion

The present study hypothesised that greater media multitasking ability would be associated with enhanced performance on inhibition, working memory and cognitive flexibility tasks. However, the pattern of relationships was not uniform across the different types of executive function. In terms of inhibition, no association with media multitasking ability was found, with performance on the main outcome measures of all inhibition tasks (Flanker task 1 and 2, Go No-go and Stop signal) not related to media multitasking ability. Performance on the working memory tasks (backwards digit span and backwards Corsi blocks) was observed to positively correlate with media multitasking ability, but these correlations did not withstand correction for multiple comparisons. Interestingly though, the present study did find cognitive flexibility to be associated with media multitasking ability, in the sense of recall of information from a media multitasking situation. Of the cognitive flexibility tasks used, better performance on the Wisconsin Card Sorting Task, Phonetic fluency and Semantic fluency tasks was associated with better media multitasking ability. Therefore, from the evidence the present study provides we can postulate a possible role for cognitive flexibility in supporting individuals' ability to media multitask. Thus, the ability to adapt one's way of thinking and alternate between varying mental sets is associated with the ability to recall more information from a media multitasking situation.

Within the present study, fluency tasks were utilised to assess cognitive flexibility, based on Diamond's (2013) theory of executive function. Performance on these tasks was found to be significantly associated with media multitasking ability. However, it is important to consider the magnitude of the associations as correlations would be classified as small to medium (Cohen, 1992). Therefore, it may be the case that cognitive flexibility has a role in individuals media multitasking ability to a greater extent than other executive functions, although that role may be moderate. Nonetheless, considering the significant association and the novel use of these tasks (to assess cognitive flexibility), the present study not only demonstrates a role of cognitive flexibility in being able to media multitask, but indicates a role for access to semantic memory. Certainly with most executive function tasks there is an element of task impurity (see Snyder et al., 2015) and fluency tasks have previously been shown to index access to semantic memory (Fisk & Sharp, 2004) as well as verbal functioning in general (Memisevic et al., 2017a). However, outside of the media multitasking literature they have been commonly used to assess cognitive flexibility based on the perceived demand they place on the varying elements of cognitive flexibility inclusive of flexible categorisation (see Amunts et al., 2020; Zmigrod et al., 2019). This is unsurprising given that media multitasking ability was indexed by an individuals' ability to recall information from a media multitasking situation.

In this regard, it is interesting that no significant association was found between media multitasking ability and performance on inhibition and working memory tasks, given that cognitive flexibility is purported to be underpinned by both inhibition and working memory (Diamond, 2013). One possibility is that the demand placed on cognitive flexibility in a media multitasking situation of this nature is far greater than that of inhibition or working memory, and thusly inhibition and working memory are involved but to a lesser extent. Which may certainly be reflected in the magnitude of the correlations found, which were small to medium for the phonetic fluency, semantic fluency and WCST tasks, indicating moderate involvement of cognitive flexibility in real-world media multitasking. Additionally, from the supplementary analysis of inhibition tasks, performance on neutral, null and incongruent trials of the number flanker task were found to be weakly significantly correlated with media multitasking, but notwithstanding a Bonferroni correction, whilst those on the arrow flanker task were not. It may be the case that although the flanker tasks are proposed to assess attentional control, they too can be subject to task impurity issues (see Snyder et al., 2015) and varying difficulty. From observing the mean reaction times for each type of trial on the arrow flanker and number flanker task it seems to be the case that overall response times on the arrow flanker task trials were quicker with less variance than responses on the number flanker task trials. Certainly, research suggests that we are more primed to attend to arrows and consequently respond quicker when required to press an arrow key in response (Ridderinkof et al., 2020; Xie et al., 2017). Therefore, it is possible that participants found this task easier than the other flanker task, resulting in less variance that may explain the non-significant association with media multitasking ability. The number flanker task could be said to be more difficult, given that numbers are symbols that are not as automatically associated (in comparison to the arrows) with the response key to be pressed. Indeed, it is important to reiterate that cognitive flexibility as a construct is underpinned by attentional control (Diamond, 2013), and is considered by some to be a higher order cognitive control process that can facilitate attentional switching in the way it changes goals and task sets (Braem & Egner, 2018). This aligns with the proposal that the present findings indicate a possible role of attention and working memory in media multitasking ability in our scenario, but that there was a stronger relationship with our measures of cognitive flexibility.

It is important to explore the possible reason for this association between media multitasking ability and cognitive flexibility. In relation to the task-switching paradigm, Kazakova et al. (2015) propose a differentiation between conceptual attention switching and visual attention switching. It is suggested that media multitasking places greater demand on being able to shift conceptually between different media streams, in comparison to the demand placed on visual attentional switching (relocation of gaze). The demand is deemed greater in that the different mediums each have different, specific processing requirements, sometimes referred to as conceptual sets (Schneider & Logan, 2014), which then need to be switched between. Thus, not only are participants switching their gaze from one location to another but are mentally switching between varying conceptual sets. Within the present study the media situation consisted of a reading task, video and instant messages and thus was conceptually taxing, requiring shifting between the conceptual set of reading comprehension, video comprehension and responding to instant messages (which includes elements of reading comprehension amongst other processes). The aspect of conceptual attention shifting is the fundamental similarity underlying the requirements of media multitasking and the fluency tasks and the WCST. The fluency tasks can be said to tax conceptual switching, as switching between mental sets, sometimes referred to as task set re-configuration, is necessary to generate words belonging to a specific category or beginning with a specific letter e.g. going from one construct such as animals then moving on to food or plants (Amunts et al., 2020). The WCST is also conceptually taxing as it requires the recognition of a change in a visual stimulus based on conceptual differences, either colour, shape or number of shapes, along with the collection of feedback to recognise a change in a sorting rule (Lange et al., 2017). The fluency and the WCST are slightly different in their taxing of cognitive flexibility, in that fluency tasks also place a demand on language processing (Whiteside et al., 2016) whilst the WCST places demand on strategic planning, and involves the utilisation of feedback in conceptual changes (Gómez-Pérez et al., 2020). However, Amunts et al. (2020) propose that the tasks are similar in terms of the level of conceptual switching inclusive of task set re-configuration. Which is why an association such as that found in the present study may be expected. A further point to note, is that within Kazakova et al.'s (2015) study they found that media multitasking lead to lower levels of conceptual processing in a subsequent task. Thus, to effectively retain information from a media multitasking situation that requires high levels of conceptual processing, one must be able to effectively switch between conceptual sets (medium specific) and thus have higher cognitive flexibility. It may also be the case that associations with fluency tasks were found given the elements of language processing taxed by the specific mediums in the media multitasking scenario.

The present study indicates that individuals higher in cognitive flexibility make good media multitaskers, whilst also proposing the possible involvement of working memory or access to semantic memory, albeit the working memory association was non-significant following a Bonferroni correction, thus further research is needed. Certainly, previous research exploring real-world multitasking, such as Watson and Strayer (2010) has found specific executive function profiles for those who are considered good at multitasking (individuals able to multitask without incurring a decline in performance from single task to dual task performance, deemed super taskers), specifically, higher scores in executive attention. Whilst others suggest that working memory capacity in relation to attentional control can enable efficient multitasking (Gruszka & Necka, 2017) Thus, the study further proposes the importance of examining what or who makes a good media multitasker.

Additionally, the present study provides some elucidation as to associations found between media multitasking and academic performance, for which previous research has demonstrated media multitasking to have a negative impact on learning, during academic settings (as found by Wammes et al., 2019). Given the association between media multitasking ability and cognitive flexibility found in the present study, it is possible that one of the mechanisms by which media multitasking effects academic performance is through placing further demand on individuals' cognitive flexibility more so than the demand placed by the learning activity. Certainly, cognitive flexibility has been shown to be fundamental in different learning processes (Georgiou & Das, 2018; Stad et al., 2019). Indeed, Van der Schuur et al. (2020) specify that limited cognitive resources may be the mechanism by which media multitasking affects academic performance. More so in the short-term, as they found no support for this longitudinally, when investigating within-person academic performance and academic media multitasking across 3 time points over a period of 6 months. However, their study predominantly focused on academic attentional problems rather than cognitive flexibility. Thus, in summary, individuals who have poorer cognitive flexibility may be more impacted by media multitasking in academic settings, especially in the short term, and longitudinal research is needed.

5.1. Mood

Within the present study, state mood inclusive of arousal, anxiety and depression were measured across three experimental time points. In this regard, self-reported anxiety only increased following the completion of the executive function battery, whereas depression increased linearly across all experimental time points and self-reported arousal only decreased significantly after completion of the media multitasking situation. Thus, the findings indicate that media multitasking may alter mood in terms of reducing individuals' self-reported level of arousal. Trait anxiety and depression were not significantly associated with media multitasking ability, which contrasts with previous research showing high levels of self-reported media multitasking to be associated with trait anxiety (Becker et al., 2013; Seddon et al., 2018). Trait anxiety and depression scores were also not associated with executive function task performance.

An individual's tendency to feel anxious or depressed was not associated with their ability to media multitask measured in terms of remembering content from the session. However, it is likely that anxiety is a driving force to compel people to engage in media multitasking in the first place, considering the associations between anxiety and how frequently individuals media multitask (Becker et al., 2013; Seddon et al., 2018). Reinecke et al. (2017) found that a specific type of anxiety, fear of missing out, was a driving force for media multitasking with internet-based content. Future research may highlight other individual characteristics that are relevant to media multitasking ability. The present study utilised a sample of young adults, predominantly students, known to choose this form of behaviour and thusly the results can be said to be more specific to this population. Future research could examine media multitasking ability across varying groups of individuals, who differ in their choice to media multitask, and attempt to build a profile of individual differences that may be key in understanding individuals' ability to media multitask. Certainly, research examining frequency of media multitasking has also looked at personality (Luo & Liang, 2018) and is beginning to explore motivations.

5.2. Device manipulation

A novel manipulation of media multitasking by device was also included in the media multitasking situation within the present study. One condition consisted of media multitasking between two devices (desktop pc and tablet pc), whereas the other condition entailed media multitasking within a single device (desktop pc). The present study found no significant difference in the recall of information from a media multitasking situation, depending on device/devices used to media multitask. The effect size also being small suggests that, within real-world media multitasking, the number of devices may not be a critical determinant of the processing of information whilst accessing multiple media. This is notwithstanding the additional motor actions which may nevertheless increase the amount of time required to enact particular responses to media as here when required to respond to a message on a different device. Indeed, individuals in the between device condition took slightly longer to respond to instant messages simply due to the need to put down the tablet before typing their response into the computer. The magnitude of this difference was found to be medium (Cohen, 1992), suggesting that when individuals are media multitasking (in the wider population) with multiple devices, involving instant messages, it may unsurprisingly take them longer to respond to a message when there is a further element of motor involvement. Thus, considering the manipulation was representative of some of the different real-world media multitasking behaviours, and the magnitude of differences found, it can be said that there was no evidence that media multitasking using multiple devices was (or will be) more cognitively taxing than media multitasking within a single device.

5.3. Limitations

The novelty of the present study advances the media multitasking literature, however the design implemented still faces the same problem as other previous studies, that is, the issue of establishing cause and effect. The naturalistic and ecologically valid tasks used within the present study reveal an association between cognitive flexibility and media multitasking ability. However, it is not possible to determine whether cognitive flexibility facilitates media multitasking ability directly or whether another variable, not measured in the current study, explains the relationship. It is also conceivable that people with a long history of multitasking with media have improved their cognitive flexibility as a consequence. Certainly, in relation to long-term use of media, recent research highlights long term effects of video gaming on cognition, with early video game experience associated with increased cognitive control (inclusive of cognitive flexibility) and brain plasticity (Palaus, Viejo-Sobera, Redolar-Ripoll et al., 2020), for a review of the literature see Palaus, Marron, Viejo-Sobera et al. (2017).

Another limitation could be that of utilising recall to reflect media multitasking ability. The motivations individuals have for multitasking with media remains somewhat under-researched, and are likely to differ depending on the situation, and therefore the recall of information from a media multitasking situation may not be deemed the most important index of media multitasking ability in all cases. However, the present study specifically implemented a media multitasking situation of studious media multitasking. Therefore, it is logical to conclude that an individual media multitasking whilst studying would want to retain at least some of the information, therefore indicating that in this specific media multitasking scenario, retaining and recalling information from a session of media multitasking was an important component and reflective of media multitasking ability in the real world. Nonetheless, this might not be the case for other specific media multitasking scenarios, and thusly, future research should consider this in naturalistic explorations of media multitasking ability in other scenarios where retention is less central. Such research could implement eye tracking methods, as used by Kazakova et al. (2015), to elucidate the patterns of engagement with the material.

A further issue is the possibility of participants not engaging with the media in a multitasking manner. Before beginning the situation, participants were instructed to respond immediately to instant messages upon receiving them and to pay equal attention to each of the media (which they would be tested on). Despite instruction, participants may have focused more on one media stream than the other. However, non-compliance protocols were developed and implemented, in the sense that responses to questionnaires were checked to see whether they were below chance, however responses to both were well above chance, in light of multiple-choice options. Responses to instant messages were also examined, in the way of determining whether messages had been responded to straight away, for which a time frame of 1 min was used as a compliance cut off, given the time intervals of messaging. It was also important to ensure that none of the messages were unanswered before receiving the next message i.e., as to avoid a message as a prompt for responding to a message.

Another limitation arises from the use of two different reading texts in the media multitasking scenario. Although having some ecological validity since students may often read from multiple texts in a single study session, using different texts here may have introduced unnecessary variance in difficulty. During the pilot testing of materials to be used in the present study, no significant differences in comprehension performance of the reading texts emerged and thus the two texts were treated as a single text and presented in a fixed order. However, it is clear that in the study, participants answered correctly on fewer questions that were based on the second text. Given the fixed presentation order, it is not possible to determine whether this is due to the difficulty of the text, or a decreasing attentional focus with increased fatigue.

5.4. Implications and future research directions

To our knowledge, the present study is the first to examine the relationship between individual's ability to media multitask, in terms of retaining information from a media multitasking situation, in relation to executive functioning. Thus, it is the first to highlight the role of cognitive flexibility in being able to media multitask. Additionally, it also highlights a possible mechanism by which media multitasking may affect individuals' academic performance in terms of their learning, as the present study specifically utilised a studious media multitasking scenario. Given the limitation noted above about the potential impact of text difficulty, future research intending to examine media multitasking ability utilising a similar scenario may feel it pertinent to systematically manipulate the reading difficulty of texts presented to participants.

It is also important to consider the motivations that underlie media multitasking behaviour. Hwang et al. (2014) have explored the role of motivation, and found multitasking using the internet was driven by both enjoyment and information-seeking. Thus, it is possible that media multitasking involving listening to music, whilst instant messaging and internet shopping might have different motivations, compared to other combinations of media, with different information streams given priority. Certainly, Aagaard (2019) suggests that within multitasking there are task hierarchies, with priority given to one task over another. Thus, it might be worthwhile to examine different task hierarchies, for example a media multitasking scenario across groups, where each group is given the same multiple media to simultaneously engage with but have the priority media different for each group. Different combinations are likely to have different associations, in the sense that the level of demand on executive functions may vary by the types of media engaged with and the level of processing each requires (Segijn et al., 2019). Furthermore, the level of executive function and processing demand of a medium may certainly have a role in the individual's choice of engaging with other specific mediums simultaneously. Ralph et al. (2020) propose that individuals' choice to media multitask, referred to as volitional media multitasking, is modulated by task demands. This suggests that individuals are aware of the impact of media multitasking on task performance and that specific choices of media multitasking may be tactically decided. It would be worthwhile for future research to further explore naturalistic tasks involving media multitasking and include combinations of, and motivations for, various media behaviours. For example, instructions to prioritise one of the tasks should lead to improved retention of information from that task even in the face of distractions from other media. It would also be fruitful for future research to consider whether cumulative negative impacts on cognition may be a result of carrying out multiple sessions of media multitasking, and thusly examine multiple sessions of media multitasking using naturalistic tasks and an experimental design.

6. Conclusion

To summarise, cognitive flexibility is associated with media multitasking ability. Specifically, the ability to recall more information from a media multitasking situation is enabled by an individual's ability to better adapt their way of thinking and change between differing mental sets. Furthermore, media multitasking across multiple devices was not found to be any more cognitively demanding than media multitasking within a single device. These findings indicate the need for future research to explore the associations between executive functioning and media multitasking ability, implementing other specific media multitasking situations, whilst considering other characteristics that may influence individuals' ability to media multitask.

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CRediT authorship contribution statement

Alexandra L. Seddon: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, preparation, . **Anna S. Law:** Conceptualization, Methodology, Writing – review & editing, Supervision, Funding acquisition. **Anne-Marie Adams:** Conceptualization, Methodology, Writing – review & editing. **Fiona R. Simmons:** Conceptualization, Writing – review & editing.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chbr.2021.100068.

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