

Media Multitasking and Cognitive Control: A Systematic Review of Interventions

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Abstract

Extending from the increasing prevalence of media in personal, social, and work environments, research has indicated that media multitasking (i.e., engaging in more than one media or non-media activity simultaneously) is associated with changes in cognitive control and failures of everyday executive functioning. While more research is required to elucidate these associations, the emergent trend, while small, suggests a negative relationship between high levels of media multitasking and aspects of cognitive control. In response, researchers have called for studies investigating the remedial efficacy of interventions targeting the effects of media multitasking on executive functioning. To provide a foundation for such research this systematic review integrates current findings concerning such interventions. Four databases (Web of Science, Scopus, Academic Search Premier, and PsycINFO) were searched to identify relevant studies, producing 2 792 results. 15 studies met the eligibility criteria. At the time of review current interventions fall into three categories: awareness, restriction, and mindfulness. While some interventions have been effective at changing behaviour or cognitive outcomes, no single category contains interventions which, categorically, produced improvements in attention-related performance. Extending from this synthesis key research gaps are identified, with suggestions for future research proposed.

Keywords: Media Multitasking, Cognitive Control, Intervention, Systematic Review

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1. Introduction

As our personal, work and social contexts become filled with more and increasingly powerful mobile computing devices, our media consumption levels inevitably rise and our behaviour becomes characterised by continuous, uninterrupted processes of device-facilitated information retrieval, social interaction and entertainment. Adapting to and coping in this hyper-connected world has cultivated high-levels of *media multitasking*, i.e., “engaging in one medium along with other media *or* non-media activities” (Zhang and Zhang, 2012, p. 1883). Members of the net generation, in particular, have been shown to be high media multitaskers or *HMMs* (Judd and Kennedy, 2011). Rosen, Carrier, and Cheever (2013), for example, found that students averaged less than six minutes on a task before switching to a media-based activity. Indeed, it has been found that, among the current cohort of university students, a majority of media use involves multitasking to some extent. (Carrier, Cheever, Rosen, Benitez, and Chang, 2009; Judd, 2014; le Roux and Parry, 2017). Media multitasking, however, is not restricted to younger generations. Studies show that, for both scholars and knowledge workers, media multitasking is particularly prevalent (Bannister and Remenyi, 2009; Hassoun, 2012; Voorveld and van der Goot, 2013).

While numerous studies conducted in the past decade have found evidence of negative associations between media multitasking and aspects of cognitive control, others have found no link between these variables (see van der Schuur, Baumgartner, Sumter, and Valkenburg, 2015, for a review). Cognitive control is seen to function through the operation of a number of executive functions, including: *inhibition/filtering*, *working memory*, *flexibility/shifting*, and *attentional control*. It has been proposed that behavioural training, motivation, and repeated behaviours, like chronic media multitasking, can come to shape the operation of these functions through neuroplasticity (Dehaene and Cohen, 2007; Locke and Braver, 2008; Dux, Tombu, Harrison, Rogers, Tong, and Marois, 2009; Botvinick and Braver, 2015). One of the key factors characterising differential outcomes is the approach to measuring cognitive control. The pattern of results produced on the basis of self-reported measures indicates that frequent media multitasking is associated with diminished everyday executive functioning — those who media multitask more *perceive* themselves to be more distractible in everyday life. In performance-based assessments, however, the general trend is less clear. Some studies

have found negative associations (e.g., Ophir, Nass, and Wagner, 2009; Cain and Mitroff, 2011; Baumgartner, Weeda, Van Der Heijden, and Huizinga, 2014), others have found no significant relationship (e.g., Minear, Brasher, Mccurdy, Lewis, and Younggren, 2013), and some have even found a positive relationship between media multitasking and cognitive control (Alzahabi and Becker, 2013).

Despite these disparities the emergent trend across the methodological approaches adopted suggests a negative relationship between high levels of media multitasking and cognitive control. Uncapher, Lin, Rosen, Kirkorian, Baron, Bailey, Cantor, Strayer, Parsons, and Wagner (2017, p. 63) support this interpretation, noting that, despite the methodological challenges and inconsistencies, the “weight of the evidence overall points to HMMs demonstrating reduced performance in a number of cognitive domains relative to LMMs” (low media multitaskers). It seems, specifically, that media multitasking is, for some individuals, associated with a broader distribution of attention and increased processing of irrelevant stimuli. Whether this relationship is due to individual differences at strategic or trait level, biases in attentional distribution, or deficits resulting from the outsourcing of cognitive control to media, there are implications for performance across numerous domains. In the face of increasingly mediated personal and work environments, the management of attentional demands and control over the direction of cognitive processes emerge as key challenges (Baumgartner and Sumter, 2017). In response, researchers have called for studies investigating the remedial efficacy of interventions targeting the effects of media multitasking (Uncapher et al., 2017).

At present, responses to such calls can, broadly, be classed along two lines: the enhancement of cognitive control or the modification of behaviour. For the first, attempts to improve cognitive control have not necessarily focused explicitly on media multitasking. Rather, results from interventions seeking to improve cognitive functioning, across a number of domains, have been applied to media multitasking (Ie, Haller, Langer, and Courvoisier, 2012; Levy, Wobbrock, Kaszniak, and Ostergren, 2012; Gorman and Green, 2016). For behaviour modification, a number of interventions have been proposed, including: increasing metacognition, decreasing boredom, limiting the accessibility of media multitasking, reducing media-related anxiety, and abstaining from media use (Gazzaley and Rosen, 2016, p. 217).

While some research suggests the prescriptive value of these approaches (e.g., Irwin, 2017; Kushlev, Proulx, and Dunn, 2016; Mark, Iqbal, and Czerwinski, 2017), little authoritative work has been completed to substantiate their effectiveness.

1.1. The present Study

The objective of the present study was to systematically review the current state of research concerning interventions targeting changes in cognitive control or related performance associated with media multitasking. Two primary objectives directed the study. Firstly, the mixed results reported in studies of the association between media multitasking and cognitive control imply that there remains a degree of uncertainty regarding the exact nature of this relationship. A systematic review of the effectiveness of proposed interventions has the potential to produce further insight into the dynamics of this association by identifying how behavioural or other changes effect cognitive control outcomes. This may address some of the observed gaps in the literature concerning the relationship between these two variables. Our second objective was to provide a useful foundation for future studies seeking to develop interventions targeting media multitasking and attention-related outcomes. It will enable, firstly, an evaluation of the current state of research concerning media multitasking related interventions, secondly, an integration of related research from numerous domains (e.g., Psychology, Media Studies, Information Science) and, thirdly, inform the development of subsequent interventions in this regard. To guide the review four objectives were outlined:

- Determine the nature of interventions employed in this regard thus far.
- Determine whether a particular type of intervention has been shown to be effective at changing behaviour.
- Determine whether such changes in behaviour had any effect on outcomes associated with cognitive control.
- Identify the key gaps in research in this regard and, on this basis, provide guidelines for future studies.

2. Method

A systematic review methodology was applied in accordance with the *Preferred Reporting Items for Systematic Reviews and Meta-Analysis* (PRISMA) guidelines (Liberati, Altman, Tetzlaff, Mulrow, Gøtzsche, Ioannidis, Clarke, Devereaux, Kleijnen, and Moher, 2009). The sections which follow outline this methodology, beginning with a description of the eligibility criteria for inclusion, followed by the search strategy, the data extraction and management procedures and, finally, the approach to data analysis.

2.1. Eligibility Criteria

The unit of analysis for the review was a *study* as defined by Littell, Corcoran, and Pillai (2008, p. 67) — an “investigation that produces one or more reports on a sample that does not overlap with other samples”. In this way, no bias towards studies producing multiple reports was introduced. Studies were included if they (i) considered nonclinical individuals who are not children, adolescents or the elderly as their units of analysis; (ii) investigated behavioural change interventions targeting either media multitasking or related behaviours, beliefs, attitudes, or experiences for those whose prior media multitasking level was either known or unknown; (iii) adopted study designs comparing outcomes for performance under treatment conditions to performance under non-treatment conditions (i.e., a control condition or an alternative treatment condition); (iv) measured cognitive control outcomes through self report measures, performance-based assessments, or measures of performance relying on executive functioning; (v) are reported in English; (vi) are either published or unpublished (in the case of grey literature); and (vii) were conducted between January 2006 and February 2018. This time frame was adopted because 2006 is the year in which the term ‘media multitasking’ was first used in research literature (Foehr, 2006). Because the review specifically targeted behavioural interventions, other forms of intervention, for instance psychiatric or pharmaceutical, were excluded from consideration. Studies considering children or the elderly were excluded due to ongoing neurodevelopmental changes and related concerns about generalisability. Similarly, studies explicitly targeting clinical populations or populations with known neurodevelopmental disorders (e.g., ADHD) were excluded.

2.2. Search Strategy

Having established the eligibility criteria for inclusion, a sample of eligible studies was acquired through a systematic search strategy comprising of four phases. The first phase involved the development of an automated search strategy targeting four bibliographic databases (Web of Science –WoS, Scopus, Academic Search Premier –ASP, and PsycINFO). A generic search string was developed and adjusted to fit the specific notational requirements of each database. The string consisted of four clauses each containing a category of terms. These categories combined synonyms related to a particular concept through the use of the OR operator. The search was then narrowed by combining these categories with the AND operator. For a result to be returned, it had to contain at least one term from each category. The first category covered the concept media and related synonyms; the second related to behaviour and included synonyms for the word ‘multitasking’; the third covered concepts relating to cognitive outcomes; and the fourth referred to interventions and improvements in these outcomes. The full search strings (applied to the title, abstract, and keywords fields) for each of the four databases are provided below:

Web of Science: Results n = 889 (15/02/2018)

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TS=((media OR smartphone OR laptop OR "social media" OR
  computer OR digital* OR phone) AND (multitask* OR switching
  OR task-switch*) AND (cognit* OR attention* OR distract* OR
  "cognitive control" OR "executive function*" OR focus*) AND
  (change OR improve* OR interven* OR mitigat* OR enhance*))
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Scopus Results: n = 1420 (15/02/2018)

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TITLE-ABS-KEY((media OR smartphone OR laptop OR computer OR
"social media" OR digital* OR phone) AND (multitask* OR
  switching OR task-switch*) AND (cognit* OR attention* OR
  distract* OR "cognitive control" OR "executive function*" OR
  focus*) AND (change OR improve* OR intervention OR mitigat*
  OR enhance*)) AND PUBYEAR > 2006 AND LANGUAGE(english OR
  afrikaans)
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Academic Search Premier Results: n = 266 (15/02/2018)

media OR smartphone OR laptop OR "social media" OR computer OR
digital* AND multitask* OR switching OR task-switch AND
cognit* OR attention* OR distract* OR "cognitive control" OR
"executive function*" OR focus* AND change
OR improve* OR mitigate* OR enhance*

PsycINFO Results: n = 235 (15/02/2018)

media OR smartphone OR laptop OR "social media" OR computer
OR digital* AND multitask* OR switching OR task-switch AND
cognit* OR attention* OR distract* OR "cognitive control" OR
"executive function*" OR focus* AND change OR improve* OR
mitigate* OR enhance*

The second phase of the search strategy involved manually searching three relevant journals and two further academic repositories for studies inadvertently missed by the automated procedures. The three journals —*Computers in Human Behaviour*, *Journal of Experimental Psychology: Human Perception and Performance*, and *Attention, Perception, & Psychophysics*— were selected on the basis of their coverage of related experimental studies considering relationships between media multitasking and cognitive control. The repositories —*ProQuest Dissertations & Theses Global* and the *Association for Information Systems (AIS) Electronic Library (AISEL) conference database*— were selected based on their indexing of relevant conference proceedings and dissertations not necessarily indexed in the other locations. Finally, these search procedures were supplemented by examining, firstly, the reference lists of those reports returned by the first three phases of the search strategy and, secondly, reports which cited those in this corpus.

2.3. Data Extraction and Management

One author implemented the search strategy by downloading the bibliographic information and abstract for each result into reference management software (Zotero version 4). Any duplicates present were noted and removed. The titles and abstracts of the remaining

reports were then screened against the eligibility criteria for inclusion in the review by the first author. The full-texts of those considered to be eligible at this stage were then further assessed to determine inclusion. In addition to this, a sample of these reports were independently screened by the second author. If ambiguities remained about the eligibility of a study, input was sought from an external reviewer within the same academic department. Guided by the primary objectives of the review, the first author extracted data from the included studies. A data extraction form, based on the checklist provided by Higgins and Green (2006, p.157), was developed for this purpose, focusing extraction on the following study components: study design, intervention details, sample composition, implementation details, behaviour change outcomes, cognitive control outcomes, task-performance related outcomes, moderation analyses, limitations, and risk of bias. The extracted data were verified by the second author.

2.4. Data Analysis Procedures

Given the heterogeneity of study objectives, interventions, comparisons, and outcomes considered in this review, meta-analysis was not possible. Consequently, a narrative synthesis methodology was adopted. This method involves a textual approach to synthesis which is particularly well suited to reviews where implementation details and effectiveness are areas of concern (Popay, Roberts, Sowden, Petticrew, Arai, Rodgers, Britten, Roen, and Duffy, 2006, p. 5). In view of the objectives of the review, the purposes of this analysis was to determine, firstly, the nature of interventions applied, secondly, the efficacy of these interventions and, finally, details of their implementation. In accordance with Popay et al. (2006), the extracted data were categorised on the basis of the intervention employed. For this purpose the *behaviour change wheel* (BCW) developed by Michie, van Stralen, and West (2011) was adopted. The BCW describes seven categories of policies, nine intervention functions, and six sources of behaviour. With regards to efficacy, analysis concerned outcomes for both behaviour and cognitive control, as well as performance ostensibly related to executive functioning. Following this, analysis concerned specific moderating factors considered in the studies reviewed. Finally, the methodological quality of the primary studies reviewed was appraised.

3. Search Results

The search strategies produced a total of 2 792 results. After duplicates ($n = 597$) were discarded the titles and abstracts of the remaining unique results ($n = 2195$) were screened. Ineligible records ($n = 2166$) were removed before the full-texts of the remaining reports ($n = 29$) were considered. This process was conducted by the first author, with separate assessment by the second. Records that were agreed to be ineligible based on the stated inclusion criteria ($n = 19$) were removed. These screening procedures produced a sample ($n = 10$) upon which forward and backward searches were conducted. The final sample, supplemented by the results of these searches ($n = 2$), was then established ($n = 12$). Figure 1 summarises this process.

4. Included Studies

While the search procedures identified 12 records, a total of 15 studies were included in this review. Hartanto and Yang (2016), Whittaker, Kalnikaite, Hollis, and Guydish (2016), and Yildirim (2017) reported two studies involving non-overlapping samples in their reports, respectively. Each study is identified by a unique ID number (ST- x). Table 1 presents a summary of the sample providing study IDs, reference details, type, study design, and an overview of the sample considered. Seven of these studies were published in peer-reviewed conference proceedings, five were published in peer-reviewed journal articles, and three were reported in PhD theses. While studies that were *conducted* between January 2006 and February 2018 were eligible for inclusion, the first report included in this review was *published* in 2012. The majority of studies included were published in 2016 (46.67%) while 26.67% were published in 2017. At the time of review none had been published in 2018.

Across the sample two study designs were adopted —between-subjects (53.33%) and within-subjects (46.67%). For studies adopting between-subjects designs the mean sample size was 73.86 ($SD = 45.20$). Across these eight studies seven involved samples of students in either the United States (Adler, Adepu, Bestha, and Gutstein, 2015; Irwin, 2017; Ie et al., 2012; Yildirim, 2017, ST-1, ST-5, ST-7, ST-14, ST-15) or Singapore (Hartanto and Yang, 2016, ST-3, ST-4). Levy et al. (2012, ST-8) considered workers employed in human-resources

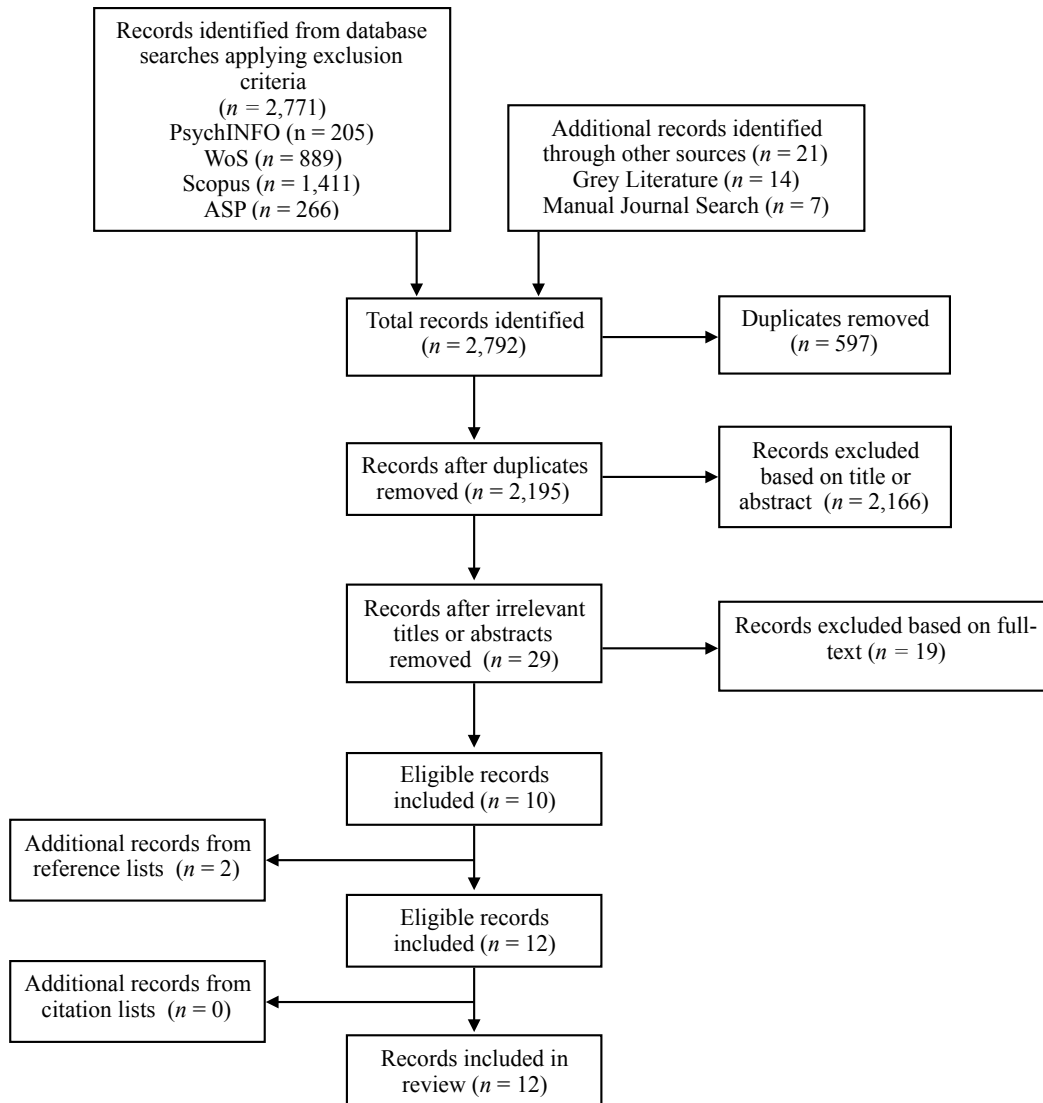


Figure 1: A PRISMA flowchart for study inclusion

jobs in the United States. For studies adopting within-subjects designs the mean sample size was 35.71 ($SD = 18.67$). Of these seven studies, one involved a sample of students in the United States (Gorman and Green, 2016, ST-2) and one (Whittaker et al., 2016, ST-13) did not specify the country of origin for their sample of students. Three involved participants who worked in an office environment in the United States (Mark, Volda, and Cardello, 2012; Mark et al., 2017; Pielot and Rello, 2016, ST-9, ST-10, ST-11), while two considered both office workers and students. Jeuris and Bardram (2016, ST-6) involved such a sample in Denmark, while Whittaker et al. (2016, ST-12) did not indicate in which country their sample was located. Overall, of the 15 studies, eight considered a student population and four a population involved in knowledge work. Only three studies (Whittaker et al., 2016, ST-12), Jeuris and Bardram (2016, ST-6), and Ie et al. (2012, ST-7) considered a sample comprised of both students and knowledge workers. With the exception of two studies conducted in Singapore, one in Denmark, and two which did not specify a country, the remaining 10 studies were conducted in the United States. Finally, across the 15 studies the mean sample size was 56.07 ($SD = 39.49$).

5. Analysis and Findings

The sections which follow outline the analysis and findings of the review. They commence with a categorisation of studies based on intervention type, followed by the efficacy of the interventions in terms of both behaviour change and cognitive outcomes. The analysis of individual differences is presented in the outcomes, followed by an assessment of the quality of evidence provided by this review.

5.1. Categorisation of Interventions

After analysis of the 15 studies, three intervention categories emerged — *awareness* (20%), *restriction* (46.67%), and *mindfulness* (33.33%). Additionally, the function of each intervention was classed according to the BCW framework and its duration. Descriptions of the interventions within each category are provided in the following sections.

Table 1: Summary of studies included in the review

ID	Reference	Type	Study Design	n	Intervention	Duration ^a
ST-1	Adler et al. (2015)	CP	Between-subjects	66	Awareness	Brief
ST-2	Gorman and Green (2016)	JA	Within-subjects	42	Mindfulness	Brief
ST-3	Hartanto and Yang (2016)	JA	Between-subjects	86	Restriction	Brief
ST-4	Hartanto and Yang (2016)	JA	Between-subjects	66	Restriction	Brief
ST-5	Irwin (2017)	T	Between-subjects	38	Restriction ^b	Long
ST-6	Jeuris and Bardram (2016)	JA	Within-subjects	16	Restriction	Brief
ST-7	Ie et al. (2012)	JA	Between-subjects	75	Mindfulness	Brief
ST-8	Levy et al. (2012)	CP	Between-subjects	39	Mindfulness	Long
ST-9	Mark et al. (2012)	CP	Within-subjects	13	Restriction	Short
ST-10	Mark et al. (2017)	CP	Within-subjects	31	Restriction	Long
ST-11	Pielot and Rello (2016)	CP	Within-subjects	30	Restriction	Short
ST-12	Whittaker et al. (2016)	CP	Within-subjects	61	Awareness	Short
ST-13	Whittaker et al. (2016)	CP	Within-subjects	57	Awareness	Short
ST-14	Yildirim (2017)	T	Between-subjects	177	Mindfulness	Brief
ST-15	Yildirim (2017)	T	Between-subjects	44	Mindfulness	Brief

Note. Type: CP = peer-reviewed conference proceedings, JA = journal article, and T = PhD thesis.

^a For duration an intervention was classified as brief if it took place in a single session, typically less than an hour. Short refers to interventions taking place during a single week, and long refers to those occurring over a period longer than a week.

^b The primary function of this intervention was restriction. It did, however, also incorporate elements of awareness as a secondary component.

5.1.1. Awareness Interventions

Three studies considered interventions employing awareness of media use, task-switching, or task importance as methods of behaviour change. One intervention, exemplifying the persuasion function in the BCW, generated popup alerts to remind participants to return to a primary task whenever they engaged in media multitasking while studying (Adler et al., 2015). Whittaker et al. (2016) assessed two awareness interventions exemplifying the education function. In ST-12 an application tracked and displayed participants' computer-based activity across different applications for a period of two days. In ST-13, in addition to this automatic tracking, the researchers required a subset of participants to use a diary to log their activity for set intervals throughout the work day. Michie et al. (2011) suggest that education interventions operate on the psychological capability and reflective motivation components of behavioural initiation. These interventions aimed to improve metacognition with regards to media multitasking and, as a consequence, alter the frequency of this behaviour and bring about changes in attentional allocation strategies.

5.1.2. Restriction Interventions

Seven studies considered interventions in which access to media was restricted either through separation from a device or through the restriction of access to certain activities or stimuli. In the BCW framework restriction interventions operate through the provision of rules (Michie et al., 2011). Such rules serve to reduce the opportunity to engage in a behaviour. In this case, restricting access to certain media was intended to reduce media multitasking behaviour and increase instances of single-tasking with media. In two studies Hartanto and Yang (2016) assessed interventions in which participants either relinquished their smartphones during a single session, or they activated silent, non-vibrating modes on their devices. Similarly, Pielot and Rello (2016) required participants to disable notifications across all media for a single day. In contrast to these interventions focusing on separation, Jeuris and Bardram (2016) developed an intervention in which different computer-based tasks were assigned to dedicated virtual workspaces. Within a single workspace only the applications associated with a particular task were available to a user. In this way, users were restricted from switching between activities. To switch a user needed to change to a new

virtual workspace. Mark et al. (2012) required participants to restrict all email activity for a period of five days. Two studies assessed interventions over longer periods of time. Mark et al. (2017) utilised software to restrict participants' access to off-task websites during work hours. Irwin (2017) designed an intervention requiring restriction of access to media for 25 days—a 'media diet'. The diet involved a structured procedure during which participants created specific plans for restricting their media use. These plans involved a target of reducing use by at least one hour per day and a series of 'if-then' statements guiding behaviour with media. Additionally, the intervention incorporated an awareness aspect, with participants tracking their media-related behaviour three times a day. As an alternate treatment half of the participants ($n = 19$) tracked their behaviour, without restricting it.

5.1.3. *Mindfulness Interventions*

Mindfulness has variously been understood as a mental state, a trait, and a practice (Brown, Ryan, and Creswell, 2007). Creswell (2017, p. 495) describes mindfulness as a process of "openly attending, with awareness, to one's present moment experience". Mindfulness interventions, accordingly, endeavour to cultivate greater attention to and awareness of one's current state, empowering an individual to enact a greater degree of control over their actions (Langer, 1989). Such interventions function through the enablement construct of the BCW framework. Mindfulness practices enable psychological capabilities to abstain from multitasking, support the development of automatic motivation to engage in focused use of media and, when faced with opportunities, enable individuals to consider their actions in light of their goals. Five studies in the review applied mindfulness practices to media multitasking. Four of these studies considered brief interventions involving short mindfulness exercises and one assessed a long-term intervention in which participants received training in mindfulness practices. A key factor distinguishing these interventions from the others considered is their objectives. In attempting to enhance participants' psychological capabilities such interventions targeted the mitigation of effects associated with media multitasking and not necessarily the behaviour itself. Ie et al. (2012) assessed two brief mindfulness interventions requiring participants to engage with a series of text-based exercises for a 20-minute period. Both Gorman and Green (2016) and Yildirim (2017, ST-14, ST-15) employed brief mindful-

ness interventions in which participants listened to 10-minute guided mindfulness recordings requiring them to focus their attention by anchoring it to their breathing patterns. In contrast to these brief interventions, Levy et al. (2012, ST-8) required participants to attend weekly mindfulness training sessions for a period of 8-weeks. Additionally, participants were provided with exercises to practice in their own time.

5.2. Intervention Efficacy

The next stage of analysis concerned the efficacy of these interventions in terms of changes in behaviour and outcomes related to cognitive control. Given the differences in outcomes reported, measures employed and scales utilised, a standardised mean difference (SMD) was calculated to enable comparisons at a high level. For studies adopting between-subjects designs the SMD or *Cohen's d* was calculated as the mean difference between groups divided by the pooled standard deviation of the groups (see Equation 1; Cohen, 1988).

$$d = \frac{M_1 - M_2}{\sqrt{\frac{(n_1-1)SD_1^2 + (n_2-1)SD_2^2}{n_1+n_2-2}}} \quad (1)$$

For studies adopting within-subjects designs the SMD was calculated as the mean difference between treatment and control conditions divided by the average standard deviation of both scores (see Equation 2; Lakens, 2013).

$$d = \frac{M_1 - M_2}{\frac{SD_1 + SD_2}{2}} \quad (2)$$

Where possible the SMD was calculated from reported sample sizes, means and SDs. If these were not reported, *F* statistics or *t*-tests were used for this purpose. Cohen (1988) suggests that effect sizes should be interpreted as small ($d = 0.2$), medium ($d = 0.5$) and large ($d = 0.8$). Lipsey and Wilson (2001), however, suggest caution. A small effect may still have meaningful practical consequences. The SMD simply reflects the effect of an independent variable (in this case an intervention) in terms of standard deviations. Primarily, in this study, as Lakens (2013) suggests, these standardised effect sizes allowed for meta-analytic comparisons to be made about the efficacy of the interventions considered, irrespective of

Table 2: Outcomes, measures and effect sizes for awareness interventions

ID	Outcome	Measure	Effect Size ^a [95% CI]
ST-1	Performance	Multiple choice quiz	<i>ns</i>
ST-12	Multiple ^b	Interviews	n/a ^c
ST-13	Focused Attention	Custom: attention strategies	-0.61 [-0.08, -1.14]
ST-13	Focused Attention	Custom: work interruption	<i>ns</i>
ST-13	Multitasking	Custom: multitasking	0.66 [0.13, 1.19]
ST-13	Multiple ^b	Exit survey	n/a ^c

^a Main effect size of study condition represented by Cohen's *d*.

^b Multiple outcomes relating to behaviour, cognition, attitudes and beliefs were considered.

^c It was not possible to calculate the effect size based on the provided information.

the measurement scales used. To follow, for each intervention category, efficacy in terms of behaviour changes and cognitive outcomes are considered.

5.2.1. Awareness Interventions

All three studies employing awareness interventions considered behavioural and cognitive outcomes. While media use was measured through automatic tracking procedures, outcomes related to cognitive control were assessed through custom measures, quizzes or interviews. These outcomes included focus-based performance, focused attention and multitasking ability. A summary of the outcomes considered, measures used, and effect sizes found is presented in Table 2.

Adler et al. (2015) found that reminders to return to a primary task did not reduce switches between browser tabs. Rather, they found that switches increased when reminders were issued. Despite this, the effect on performance was non-significant. Participants who received reminders to remain on-task did not perform any better than those who did not. While these reminders may have increased switches, evidence from an assessment of a more unobtrusive intervention suggests that increasing metacognition with regards to media multitasking is associated with behaviour changes. In ST-12 Whittaker et al. (2016) found that awareness of application usage reduced the total use-time¹ across all applications by 28%,

¹In this study general use was considered to involve media multitasking.

a calculated intermediate effect size of $d = 0.59$. Specifically, awareness reduced time spent browsing by 21% ($d = 0.60$), using social media by 44% ($d = 0.53$), and email by 30% ($d = 1.20$). The change in use-time for work-related applications (e.g., word processing, spreadsheet software, document reading) was non-significant. Through a series of semi-structured interviews, Whittaker et al. (2016) found that participants considered themselves to have a greater command over the allocation of their attention when they were made aware of their behaviour with media. In ST-13 Whittaker et al. (2016) replicated the behaviour-change results of ST-12. While significant, the effect size ($d = 0.37$) was small. Again, awareness reduced social media use ($d = 0.76$) and email ($d = 0.77$), while not effecting use of work-related applications. In terms of cognitive control, awareness of media use negatively affected participants' personal strategies for remaining on task, had no significant affect on time on task, but positively affected perceptions of multitasking abilities. Where significant, the effect sizes were moderate. Following the intervention participants in both conditions reported that an awareness of their media use supported them in maintaining allocation of their attention to task-related activities. While participants reported improvements in concentration, as was the case with Adler et al. (2015), those in the manual logging procedure felt that this task presented as a distraction itself.

Overall, the evidence in support of awareness interventions is inconclusive. Only three studies have considered the effect of such interventions on behaviour and cognitive control. While the efficacy of such interventions has been assessed on both student and knowledge worker samples, no assessment has taken place over a period longer than two days. The long-term sustainability of these interventions is unknown. At present, these findings indicate that, when it is not perceived as a distraction itself, provision of information pertaining to media multitasking is associated with changes in how individuals structure their time when using a computer. Whether such results hold across other media is unknown at this stage. These findings indicate that improving metacognition with regards to media multitasking can empower individuals to regulate their behaviour and, as a result, maintain allocation of attention to task-related activities. As Whittaker et al. (2016) note, further work is required to determine if goal-specific information would have a greater effect on media multitasking. Finally, while interviews indicate that, in the short-term, awareness improves attentional

allocation, the direct effect of such interventions on cognitive control has not been assessed through standardised measures.

5.2.2. *Restriction Interventions*

Of the seven studies assessing restriction interventions three evaluated outcomes related to both behaviour and cognition (e.g., Mark et al., 2012; Pielot and Rello, 2016; Irwin, 2017, ST-9, ST-11, ST-5), while four enforced media-related restrictions to isolate cognitive control outcomes (e.g., Hartanto and Yang, 2016; Jeuris and Bardram, 2016; Mark et al., 2017, ST-3, ST-4, ST-6, ST-10). Changes in media-related behaviour were assessed through both automatic and manual procedures. For instance, Mark et al. (2017) utilised computer-logging software to track participants' behaviour on their computers, while Pielot and Rello (2016) conducted semi-structured interviews with participants and Irwin (2017) considered post-experiment estimates, experience-sampling data and data from pre- and post-measures of media multitasking. For cognitive control outcomes, across the sample, both performance-based and self-report scales were used. Outcomes considered include: cognitive flexibility, working memory, inhibitory control, and attention. Additionally, the combined performance of the executive functions was assessed in terms of distraction, productivity, self-control and task performance. A summary of the outcomes considered, measures used, and effect sizes found is presented in Table 3.

In the first of the three studies reporting on behaviour change outcomes Mark et al. (2012) found that, when email activity was restricted, the duration of time allocated to other media activities increased. The effect size of this difference, while significant, was small ($d = -0.06$). For multitasking, restriction significantly increased the duration of time allocated to each window, with a mean of 81.81 seconds ($SD = 27.02$) at baseline to a mean of 143.73 seconds ($SD = 51.27$) when email was restricted ($d = 1.51$) and decreased the frequency of switches between windows from a mean of 36.09 ($SD = 10.99$) to a mean of 18.73 ($SD = 7.51$) ($d = 1.85$). Pielot and Rello (2016) presented two findings in this regard. First, participants felt that they forgot to attend to their phones for an extended period of time to a greater extent when notifications were restricted — $M = 3.5$ ($SD = 1.2$)— than when they were not — $M = 3.1$ ($SD = 1.39$). The effect size of this change, however, was

Table 3: Outcomes, measures and effect sizes for restriction interventions

ID	Outcome	Measure	Effect Size ^a [95% CI]
ST-3	Cognitive Flexibility	CSST- efficiency	-0.93 [-1.38, -0.48]
ST-3	Cognitive Flexibility	CSST- accuracy	<i>ns</i>
ST-4	Working Memory	Rotation-span task	0.51 [0.00, 1.01]
ST-4	Inhibitory Control	Stroop Task - RT	-0.54 [-1.03, -0.49]
ST-4	Inhibitory Control	Stroop Task - accuracy	0.58 [0.09, 1.08]
ST-5	Attention	ANT - executive control	<i>ns</i>
ST-5	Attention	ANT - alerting	<i>ns</i>
ST-5	Attention	ANT - orienting	<i>ns</i>
ST-5	Self-Control	BSCS	<i>ns</i>
ST-5	Attention	ARCES	<i>ns</i>
ST-6	Task Productivity	Computer-based task-related	<i>ns</i>
ST-6	Task Accuracy	Computer-based task-related	<i>ns</i>
ST-9	Focus	Semi-structured interviews	n/a ^b
ST-10	Focused Attention	FI subscale of the CA scale	0.51 ^c
ST-10	Productivity	Custom Measure of Productivity	0.62 ^c
ST-11	Distraction	Custom Measure “I felt distracted”	-0.66 [-1.18, -0.14]
ST-11	Productivity	Custom Measure “I felt productive”	0.58 [0.06, 1.10]

Note. CSST = colour-shape switching task, ANT = attention network task, BSCS = brief self-control scale; ARCES = attention-related cognitive errors scale, FI = focused immersion, CA = cognitive absorption.

^a Main effect size of study condition represented by Cohen’s *d*.

^b It was not possible to calculate the effect size based on the provided information.

^c These effect sizes were computed according to the formula for paired t-tests provided by Rosenthal (1991).

low ($d = 0.31$). Despite this, reports of turning on a device to check for missed notifications increased when notifications were restricted — $M = 3.5$ (0.97) versus $M = 3.1$ (1.20). Again, the effect size ($d = 0.37$) was low. While these two findings are seemingly contradictory, the effect sizes suggest low practical significance. Irwin (2017) evaluated participants' media use through a number of different measures. First, from post-intervention estimates it was shown that those in the media diet condition felt that they were successful at restricting their media use. Participants in the media diet condition estimated that they reduced their media use more so than those in the tracking only condition ($d = 1.13$). On average, however, they failed to reach the reduction goal of 60-minutes per day. In terms of changes in habitual media use, while the effect of condition was non-significant, the effect of time (the duration of the intervention) was significant ($d = 1.08$). Participants in both conditions reduced their habitual media use following the intervention. For media multitasking, while there was no significant effect of condition, the effect of time was large ($d = 1.40$). Participants in both conditions reported reductions in their media multitasking. Without the presence of a control group it is not possible to confirm whether these changes occurred as a result of the interventions or whether external factors were responsible.

While only three studies reported behavioural outcomes, all seven studies reported outcomes for measures related to cognitive control. Three studies only considered performance-based outcomes (ST-3, ST-4, ST-6), two only considered self-reports (ST-10, ST-11), and one considered both (ST-5). Across the seven studies 17 outcomes related to cognitive control were considered. Six of these were evaluated by means of self-report scales (three standardised, three custom measures), one through interview procedures, and 10 by means of performance-based measures (eight standardised, two custom tasks).

In terms of performance-based outcomes Jeuris and Bardram (2016) found no significant effect of condition on performance for writing, searching, comparing or organising tasks. Hartanto and Yang (2016) assessed the impact of smartphone separation on three executive functions —cognitive flexibility, working memory and inhibitory control— by means of standardised performance-based tasks. For cognitive flexibility, separation decreased switching efficiency ($d = -0.93$), but had no effect on accuracy. For working memory, those in the separation condition performed worse than the control ($d = 0.51$). For inhibitory control

there was a significant effect of condition for both reaction time ($d = -0.54$) and accuracy ($d = 0.58$). Irwin (2017) made use of the attention network test, a measure that isolates alerting, orienting and executive attention functions to assess cognitive outcomes. For both conditions there was no significant effect on the alerting function, improvements in executive functioning, and reductions in orienting functioning. Specifically, for orienting attention, while there was no effect of condition, there was an effect of time — performance for participants in both conditions diminished over the period of the study. While statistically significant, upon analysing the variance in mean error proportions (1.47%) the effect was judged to be negligible. For executive attentional functioning there was a significant effect of time, with performance for both conditions improving following the intervention. In particular, reaction times in incongruent trials significantly improved following the interventions — $d = 0.31$ for media diet and $d = 0.38$ for daily tracking. This outcome, though small, indicates an improvement in the inhibition of irrelevant stimuli in support of the endogenous maintenance of sustained attention. Three factors limit the extent to which causality in these findings can be inferred. First, as both conditions incorporated behaviour tracking, its effect cannot be isolated from the effect of media restriction. Similarly, without a control condition the effect of either condition cannot be isolated from events external to the study. Finally, the inconsistencies in the extent to which behaviour changed during the study undermine the degree to which any effect can be attributed to the manipulations.

Irwin (2017) further assessed intervention efficacy by means of two self-report scales, finding no effect of condition or time for self-control. Similarly, for attention-related behavioural errors no effect of condition was found. There was, however, an effect of time. For participants in both conditions reports of attention-related errors decreased following the study ($d = 1.34$). In a similar manner Mark et al. (2017) found a significant positive effect of restriction on focused immersion² ($d = 0.51$) and productivity ($d = 0.62$). Pielot and Rello (2016) utilised two custom measures for distraction and productivity, finding a significant effect of condition on productivity ($d = 0.58$) and distraction ($d = -0.66$). Finally, Mark et al.

²Focused immersion is associated with the concept of flow, a state of total attention to a task where other attentional demands are inhibited (Agarwal and Karahanna, 2000, p. 673).

(2012) assessed efficacy by means of semi-structured interviews, finding that an increase in the ability to focus on work emerged as a common theme. Related to this, as is evident in the behavioural data, a second theme encapsulates perceptions of remaining on-task for a longer duration.

Overall, restriction interventions have produced varied results for both behavioural and cognitive outcomes. There exists a balance in samples considered, with three studies making use of a student sample, three a sample of knowledge workers, and one of both students and knowledge workers. Similarly, for intervention duration, three studies assessed interventions occurring in a single session, one considered an intervention in place for five days, and three considered interventions with a duration longer than a week. While all seven studies implemented interventions requiring changes in behaviour, only three reported on such outcomes. Of these, again, outcomes are inconsistent. In terms of media multitasking, where measured, restricting media use was associated with decreases in switches recorded and media multitasking tendencies. While possibly indicative of an effect, only two studies explicitly assessed whether imposing restrictions on media use affects media multitasking. To further understand this relationship more research is required. In particular, while Mark et al. (2012) targeted a single activity (email), Irwin (2017) was indiscriminate in the type of media or use patterns restricted. For this reason, future investigations should consider the effect of restricting specific patterns of media use. Moreover, emphasis should be placed on understanding failures to change behaviour.

In terms of cognitive control, for self-report measures, four of the six outcomes indicate improvements in attention, focus, or task-related productivity, while two indicate no change as a result of restriction. For performance-based outcomes the findings are more nuanced. While four outcomes indicate impaired executive functioning, the intervention in this case was conducted over a single 20-minute session in a lab-based setting. In contrast, the remaining studies were conducted in the course of participants' everyday activities. While this contributed to the ecological validity of these studies, no significant interactions were found between interventions and measures for cognitive control. Although main effects of condition were not found, Irwin (2017) did, however, find that both tracking and restricting media behaviour improved executive attentional functioning. As noted previously, interpretations of

this outcome are hindered by the absence of a control condition. Determining whether such changes occurred as a result of improvements in metacognition or the restriction of media use requires further research.

To summarise, as is the case with the association between media multitasking tendencies and cognitive control, relationships between restriction-based interventions and cognitive control assessed by means of performance-based measures differ from those assessed by means of self-report measures. Given the goal-related nature of media multitasking, the functional assessment of cognitive control may not capture reflections on action in context in the manner that self-report measures do. At a functional level these interventions may not affect cognitive control. At a reflective level, however, in the context of participants' everyday lived experiences, perceptions of control over action, focus, and capacities to remain on-task may be affected. While not influencing underlying capacities for cognitive control, restriction-based interventions may serve to bring about changes in how individuals allocate their attention—they affect attentional strategies.

5.2.3. Mindfulness Interventions

All five studies employing mindfulness interventions primarily assessed outcomes related to cognitive control or performance. Four of the five interventions took place in a single experimental session (e.g., Gorman and Green, 2016; Ie et al., 2012; Yildirim, 2017, ST-2, ST-7, ST-14, ST-15). Only Levy et al. (2012, ST-8) considered an intervention taking place over a longer period of time (8 weeks). The four brief interventions, while prescribing changes in behaviour, primarily considered the relationship between mindfulness practices and executive functioning for those whose media multitasking level was known. As was the case with awareness and restriction-based interventions, outcomes were assessed by means of performance-based and self-report measures. Outcomes considered include: working memory, sustained attention, cognitive flexibility, inhibitory control. Additionally, the combined performance of the executive functions was assessed in terms of task and multitasking performance. Across the five studies examining such interventions 18 outcomes related to cognitive control were considered. Four of these were evaluated by means of self-report scales (four custom measures) and 14 by means of performance-based measures (nine standardised, five

Table 4: Outcomes, measures and effect sizes for mindfulness interventions

ID	Outcome	Measure	Effect Size ^a [95% CI]
ST-7	Focus-based Performance	Composite score	<i>ns</i>
ST-8	Multitasking-completion time	Custom multitasking test	<i>ns</i>
ST-8	Multitasking-activities	Custom multitasking test	-0.85 [-0.05, -1.65]
ST-8	Multitasking-time per activity	Custom multitasking test	<i>ns</i>
ST-14	Working Memory	OSPAN Task	<i>ns</i>
ST-14	Focus-based Performance	Comprehension Test	<i>ns</i>
ST-14	Mind wandering	Self-caught mind wandering	<i>ns</i>
ST-14	Mind Wandering	Probe-caught mind wandering	<i>ns</i>
ST-14	Mind Wandering	Retrospective mind wandering	<i>ns</i>
ST-15	Sustained Attention	SART - errors	<i>ns</i>
ST-15	Sustained Attention	SART - RT	<i>ns</i>
ST-15	Mind Wandering	Retrospective mind wandering	<i>ns</i>
ST-2	Cognitive Flexibility	Filter Task	<i>ns</i>
ST-2	Inhibitory Control	TOVA	n/a ^b
ST-2	Inhibitory Control	Flanker Task	<i>ns</i>
ST-2	Cognitive Flexibility	Task Switching Task	<i>ns</i>
ST-2	Working Memory	Backwards Digit Span	n/a ^b
ST-2	Cognitive Flexibility	Alternate Uses Task	n/a ^b

Note. OSPAN = Operation span task, SART= Sustained attention to response task, TOVA=Test of variables of attention.

^a Main effect size of study condition represented by Cohen's *d*.

^b It was not possible to calculate the effect size based on the provided information.

custom tasks). A summary of the outcomes considered, measures used, and effect sizes produced is presented in Table 4.

For the four studies prescribing brief mindfulness exercises, with the exception of mind wandering, all outcomes were assessed by means of performance-based measures. Through a custom measure Ie et al. (2012) found no effect of condition on multitasking performance. Gorman and Green (2016) assessed efficacy by means of six standardised measures of cognitive control. No effect of condition was found for cognitive flexibility or inhibitory control as measured by the filter task, the task switching task and the Flanker task, respectively. While the specific outcomes for the three remaining assessments were not reported, Gor-

man and Green (2016) report that, overall, a significant positive effect of the intervention was found ($d = 0.99$). In contrast, Yildirim (2017, ST-14) found no significant effect of a 10-minute mindfulness intervention on in-lecture mind wandering, working memory, or test performance. In a follow-up Yildirim (2017, ST-15) again found no significant effect on mind wandering. Moreover, no effect on sustained attention was found. In contrast to these studies which assessed the effects of brief mindfulness interventions Levy et al. (2012, ST-8) assessed the effects of an 8-week mindfulness training program. For this purpose the authors made use of a custom, quasi-naturalistic test in which a number of typical computer-related tasks were performed under conditions of distraction. No significant effect of condition on test completion time or time per activity was found. While there was no effect for completion time, a significant negative effect of condition on the number of activities engaged in was found. This measure was used as a proxy for task-switching frequency. Therefore, while not affecting performance, mindfulness training reduced tendencies to task-switch while working.

Overall, relationships between mindfulness interventions and cognitive control outcomes are inconclusive. With the exception of Gorman and Green (2016), brief mindfulness interventions had no significant effect on outcomes for cognitive control. With only one out of three studies showing any effect on attention-related outcomes the evidence supporting the efficacy of brief mindfulness interventions is weak. The effects of a long-term mindfulness intervention on multitasking performance have only been assessed in a single study amongst knowledge workers. No assessment in this regard has been conducted with a student sample. While it was shown that mindfulness training reduces task-switching frequency, it is unknown, firstly, if this extends to behaviour outside of laboratory conditions, and, secondly, if it affects cognitive control.

5.3. Individual Differences in Outcomes

To explicate the effect of various moderating factors it is necessary to briefly consider the reported presence of individual differences in behavioural and cognitive outcomes. Particular emphasis is placed on analyses considering the moderating effect of media multitasking tendencies.

In the studies reviewed media multitasking tendencies were assessed by means of either

Ophir et al.'s MMI (Ie et al., 2012; Gorman and Green, 2016; Yildirim, 2017, ST-7, ST-2, ST-14, ST-15) or Baumgartner, Lemmens, Weeda, and Huizinga's MMI-S (Irwin, 2017, ST-5). Gorman and Green (2016) found a significant moderating effect of media multitasking on intervention efficacy for attention-related outcomes but not for working memory or cognitive flexibility. The change in performance, following mindfulness exercises, for HMMs was larger than that of LMMs. In contrast, Yildirim (2017, ST-14) found no significant moderating effect of media multitasking tendencies on mind wandering, nor did he find a moderating effect of media multitasking for relationships between mind wandering and task-performance. Similarly, Ie et al. (2012) found no significant moderating effect of media multitasking on intervention efficacy. In ST-15, while media multitasking was measured, moderation analyses were not reported. Finally, while outcomes were reported for media multitasking behaviour, Irwin (2017) did not report the moderating effect of these tendencies.

In addition to media multitasking, a number of other moderating and mediating factors have been reported. Adler et al. (2015), for instance, found that gender moderated the effect of awareness. While females performed significantly better when they received reminders males performed worse. In ST-3 and ST-4 Hartanto and Yang (2016) found that the negative effects of smartphone separation on executive functioning were mediated by anxiety. While not considering relationships with executive functions, such an association has previously been demonstrated (Cheever, Rosen, Carrier, and Chavez, 2014). Mark et al. (2012) found no moderating effect of polychronicity on relationships between media restriction and task-switching. Finally, only one of the three studies to consider a sample comprised of both students and knowledge workers examined whether the intervention held differential effects. Whittaker et al. (2016) found that, for knowledge workers, when aware of their usage patterns, the reduction in media use was greater than for students. While this interaction was significant, no performance difference was found.

5.4. Quality of Evidence

As prescribed in the PRISMA guidelines the final stage of synthesis involved an assessment of methodological quality. Through the use of the NHLBI (2018) quality assessment tools each of the 15 studies reviewed were assessed for risk of bias. For studies adopting

between-subjects designs the *Quality Assessment of Controlled Intervention Studies* tool (referred to as NHLBI-1) was used, and for studies adopting within-subjects designs the *Quality Assessment Tool for Before-After (Pre-Post) Studies With No Control Group* (NHLBI-2) was used. While studies were rated for each criterion, the purpose is not to produce an evaluation through the tallying up of scores. Rather, these tools are designed to guide the assessment of quality through a systematic process. Following assessment the reviewed studies were rated as ‘poor’, ‘fair’ and ‘good’. Of the three ratings a good study has the lowest risk of bias, with results considered to be generally valid. While a study rated as fair may hold a degree of bias, this is considered insufficient to invalidate results. In contrast, a poor rating is indicative of a significant risk of bias. While studies adopting within-subjects pre-post designs could be adequately assessed though NHLBI-2, evaluations of studies adopting within-subjects post-only designs were restricted. As has been the case in previous reviews concerning media use and psychological outcomes, where this was the case, a maximum rating of fair was given. The outcomes of these assessments are summarised in Table 5.

Overall, of the 15 studies assessed, four were rated as poor, five as fair, and six as good. There is, therefore, a degree of variability with regards to risk of bias. No study assessed with NHLBI-2 received a rating of good, while only two of the eight assessed with NHLBI-1 received ratings other than good. The key difference between studies assessed with each of these tools was the manner in which comparisons were conducted. Those assessed with NHLBI-1 adopted between-subjects study designs. In such cases the performance of a treatment group was compared to that of either a control group or a group that received an alternative treatment. In contrast, those assessed with NHLBI-2 adopted within-subjects designs. No control or comparison groups were employed. Rather, performance for the same individuals was compared under treatment and control conditions. While such designs can control for high variances between groups before assessment, internal validity is threatened due to external confounding variables (especially in the case of *in situ* experiments), and time-related factors such as testing effects, order effects or statistical regression (Shadish, Cook, and Campbell, 2005). Moreover, as noted previously, studies failing to assess key outcomes before the implementation of an intervention were limited to a maximum rating of fair. In terms of intervention categories, no study assessing an awareness intervention

Table 5: Summary of methodological quality assessment outcomes

Study ID	Intervention Category	NHLBI-1	NHLBI-2
ST-1	Awareness	poor	
ST-2	Mindfulness		fair ^a
ST-3	Restriction	good	
ST-4	Restriction	good	
ST-5	Restriction	good	
ST-6	Restriction		poor ^a
ST-7	Mindfulness	good	
ST-8	Mindfulness	poor	
ST-9	Restriction		fair
ST-10	Restriction		fair ^a
ST-11	Restriction		poor ^a
ST-12	Awareness		fair ^a
ST-13	Awareness		fair
ST-14	Mindfulness	good	
ST-15	Mindfulness	good	

^a Maximum rating limited to 'fair'.

received a good rating, while three studies assessing mindfulness or restriction interventions received good ratings.

While study designs and implementations differed, across studies rated as fair or poor a number of factors contributing to a heightened risk of bias were identified. For instance, the target populations of interest were either not clearly defined or such details were entirely neglected. Similarly, eligibility criteria were not pre-specified. In such cases, samples were characterised by convenience. In a related manner, only two studies (Pielot and Rello, 2016; Yildirim, 2017, ST-11, ST-15) conducted power analyses to determine the sample sizes required to detect a between groups difference with at least 80% power. While the sample sizes considered in these studies did not differ significantly from those in the remaining 13 studies, no other studies explicitly reported prior alpha levels, targeted statistical power, or power-based sample sizes. Another factor present in studies rated as fair or poor was a lack of adequate blinding. Blinding with regards to allocation and assessment was either not conducted or not reported. It is acknowledged that, given the nature of the behavioural interventions employed, it would not have been possible to blind participants to their allocation. In a majority of cases, however, it was not reported whether researchers were aware of a participants' allocation status when assessing outcomes. Finally, while a number of studies relied on standardised measures with known validities and reliabilities, other studies made use of custom instruments for various outcome measures. While this in itself does not present a cause for concern, in these instances, assessments for internal validity and reliability were not reported. Studies rated as good were generally characterised by experimental designs with strong control procedures, clearly specified target populations, adequate randomisation, sufficient blinding, low attrition, and outcome assessment through valid and reliable measures.

6. Discussion

Despite the importance of attention management in the face of increasingly mediated personal, social and work environments, there is, at this stage, a paucity of research considering behavioural change interventions targeting improvements in cognitive control or performance in relation to media multitasking. The lack of clarity in regard to the negative

effects of media multitasking may, in part, account for this shortage. This systematic review aimed to consider the current body of evidence and, on this basis, determine, firstly, the nature of interventions employed and, secondly, the efficacy of these interventions in terms of both behaviour change and changes in outcomes related to cognitive control.

The systematic search identified 12 studies assessing 15 distinct interventions in three categories —restriction, awareness, and mindfulness. In general, while interventions have targeted accessibility, psychological capabilities, and metacognition, the role of individual needs or situations has been ignored in intervention development. Only a single study (i.e., Irwin, 2017) explicitly considered individual intentions for behaviour with media. Interventions within all three categories endeavoured to promote the engagement in single-tasking. While some interventions focused on the mitigation of possible negative effects, others focused on achieving changes in performance and attention through fostering changes in behaviour. As eight of the 15 interventions were conducted in the course of a single experimental session, and only three conducted over a period longer than a week, the long-term sustainability of any interventions in this regard requires further research.

As with the relationship between media multitasking and cognitive control there remains little clarity with regard to intervention efficacy. In terms of behaviour change, while evidence is limited, improvements in metacognition of media multitasking and associated attentional strategies have been associated with changes in self-regulation strategies. In terms of self-regulation, as propagated by Baumeister and Heatherton (1996), these interventions can be framed as improving an individual’s ability to *monitor* their behaviour and, on this basis, *operate* to remain on-task. Interventions requiring the restriction of media use have produced varied results, with restriction of one medium, in some instances, being associated with increased use of another. For media multitasking, restriction of overall media use or restriction of particular activities decreased recorded switches between media and led to decreases in perceptions of media multitasking tendencies. While mindfulness interventions required changes in behaviour, the studies assessed in this review did not explicitly report on such changes. Therefore, while it may be reasoned that such interventions would have an effect on behaviour, further study is required to elucidate these effects.

As is the case with behaviour-related outcomes, effects on outcomes related to cognitive

control have been varied. The inconclusive and sometimes ineffectual results of the former may account for such outcomes in the latter. Another factor may be the differential relationship between media multitasking and cognitive control. van der Schuur et al. (2015, p. 212) note that media multitasking is negatively associated with self-reports of cognitive control in everyday life, but when assessed in a performance-based manner, it relates to some cognitive control processes but not others. In this review it was found that no single category contains interventions which, categorically, engendered a narrower distribution of attention or improvements in attention-related performance. Within each of the three categories some interventions positively effected such outcomes and others did not. While some interventions produced null effects, no intervention was shown to diminish performance or lead to perceptions of greater distractibility.

A key difference across studies is the relationship between intervention efficacy and measurement paradigm. Outcomes assessed by means of self-report measures generally indicated a positive effect. In comparison to normal conditions, those experiencing an intervention perceived improvements in their ability to allocate their attention selectively, to remain focused, to switch between tasks, and to perform optimally. In contrast, when effects of interventions were assessed by means of performance-based tasks, the general pattern of effect is less clear. At a functional level cognitive control may not be affected by awareness, restriction or mindfulness interventions. However, at a reflective level, in the context of everyday lived experiences, such interventions may effect perceptions of distractibility, focus, control over action, and task-performance. Therefore, it is argued, the primary effect of these interventions is, rather, a strategic one. Moreover, it is argued that a key aspect present in all three categories is metacognition. Whether through restricting behaviour with media, practicing mindfulness, or explicitly providing information about media use, awareness of behaviour with media and related attentional outcomes is enhanced. Mindfulness and awareness interventions endeavoured to isolate this effect. In such cases responses or strategies were left to the participants. Restriction interventions, on the other hand, enforced a particular response to this awareness.

This assessment corresponds to Ralph, Thomson, Seli, Carriere, and Smilek (2015)'s strategic hypothesis for the relationship between media multitasking and cognitive control.

Just as HMMs adopt an attentional strategy permitting themselves to become distracted, a greater awareness of switching behaviour, media use or attentional distribution promotes an attentional strategy fostering a narrow distribution of attention. Moreover, as Ralph et al. (2015) suggest, such strategies may be reflected in self-report measures, but not controlled performance-based measures. This implies that, as with media multitasking, any effect of these interventions on cognitive control will not manifest reliably at an isolated functional level. Rather, as with media multitasking, effects manifest at a reflective, contextual level.

It is important to consider the implications of these findings for the mixed results reported in studies of the association between media multitasking and cognitive control. Firstly, it must be acknowledged that the short duration of the interventions reviewed implies that it is unlikely that changes could have been produced at the level of executive functions. We cannot, consequently, reject the proposition that chronic media multitasking may produce changes in executive functions. Long-term interventions can provide greater insight in this regard. However, the findings support the notion that media multitasking is positively associated with perceptions of distractability. The ability of interventions to bring about changes in these perceptions suggests that they affect choices for action in context and, therefore, choices for how attentional and cognitive resources are allocated. This, in turn, affects perceptions of focus and performance.

Finally, in addition to the nature and effect of interventions employed, this review considered a number of factors affecting risk of bias in the sample. Four of the 15 studies were rated as poor, five as fair, and six as good. Studies rated as good adopted experimental designs with clearly specified populations of interest, sufficient randomisation and control, and outcome assessment via valid and reliable measures. In contrast, key factors contributing to a heightened risk of bias include inadequate control procedures, vague or undefined target populations, no pre-specified power analyses, inadequate blinding, and unvalidated assessment measures. Overall, the degree to which bias may be present in the sample reviewed presents a challenge to any interpretations made on the basis of the synthesis provided. While six of the 15 studies were rated as good, a majority were rated as either fair or poor. Therefore, while it is believed that the synthesis presented in this systematic review provides a useful foundation for future work, there is a need for high quality primary studies to

advance research in this domain.

To summarise, there remains little clarity with regards to the effects of changing behaviour with media. While three categories of intervention have been implemented, relationships between changes in behaviour and commensurate changes in performance or cognitive control require further investigation. On the basis of this systematic review the following directions for future research are proposed in the closing sections.

6.1. Explicitly Target Media Multitasking

While some studies have targeted particular activities or stimuli, others have targeted media use in general. Future studies should, through the use of fully randomised and controlled designs, investigate the effect on behavioural and cognitive outcomes of interventions explicitly targeting media multitasking. As Irwin (2017) suggests, for long-term in situ interventions, a more limited set of behaviours should be targeted. For instance, future investigations could target media multitasking with a specific device (i.e., a smartphone in conjunction with other media or non-media activities), in a specific context (i.e., in a lecture, while studying, or while in a meeting), in response to specific cues (i.e., notifications, email, the initiation of a particular application), or through specific combinations (i.e., smartphone in conjunction with laptop, email and browsing, conversations and instant messaging, or studying and using SNSs).

6.2. Greater Emphasis on individual Differences

Although interventions have been assessed on both student and knowledge worker populations, more explicit emphasis on understanding individual (i.e., motivations, intentions, or gratifications) and situational (i.e., social, work, or home) differences is required. Moreover, future studies should endeavour to assess media multitasking-related interventions for those who self-report as heavy media multitaskers. As such individuals engage in media multitasking to a greater extent and, arguably, are more likely to experience possible negative attentional effects, interventions are likely to be more relevant and have a greater effect on such a population. LMMs, in contrast, media multitask less and, it may be argued, are less likely to experience possible negative attentional effects.

6.3. Investigate Causal Mechanisms

While evidence of an association is building, establishing the direction of causality between media multitasking and cognitive control remains a challenge in this domain. Moreover, a majority of studies in this regard are correlational and cross-sectional in nature. Consequently, studies experimentally assessing the effects of changes in media multitasking in relation to cognitive control outcomes will provide a valuable contribution to research in this regard. In addition to considerations of causality for underlying relationships, future research concerning the possible causal mechanisms of effective interventions is required. In particular, research is required to establish why some interventions have an effect on behaviour or cognitive outcomes and others do not. Key steps toward examining causality in both cases include the use of proper control procedures, successful manipulations of media multitasking behaviour, and longitudinal study designs. Finally, given the need to consider long-term changes in media multitasking behaviour, further study is required to determine the duration required to identify the presence of an effect and, if found, the sustainability of such effects.

7. Conclusion

In response to findings indicating possible negative associations between increased media multitasking and cognitive control researchers have called for studies investigating interventions targeting the effects of media multitasking. The aim of this systematic review is to present an integration of current work in this regard and, on this basis provide a basis for future work to build upon. As with research into the underlying relationship between media multitasking and cognitive control, there remains a distinct lack of clarity in terms of effects of behavioural interventions on behaviour and cognitive control. What is evident at this stage is that more targeted research is required to determine the prescriptive validity of changes in behaviour with media as a means of responding to increasingly mediated personal, social and work environments. Finally, the synthesis presented in this review must be interpreted in the light of the following limitations: (i) the risk of bias and limitations present in the primary studies reviewed; (ii) the possibility of the search procedures failing

to acquire a representative sample; (iii) the possible distorting presence of a publication bias and (iv) the interpretative nature of the synthesis presented.

8. Reference List

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