Media Multitasking and Cognitive Control: Assessing the Feasibility of an Intervention Requiring the Self-regulation of Smartphone Use

by

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Declaration

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Date: ....December 2019..........

Abstract

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Increasingly our personal, work, and social contexts are characterised by engagements with communications media. Adapting to and coping in this hyper-connected world has cultivated high levels of *media multitasking* —the simultaneous use of one medium alongside other media or non-media activities. Over the preceding decade researchers have investigated possible associations between media multitasking and changes in cognitive control. While extant research is characterised by both convergent and divergent findings, overall, current evidence supports the suggestion that those who frequently engage in media multitasking are more likely to underperform relative to lighter media multitaskers in a number of cognitive domains. In particular, research suggests that media multitasking is negatively associated with attentional capacities, working memory, task-switching ability, and interference management. In response to calls for investigations considering the remedial efficacy of interventions targeting media multitasking and related cognitive effects the study presented in this dissertation endeavoured, firstly, to investigate existing behavioural interventions targeting cognitive outcomes associated with media multitasking; secondly, to develop a novel media multitasking intervention; and, thirdly, to assess the feasibility of this intervention for a student population.

To address the study objectives a three-phase mixed-methods investigation was executed. Owing to the interdisciplinary nature of research in this domain, the first phase involved reviewing relevant literature from cognitive psychology, media and communication, and social informatics to provide a conceptual foundation for the phases to follow. Subsequently, building on theories of behaviour, cognition, media use, and self-regulation the patterns and drivers of media multitasking were considered and summarised through the provision of an integrative model of media multitasking behaviour. While not empirically tested in this study, the model, as a summary of previous research, guided the subsequent intervention evaluations. The phase concluded with an evaluation of the current state of research into associations between media multitasking and cognitive control.

In phase two a systematic review methodology was adopted to consider previous interventions targeting the effects of media multitasking on executive functioning. This review aimed to determine, firstly, the nature of interventions assessed, secondly, the efficacy of these interventions in terms of both behaviour change and changes in outcomes related to cognitive control and, finally, to identify the factors affecting implementation. At the time of review interventions fell into three categories: awareness, restriction, and mindfulness. While some were shown to 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.

In the third phase, informed by the outcomes of the review and the theoretical basis established in phase one, a novel media multitasking intervention was developed. To produce rich insights into the feasibility of the proposed intervention and related aspects of behaviour with technology, a mixed-methods design involving the collection of both quantitative and qualitative data was implemented. Specifically, to assess the demand, acceptability, implementation, and efficacy dimensions of feasibility, the pre/post design involved the collection of quantitative data relating to media multitasking, demographics, cognitive control, everyday executive functioning, and intervention-application, as well as qualitative interview data relating to experiences and impressions of the intervention.

Following from these methods the overall feasibility of the intervention was analysed. While the implementation and demand dimensions of the intervention were regarded to be feasible, acceptability was shown to be only partially feasible. Moreover, for the intended outcomes, the intervention was shown not to be effective. No evidence to support the targeted improvements in cognitive control ability were found. Despite this, the intervention was seen to bring about behavioural changes and engender increased instances of single-tasking. This was seen to be a positive outcome and prompts consideration of the differences between state-level effects and trait-level effects. Consequently, it is proposed that, as an intervention targeting improvements in cognitive control, the assessed procedures are not feasible but, as an intervention targeting alignment between media behaviour and longer-term goals, preliminary support for its feasibility was shown. While many of the findings are particularly nuanced and open up new questions, the outcomes hold a number of important implications for research and practice in a variety of domains. The study findings are of interest because of their relevance for research concerning media multitasking interventions, associations between media multitasking and cognitive control and, more generally, behaviour with technology.

Uittreksel

Media Multitasking en Kognitiewe Beheer: Die Evaluering van die Uitvoerbaarheid van 'n Intervensie wat die Selfregulering van Slimfoongebruik vereis

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Ons persoonlike, werk en sosiale kontekste word toenemend gekenmerk deur die konstante gebruik van kommunikasiemedia. Aanpassing aan en omgaan met hierdie hipergekoppelde wêreld het hoë vlakke van *media multitasking* — die gelyktydige gebruik van een medium gelyktydig met ander media- of nie-media-aktiwiteite — gekweek. Tydens die afgelope dekade het navorsers ondersoek ingestel na moontlike assosiasies tussen media multitasking en veranderinge in kognitiewe beheer. Alhoewel bestaande navorsing gekenmerk word deur beide konvergente en divergente bevindings, ondersteun die huidige bewyse die feit dat diegene wat gereeld media multitask swakker presteer as ongereelde media multitaskers in 'n aantal kognitiewe domeine. Navorsing dui spesifiek daarop dat media multitasking negatief assosieer met aandagskapasiteit, werkende geheue, taak-wisselingsvermoë, en die bestuur van afleidings. In reaksie op oproepe vir ondersoeke oor die remediërende doeltreffendheid van intervensies wat gerig is op media-multitasking en verwante kognitiewe effekte, het die studie wat in hierdie proefskrif aangebied word, eerstens, bestaande gedragsintervensies wat fokus op kognitiewe uitkomste wat geassosieer word met media multitasking ondersoek; tweedens, 'n nuwe media-multitasking-intervensie ontwikkel; en derdens, die uitvoerbaarheid van hierdie intervensie vir 'n studentepopulasie evalueer.

Om die studie se doelwitte te beriek, is 'n drie-fase gemengde-metodes ondersoek uitgevoer. As gevolg van die interdissiplinêre aard van navorsing binne hierdie domein, het die eerste fase die hersiening van relevante literatuur behels. 'n Versameling literatuur uit kognitiewe sielkunde, media- en kommunikasiestudies en sosiale informatika is hersien om 'n konseptuele basis vir die volgende fases te ontwikkel. Gebaseer daarop word die patrone en drywers van media multitasking identifiseer en beskryf met verwysing na teorie´e van gedrag, kognisie, mediagebruik en selfregulering. Dit word opgesom deur 'n integrerende model van media multitasking as gedragspatroon. Hoewel die model nie in hierdie studie empiries getoets is nie, het die model, as 'n opsomming van vorige navorsing, struktuur gegee aan die daaropvolgende intervensie-evaluerings. Die fase is afgesluit met 'n evaluering van die huidige stand van navorsing oor assosiasies tussen media multitasking en kognitiewe beheer.

In fase twee is 'n sistematiese hersieningsmetodologie toegepas om vorige intervensies te oorweeg wat die impak van media multitasking op uitvoerende funksionering aanspreek. Hierdie hersiening het ten doel, eerstens, om die aard van intervensies te bepaal; tweedens, om die effektiwiteit van hierdie intervensies in terme van beide gedragsveranderinge en veranderinge in uitkomste wat verband hou met kognitiewe beheer te bepaal; en, ten slotte, om die faktore wat die implementering beïnvloed, te identifiseer. Tydens hersiening het intervensies in drie kategorieë geval: bewustheid, beperking en *mindfulness*. Alhoewel sommige intervensies gedrags- of kognitiewe uitkomste affekteer het, het geen enkele kategorie van intervensies deurlopend verbeterings in aandagverwante prestasie tot gevolg gehad nie. Op grond van hierdie bevindinge is navorsingsgapings identifiseer en voorstelle vir toekomstige studies gemaak.

In die derde fase word 'n nuwe media-multitasking-intervensie ontwikkel op grond van die uitkomste van die eerste twee fases. Om betekenisvolle insigte te bekom oor die haalbaarheid van die voorgestelde intervensie en verwante aspekte van gedrag met tegnologie, is 'n gemengde-metodesontwerp geïmplementeer. Die aanvraag-, aanvaarbaarheids-, implementerings- en doeltreffendheidsdimensies van haalbaarheid is evalueer deur die insameling van kwantitatiewe data wat verband hou met media multitasking, demografie, kognitiewe beheer, daaglikse uitvoerende funksionering en intervensie-toepassing behels, asook kwalitatiewe onderhoudsdata wat verband hou met ervarings en indrukke van die intervensie.

Na aanleiding van hierdie metodes is die algehele haalbaarheid van die intervensie ontleed. Hoewel die implementering en vraag dimensies van die intervensie haalbaar bevind is, is aanvaarbaarheid slegs gedeeltelik haalbaar bevind. Verder is die intervensie bevind om nie effektief is nie. Geen bewyse ter ondersteuning van die geteikende verbeterings in kognitiewe beheervermoë is gevind nie. Ten spyte hiervan het die intervensie gedragsveranderinge en verhoogde gevalle van *single-tasking* teweeg te bring. Dit is 'n positiewe uitkoms en dui op moontlike verskille tussen kort-termyn-vlak effekte en eienskaps-vlak effekte. Gevolglik word voorgestel dat, as 'n intervensie gerig op verbeterings in kognitiewe beheer, die geassesseerde prosedures nie haalbaar is nie, maar, as 'n intervensie gerig op die aanpassing van mediagedrag en langtermyndoelwitte, voorlopige steun vir die uitvoerbaarheid daarvan getoon is. Hoewel baie van die bevindinge genuanseer is en dikwels tot nuwe vrae lei, bied die uitkomste 'n aantal belangrike implikasies vir navorsing en praktyk in verskeie domeine. Hierdie bevindinge is belangrik weens hul relevansie vir navorsing rakende media multitasking intervensies, assosiasies tussen media multitasking en kognitiewe beheer, en gedrag met tegnologie in die algemeen .

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The project presented in this dissertation would not have been the same without the valuable and insightful suggestions from the admissions committee. Through their feedback and discussions important changes were made to the early proposal which, upon reflection, have proven to be particularly consequential for the final project. In a similar manner, I acknowledge the time and valuable comments provided by the examining committee and thank them for their feedback.

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Over the course of this project I made use of number of open source programs, packages, tools, libraries, and services. I extend my gratitude to the enumerable creators of these tools so integral to the design and execution of this project.

This project is not just the culmination of the last three years, the last five years, or even my whole university career. It is the present culmination of twelve years of schooling and nine years of tertiary education. I extend my sincerest gratitude to my parents for supporting me throughout this journey thus far and setting me on a path to bring me to where I am today.

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We do not ride on the railroad; it rides upon us

Henry David Thoreau, 1854

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List of Abbreviations and Acronyms

AC-D Attentional control-distractibility

AC-S Attentional control-switching

ACT-R Adaptive control of thought-rational

ADHD Attention deficit hyperactivity disorder

AIS Association for information systems

AISeL AIS electronic library

AMM Average media multitasker

ANT Attention network task

ANCOVA Analysis of Covariance

ARCES Attention-related cognitive errors scale

ASP Academic search premier

ASRS Adult ADHD self-report scale

AVGP Action video game player

BCW Behaviour change wheel

BRIEF Behavioural rating inventory of executive function

CFQ Cognitive failures questionnaire

CMMC Communication and mass media complete

COM-B Capability, Opportunity, Motivation, Behaviour

CPT Continuous performance task

ERIC Education resources information center

FBM Fogg behaviour model

fMRI functional magnetic resonance imaging

FoMo Fear of missing out

GSR Galvanic skin response

HCI Human-computer interaction

HMM Heavy media multitasker

ICT Information and communications technology

IFT Information foraging theory

IS Information Systems

IM Instant messaging

IMM Intermediate media multitasker

IQR Interquartile Range

LMM Light media multitasker

LTM Long term memory

MAAS-LO Mindful attention awareness scale-lapses only

MFG Memory for-goals

MFS Memory failures scale

MM Media multitasking

MMI Media multitasking index

MMI-L Media multitasking index-long

MMI-S media multitasking index-short

MMM-L Media multitasking measure-long

MMM-S Media multitasking measure-short

MMT Media multitasking time

MPI Multitasking preference index

MRT Metronome response task

MUQ Media use questionnaire

MVT Marginal value theorem

MW-D Mind wandering-spontaneous

MW-S Mind wandering-deliberate

OTMU Off-task media use

PICO Populations, interventions, comparisons and Outcomes

POPC Permanently online and permanently connected'

PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analysis

PQTD-G ProQuest Dissertations & Theses Global

RAA Reasoned action approach

RCT Randomised control trial

RT Response time

SART Sustained-attention-to-response-task

SAS Supervisory attentional system

SAT Scholastic aptitude test

SCT Social cognitive theory

SD Standard deviation

SNS Social networking service

SST Social Shaping of Technology

STM Short term memory

TCT Threaded cognition theory

TIM Technology Integration Model

TPB Theory of Planned Behaviour

TRA Theory of Reasoned Action

TV Television

UGT Uses and gratifications theory

UIS Ubiquitous Information Systems

WM Working memory

WOFO Work and family orientation questionnaire

WoS Web of science

Chapter 1

Introduction

The ubiquitous presence of digital communications *media* as key components of 21st Century life has dramatically altered how individuals behave with technology. Increases in accessibility have brought about a myriad of opportunities for communication, information retrieval, and entertainment (Cheung *et al.*, 2011). Vorderer *et al.* (2016, p. 694) propose that "one of the most striking consequences of these developments seems to be a fundamental change in how people deal with electronic media today". Rather than approaching interactions with media as singular engagements, media use has come to be characterised as a pervasive component of contemporary existence (le Roux and Parry, 2017*b*; van Koningsbruggen *et al.*, 2018). Individuals are "permanently online and permanently connected" (Vorderer *et al.*, 2016, p. 695), a state characterised by protracted use of digital media and a subjective sense of constant communicative vigilance.

One way in which this phenomenon manifests is the continued, widespread multitasking characterising media use for many individuals (Wang and Xu, 2017). This behaviour has come to be termed *media multitasking* and has been defined as either the simultaneous use of two or more media, or media use in conjunction with other media or non-media activities (Zhang and Zhang, 2012, p. 1883). Members of Generation Z (those born between 1995 and 2010), in particular, have been shown to be frequent media multitaskers (Carrier *et al.*, 2009; Judd and Kennedy, 2011). Among the current cohort of university students, specifically, a majority of media use involves multitasking to some extent (Judd, 2014; Parry, 2017). Media multitasking is, however, not only common among students. Research indicates that, for adolescents, knowledge workers and even older generations, media multitasking is particularly prevalent (Bannister and Remenyi, 2009; Pea *et al.*, 2012; Voorveld and van der Goot, 2013).

Multitasking, by definition, involves a process of rapid switching between ongoing activities (Salvucci *et al.*, 2009). Researchers, therefore, have associated media multitasking with a number of adverse cognitive, psychosocial, and performance-related outcomes (see van der Schuur *et al.*, 2015, for a review). Extending from this, given the extent of task-switching associated with frequent, habitual media multitasking, researchers and popular commentators alike have raised concerns about the possible implications this behaviour might hold for attentional capacities (Carr, 2010; Wallis, 2010; Harris, 2016; Baumgartner *et al.*, 2017*b*). Over the past decade, associations between media multitasking and the *executive* or *cognitive control* processes theorised to underlie the execution of goal-directed behaviour have been investigated (e.g., Ophir *et al.*, 2009; Ralph and Smilek, 2017). In a recent review Uncapher and Wagner (2018, p. 9890) conclude that, while extant research is characterised by both convergent and divergent findings, overall, "the weight of current evidence shows that in some contexts heavier media multitaskers underperform relative to lighter media multitaskers in a number of cognitive domains". In particular, research suggests that media multitasking is negatively associated with attentional capacities, working memory, task-switching ability, and interference management (see van der Schuur *et al.*, 2015; Uncapher and Wagner, 2018, for reviews).

1.1 Research Problem and Objectives

Acknowledging the associations between media multitasking and diminished attentional capacities, researchers have called for investigations considering the remedial efficacy of interventions targeting media multitasking and related cognitive effects (e.g., Wagner, 2015; Gazzaley and Rosen, 2016; Uncapher *et al.*, 2017; Parry and le Roux, 2018; Uncapher and Wagner, 2018). Given the commoditisation of attention in the *attention economy* characterising much of 21st century life, in the face of increasingly mediated personal, social and work environments, the management of attentional demands and control over the direction of cognitive processes emerge as key challenges. Increasingly, success across a variety of domains, from academic and professional to social and affective, is contingent on the management of interferences in support of effective single-tasking. It has been proposed that, just as media multitasking may alter cognitive functioning, changes in behaviour with technology can, firstly, address media multitasking related interferences and, secondly, enhance cognitive control (Gorman and Green, 2016). Suggestions of possible approaches include: education, meditation, physical exercise, cognitive exercise, self-regulation, altering the accessibility of media and, at an extreme, abstaining from all media use (Levy *et al.*, 2012; Gazzaley and Rosen, 2016; Terry *et al.*, 2016; Parry and le Roux, 2019*b*). In response to the increasing prevalence of media multitasking, associated attentional effects and the growing need to understand how individuals can manage these interferences, the research study presented in this dissertation endeavoured, firstly, to investigate existing behavioural interventions targeting cognitive outcomes associated with media multitasking; secondly, to develop a novel media multitasking intervention; and, thirdly, to assess the feasibility of this intervention for a student population. To structure the investigation two objectives were formulated.

Research Objective 1: *Investigate and review existing behavioural interventions targeting cognitive control outcomes associated with media multitasking.*

Research Objective 2: *Propose, informed by the outcomes of the first research objective, a novel media multitasking intervention targeting cognitive control outcomes associated with media multitasking and assess its feasibility for a student population of heavy media multitaskers.*

1.2 Research Design

A three-phase, mixed-methods study was executed to address these objectives. The first phase concerned the development of a foundation upon which the subsequent two phases, addressing the two primary research objectives, could build. In phase one, to establish a theoretical basis for understanding associations between media multitasking and cognitive control, relevant literature from Cognitive Psychology, Social Informatics, and Media Studies were considered. To develop a framework for describing the factors underlying media multitasking, relevant theory from Behavioural Psychology and recent research concerning behaviour with technology were considered. The phase concluded with an evaluation of the current state of research into associations between media multitasking and cognitive control. In phase two, to address the first research objective, a systematic review methodology was adopted to consider previous interventions in this regard. The outcomes of this review, in conjunction with the theoretical basis established in phase one, informed the development of the intervention assessed in this study. In the third phase, to address the second research objective and investigate the feasibility of the proposed intervention, an experimental methodology was adopted. To develop rich insights into the feasibility of the proposed intervention and related aspects of behaviour with technology a mixed-methods design involving the collection of both quantitative and qualitative data was implemented. Noting the general absence of mixed-methods research in *Information Systems* (IS) and related domains, Venkatesh *et al.* (2013) propose that such an approach is necessary for the development of a deep understanding not possible through a single research paradigm. To provide specific direction to the investigations conducted, when required, explicit secondary objectives, research questions or hypotheses are proposed. In Section 1.5 an outline describing the mapping of these study phases to the structure of the dissertation is provided.

1.3 Situating the Study

This dissertation is presented for a doctoral degree in *Socio-Informatics*, which is understood to entail the study of technical systems and the individual, societal and organisational systems in which these are embedded and enacted. Globally, this field is commonly referred to as *Social Informatics* and is simultaneously understood as a sub-field of IS and a distinct discipline itself. To situate the present study this section briefly considers Social Informatics as an academic discipline.

Kling (1999, p. 1) defines Social Informatics as the "interdisciplinary study of the design, uses and consequences of information technologies that takes into account their interaction with institutional and cultural contexts". Sawyer and Rosenbaum (2000, p. 90–91) suggest that Social Informatics concerns the "socio-technical relations between people and the ICTs they use". While these authors consider there to be a substantial overlap between Social Informatics and IS, they regard the former to be a distinct field.

A challenge to this conceptualisation is the absence of a common knowledge core for Social Informatics. In response, researchers have identified core findings and areas of research. For instance, Sawyer (2005, p. 10) outlines five key findings of Social Informatics research: "(i) uses of ICTs lead to multiple and sometimes paradoxical effects; (ii) uses of ICTs shape thought and action in ways that benefit some more than others; (iii) the differential effects of the design, implementation and uses of ICTs often have moral and ethical consequences; (iv) the design, implementation and uses of ICTs have reciprocal relationships with social contexts; and (v) the phenomenon of interest will vary by the level of analysis". These findings, he argues, are archetypal of this domain. Vehovar (2006) describes the research areas of Social Informatics as (i) the interaction between ICTs and humans at the personal, organisational and social level; (ii) ICT applications in the social sciences; and (iii) the use of ICT as a tool for studying social phenomena. More recently, Rosenbaum (2014, p. 19-20) describes five assumptions considered to constitute the knowledge core of Social Informatics: "(i) sociotechnical systems include both technical artefacts (software and hardware) and social components (people, organisations, norms); (ii) these systems do not exist in technical or social isolation; (iii) components of sociotechnical systems are continually re-shaped on the basis of their interactions; (iv) ICTs constantly evolve, and can be used for purposes and in contexts different from that for which they were originally designed; and (v) there is a discrepancy between the design of ICTs and their enactment".

Despite the assertion that Social Informatics presents as a distinct discipline, it is noted that many researchers regard it to exist as a sub-discipline of IS (Järvinen, 2006; Cronin, 2008; Davenport, 2008). For this reason, the study can, broadly, be situated within the discipline of IS. Specifically, it addresses key aspects of a research agenda for IS proposed by Vodanovich *et al.* (2010). Citing Srivastava (2004)'s notion of the 'ubiquitous information society', these researchers call attention to the ever increasing ubiquity of digital media (what they term ubiquitous information systems - UISs) and propose that, for digital natives, this concept captures the indispensability of the Internet and the rapid uptake of mobile digital technologies. Extending from this, they propose a research agenda focusing on how members of this generation are interacting with digital technologies, how such technologies can be designed, and what impacts are associated with the ubiquitous use of digital technologies. Specifically, Vodanovich *et al.* (2010) propose four key questions facing IS researchers: (i) how and why are digital natives engaging with UISs? (ii) how are traditional ISs being transformed by digital natives and UISs? (iii) how do we design and implement UISs for digital natives? and (iv) what are the positive and negative impacts of UISs on digital natives, organisations and society?

Given the conceptualisations of Social Informatics, this study can be understood as an investigation of UISs and their users at the personal level. Moreover, this study holds, as basis, that uses of ICTs shape thought and action in ways that lead to positive and, potentially, negative effects for their users. In particular, the focus falls on individual interactions with technology and the effects these have on behaviour and cognitive functioning. Emphasis is placed on, firstly, understanding how and why digital natives are enacting a particular form of behaviour with media (multitasking), secondly, understanding the effects of the behavioural pattern and, thirdly, how this behaviour can be changed to reduce negative effects for cognitive control. As such, grounded in core areas of Social Informatics, this study draws heavily on the related disciplines of Psychology, Human

Computer Interaction (HCI) and Communication Studies. Research in this domain is interdisciplinary, with previous studies in this regard having been conducted by Psychologists (e.g., Ophir *et al.*, 2009; Alzahabi *et al.*, 2017), Information Scientists (e.g., Benbunan-fich *et al.*, 2011; Mark *et al.*, 2012), Media and Communication scholars (e.g., Hwang *et al.*, 2014; van der Schuur *et al.*, 2015), Neuroscientists (e.g., Cain *et al.*, 2016; Moisala *et al.*, 2016), and Educationalists (e.g., Karpinski *et al.*, 2013) amongst others.

1.4 Motivation for the Study

This study concerns, fundamentally, behaviour with technology (specifically communications media) and how this behaviour can affect the cognitive functioning necessary for success across personal, social, academic and professional situations. Central concerns of IS, and by definition Social Informatics, research are behaviour and interactions with technology. However, as Benbunan-Fich *et al.* (2009, p. 2) note, "surprisingly, the IS literature has been mostly silent on the topic of multitasking". Since this comment, over the last decade, there has been dramatic growth in research attention afforded to the topic of multitasking and, more specifically, to media multitasking. Across academic disciplines researchers have developed media multitasking measures, examined antecedents and triggers, considered relationships with academic performance, cognitive control and well-being, and proposed interventions. While much progress has been made, as noted by Uncapher and Wagner (2018), many unanswered questions still remain.

The execution of this study is motivated by two themes. First, the study is designed to contribute to ongoing efforts to address the open questions facing this nascent domain and, second, to provide insights about behaviour with technology which may hold relevance beyond academic environments for individuals and society at large. Remarking on a series of investigations into the effects of media multitasking on the mental health of adolescents, van der Schuur (2018, p. 145) suggests that, given the continued integration of media into their lives, the manner in which such individuals "deal with the omnipresence of media and communication devices" becomes a question of primary importance for research moving forward. Moreover, Rheingold (2012, p. 2) contends that, in response to the potential for information overload and distraction, the management of attention "in relation to available media is key today for success in education, business, and social life". On the back of these concerns, the study objectives were formulated to provide greater insight into the design, nature, and feasibility of interventions targeting aspects of media multitasking and the effects thereof. Such a contribution is of value not only for addressing the open questions regarding the nature and potential effects of interventions but, in addition, it may provide further insight into the causal dynamics of associations between behaviour with technology and changes in cognitive processes. Furthermore, the findings are likely to be of value to those seeking to manage their media multitasking and address the interferences this form of behaviour engenders.

1.5 Chapter Outline

The dissertation consists of four parts. In the first, presented in three chapters, a conceptual foundation is established upon which the remainder of the dissertation builds. In Chapter 2 brief reviews of four concepts pertinent to this study—media, cognitive control, goal interference and human behaviour— are presented. Extending from this, in Chapter 3, the patterns and drivers of media multitasking are considered. The final chapter in Part I provides an overview of research concerning associations between media multitasking and cognitive control. To address the first research objective, the second part of the dissertation presents a systematic review of relevant interventions targeting changes in outcomes related to cognitive control. Chapter 5 outlines the objectives of this review and the methodology through which they were addressed, with the outcomes and a discussion thereof presented in Chapter 6. A version of chapters 5 and 6 has been published in the journal *Computers in Human Behavior* as Parry and le Roux (2019*a*). The third part of the dissertation addresses the second research objective of the study and describes the methodology, analysis, and results of a feasibility assessment of the behavioural intervention developed on the basis of the background literature reviewed and the outcomes of the first research objective. Specific research questions were posed to guide the feasibility assessment and, to assess the efficacy of the intervention, relevant hypotheses were formulated. These are presented in Chapter 7 which outlines the research design adopted in this assessment. Thereafter, the analysis of the data and findings made are presented in Chapter 8. The fourth part of the dissertation presents a final chapter which provides a conclusion to the study. Specifically, in Chapter 9 the findings are discussed in relation to the research objectives, the current body of knowledge and, finally, their implications for research and practice. Additionally, the chapter includes a consideration of limitations present in the study and, extending from the limitations and findings, recommendations for future research.

Part I

Background and Literature Review

Chapter 2

Theoretical Background

To provide a conceptual and theoretical basis upon which the remainder of this dissertation builds, this chapter presents a brief overview of four key concepts. First, to provide a pragmatic working definition, 'media' as a concept is considered. Second, the concept of cognitive control is examined. The third section concerns the nature of behavioural and cognitive interference. In the course of this consideration multitasking as a concept is defined. Finally, to inform the systematic review and intervention assessment, the fourth section considers a number of prominent theories of human behaviour.

2.1 Conceptualising Media

There is much ambiguity surrounding '*media*' as a concept, with the term used, simultaneously, to refer to the artefacts of communication as well as the associated processes and systems of communication. Hodkinson (2016, p. 1), for instance, defines a medium as the "means by which content is communicated between an origin and a destination", whereas Lievrouw and Livingstone (2006, p. 23) consider media to consist of the "artefacts or devices used to communicate or convey information, the activities and practices in which people engage to communicate or share information, and the social arrangements or organizational forms that develop around those devices and practices". Given the varying notions of what the term media encompasses, the different domains in which it is used and the discursive nature of its construction, presenting a single conceptualisation for media is challenging. Indeed, in the literature reviewed the term media is simultaneously used to refer to artefacts, processes, cultures, enactments, and even extensions of human capabilities. Further contributing to this ambiguity is the term '*new media*', which captures the notion that, since the 1980s, media are evolving to an extant not seen previously (Lister *et al.*, 2009, p. 2). The purpose of this section is to consider prominent discourses and conceptualisations of media and, on this basis, present a working definition to be adopted for the remainder of this dissertation. This commences with an overview of two prominent theoretical discourses on the relationship between media and their users. This establishes a basis upon which a subsequent assessment of key characteristics builds.

2.1.1 Historical Discourses in Media Theory

In 1882 Thoreau published *Walden* —a reflection upon simple living. Despite its age, Thoreau's insights hold relevance today (Dolis, 2005). In reference to technological innovations, Thoreau (1882, p. 31) proclaims that "they are an improved means to an unimproved end". By this, he suggests that any new invention, ICTs for instance, should be viewed with skepticism. Commenting on this assertion Cafaro (2010, p. 92) explains that this entails considering the purpose of any technology, as well as the possibility of unintended side effects associated with its use. It does not preclude the recognition that media enable numerous positive, beneficial functions. Rather, the work of Thoreau suggests that, to understand media, it is necessary to not only consider intended purposes, but also the unintended consequences of their use. On this basis, this sub-section presents a brief discussion of two theoretical accounts of media —those of Marshal McLuhan and Neil Postman. It is acknowledged that considering the views of only two theorists creates a limited perspective. The purpose of this sub-section, however, is not to present a rigorous evaluation of all media theory. Rather, it serves to provide direction to the development of a pragmatic working definition for the term media.

In coining the phrase 'the medium is the message' McLuhan (1964) argues that, to understand media, the study of mediated content holds little value in comparison with the analysis of the underlying technologies. For McLuhan (1964, p. 9), the characteristics of a medium determine how the "scale and form of human association and action" are influenced. Essentially, McLuhan argues that it is a medium's properties, rather than the content it conveys, that have a capacity to impact perception and behaviour. Prior to this, McLuhan (1962) asserted that mediated experiences involve a perceptual interaction with the senses, shaping experiences of reality. Accordingly, he contends that different modes of communication, facilitated by different media, enable different experiences of reality —as a result of their selective biases (Vieta and Laureano, 2013). This notion of selective bias can be related to the concept of *affordances* proposed by Gibson (1979). In design theory affordances describe the perceived and actual properties of an object determining how it can be used (Norman, 1988, p. 9). For instance, Baron (2008) describes the capacity of paper to record the written word without the need for an electrical power source as an affordance of this medium. As another example, she describes the capacity of mobile phones to extend the physical locations within which communication can occur as an affordance of such media. Affordances describe the action possibilities a medium enables. Through the enactment of an affordance specific behaviours are facilitated.

In describing media as "extensions of ourselves" McLuhan (1964, p. 22) highlights how different media and, therefore, different affordances, extend the senses in different ways, enabling certain patterns of behaviour and preventing others. Such patterns, however, are not only a function of the medium itself, but also the context in which it is used. McLuhan (1964, p. 26) explains that "no medium has its meaning or existence alone, but only in constant interplay with other media", suggesting that individual media experiences are dependent on inter-media interactions. This interplay is particularly evident given the increasing convergence of new media. Jenkins (2006, p. 2) describes convergence as the "flow of content across multiple media platforms, the cooperation between multiple media industries, and the migratory behavior of media audiences". Rather than viewing convergence as a technological process, Jenkins views it as a cultural shift, emphasising the information-seeking nature of media interactions. Consequently, any effects of media are contingent on subjective-situational factors as well as interactions with other media.

In *Amusing Ourselves to Death: Public Discourse in the Age of Show Business*, Postman (1985) distinguishes between the Orwellian vision of the future depicted in *Nineteen Eighty-Four* and that offered by Huxley in *Brave New World*. Postman employs these fictional accounts as lenses through which to consider television's effect on the nature of public discourse. While primarily concerned with television, the author offers a number of assertions pertinent to new media in general. The fundamental premise underlying his argument is that the "media of communication available to a culture are a dominant influence on the formation of the culture's intellectual and social preoccupations" (p. 10). By this, he suggests that media engender a particular view of reality. As such, this position corresponds with McLuhan (1964)'s assertion that the 'medium is the message'. Postman, however, contends that McLuhan's maxim requires revision. Recasting McLuhan's aphorism as 'the medium is the metaphor', Postman suggests that the comparison with a 'message' is inappropriate, as messages denote specific statements about the world —something which, he argues, media do not. Rather, he likens media to 'metaphors', suggesting that they work through unobtrusive but powerful implication to enforce their conceptions of reality on those who interact with them.

Postman (1985, p. 84) distinguishes between a 'technology' and a 'medium', describing a technology as "merely a machine" and a medium as the "use to which a physical apparatus is put [...] the social and intellectual environment a machine creates". A smartphone as a technology is an assemblage of components, whereas a smartphone as a medium is a ubiquitous means of communication, entertainment and, arguably, disruption. A medium is the social and cognitive environment dictated by the manner in which it is used. This definition builds on the notion that, through technological affordances, behaviour is directed in particular ways. Postman (1985) argues that these biases enable media to impact the character of social and personal environments, to alter the nature of epistemology, and to direct attention. Written text as a medium favours linear, systematic analysis, whereas television favours immediacy and entertainment. Computers, in contrast, favour information exchange. Summarising this, Postman (1998, p. 3) states that "every technology has a philosophy which is given expression in how the technology makes people use their minds, in what it makes us do with our bodies, in how it codifies the world, in which of our senses it amplifies, in which of our emotional and intellectual tendencies it disregards". It is important to note that Postman is careful not to claim that media produce changes in neural structures or cognitive capacities. Rather, he restricts his argument to the impact of media on the shape of social and political discourses.

While Postman distinguishes between a medium and a technology, McLuhan does not. In providing electric lights, the wheel, or books as examples of media as 'extensions of ourselves', McLuhan draws attention to the physical nature of these media and how, as tools, these artefacts extend human capabilities. The characteristics or affordances of a medium, as physiological extensions, can come to alter "the whole psychic and social complex" (McLuhan, 1968, p. 11). McLuhan (1962), accordingly, asserts that media alter the 'ratio' between various human senses. In this way, specific affordances can come to shape an individual's sensory relationship with the world (Lister *et al.*, 2009). For Postman, a technology is merely the artefact of communication. Media, in contrast, are the use to which these artefacts are put, and the ensuing cognitive and social environments they engender. For both of these theorists then, media refer to more than simply the artefacts of communication. Media imply an association between a tool, the uses to which it can be put, and the behaviour and thought processes that it engenders. While McLuhan emphasises the physical or technological nature of media, Postman along with Williams (2003), however, contends that rather than referring to a specific technological artefact, a medium is a particular use for an artefact.

Since Postman and McLuhan view the technological biases inherent in media as key to the determination of related cognitions and behaviour, their views have been regarded as technologically determinist (Bolter, 2003). Technological determinism presumes that technology functions as an independent factor —shaping society, and changing behaviours (Hodkinson, 2016). In proposing that media are the 'message' or the 'metaphor', they presume that the biases inherent in media direct their use in predictable ways "regardless of who develops and controls them, who uses them and what socio-cultural context they are placed within" (Hodkinson, 2016, p. 24). McLuhan (1964) does, however, acknowledge the role of social contexts and inter-media interactions. As such, his work has been considered to be *softly* determinist —both technological affordances and human agency drive behaviour (Logan, 2013). This notion is captured in the complementary terms 'Medium Theory' and 'Media Ecology' conceptualised by McLuhan in 1964 and formalised by Postman (1970). Medium theory focuses on media as a form of technology, whereas its counterpart, media ecology, concerns the interaction between media-technologies and their environments (Van Loon, 2008).

Williams (2003, p. 133) suggests that technological determinism ignores those responsible for the development of media. Likewise, Hill (1988, p. 15) argues that technological innovation is a function of the "alignment between technological possibilities and the society and culture that exists". Additionally, Kritt and Winegar (2007, p. 5) argue that technological progress is driven by a profit motive, implying that those responsible for the development of technologies hold vested interests in their adoption and continued use. Such notions are described as the *Social Shaping of Technology* (SST) and illustrate how the design and use of media, as technological artefacts, are influenced by multiple technical, social, and economic factors (Williams and Edge, 1996). In contrast to the passive interpretation of the technological determinists, such a perspective holds that human actors play a key role in determining the nature, use and effects of media. Of particular relevance is the manner in which those responsible for the design and development of media embed their world-views, motives, and practices into their products (Williams, 2003). This is exemplified by the increasing influence of *persuasive design*[1] on the nature of media (Lockton *et al.*, 2008). A further aspect of the SST, central to this dissertation, is the notion that, while media may present specific affordances to their users, biasing behaviour in certain directions, such affordances can be enacted in numerous diverse and unexpected ways (Boudreau and Robey, 2005; Leonardi, 2011; le Roux, 2013).

[1]Persuasive design focuses on designing products or services (typically software services), in such a way so as to influence behaviour towards desired outcomes (Fogg, 2002).

The medium, then, is *not* the *only* message. Rather, in addition to the affordances of media, use and effects are contingent on contextual, economic, normative, and personal factors. Moreover, Williams (2003, p. 132) proposes that media frequently become appropriated for unintended uses, often with unexpected consequences. For instance, text-messaging on mobile phones, now a popular feature, was never expected to be used outside of very specific use-cases (Deuze, 2012, p. 46). Both McLuhan and Postman emphasise the importance of understanding the role of media in shaping cognitive, social, and cultural experiences, reasoning that media's inherent biases direct behaviour and, potentially, determine perceptual and cognitive experiences. In proposing that media are the 'message' or the 'metaphor' they recognise that the effects of media extend beyond simply their content. The affordances of media shape the characteristics of both the content and the manner in which interaction takes place. To further understand the relationship between media and cognition it is evident that, in addition to appreciating the nature of media, it is also necessary to examine the subjective and situational factors surrounding media use. The remainder of this section considers the characteristics of media, while Chapter 3 concerns the latter factors.

2.1.2 Media Affordances

The term 'new media' avoids emphasising specific technologies or artefacts. Its abstract nature enables it to capture a number of continually evolving technological, ideological and experiential changes (Lister *et al.*, 2009). Key to these changes are the affordances of such media. As noted, the term affordance refers to the action possibilities a medium enables. There is, however, much debate about how this concept should be understood. Affordances, as first used by Gibson (1979), describe a relation between an organism and its environment. In HCI, affordances are understood as properties of an artefact —either perceived or actual— directing behaviour (Norman, 1988). Emphasising how media can simultaneously be socially constructed *and* behaviour-directing, Hutchby (2001, p. 30) suggests that the concept of affordances provides a solution to the incongruence between technological determinism and social constructivism. Bucher and Helmond (2017) note that this position has been adopted in research considering media to describe how they "alter communicative practices or habits" (Schrock, 2015, p. 1232). This perspective argues against understanding affordances as specific features of a medium. Rather, emphasis is placed on high-level abstractions of what media afford. This implies understanding both the characteristics of a medium, at a low level and, at a high-level, understanding how these features combine to enable specific actions. Helles (2013, p. 14), for instance, states that "the central affordance of mobile phones is not the mobility of the device per se, but rather the fact that the user becomes a mobile terminus for mediated communicative interaction across the various contexts of daily life". Therefore, a hierarchy emerges, with low-level affordances describing features and high-level affordances describing the enactment of these features. Consequently, when considering media effects, researchers appreciate affordances at multiple levels, considering both low-level features and high-level enactment (Bucher and Helmond, 2017). In this sub-section two high-level affordances of media are considered. These should not be viewed as constituting all possible affordances of new media, nor should they be understood as being present in all media simultaneously. Rather, as high-level abstractions, they are useful for considering possible forms of behaviour with media.

2.1.2.1 Hypertextual Interactivity

The term *hypertext* describes a resource providing a network of links to other resources external to itself (Nelson, 1965). While initially referring to the linking of text, the underlying concept of hypertextuality —the nonlinear linking of nodes— has been adopted to a number of computing paradigms (Conklin, 1987). A prominent extension of hypertext is *hypermedia* —a nonlinear method of information display occurring across a range of media, including: audio, graphic, video, and text (Nielsen, 1995, p. 5–9). The *World Wide Web*, or simply the *web*, is arguably the most important example of a hypermedium. As outlined by Berners-Lee (1989) the web is a network of interlinking hypermedia objects. Lister *et al.* (2009, p. 29) suggest that hypertextuality alters the nature of information exchange and communication. Since the introduction of the moveable-type printing press in the 15^{th} century mediated information exchange has, primarily, taken place in a linear, sequential manner (Ong, 2013). The hypertextuality of new media, disrupts this order, bringing about the possibility of non-sequential, non-linear information exchanges (Conklin, 1987; Nielsen, 1990). People are no longer required to engage with media in a linear, pre-determined manner. Rather, they are afforded the ability to move from one page, channel, activity, or even medium to another (McAleese, 1999). This hypermediacy "multiplies the signs of mediation and in this way tries to reproduce the rich sensorium of human experience" (Bolter and Grusin, 1999, p. 33).

Interactivity and multidirectional communication are among the primary attributes characterising new media (Lister *et al.*, 2009). Prior to digitalisation and widespread networked technologies, media were characterised by passive, uni-directional communication.

Now, as a result of their networked nature new media operate in a many-to-many manner (Manovich, 2001). Each individual user is a node in a web of interconnected nodes. Moreover, Wittel (2001, p. 51) proposes that mediated social relations should be viewed as being driven by a *network sociality* —as a result of the networked, peer-to-peer nature of new media, relations are iterative, based on exchange of information and 'catching up'. people are able to exchange information with a range of individuals or groups at any time and from any location (Ha and James, 1998).

Through interactivity mediated communication no longer consists of active senders and passive receivers. Rather, all *users* actively engage in the transmission, reception and modification of information in a manner which draws upon their existing identities, contexts and capacities (Hodkinson, 2016). Rogers (1995, p. 314) describes interactivity as the "degree to which participants in a communication process can exchange roles in, and have control over mutual discourse". Rheingold (1993) suggests that asynchronicity is an essential feature of interactivity. Synchronous communication requires all users to be participating concurrently (e.g., telephone calls, or radio broadcasts). In contrast, asynchronous communication does not require temporal overlap (e.g., email). Other forms of mediated communication, for instance instant messaging, can take place either synchronously or asynchronously (Dennis *et al.*, 2008). It is not the synchronicity that determines interactivity. Rather, it is the networked multi-directionality —the ability of users to receive and transmit information across time and space— that characterises a medium as interactive. Stiegler (1998) proposes that this dislocates experiences from spatial and temporal contexts. Mediated interactions are reduced to a 'real-time present'. Castells (2011, p. 491), accordingly, notes how media engender experiences of 'timeless time' in which both simultaneity and timelessness characterise interaction.

2.1.2.2 Centrality

Extending from technological advances in processing power, mobility, energy storage, and information transmission, access to and use of digital communications media has risen dramatically over the course of the 21st century (Pew Research Center, 2017, 2018). These advancements, coupled with increases in accessibility and continued developments in software capabilities, have enabled considerable improvements in the extent to which digital communications media can gratify both utilitarian and hedonic needs. Media are, consequently, *central* to how people work, socialise, communicate, and interact with the world around themselves (Cheung *et al.*, 2011; Bolton *et al.*, 2013; Ward, 2013;

Vorderer *et al.*, 2016). The notion of centrality is used to capture the importance of media across all aspects of 21st century life. It is argued that media are central to individuals lived-experiences to such an extent that, as Baudrillard (1985) suggests, distinctions between physical interactions and mediated interactions have become increasingly blurred (Broughton *et al.*, 2019).

While the centrality of media may arise due to both utilitarian and hedonic motives, media with a social element, in particular, enable ongoing processes of identity construction, communication, information gathering, and entertainment which, arguably, contribute to increased use-instances and the centrality of such media for 21st century life. Social networking services (SNSs), as a case of such media, enable users to "construct a public or semi-public profile within a bounded system, articulate a list of other users with whom they share a connection, and view and traverse their list of connections and those made by others within the system" (Boyd and Ellison, 2008, p. 211). These services are adopted by billions of people as central components in their everyday lives for communication, information gathering, and connectivity amongst other uses (Hodkinson, 2016).

The centrality of SNSs and instant messaging platforms has contributed to the increasing volume of media competing for attention (Rosen *et al.*, 2013*a*). Moreover, mediated experiences are increasingly designed to compete for attentional allocation (Kritt and Winegar, 2007), with interactions momentarily attracting attention, before being replaced by the next (Hodkinson, 2016). Accordingly, such media promote rapid-switching between various temporarily engaging activities (Carrier *et al.*, 2009). Hodkinson (2016, p. 269) explains that responses to such engagements are "dominated by emotional reactions, snap judgements and, ultimately, a thirst for the next bite-sized snippet of content". This extends from the increasingly competitive *attention economy* (Simon, 1971) promoting the development of media designed to compete for attention. Moreover, information of a social nature initiate a greater degree of attentional allocation than other forms of mediated communication (Atchley and Lane, 2014). Commenting on this Atchley and Lane (2014, p. 161) note that "when paired with devices and applications that can deliver that information rapidly and on a massive scale, a normally rational expense of attention to monitor social information of limited temporal value from a small set of physically nearby people, becomes an irrational attempt to monitor and respond to networks much larger than those for which our brains were adapted".

Whether use is motivated by hedonic or utilitarian gratifications, rational or irrational responses, or a combination of these factors, media have come to form a central component of how people work, play, socialise, and go about their daily activities across generations, situations, and geographic locations. It is argued that, given the technological advances and the increases in centrality that this has brought about, Baudrillard (1985)'s suggestion that the distinction between physical interactions and mediated interactions has become increasingly blurred holds true more so now than ever before. Moreover, such media are increasingly designed to attract attention and embed themselves in individual's lives in evermore persuasive ways (Lockton *et al.*, 2008; Wendel, 2013).

2.1.3 Conclusions

At the outset of this section it was acknowledged that there is a degree of conceptual ambiguity surrounding media. In considering McLuhan and Postman's theses, it is clear that media refer to more than simply the artefacts of communication. A medium implies a relation between an artefact, its affordances, and ensuing behavioural, cognitive and social processes. These theorists emphasise the role of media in determining such outcomes, arguing that inherent technological biases direct behaviour in predictable ways. The term media has been used variously to refer to any one of these factors —artefacts, affordances and their implications— as well as related organisational and social constructs. This multifarious use contributes to the conceptual ambiguity and difficulty in producing a single definition for media. Given this ambiguity, it is necessary to consider a working definition for the purposes of this dissertation. It is acknowledged that such a definition will not satisfy all conceptualisations and domains in which the concept is used. Rather, it aims to enable a pragmatic use of the term in the context of this dissertation.

For the purposes of this dissertation a medium is understood to be an emergent hierarchy consisting of *artefacts*, their *affordances*, the *enactment* of these affordances, and the *culture* that this enactment creates. The term artefact will be used to describe technological artefacts typically referred to as *Information and Communications Technologies* (ICTs). This designation includes two categories: hardware or devices (e.g., laptops, smartphones) and software or services (e.g., SNSs, web browsers, or other platforms). A medium, therefore, is inclusive of the underlying technologies (material, or virtual) that constitute an artefact, its affordances, the enactment of these affordances, and the ensuing culture that emerges as a result of shared enactments of these affordances. Consequently, the medium is the enactment of affordances which emerges as a result of the interplay between technological features and subjective-situational factors. Moreover, through repeated enactment, a shared culture of behaviour, customs, and norms develops for particular artefacts and actions. This definition incorporates McLuhan (1964)'s view that the characteristics of a medium can influence human association and action, Postman (1985)'s suggestion that a medium is the social and intellectual environment a machine creates, and Williams (2003)'s notion of a medium being a use to which an artefact is put, as well as providing a conceptual bridge between technological artefacts and human behaviour. For the sake of brevity, the term *media* will be adopted when referring to new media for the remainder of this dissertation. Where necessary, specific aspects of media, artefacts or affordances for instance, may be referred to in isolation.

2.2 An Understanding of Cognitive Control

Cognitive control refers to the theorised mechanisms underlying the execution of goal-directed behaviour (Gilbert and Burgess, 2008). Altmann and Trafton (2002, p. 39) define a goal as a "mental representation of an intention to accomplish a task, achieve some specific state of the world, or take some mental or physical action". Cognitive control has, accordingly, come to be associated with a diverse range of behavioural competencies, including: decision-making, problem-solving, performance regulation, and multitasking (McCabe *et al.*, 2010). The execution of these competencies requires fundamental cognitive or *executive* functions such as inhibitory control, working memory, cognitive flexibility and attentional control. While distinctions can be drawn between these functions, their operational unity has been acknowledged (Miyake *et al.*, 2000).

Neurologically, cognitive control functions through representations manifested in the prefrontal cortex, which modulate neural activity through distributed neural networks. Miller and Cohen (2001, p. 193) note that, "depending on their target of influence, representations in the prefrontal cortex can function variously as attentional templates, rules, or goals by providing top-down bias signals to other parts of the brain that guide the flow of activity along the pathways needed to perform a task". Gazzaley *et al.* (2005) corroborate this, showing that both the magnitude and the speed of neural processing are modulated on the basis of current goals. Cognitive control is, consequently, not a static or fixed trait. For instance, it changes as a function of age, with improvements during childhood and adolescence mirroring the development of the prefrontal cortex (McAvinue *et al.*, 2012). Moreover, it functions as a result of an interplay between relatively static traits and more dynamic states. States shown to degrade cognitive control include: sleep deprivation (Ratcliff and Van Dongen, 2008), stress (Staal, 2004), and intoxication (Dry *et al.*, 2012). Additionally, cognitive control is limited in its operation (Eysenck and

Keane, 2013). While cognitive control directs behaviour on the basis of consciously selected goals, it is possible for goals to become *unconsciously* activated (Moskowitz, 2012). Moreover, the operations of cognitive control compete with bottom-up, exogenously initiated behavioural responses (Posner, 1980).

It is necessary to acknowledge that the exact nature of these executive systems is difficult to define. This is largely due to the functional unity of executive operations and the goal-related nature of cognitive control. Burgess (2004) explains that the term 'executive functions' is not an operational definition. Rather, in his view, it is a theoretical definition. Performance of these functions can only be observed by measuring other cognitive processes. Burgess (2004), however, notes that this raises the problem of cognitive congruence —performance on any one cognitive task typically correlates with performance on others. Consequently, *theories* of executive functioning have largely been based on research involving patients with brain-lesions in areas with known functional associations. For this reason, there exists a multitude of models and theories describing the operation of cognitive control. This section provides an examination of the theorised operation of three core executive functions: working memory, cognitive flexibility, and inhibitory control. Additionally, it concludes by considering a fourth process, closely related to the operation of these executive functions, attentional control.[2]

2.2.1 Working Memory

Working memory (WM) describes a cognitive function, available in limited supply, responsible for temporarily maintaining the availability of task-related information (Shah and Miyake, 1999). Since Miller *et al.* (1968)'s early conceptualisation the term 'working memory' has been used synonymously with 'short-term memory' (STM). There is, however, a distinction between the two. STM refers to the storage of information over a brief period of time (Cowan, 2009). In contrast, WM is theorised to account for the manipulation of stored information (Diamond, 2014). For both, stored mental representations decay over time (Vogel *et al.*, 2001). The operation of WM is theorised to relate closely to that of attention. For instance, the *Integrated Competition* theory postulates that there exists a single selection mechanism for both WM and attention, with attentional selection functioning on the basis of WM contents (Duncan, 1996). Similarly, Cowan (1998) proposes that WM is composed of two components: a capacity-limited focus of

[2]There is much debate about whether attentional control should be considered a fourth executive function, or whether it occurs as a result of the combined operation of these core executive functions.

attention and activations of representations retrieved from long term memory (LTM). While these theories support a unitary view, other researchers indicate that this is not the case (e.g. Posner and Petersen, 1990; Smith and Jonides, 1999). Fougnie (2008) suggests that attention is key to the encoding and manipulation of information in WM, but its involvement with the maintenance of stored representations is limited. Therefore, while closely related there is, nonetheless, a distinction between WM and attention.

To account for the operation of WM Baddeley and Hitch (1974) proposed the *Multicomponent Model* consisting of three components: the central executive, the phonological loop, and the visuospatial sketchpad. Subsequently, Baddeley (2000) extended the model, adding a fourth component, the episodic buffer. The central executive regulates the operation of the other components, the phonological loop stores information in a linguistic structure, the visuospatial sketchpad stores visual information, and the episodic buffer provides a link between WM and LTM. The interpretation of the central executive as a 'controller' of the other components has developed substantially since its early description. Repovš and Baddeley (2006, p. 12) note that, originally, the concept was used as a "convenient ragbag for unanswered questions related to the control of working memory and its two slave subsystems". Baddeley (1996) describes four functions of the central executive: switching of retrieval plans, time-sharing across dual-task situations, selective attention, and temporary activation of LTM. He does, however, note that while there exist flaws in the description of the central executive as a unitary system, it remains, nonetheless, a useful conceptualisation for the operation of WM. This description of the central executive corresponds with Miyake *et al.* (2000)'s description of cognitive control, suggesting a degree of conceptual overlap between the central executive and cognitive control. Some researchers consider the central executive to be synonymous with cognitive control (e.g. Engle *et al.*, 1999; Kane and Engle, 2000). Others (e.g. Miyake *et al.*, 2000; Diamond, 2014) argue that there is a distinction between the two.

2.2.2 Cognitive Flexibility

Cognitive flexibility describes the switching of processing from one concept or activity to another (Martin and Rubin, 1995). In an early definition Scott (1962, p. 405) describes this function as: "the readiness with which the person's concept system changes selectively in response to appropriate environmental stimuli". Miyake *et al.* (2000, p. 55) expand upon this definition, suggesting that cognitive flexibility refers to the capacity to shift attention between different tasks in response to changes in either the environment *or* goals. Cognitive flexibility has, therefore, been designated the *task switching* or *attention shifting* ability. During task performance associated mental representations or task sets are activated (Schneider and Logan, 2005). Shifting to a different task implies a switching cost —the task sets associated with the new task need to be represented in WM (Rogers and Monsell, 1995). When task switching, performance is slower and less accurate (Allport *et al.*, 1994; Monsell, 2003). Two theories describe the cognitive basis for these switch costs: task-set reconfiguration and task-set priming. The reconfiguration of task-sets supports the performance of goal-directed behaviour, with switch costs arising as a result of the executive processes required for the implementation of task sets associated with a new task (Rubinstein *et al.*, 2001). In contrast, proponents of task-set priming contend that switch costs result from associative priming (Allport *et al.*, 1994; Waszak *et al.*, 2003). Priming describes how common stimuli-response associations are retrieved, irrespective of the suitability of a particular response for current goals (Schneider and Logan, 2005). Irrespective of the basis, switch costs imply that, while people are capable of engaging in multiple tasks concurrently, performance is diminished.

2.2.3 Inhibitory Control

Inhibitory control describes the processes necessary for the enactment of control over thoughts or behaviour through the inhibition of either internal mental representations or responses to external stimuli (Diamond, 2014). Moreover, it is associated with the notion of interference resistance or filtering. Dempster and Corkill (1999, p. 397) describe interference resistance as “the ability to ignore or inhibit irrelevant information while executing a plan”, highlighting its importance for goal-directed behaviour. Additionally, it underlies the suppression of prepotent mental representations —extraneous thoughts or memories (Diamond, 2014, p. 2). Nigg (2000) describes a taxonomy for inhibitory processes comprised of four classes of effortful, endogenous inhibition: interference control, cognitive inhibition, behavioural inhibition, and oculomotor inhibition. Interference control refers to the suppression of interference resulting from external stimuli. Cognitive inhibition refers to the suppression of task-irrelevant representations in WM. Behavioural inhibition describes the suppression of prepotent responses, and oculomotor inhibition describes the suppression of reflexive saccades. Cognitive inhibition has been shown to be crucial for selective attention (MacLeod, 2007). Rafal and Henik (1994) review studies considering the basis for inhibitory processes in attention and outline the following roles: the inhibition of responses to stimuli in unattended channels, the inhibition of response reflexes, and the reflexive suppression of subsequent signals emanating from unattended stimuli. These processes relate to either response inhibition or signal suppression. Inhibitory control has also been shown to underly endogenously directed selective attention and the enactment of self-control (Diamond, 2014) and, in this way, enables the suppression of momentary impulses and sensory distractions, facilitating delayed gratification.

2.2.4 Attentional Control

Attentional control describes the capacity to direct the allocation of attention. Hale and Lewis (1979, p. 31) state that 'attending' refers to perception in relation to a task or goal. As noted, the operation of attentional control is closely related to that of WM and inhibitory control (Posner and Petersen, 1990). For the purposes of this dissertation, it is not necessary to determine if attentional control is distinguishable as a unique executive function, or if it is an emergent ability. Rather, it is important to understand the functional operation of attentional control and how attentional processes are conceptualised. Such an understanding will enable a more complete examination of attention-related interferences. This sub-section considers a number of key components of attentional control, including the orienting, distribution and sustaining of attention. Prior to this, however, it is necessary to establish a working definition for attention itself.

2.2.4.1 Towards a Working Definition For Attention

Attention refers to the cognitive processes associated with selecting a subset out of all stimuli for further processing (Gazzaniga *et al.*, 2009). This notion of *focalisation*, concentrating on a particular element while disregarding other elements, was first suggested by William James in 1890. James (1890, p. 403) defined attention as "the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought [. . .] it implies withdrawal from some things in order to deal effectively with others". Selectively processing only a subset of all concurrently available stimuli is known as *selective attention* (De Weerd, 2003). Before concluding with a working definition a number of key theories of attention are briefly considered.

Historically, attention has been framed in terms of a *bottleneck* on the sequential processing of stimuli (see Cherry, 1953; Cherry and Taylor, 1954), with research focusing on the location of the bottleneck —the timing of selection. In early selection models stimuli are filtered on the basis of their physical characteristics, prior to semantic processing (Broadbent, 1958). Such theories do not stand up to evidence presented in subsequent studies indicating that processing takes place on purportedly unattended stimuli (e.g. Treisman, 1960; Triesman, 1964; Wood and Cowan, 1995). On the basis of such findings an attenuation theory was developed, with selection occurring at different stages of processing, based on subjective considerations of importance or objective probabilities (Triesman, 1964). Deutsch and Deutsch (1963)'s late-selection theory proposes that all stimuli receive a modicum of semantic processing, with selection occurring after this analysis. This theory has received little support with subsequent experimental and neurophysiological studies disputing its propositions (e.g. Treisman and Riley, 1969; Lachter *et al.*, 2004; Coch *et al.*, 2005). Common to all sequential processing theories is the notion that attention cannot be allocated to all stimuli. The primary distinction arises as a result of when selection occurs during processing. Lachter *et al.* (2004) criticise this early work, noting the reliance on assessments within an auditory modality. With dichotic listening tasks it is difficult to ensure that attention does not switch between channels. Lachter *et al.* (2004, p. 881) contend that many studies reporting processing from unattended channels failed to adequately ensure that unattended stimuli were actually unattended. These findings then occurred either as a result of *slippage* —allocation of attention to irrelevant stimuli, or *leakage* —semantic processing of irrelevant stimuli while attention is directed elsewhere. Although both account for previous findings, evidence from a number of studies (e.g. Conway *et al.*, 2001; Lachter *et al.*, 2004) suggests that slippage holds greater value than leakage for the prediction of selective attentional processing. While the sequential approach has contributed significantly to the understanding of attention, it addresses only a single component of selective attention —when it occurs. As Styles (1997, p. 28) indicates, this "may not help us to understand *why* or *how* it happens".

A central capacity approach to attention is useful for considering the implications of multiple simultaneous attentional demands occurring across numerous sensory modalities. The principal concept within this approach is that there exists some central capacity, whether it is attention, or the combined capacity of the cognitive functions, that can be employed in a flexible manner across multiple stimuli (Kahneman, 1973). This conceptualistion of attention is not in conflict with other theories, rather, it augments earlier theories of attention (Kahneman, 1973, p. 11). In contrast to the transmission line analogy describing sequential theories, Moray (1967, p. 87) proposed the metaphor of a *central processor* to describe selective attention. Building on this Kahneman (1973) proposed the *Capacity Model of Attention*, emphasising the allocation of attention rather than the processes through which stimuli are selected. In doing so he highlights the importance of intensity for attention. In contrast to Berlyne (1960), who primarily considered the involuntary allocation of attention, Kahneman (1973, p. 4) suggests that these intensive aspects of attention should be considered for both voluntary and involuntary selection. Kahneman (1973, p. 8) proposes that there exists a "general limit on man's capacity to perform mental work". Within this model, attention is defined as a resource requiring the allocation of mental effort. The allocation of attention is determined by available attentional capacity —a resource directly influenced by current levels of arousal. In addition to mental effort, arousal operates as a function of factors such as stress, sleep, and the ability to evaluate current attentional demands. These factors represent an individual's capacity to allocate attention. Kahneman proposes that this capacity is distributed by means of an *allocation policy*, influenced by enduring dispositions (goals), momentary intentions, the available capacity, and current evaluations of attentional demands.

Subsequent theories adopting the central capacity approach differ on the degree to which attentional resources may be simultaneously allocated as well as the basis for this allocation. Examples include the *Multiple Resource Theory* and the *Multimode Theory*. An alternative perspective, building on findings described by Treisman and Davies (1973), suggests that rather than a central capacity, particular combinations of tasks interfere with each other. Known interferences include semantic domain (Hirst and Kalmar, 1987), common spatial encoding (Baddeley and Lieberman, 1980), and simultaneous phonological encoding (Salame and Baddeley, 1982). Contending that these fail to account for subsequent findings Bourke *et al.* (1996, p. 526) suggest that dual-task interference is related to the *quantity* of cognitive processes involved in a situation. This notion relates to *Perceptual Load Theory*, which postulates that stimuli are automatically processed until capacity is completely allocated (Lavie *et al.*, 2004). When perceptual load is low, both relevant and irrelevant stimuli receive semantic processing. Conversely, when perceptual load is high, only relevant stimuli are processed. This theory implies that, under high perceptual load, irrelevant stimuli do not affect performance (Lavie *et al.*, 2004).

A third approach considers the manner in which stimuli are represented in WM. Neisser (1967, p. 89–91) describes a two-stage model of attention consisting of pre-attentive and attentive processes. Pre-attentive processes, detached from voluntary control, distinguish physical characteristics of sensory stimuli. Subsequently, controlled attentive processes, requiring attentional resources, operate on stimuli. Studies distinguishing between automatic and controlled attentional processes support this two-stage allocation procedure (Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977). Neisser and Becklen (1975, p. 481) contend that stimuli are processed into *representations* or *schemas* of objects or events. Stimuli not necessary for the construction of a schema are ignored. They assert that the process of selectively attending to a particular stimulus does not involve distinct mechanisms to rebuff undesirable or unnecessary information. Rather, this ability is as a result of "skilled perceiving" (Neisser and Becklen, 1975, p. 480). It is not the modality or physical characteristics of a stimulus that distinguish it from other stimuli. Rather, it is the "intrinsic properties and structure" of the stimulus that direct attentive processes (Neisser and Becklen, 1975, p. 480). Once representations are constructed, it requires a degree of cognitive effort to switch attention from one representation to another.

2.2.4.2 Defining Attention

Common to all the approaches considered is the understanding that people do not possess the capability to attend to all possible demands on their attentional systems. On the basis of this examination, for the purposes of this dissertation, the following working definition for attention is adopted: *Attention describes the allocation of cognitive resources to a subset of all concurrently possible stimuli, originating either internally or externally, leaving the remaining stimuli unprocessed, either due to a limit in the capacity of available resources, the prevailing conditions within an allocation policy, or their value for schema construction.* So it follows that, primarily, a central capacity interpretation of attention is adopted. Accordingly, the definition incorporates the notions of cognitive arousal and effort as integral components for the operation of attention.

2.2.4.3 Attentional Orienting

Posner (1980, p. 4) defines orienting as the "aligning of attention with a source of sensory input or an internal semantic structure stored in memory", explaining that it is directed by either internal (endogenous) or external (exogenous) processes. Goldstein and Gigerenzer (2009) note that involuntary attention is characterised by exogenous stimuli diverting attention to themselves in a bottom-up, reflexive manner. In contrast, voluntary attention enables goal-oriented behaviour. Emphasising differences between automatic and controlled processes, studies have found processing differences between endogenous and exogenous attention (Schneider and Chein, 2003; Berger *et al.*, 2005). Jonides (1981) notes that exogenous orienting is less affected by cognitive load than endogenous orienting and, additionally, that it is easier to suppress an attentional shift induced by an endogenous cue than it is for an exogenous cue. Subsequently, Folk *et al.* (1992) found that involuntary attention shifts are contingent on the relationship between the properties of the eliciting event and the properties required for task performance. These authors proposed a model of exogenous attentional control in which distractors resembling task-relevant stimuli have a higher probability of involuntarily attracting attention than particularly salient or distinctive distractors. While Folk *et al.* (1992) propose that exogenous allocation operates as a function of an individuals' current goals, in contrast, Jonides and Yantis (1988) postulate that involuntary shifts of attention occur as a result of characteristics inherent in the stimulus.

2.2.4.4 Attentional Distribution

Two models, the *spotlight* and the *zoom-lens*, describe attentional distribution. While both relate to the visuospatial modality, they provide useful insights for considering the distribution of attention in other modalities. Underlying these models is the premise of a two-stage process, described by Jonides (1983), building on Neisser (1967). Attention is distributed uniformly before being focused on a specific stimulus. Posner *et al.* (1980) use the metaphor of a 'spotlight' to highlight how visual attention functions in a searching manner, moving about, focusing on a particular target when required. As is the case with a spotlight, this attentional 'beam' cannot be divided amongst several simultaneously present stimuli. Eriksen and Yeh (1985) argue that the distributed and focused functions of attention are not two distinct modes. Rather, they should be considered as two extremes on a continuum. They advance a zoom-lens as a more apt analogy for attentional distribution. With a zoom-lens there is a relationship between the level of detail available and the size of the field of view. With a wide field of view (distributed, breadth-oriented attention) there is limited capacity for detail discernment, whereas with a narrow field of view (focused attention) the capacity for detail discernment increases. As with the multimode theory, there is an inverse relationship between the distribution of focus and the efficiency of attentional processing (Eriksen and Yeh, 1985).

2.2.4.5 Sustained Attention

Sustained attention describes the ability to maintain the allocation of attention to a stimulus (Davies and Parasuraman, 1982). Oken *et al.* (2006) deacribe three factors underlying sustained attention: motivation, stimuli characteristics, and stress. Motivation can be defined along two lines —extrinsic and intrinsic (Porter and Lawler, 1968). Intrinsically motivated activities are considered to be inherently interesting —utility is derived from their performance. In contrast, extrinsic motivation manifests as a result of the consequences of an activity. For individuals who do not directly value the outcome associated with a particular activity, or who do not gain satisfaction from its performance, their motivation to continue is diminished, reducing their ability to sustain allocation of attention to such behaviour. The second factor, characteristics associated with a stimulus, closely relates to motivation. For instance, the modality, the intensity, the duration and the regularity of a particular stimuli all impact motivation, and consequently, attention (Parasuraman *et al.*, 1998). For the third factor, stress, Hancock and Warm (1989) propose that, through associations between stress and motivation, increases in stress levels are associated with diminished capacities to sustain attention.

2.3 The Nature of Interference

When considering the implications of media multitasking for cognition it is necessary to understand the nature of interference first. At this stage, this examination does not consider specific cognitive outcomes —Chapter 4 considers such outcomes. Rather, this section presents a discussion of interference itself, commencing with an overview of the interference conceptual framework, before considering specific aspects of goal-related interference. In the course of this review the concept of multitasking is introduced.

2.3.1 The Interference Conceptual Framework

Gazzaley and Rosen (2016, p. 5) describe goal interference as the obstruction of goal completion. Similarly, Lleras *et al.* (2014) describe interference as the performance effects resulting from stimuli generally relevant to behaviour, but irrelevant to current tasks. This distinction between relevant and irrelevant interference supports the *Interference Conceptual Framework* proposed by Clapp and Gazzaley (2013), depicted in Figure 2.1. This framework outlines how interferences can be induced internally or externally as either distractions or interruptions. Both distractions and interruptions require the reallocation of task sets, which suggests that interference is associated with decreased task efficacy (Monsell, 2003). The distinction between distractions and interruptions arises as a result of their goal relevance (Gazzaley and Rosen, 2016, p. 6). Distraction describes interferences considered to be irrelevant to goal-directed behaviour, whereas interruptions occur as a result of explicit, goal-directed decisions to engage in more than one task concurrently. In the following sub-sections this distinction is considered.

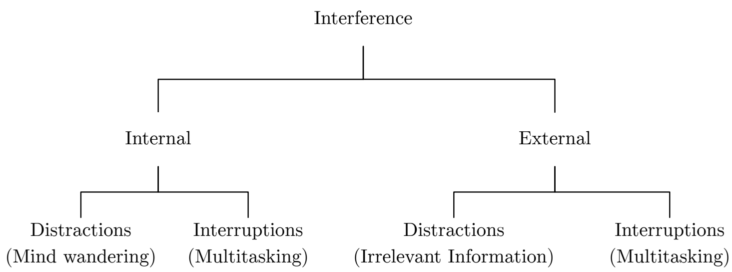

Figure 2.1: Interference Conceptual Framework (Clapp and Gazzaley, 2013)

2.3.2 Distractions

Previously, when introducing the concept of attentional focalisation, James (1890)'s early definition for attention was provided. The definition further asserts that "attention has a real opposite in the confused, dazed, scatterbrained state which in French is called *distraction*" (p. 403). This definition suggests that, in a state of distraction, attention is scattered. More recent definitions, however, indicate that rather than a scattered state, distraction describes the redirection of attention from one stimulus to another. For instance, Lleras *et al.* (2014, p. 262) make use of James's definition for attention, modifying it to refer to distraction as "the taking possession in clear and vivid form by a thought or stimulus *that one never intended to processes in the first place*". The allocation of attention to task-irrelevant distractors can impede the performance of goal-directed behaviour (Wais and Gazzaley, 2014). Due to their apparent goal-irrelevance, typically, attempts are made to inhibit their further processing. Distraction can include the diversion of attention to internal mental representations or stimuli encountered externally. Here, both internally and externally induced distractions are briefly considered.

2.3.2.1 Internal Distractions

Internal distraction refers to mental intrusions or *mind wandering* —a shift of attention away from a primary task towards task-unrelated thoughts or memories (Smallwood and Schooler, 2006). This form of distraction has been shown to relate to a general propensity for external distraction (Forster and Lavie, 2014), and is typically initiated automatically (Bargh, 1997). Smallwood and Schooler (2006, p. 131) propose that mind wandering occurs when cognitive control is itself shifted from a primary to a secondary goal. This proposal, seemingly, contradicts the notion that mind wandering occurs unintentionally. In noting this paradox Smallwood and Schooler (2006) suggest two considerations necessary for its resolution. First, as supported in a subsequent review (Schooler *et al.*, 2011), the absence of deliberate intent is as a result of deficiencies in *metacognition* (an individual's explicit knowledge of the current contents of their thoughts). Second, on the basis of earlier research (e.g. Bargh, 1997; Gollwitzer, 1999), they contend that goal-directed processes can be initiated automatically. Consequently, mind wandering refers to situations in which an individual is unaware that their primary goal has been supplanted by a secondary goal. Building on perceptual load theory, this is more likely to occur when there is excess cognitive capacity. In a study investigating relationships between WM capacity, mind wandering, and goal neglect McVay and Kane (2009) found that subjects with lower WM capacities engaged in a greater degree of mind wandering than those with higher capacities. They contend, accordingly, that mind wandering represents a failure of cognitive control to maintain task-related thoughts. Individuals with larger WM capacities maintain the accessibility of their goals to a greater extend than those with lower capacities (McVay and Kane, 2012; Miyake and Friedman, 2012). These individual differences in WM capacity contribute to 'goal-neglect' and, consequently, to failures in maintaining task-relevant thoughts (McVay and Kane, 2012). Therefore, mind wandering can either represent instances of goal-neglect or it can represent instances of goal-replacement. In both cases attention is allocated to task-unrelated thoughts.

2.3.2.2 External Distractions

External distractions manifest as sensory stimuli encountered within the environment (Gazzaley and Rosen, 2016, p. 5). Examples of such stimuli include: sounds (e.g., conversations or music), sights (e.g., nearby screens), or even smells. The execution of goal-directed behaviour requires active suppression or inhibition of these stimuli (Ziegler *et al.*, 2015). Despite their goal-irrelevance distractions can exogenously attract attention, shifting focus from goal-directed tasks to themselves, regardless of top-down intentions to inhibit them (Hasher and Zacks, 1988). As a consequence of negative implications for WM functions, the presence of external distractions in working environments has been shown to interfere with task performance (Ziegler *et al.*, 2015, p. 9). For instance, Berry *et al.* (2009) describe a negative relationship between task related WM performance and the degree to which participants were required to suppress external distractions. Similarly, Clapp *et al.* (2010) studied the mechanisms underlying WM disruption by external interferences (both distractions and interruptions), showing that attentional allocation towards external distractions negatively predicted WM performance.

2.3.3 Interruptions

Interruptions occur as a result of goal-directed decisions to engage in multiple tasks simultaneously, with the simultaneous performance of two or more tasks, each related to distinct goals, called *multitasking* (Cheshire, 2015). The term 'multitasking' is borrowed from Computer Science where, in 1965, it was first used in reference to the *apparent* capability of the IBM 'System/365' to perform several tasks concurrently (Witt and Ward, 1965). This notion of multitasking has been adopted to refer to the "human attempt to do simultaneously as many things as possible, as quickly as possible" (Rosen, 2008, p. 105). Multitasking can arise as a result of external interruptions or through discretionary task switching (Benbunan-fich *et al.*, 2011). Interruptions can also be viewed as the shifting and re-prioritisation of goals (Mark *et al.*, 2005, p. 328). González and Mark (2004) suggest that the shifting of goals can be triggered by both external and internal forces. Adler and Benbunan-Fich (2013) describe how external interruptions, such as environmental cues, elicit the re-organisation of goals, prompting the allocation of attention to themselves. Similarly, they describe how, in the absence of an external trigger, internal interruptions occur as a result of decisions to switch tasks. Here, these two forms of multitasking driven interferences are considered. Prior to this it is necessary to examine the concept of multitasking itself.

2.3.3.1 Characterising Multitasking

At face value the term 'multitasking' appears self-evident. Despite this, as Benbunan-Fich *et al.* (2009, p. 2) note, the behaviour has proven difficult to conceptualise and evaluate. They suggest that the definition for multitasking —multiple tasks performed at the same time— is particularly ambiguous and open to misinterpretation. They propose that more concise definitions of task and time are necessary. At a conceptual level, tasks are self-contained units incorporating all elements necessary for their enactment. Building on the origins of the term multitasking, Benbunan-Fich *et al.* (2009, p. 2) propose that the time dimension should be understood in the form of a session with a beginning and an end. For the simultaneous performance of multiple tasks to be classified as multitasking each task must, therefore, be independent and occur in the same session (Benbunan-fich *et al.*, 2011). Three categories of multitasking have been proposed: concurrent, interspersing, and sequential (Salvucci *et al.*, 2009). Studying while listening to music, for example, is concurrent multitasking. Dzubak (2000), however, suggests that multitasking involves processes occurring in succession. In sequential task-switching there is a longer

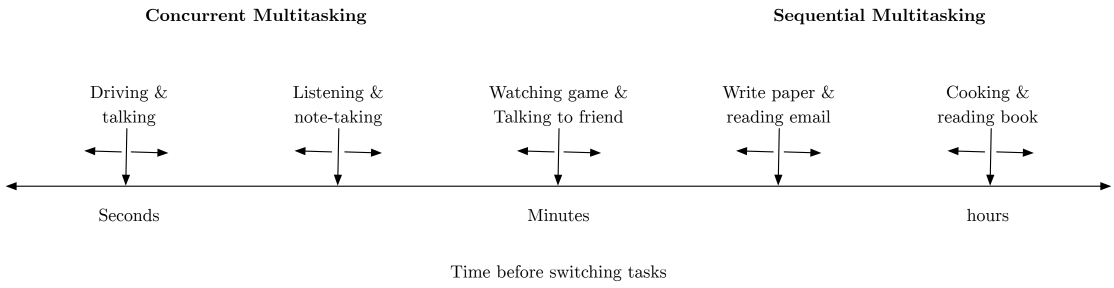

Figure 2.2: The Multitasking Continuum (Salvucci *et al.*, 2009)

duration between the execution of each task. Examples include checking an application followed by another, or reading an article and then watching a video. Between these extremes Benbunan-Fich *et al.* (2009) offer a third —task-interspersing. This refers to the switching of attention from one task to another. For example, writing an article and reading email, or reading a book and responding to text-messages.

Combing these categories Salvucci *et al.* (2009) propose the *Unified Theory of the Multitasking Continuum*. Along this continuum, depicted in Figure 2.2, multitasking is classified according to the amount of time spent on a task before switching to another. The left side represents concurrent, and the right, sequential multitasking. Building on *Threaded Cognition Theory* (Salvucci and Taatgen, 2008) and *Memory-for-goals Theory* (Altmann and Trafton, 2002), Salvucci *et al.* (2009) describe both concurrent and sequential multitasking in terms of goals. In this theory tasks are represented as goals and maintained as distinct interdependent cognitive threads. Drawing on the central capacity approach, these threads compete for the same cognitive, perceptual, and motor resources. Moreover, the processes of task interruption and resumption function in relation to goals. The goal associated with an inactive task must be activated to a greater degree than the goal associated with the currently active task to cause the new task to become activated. The importance associated with all goals is continually changing, with endogenous control being directed to the task holding the greatest current weighting, while tasks associated with other goals are maintained in parallel threads.

While this is a useful typology for multitasking, it does not account for how multitasking functions neurologically. At a neural level the brain is incapable of parallel processing (Gazzaley and Rosen, 2016, p. 77). Rather, when engaging in multiple tasks competing for cognitive resources, the brain employs neural network switching to dynamically switch between different cognitive networks (Clapp *et al.*, 2010). As noted in Section 2.2.2, switching is detrimental for task performance (Monsell, 2003). Dux *et al.* (2008, p. 1109) state that: "When humans attempt to perform two tasks at once, execution of the first task leads to postponement of the second one". The relevance of the interruption to the primary task is an important factor in determining the impact of multitasking on task completion. When a secondary task is relevant to the primary task, such as reading an article while writing a report, the schema associated with the primary task is also relevant to the secondary task (Salvucci and Taatgen, 2015). Conversely, when the interrupting task is irrelevant to the primary task the schema must be replaced.

2.3.3.2 Internal Interruptions

Internal interruption refers to the *voluntary* interruption of one task with another (Adler and Benbunan-Fich, 2013). Such behaviour, known as *self-interruption*, can take place across the multitasking continuum. Integrating insights from *Flow Theory* (Csikszentmihalyi, 1990) and *Self-regulation Theory* (Bandura, 1991) Adler and Benbunan-Fich (2013) developed a typology of internally induced multitasking, proposing that self-interruption occurs when an individual fails to achieve a 'flow state' with respect to the ongoing task and, therefore, self-regulates with the aim of improving task performance.

As Bandura (1991) explains, self-regulation of behaviour, in the aid of pro-actively attaining desired outcomes, occurs through a set of related processes. As a necessary point-of-departure, a goal or *standard* for desirable behaviour in a given situation is required. Baumeister and Heatherton (1996, p. 2) refer to such standards as "ideals, goals, or other conceptions of possible states". The second key process for self-regulation is the *monitoring* of one's thoughts, feelings, actions, and performance. Monitoring enables the evaluation of one's current state in relation to the pre-established standards (Baumeister *et al.*, 2007, p. 535). Bandura (1991) describes how, on the basis of these evaluations, *responses* are applied. If present behaviour corresponds to the desired standards, responses motivate and support the continuation of this behaviour. However, if behaviour is judged to be in conflict with the standard, responses involve attempts to address this by *operating* on behaviour to alter the current state to bring it in-line with the standard.

Flow describes a state in which an individual is immersed in an activity allocating as much attention as possible to it (Csikszentmihalyi, 1990). This state is typically associated with tasks considered to be highly engaging. Adler and Benbunan-Fich (2013) interpret this to suggest that an individual in a state of flow would be unlikely to interrupt themselves through multitasking. Csikszentmihalyi *et al.* (2005) describe three conditions necessary for the achievement of a flow state. First, the activity must hold clear goals and means of progression. Second, feedback on performance must be available. Third, there must exist a balance between the difficulty of the activity and the task-performer's perception of their skills. Commenting on these conditions Adler and Benbunan-Fich (2013) argue that people are prone to self-interruption in situations in which there exists a disparity between their skills and the challenge of a task. They propose, consequently, that such a task would not be engaging, either through an inability to progress or as a result of effortless completion. Accordingly, they suggest that in this state of *anti-flow* —a mental state characterised by boredom and the lack of challenge associated with the performance of undesired activities— individuals regulate their behaviour. In switching from tasks associated with one goal to another concurrent goal, individuals attempt to balance their skills and task demands (Carver and Scheier, 2009). Therefore, through self-regulation, when disengaged, attention and other cognitive resources are shifted to the attainment of other goals. According to this view self-interruptions represent attempts to produce a more favourable experience. On this basis, Adler and Benbunan-Fich (2013) propose a typology, depicted in Table 2.1, describing six triggers for self-interrupting multitasking.

Table 2.1: Adler and Benbunan-Fich's Typology of Self-interruptions

Self-Interruption	Description
Negative Triggers	
Frustration	Ongoing task is too difficult given skill levels
Exhaustion	Experiences of cognitive fatigue
Obstruction	Temporary barrier to task performance
Positive Triggers	
Stimulation	Ongoing task is too easy given skill levels
Reorganization	Restructuring of workload to improve performance
Exploration	Search for engaging alternative tasks

This typology introduces the notion of engagement into the conceptual frame. While disengagement or anti-flow has been associated with tendencies to multitask (Flanigan and Babchuk, 2015; Parry, 2017), the suggestion that this results *only* from an imbalance between an individual's skills and the challenge provided by a task is tenuous. In studies approaching engagement from other perspectives disengagement or boredom are not viewed in terms of a skills discrepancy. Rather, they are associated with an affective state in which there is an absence of interest to allocate attention to a task (Fisher, 1993) or there is an inability to sustain attentional allocation (Damrad-Frye and Laird, 1989). Cheyne *et al.* (2006, p. 3) describes three situations in which disengagement arises: (i) the prevention from engaging in a desired activity; (ii) forced performance of an undesirable activity; and (iii) a general proclivity towards boredom. In a study concerning self-interruption in the context of computer-based activities Jin and Dabbish (2009) identified seven categories of computer-related self-interruption (see Table 2.2). A key contribution of this categorisation is the notion of habitual multitasking, a factor indicated in a number of other studies (e.g. Aagaard, 2015; Parry, 2017). Despite these assertions, Katidioti *et al.* (2016, p. 907) note the difficulty of elucidating the factors underlying self-interruption. Given the possible motivations, situations, and intentions underlying such behaviour, providing a single cause for self-interruption is challenging.

Table 2.2: Jin and Dabbish's categories of computer-related self-interruption

Category	Description
Adjustment	Changing the environment to aid completion of a primary task
Break	Switching to ease fatigue or frustration linked to a primary task
Inquiry	Searching for information to support completion of a primary task
Recollection	Recalling the need to perform an unrelated secondary task
Routine	Performing a secondary task out of habit
Trigger	Initiating a secondary task as a result of a cue in a primary task
Wait	Performing a secondary task to fill idle time

2.3.3.3 External Interruptions

External interruptions occur as a result of goal shifts prompted by sensory stimuli (Carrier *et al.*, 2015). A key factor separating external interruption from distraction is the relevance of these stimuli to goals. External interruption describes the initiation of multitasking by external stimuli related to secondary goals, unrelated to the current task (Ziegler *et al.*, 2015, p. 8). Gazzaley and Rosen (2016, p. 8) explain that, in many cases, the actual stimuli inducing either distraction or interruption are the same. The key distinction arises as a result of the responses they initiate. While external interruptions initiate engagement, attempts are made to suppress external distractions. Interruptions prompt the reorganisation of goals and the subsequent allocation of attention to their concurrent operation (Carrier *et al.*, 2015). Clapp *et al.* (2010) show that external interruption has a greater negative impact on WM performance than that of external distraction. In terms of differences between external and internal interruptions Dumontheil *et al.* (2010) found that, at a neurological level, self-interruption and environmentally induced interruption do not differ. Moreover, they found no difference in switching costs between the two. In contrast, Katidioti *et al.* (2016) found that interruptions initiated externally imposed less interference than self-interruptions.

2.4 Theories of Behaviour

In Section 2.1 media were defined as a hierarchy involving artefacts, affordances, and the enactment of these affordances. This enactment is considered as a form of behaviour. To understand this enactment the social, personal and situational factors surrounding media use need to be considered. A necessary precursor to this is the development of an understanding of human behaviour in general. This section presents a brief review of four approaches to the examination of behaviour. Taken together, these approaches provide a number of useful insights for understanding the factors that underly an individual's choice to media multitask. Additionally, given the research objectives posed in this study, such insights provide a valuable contribution towards the examination and design of behavioural interventions. Specifically, Michie *et al.* (2011, p. 2) assert that any consideration of behavioural change techniques should be underpinned by a comprehensive model of factors that influence behaviour. This section concludes by describing a model of behaviour useful for this purpose.

2.4.1 The Reasoned Action Approach

Following early work considering attitude formation Fishbein and Ajzen (1975) developed the *Theory of Reasoned Action* (TRA) which postulates that behaviour is preceded by intention. Behavioural intentions are themselves determined by attitudes towards the behaviour as well as perceptions of relevant subjective norms (Ajzen and Fishbein, 1980). The TRA can be modelled as: $BI = (A_B)W_1 + (SN)W_2$, where BI represents behavioural intentions. The behavioural attitude A_B describes beliefs about the potential outcomes associated with a particular action, weighted by the importance W_1 of the attitude. Fishbein and Ajzen (1975) describe behavioural attitudes as the sum of belief strength, or the certainty with which the belief is held, and belief evaluation, a determination of whether the outcome is positive or negative. Subjective norms SN describe the perceived social pressure to engage in a behaviour. As with behavioural attitudes, the influence of social norms on intentions is weighted by W_2 the importance of normative influences for an individual. Consequently, the TRA adopts an expectancy-value approach to modelling behaviour. Behavioural attitudes and perceptions of social norms are informed by the beliefs held about the consequences of a particular action. These beliefs do not have to be accurate or rational. They may be derived from incorrect information, or be biased as a result of emotional, cognitive or motivational processes (Ajzen and Albarracin, 2007,

p. 8). Ajzen (1985) extended the TRA, proposing the *Theory of Planned Behaviour* (TPB) to expand the scope of behaviour accounted for by the model. The TPB includes an additional construct, *perceived behavioural control*, describing an individual's ability to enact the behaviour. Perceived behavioural control moderates the impact of intention on action through internal (skills, abilities) or external (time, resources) factors facilitating or hindering action (Fishbein and Ajzen, 2010). This factor operates as a function of beliefs about the presence of resources necessary for the performance of an action and perceived power, the extent to which these resources facilitate or inhibit action.

Through continued development these theories are now termed the *Reasoned Action Approach* (RAA). This approach, depicted in Figure 2.3, described by Ajzen and Albarracin (2007), and elaborated upon by Fishbein and Ajzen (2010), extends the TPB with the specification of two additional constructs: actual control and background factors. All behavioural influences not explicitly accounted for are treated as background factors, capable of influencing behaviour through beliefs. While intention remains the key determinant of behaviour, actual control moderates this relationship. Ajzen and Albarracin (2007, p. 5) state that "given a sufficient degree of *actual* control over the behaviour, people are expected to carry out their intentions when the opportunity arises". Additionally, actual control contributes to perceptions of behavioural control. Finally, performance of a specific action feeds back to the beliefs underlying the determinants of intention. In addition to its value for the modelling of behaviour the RAA holds a number of important implications for interventions seeking to bring about behavioural change (Fishbein and Ajzen, 2010, p. 321). Extending from the premise that intentions are the primary determinant of action, it follows that modifications to intentions should result in changes in behaviour (Ajzen and Albarracin, 2007). This requires changes in the relevant behavioural, normative and control beliefs. Therefore, within this approach, interventions should target the relevant beliefs specific to the behaviour in question. Given the presence of sufficient control, these modifications should result in behavioural change.

2.4.2 Social Cognitive Theory

Another category of theories considering behaviour acquisition and change are learning theories. These theories outline how complex behaviours, such as media multitasking, emerge as a result of learning processes (Skinner, 1950). This view adopts a behaviourist approach to understanding action —behaviour is seen to result from reflexes in response to stimuli, comprehension of associated outcomes, and motivations. Grounded in So-

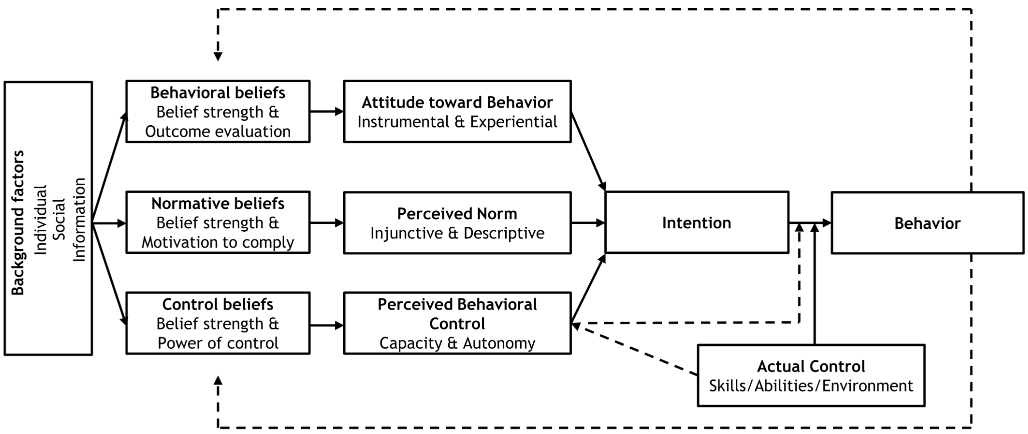

Figure 2.3: Causal Model of The Reasoned Action Approach (Fishbein and Ajzen, 2010)

cial Learning Theory, the *Social Cognitive Theory* (SCT) accepts that learning occurs as a consequence of drives, cues, responses and rewards. The SCT holds that social motivation is a key driver of behaviour acquisition. Behaviours are acquired through the observation of models —for instance parents or peers— performing a specific action, and the subsequent consequences resulting from this action (Bandura, 1986). Imitation is contingent on whether the consequences for the model are positive or negative. Emphasising the role of cognition in the encoding and performance of behaviour, Bandura (1986, p. 24) argues that behaviour results from personal (cognitive, affective, and biological), environmental, and behavioural factors. These factors are represented through his schematisation of triadic reciprocal causation depicted in Figure 2.4.

This schema illustrates how reproduction of an observed behaviour is influenced by the interaction between these three factors. Behavioural factors describe the consequences resulting from an action. Environmental factors refer to external factors influencing the ability to perform a behaviour, and personal factors relate to an individual's self-efficacy towards the behaviour. The interaction between these constructs takes occurs through four factors underlying the SCT: modelling, outcome expectancies, self-efficacy, and identification (Bandura, 1986). As noted previously, through the observation of models individuals learn contextually appropriate behaviour. For a behaviour to become assimilated, an individual must first understand the potential consequences of its performance and, secondly, believe that they are capable of its performance (Bandura, 1977). Moreover, the SCT holds that learning occurs in situations when there is a close identification between the observer and the model. The SCT implies that social norms, contextual cues, outcome expectancies, cognitive abilities, personal beliefs, and attitudes —all reinforced through repetition, habit and conditioning— are central factors in the initiation, acquisition and adjustment of behaviour.

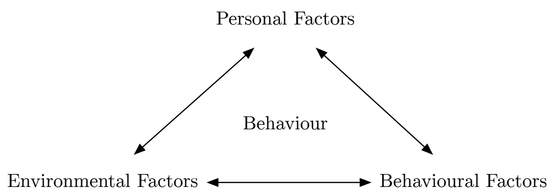

Figure 2.4: Bandura (1986)'s triadic reciprocal schema of behaviour

2.4.3 The Fogg Behaviour Model

While the RAA and SCT seek to model behaviour in general, a more recent theory, the *Fogg Behaviour Model* (FBM; Fogg, 2009), is presented as a model for persuasive design. Described by Fogg (2009, p. 1) as a new model for understanding human behaviour, this approach seeks to understand how technological artefacts "encode experiences that change behaviours" through the identification and definition of three factors fundamental to the performance of any behaviour —*motivations*, *abilities*, and *triggers*. Consequently, it provides a framework for the development of persuasive technological artefacts. It is, however, also useful for considering the factors underlying behaviour in general. Within this model actions are contingent on the concurrent presence of these three factors. As a framework for the design of technological artefacts, this model focuses attention on adapting motivations, abilities, and triggers to initiate targeted behaviour.

Fogg (2009) outlines three motivators each comprised of two dimensions. The first motivator, *pleasure/pain*, describes responses to stimuli to either induce pleasure or avoid pain. This hedonic motivational principle has been employed across many domains, including theories of decision making (e.g. Kahneman and Tversky, 1979), conditioning (e.g. Thorndike, 1935), and personality development (e.g. Atkinson, 1964). The second, *hope/fear*, is characterised by the anticipation of an outcome associated with a particular action —hope for positive outcomes and fear for negative outcomes. The third, *social acceptance/rejection*, describes how behaviour can be motivated by a desire to attain social acceptance or to avoid social rejection. Fogg (2009) associates ability with the *simplicity* with which an action can be performed. A behaviour is described as simple if: (i) an individual has time available for its performance, or if it does not require a large amount of time; (ii) its performance is not constrained by financial resources; (iii) it does not require a significant physical effort; (iv) it does not require significant cognitive capacity; (v) its performance conforms with prevailing social norms; and (vi) it is routine, or familiar. These factors can differ at both an individual and a contextual level. Furthermore, simplicity operates as a "function of a person's scarcest resource *at the moment a behaviour is triggered*" (Fogg, 2009, p. 6). In the FBM motivation and ability are inversely related, such that simpler behaviours require less motivation to initiate than is the case for more complex behaviours. Triggers refer to stimuli signalling when a behaviour should be performed (Fogg, 2009). Triggers are predominantly perceptual, however, they can manifest internally. Within the FBM, three types of triggers are outlined: *sparks*, which motivate behaviour; *facilitators*, which make behaviour easier; and *signals*, which prompt action. Commenting on these distinctions Fogg (2009) notes that signals and facilitators hold the most value for inducing behaviour change as such triggers act on behaviours for which motivation already exists.

2.4.4 Habitual Behaviour

The approaches considered in the previous sections take as a theoretical point of departure a rational evaluation of the consequences of action. Rationality, however, is bound by constraints of time, knowledge, and cognitive capacity (Simon, 1972). Acknowledging this distinction dual process theories describe two modes of thinking: *automatic* and *controlled* (Evans, 2003). Designating these modes *intuitive* and *deliberative*, Kahneman (2003, p. 699) notes the anthropomorphic simplification of this relationship indicating that, rather than describing a hierarchy, it refers to a hypothesis about what would happen if the operations of controlled thought were disrupted. The intuitive mode is characterised by the spontaneous manifestation of thoughts. The ease of manifestation is related to accessibility —the amount of effort required for particular mental representations to emerge. Kahneman (2003, p. 700) describes this accessibility as a continuum, with automatic, habitual operations occurring at one end and slower, effortful operations at the other. In a given situation, however, what becomes accessible is dependent on the properties of the eliciting stimuli, with motivationally relevant and emotionally arousing stimuli exogenously attracting attention and subsequent consideration for action.

The RAA, in particular, ascribes behaviour to deliberative processes. Such processes are slow and, as a result of the need for WM, limited in their capacity to process simultaneous demands (Evans, 2003). In contrast, intuitive processes are automatic and rapid, employing previous experiences (Evans, 2003), habits (Wood and Neal, 2007), or heuristics (Tversky and Kahneman, 1973, 1974) to guide actions. These intuitive behavioural drivers direct behaviour in predictable ways. For instance, a habit is a repeated pattern of behaviour that occurs in response to environmental or psychological cues (Wood and Neal, 2007, p. 843). Automatically triggered behavioural patterns draw on the notion of automatic, exogenous attentional orienting. In this instance, intuitive behaviour occurs independent of cognitive control (Evans and Stanovich, 2013, p. 236) — control is "outsourced" to environmental cues (Wood and Neal, 2007, p. 853). For habits, through previous experiences, cues create a relationship between a trigger, behaviour, and a reward (Wood and Neal, 2007). Once a habit has formed the reward does not drive behaviour. Rather, the habit has become automatic. Cues can trigger behaviour irrespective of whether the related reward is received or not.

Habit, as a psychological construct, has historically been linked with behaviourism (Wood and Neal, 2007). The first wave of this perspective began to fall into decline following two critiques disparaging the reduction of complex human behaviour to a series of stimulus-response relationships (Chomsky, 1959; Mowrer, 1963). These criticisms coincided with the burgeoning school of Cognitive Psychology. As described in Section 2.2, such an approach rejects the environmental restrictions of behaviourism. Rather, behaviour is ascribed to internal processes contingent on the operation of various executive functions. Wood and Neal (2007, p. 844) note that, beginning at the turn of the 20th century, a *social-cognitive-behaviourist* synthesis has emerged, incorporating key elements of behaviourism within a framework considering action to emerge on the basis of goals. Specifically, the causal role of the environment has been incorporated into models of cognitive control. From this perspective, Wood and Neal (2007) outline a theory of habitual behaviour, integrating the stimulus-response mechanism present in behaviourism, with cognitive theories of goal-directed behaviour. In this theory goals are required for the learning and performance of habitual behaviour, but not for their initiation. Rather, habitual behaviour is triggered by cues that have covaried with previous performance instances. This theory is outlined by means of three principles, each describing different aspects of the relationship between goals, contexts, and behavioural responses.

The first principle outlines the contextual triggering of habitual responses. Wood and Neal (2007) describe how the automaticity of habitual behaviour is developed through repeated patterns of covariation between contexts, cues, and responses in one of two ways. In direct cuing, habits are formed on the basis of associations between stimuli and responses or, in motivated cuing, habits are formed through motivation related to previous experiences of rewards in the associated context. Evidence supporting the role of contextual cues for habitual responses has been found in both laboratory and naturalistic studies (e.g. Wood *et al.*, 2005; Neal and Wood, 2007). The second principle concerns the absence of goal mediation in the context-response relationship. Wood and Neal (2007) account for goal-directed behaviour in describing habits as the 'residue' of repeated instances of goal-directed action. Therefore, in their model, goals are necessary for the development of habitual behaviour, but not required for subsequent initiation of behaviour. Support for this principle has been found in both behavioural and neurophysiological studies (e.g. Sheeran *et al.*, 2005; Moors and De Houwer, 2006). The third principle describes the interface between habits and goals. As enduring behavioural patterns, habits are not affected by current goals or intentions. Rather, the interface between habits and goals is constrained in such a way that, if necessary, they can drive each other. Goals direct the formation of habits but, as Wood and Neal (2007) describe, habits can be used to make assumptions about goals. Consequently, they interface such that, in certain situations, behaviour is habitual, while in others the habitual action is inhibited in favour of a different goal-directed response. Evidence supporting this principle has been observed in experience sampling, observational, and experimental studies (e.g. Ouellette and Wood, 1998; Wilkinson and Shanks, 2004).

2.4.5 Conclusions

While each of these approaches presume to propose a complete model of behaviour, if considered together, a more comprehensive understanding of the factors underlying behaviour can be produced. In considering the RAA, the importance of behaviour-specific attitudes, beliefs and intentions was noted. While this theory accounts for factors underlying behavioural intentions, other than social norms, it does not consider environmental factors which may have an influence on such intentions. The SCT, in contrast, emphasises the reciprocal interactions between individuals, their environments, and behaviour. The FBM emphasises the necessary requirements for an action —motivation, simplicity and a trigger. Finally, through considering intuitive, habitual behaviour the role of goals in the acquisition, but not necessarily the initiation of habitual behaviour was noted. While differences do exist, many constructs specified in one theory relate to those described in another. For instance, perceived behavioural control, within the RAA, corresponds with abilities in the FBM, or the notion of self-efficacy within the SCT.

Following this examination it is concluded that behaviour, media multitasking for instance, is acquired, enacted, and initiated through a complex mix of internal factors —goals, motivations, abilities, triggers, perceptions, and outcome expectancies— and external factors —triggers, cues, social contexts, and norms. Of particular relevance is the importance of goals for both deliberative and intuitive behaviour. Whether such intentions are formed through attitudes, beliefs, modelling or other motivations, they imply that behaviour is purposeful. Bandura (1991) asserts that actions are pro-actively directed in accordance with desires to attain specific outcomes. To consider the nature of media multitasking, given the importance of goals and environmental and social cues in the initiation of behaviour, it is necessary to understand the intentions brought to such engagements as well as the situational factors present. In particular, given the affordances of media, a comprehensive understanding of the ensuing enactment of these affordances requires considering the needs people desire media to fulfil and how fulfilment of such needs produces particular patterns of behaviour.

In the context of this dissertation this section served two purposes. First, the consideration of factors influencing behaviour is intended to guide the examination of media multitasking behaviour. Second, the establishment of a theoretical framework for behaviour is necessary for producing a behavioural intervention (Michie *et al.*, 2011). While the first can be addressed through the narrative discussion presented thus far, the second requires the development of a pragmatic model capable of guiding the analysis and development of behavioural interventions. Michie *et al.* (2011) describe a model of behaviour suitable for this purpose, COM-B. In this model, depicted in Figure 2.5, the interaction between capability (C), opportunity (O), and motivation (M) produces behaviour (B), which itself reciprocally influences these components. Michie *et al.* (2011, p. 6) define capability as the "psychological and physical capacity to engage in the activity concerned". Opportunity refers to all factors external to the individual that either prompt or enable an action. The authors distinguish between physical and social opportunities. Finally, they define motivation as the "brain processes that energise and direct behaviour" (p. 6). This construct includes both intentional, as well as habitual and emotionally directed motivations. Given the conceptualisations for these constructs, it is evident that the COM-B model incorporates, at an abstract level, the key positions of the four approaches considered previously. In abstracting these processes this model is intended to be useful for the consideration and development of behavioural interventions.

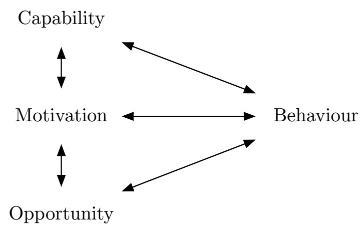

Figure 2.5: The COM-B model of behaviour

2.5 Summary

In this chapter four key areas pertinent to this study were considered. This began with a framing of media as both the artefacts of communication and the enactment thereof. In considering two high-level affordances of media the manner in which such affordances shape or bias behaviour was discussed. To reduce the conceptual ambiguity surrounding media a working definition, considering media to be an emergent hierarchy consisting of *artefacts*, their *affordances*, the *enactment* of these affordances, and the ensuing *culture* that surrounds this enactment, was formulated.

Next, an overview of theories accounting for four functions of cognitive control was presented. While each function is distinct, there exists a degree of unity in their operation. WM is responsible for the maintenance and manipulation of recently acquired information or task-schemas, while cognitive flexibility is fundamental to the switching of attention from one concept to another. Inhibitory control enables the suppression of prepotent responses and attentional allocation to both sensory stimuli and representations in WM and attentional control is fundamental to the selective allocation of attention to particular stimuli. Together, these functions enable the execution and performance of goal-directed behaviour, irrespective of the nature of these goals.

Building on this, through the introduction of a conceptual framework, the third section considered interference as it relates to goals. Within this framework interferences are distinguished along two dimensions. Firstly, on the basis of their goal-relevance and, secondly, on where they originate. Distractions are interferences considered to be irrelevant to current goals, whereas interruptions are interferences pertinent to prevailing goals. As such, interruption has come to be described as multitasking. For the second distinction, internally induced interference describes interferences induced either as a result of excess cognitive capacity or as a result of self-initiated task-switching. External interference describes disruptions initiated as a result of external triggers. Such triggers either redirect limited cognitive resources, in the case of distractions or, for interruptions, prompt the reprioritisation of goals. To address the issue of whether media present to individuals as a distraction or whether individuals interrupt themselves through media multitasking, the insights from this section suggest that media-related goal-interference is not contingent on the mere presence of an interfering stimuli, such as media. Rather, media induced interference involves a conscious decision to convert a distraction into an interruption. This is ultimately dependent on prevailing behavioural goals. Deficiencies in cognition of the nature of these goals emerges as an important factor in this regard.

Finally, to provide a theoretical basis for considering media multitasking behaviour, relevant theories of behaviour were considered. On this basis a model to be utilised in the analysis and development of behavioural interventions was presented. Along with a brief exploration of the role of habits in intuitive behaviour, three theories of deliberative behaviour were considered. While these approaches differ in their interpretation of the factors underlying the acquisition, enactment, and initiation of behaviours, they all acknowledge the importance of intentions or goals. In the course of the following chapter an examination of the specific factors driving media multitasking is presented. Given the theoretical basis established in this section, this examination focuses on the needs people desire media to gratify, as well as the situational and normative factors related to such behaviour. While these factors are sufficient for guiding this narrative investigation of media multitasking, a more concrete model is required for considering behavioural interventions. Therefore, the COM-B model, which captures key aspects present in the theories reviewed, is to be adopted.

Chapter 3

Patterns and Drivers of Media Multitasking

In this chapter research concerning two aspects of media behaviour is reviewed. Section 3.1 commences with the establishment of a working definition for media multitasking, before considering the measurement and prevalence of this behaviour. Following this, in Section 3.2 factors considered to drive media multitasking are reviewed. The purpose of this chapter is twofold. First, it is important to establish the nature and extent of university students' (typically aged between 17 and 23) — the population of interest in the empirical work to follow— behaviour with media prior to considering how such behaviour interacts with cognitive control. Second, such a consideration is necessary for understanding interventions targeting this behaviour. Given the primary research objectives, understanding why students media multitask is key to considering the feasibility of related interventions.

3.1 Media Multitasking

As noted in Chapter 2 multitasking describes the concurrent performance of several tasks, each associated with distinct goals. Key to this are task independence and performance concurrency (Benbunan-Fich *et al.*, 2009, p. 3). *Media multitasking* has been characterised as a form of multitasking along two lines: multiple media use (Ophir *et al.*, 2009) and media use in conjunction with non-media activities (Jeong and Fishbein, 2007). The first, viewing media multitasking as the simultaneous use of two or more media, ignores concurrent non-media activities. A more inclusive definition views media multitasking as "engaging in one medium along with other media *or* non-media activities" (Zhang and Zhang, 2012, p. 1883). Because of the breadth in coverage, and correspondence with observed behavioural patterns (Hassoun, 2014; Yeykelis *et al.*, 2014), this definition is adopted in this study. Extending Benbunan-Fich *et al.* (2009, p. 3), media multitasking can be understood to be a function of how users combine multiple independent tasks in a segment of time and the degree of concurrency with which these tasks are performed. In this section the measurement and prevalence of media multitasking are considered.

3.1.1 Measuring Media Multitasking

The most common measure for media multitasking is the media multitasking index (MMI) developed by Ophir *et al.* (2009) to classify individuals as either heavy media multitaskers (HMMs) or light media multitaskers (LMMs). To calculate an MMI score a media-use questionnaire addressing use of 12 media[1] was developed. For each medium the total use-hours per week is elicited, along with indications of the extent to which the other 11 media are used concurrently.[2] The responses for each primary medium are weighted according to the total time for which it is used. Each of these weighted scores are summed across all 12 media and then divided by the total number of hours in which media are used. This is depicted in Equation 3.1, where m_i is the total media used while using a primary medium, i; n is the number of media considered; h_i is the number of hours per week spent using i, and h_{total} is the total hours per week using all media.

$$MMI = \sum_{i=1}^{n} \frac{m_i \times h_i}{h_{total}} \tag{3.1}$$

Baumgartner *et al.* (2017*a*) outline a number of limitations of the MMI. First, they explain that the exhaustive nature of the media-use questionnaire may result in participant fatigue and poor response quality. Second, the distribution of scores produced by the MMI is skewed to the left. They suggest that this occurs because the MMI includes combinations which, they argue, rarely occur in the course of everyday life (e.g., reading while gaming). Baumgartner *et al.* (2017*a*, p. 6) explain that, as a result of the "arbitrary assignment of values to the response categories", the scores produced by the MMI may

[1]Print media, television, computer-based video, music, non-music audio, video or computer games, telephone and mobile phone calls, instant messaging, text messaging, email, web surfing, and other computer-based applications.

[2]A 4-point scale with response options: 'never' (0), 'a little of the time' (.33), 'some of the time' (.67), and 'most of the time' (1).

not realistically reflect everyday media multitasking. Furthermore, they note that, as interpreted by Ophir *et al.* (2009), an MMI of x suggests that x media are used concurrently with a primary medium during an average hour of use. Without substantiating their assertion, the authors maintain that this is an unrealistic assessment of media multitasking, suggesting that the MMI should be interpreted as providing a *general* level of media multitasking, not an *absolute* count of concurrent media use.

In response Baumgartner *et al.* (2017*a*) modified the MMI, basing their measure on the premise that "it may be sufficient to only assess the most *prevalent* media multitasking combinations" (p. 7). As part of a longitudinal study they proposed a short measure for media multitasking (MMM-S), developed on the basis of Ophir *et al.*'s media-use questionnaire. As they were targeting an adolescent sample, they reduced the media from 12 to four, focusing on what they believed to be the most popular media amongst this population.[3] To produce a score the same approach employed by Ophir *et al.* (2009) was adopted. Noting the correlations between the MMI-S and media use ($r = .67, p < .001$), the authors suggest that, while this indicates that media multitasking is related to media use, it also supports the notion that it is distinct concept. The test-retest reliability of the measure was assessed two years after the initial measurements, with a comparable mean value found. Despite being designed for and evaluated with adolescents, Baumgartner *et al.* (2017*a*) surmise that this measure may be equally applicable for student samples.

A limitation with both Ophir *et al.* (2009) and Baumgartner *et al.* (2017*a*)'s approaches is the reliance on self-reported estimates of media use. Boase and Ling (2013) show that such estimates are especially difficult for mobile device use. Rigby *et al.* (2017), however, show a strong association between self-reported MMI and observed media multitasking in the context of television viewing. It is noted that such measures do not provide an absolute indication of media multitasking frequency. Other measures such as diaries (Voorveld and van der Goot, 2013) or automatic tracking (Andrews *et al.*, 2015) may be necessary to gather such data. Additionally, such measures for media multitasking only account for multitasking involving two or more media. Media use in conjunction with non-media activities is not accounted for. In Chapter 4, when discussing methodological challenges facing research in this domain, these issues of measurement are returned to.

[3]TV, music, messaging via phone or computer, and SNSs.

3.1.2 Prevalence of Media Multitasking

Given the affordances of modern media, over the past decade, the prevalence of media multitasking has grown among adolescent, student and adult populations. Findings from a number of studies indicate that media multitasking is the dominant manner in which members of Generation Z behave with media (Foehr, 2006; Jeong and Fishbein, 2007; Moreno *et al.*, 2012). For students, as members of this generation, studies suggest that a majority of media use can be considered media multitasking (Judd, 2013; le Roux and Parry, 2017*b*; Szumowska *et al.*, 2018). In one of the first reports on media multitasking prevalence, Foehr (2006) show that, for American youth, 29% of all media use involves multitasking. In an early study in this regard Fried (2008) considered students' media multitasking through a series of weekly surveys, and found that 64% of those surveyed reported using their laptops during lectures for web-browsing, gaming, instant messaging and email. Similarly, Burak (2012) found that 94.4% of those surveyed ($n = 774$) reported that they media multitask during lectures. Junco and Cotten (2012) found comparable results following a survey of a larger sample of students ($n = 3866$). In South Africa, Leysens (2016) obtained similar results, finding that 95% of those sampled reported media multitasking during lectures.

In response to the reliance on self-report measures and the focus on lecture contexts, Moreno *et al.* (2012) adopted an experience-sampling methodology to assess students' ($n = 189$) media multitasking, finding that 56.5% of media use involved multitasking. Additionally, it was found that participants clustered their media use into consistent combinations. For instance, social networking, email, work and browsing were found to commonly co-occur together in a single session. In another study Judd (2013) analysed the use-logs of 3 372 computer-based study sessions, classifying media use into three categories: focused, sequential, and multitasking. Focused behaviour involves little or no task switching. Sequential behaviour describes the engagement with tasks one after the other. Multitasking behaviour was grouped into one of two subcategories. Classical multitasking refers to sessions in which a participant switched back and forth between tasks. A common example of this was switching between a learning management system and *Facebook*. Mixed multitasking, on the other hand, refers to sessions where repeated tasks are combined with other unique, one-off tasks. For instance, browsing punctuated with regular visits to different SNSs. The researcher found this to be the most common form of media multitasking. Over 70% of sessions involved multitasking to some extent, with 35% consisting entirely of multitasking.

In the same year Rosen *et al.* (2013*a*) conducted an observational study of students' (n = 263) media use while studying. These observations were augmented with a questionnaire assessing task-switching preferences and media usage. The authors found that students averaged less than six minutes on-task before switching. SNSs and text-messaging, in particular, were found to be the primary reason for these switches. Moreover, it was found that those participants indicating a preference for task-switching studied in an environment with a greater number of media available to them and, therefore, were more likely to media multitask. In another observational study, irrespective of age, over a ten-minute period, 80% of participants (n = 160 adults, 164 children) failed to remain on-task, switching to other media (Baumgartner and Sumter, 2017). Calderwood *et al.* (2014) used surveillance cameras, head-mounted point-of-view cameras, and mobile eye trackers to observe a sample of students (n = 58) during a self-directed study session. On average, the participants engaged with 35 off-task mediated activities, with an aggregated mean duration of 25 minutes.

While only a few studies were considered in detail in this section, their results are congruent with the larger body of work in this regard. On this basis, the following conclusion is made. For students, media are used extensively throughout the course of their everyday lives — in social, personal, and academic contexts. Moreover, whether media are used in conjunction with other media or non-media activities, it has been argued that, for this population, a majority of media use involves multitasking (le Roux and Parry, 2017*b*). This position is supported by studies conducted over the preceding decade which, through a variety of methodologies, measures, and contexts, show that, for students, media multitasking behaviour is both normal, and particularly prevalent.[4] While these studies indicate that, for students, media multitasking is the norm, they do not, however, speak to the effectiveness of their multitasking. Kirschner and De Bruyckere (2017, p. 139) argue the importance of not equating frequent multitasking with effective multitasking, stating that "it has been broadly shown that rapid switching behaviour, when compared to carrying out tasks serially, leads to poorer learning results in students and poorer performance of the tasks being carried out".

[4]These include, but are not limited to: Carrier *et al.* (2009), Judd and Kennedy (2011), Junco and Cotten (2012), Levine *et al.* (2012), Moreno *et al.* (2012), Pea *et al.* (2012), Karpinski *et al.* (2013), McDonald (2013), Rosen *et al.* (2013*a*), Risko *et al.* (2013), Voorveld and van der Goot (2013), David *et al.* (2014), Gaudreau *et al.* (2014), Judd (2013), Ragan *et al.* (2014), Ravizza *et al.* (2014), Carrier *et al.* (2015), Kononova and Chiang (2015), Baumgartner *et al.* (2017*a*), Wang and Xu (2017), Baumgartner *et al.* (2017*b*), and Deng *et al.* (2018).

3.2 Drivers of Media Multitasking Behaviour

In Section 2.1 it was established that, while the affordances of media certainly affect media use, they are not the sole factor underlying this behaviour. Subsequently, in Section 2.4, it was shown that behaviour is contingent on goals, personal psychologies, situational contexts, and the presence of facilitating factors. Consequently, it is necessary to examine the personal and situational factors surrounding behaviour with media. Understanding the dynamics of media multitasking behaviour is, firstly, necessary for considering how such behaviour potentially shapes cognitive control and, secondly, for the consideration and development of related behavioural interventions. Before considering the factors underlying media multitasking, it is worth noting that, while it be can argued that students engage in media multitasking simply because they find it more enjoyable or rewarding than single tasking (Hwang *et al.*, 2014; Chinchanachokchai *et al.*, 2015), implicit in the definition of multitasking is the notion of multiple distinct goals (Salvucci *et al.*, 2009). Reducing media multitasking to an hedonic gratification oversimplifies the complex interaction between these goals or needs, situations, and the affordances of media. To explicate students' media multitasking the following sections consider, firstly, the uses and gratifications associated with media multitasking, secondly, extending from this, the information seeking nature of media multitasking and, finally, the situational and normative factors associated with media multitasking.

3.2.1 Uses and Gratifications

Uses and Gratifications Theory (UGT) has been extensively employed to examine media use in general (e.g. Larose *et al.*, 2001; Stafford *et al.*, 2004; Pornsakulvanich *et al.*, 2008), and media multitasking specifically (e.g. Guo *et al.*, 2010; Wang and Tchernev, 2012; Zhang and Zhang, 2012; Rosen *et al.*, 2013*a*). As a user-centered approach, UGT explains media use in terms of media's capacity to gratify a set of needs (Rubin, 2009). Three assumptions are fundamental to this approach: (i) behaviour is goal-directed; (ii) users are aware of their needs; and (iii) users actively seek to gratify these needs through media use. Applying UGT to media multitasking Zhang and Zhang (2012, p. 1884) note that it is "expected that computer multitasking can be explained by users' needs". Early studies in this regard identified five motivation dimensions gratified by media use: (i) information seeking; (ii) entertainment; (iii) interpersonal utility; (iv) convenience; and

(v) diversion[5] (Flanagin and Metzger, 2001; Stafford and Stafford, 2001; Wei and Leung, 2001). Findings from contemporary studies are largely congruent with these dimensions (Guo *et al.*, 2010; Wang and Tchernev, 2012; Zhang and Zhang, 2012).

Through a series of interviews Guo *et al.* (2010) elicited the needs students desire media to gratify. Following this, through a questionnaire completed by 266 students, the affordances perceived to fulfil these needs were identified. From these procedures seven dimensions of motivation for media use were identified: (i) information seeking; (ii) convenience; (iii) connectivity; (iv) problem solving; (v) content management; (vi) social presence; and (vii) social context cues. For each of these needs specific affordances promoting their gratification were determined. For information seeking, affordances demonstrating the 'range and quality of information' communicated were identified. Convenience relies upon affordances enabling ease-of-use. The third dimension, connectivity, depends on affordances supporting communication across time and space. Problem solving is facilitated by access to information. Content management, again, revolved around information exchange and communication. Social presence is gratified by means of affordances facilitating interactive communication. Finally, social context cues were found to be supported by media enabling multi-dimensional communication. Interpreting these outcomes the authors note that, as a result of media affordances, information seeking and communication have emerged as primary reasons for media use, with many other needs relying on information exchange.

Through a survey Zhang and Zhang (2012) assessed the roles of both situations and gratifications in facilitating computer-based media multitasking. In terms of gratifications[6] they found that different needs predicted different types of multitasking. Three forms of media multitasking were identified —multiple media (activities occurring across multiple media), interaction (activities associated with computer-mediated-communication) and work-related (activities associated with utilitarian tasks)— with multiple media being the most prevalent. Following this, Zhang and Zhang (2012) classified specific needs into three categories. The first, and most popular category —'convenient/easy/instant'— includes gratifications only possible given the affordances of media (e.g., instant messages), as well as those possible without media (e.g., maintaining social connections). The second category —'control/habitual'— presents somewhat of a contradiction. On the one hand, it describes media multitasking as gratifying habitual needs, on the other, it refers to media multitasking as an effort to control information overload, allowing personal control

[5]This dimension refers to a need to escape from routine to seek emotional release (Katz *et al.*, 1973).
[6]Zhang and Zhang (2012)'s findings related to situations are reported in Section 3.2.3.

over the pace of information intake. The third category —'social/affective/relaxation'— emphasises the non-instrumental, or emotional needs associated with media multitasking.

Wang and Tchernev (2012) conducted an experience sampling study involving 19 students over four weeks, concluding that media multitasking is driven by current needs. The authors found that media multitasking is driven by cognitive needs (information seeking motivations) but, while information seeking drove media multitasking, these needs were not gratified by the behaviour. The authors offered two interpretations for this. First, while media multitasking did not gratify cognitive needs, it did, however, gratify emotional needs. Emotional needs were not actively sought when media multitasking. Commenting on this outcome the authors provide an example to illustrate how this might transpire —"if participants were, for example, studying for a test while watching TV, their multitasking might lead them to feel satisfied not because they were effective at studying, but rather because the addition of TV made the studying entertaining" (p. 509). The emotional gratifications associated with media multitasking are a side-effect, an unintended 'by-product'. Wang and Tchernev (2012) postulate that, over time, this emotional gratification creates an implicit emotional drive to engage in media multitasking. Additionally, they explain that media multitasking is self-reinforcing and, as their data show, habitual. Needs and gratifications associated with previous instances of media multitasking are integrated into current situations. Subsequent studies corroborate this interpretation of media multitasking (Aagaard, 2015; Parry, 2017).

3.2.2 Information Foraging

Observing the informational needs associated with media multitasking Gazzaley and Rosen (2016, p. 13) hypothesised that "we engage in interference-inducing behaviours because, from an evolutionary perspective, we are merely acting in an optimal manner to satisfy our innate drive to seek information". This hypothesis, supported by Coulter-smith (2018), was proposed on the basis of findings indicating that neural and physiological processes previously considered in relation to foraging for food also relate to *information foraging* (e.g. Hills, 2006; Hills *et al.*, 2007; Hantula, 2010; Metcalfe and Jacobs, 2010). Supporting this interpretation, Edge *et al.* (2018) developed a 'foraging theory' model of app switching to account for switching between mobile applications as a function of the user's needs and the contextual decision set (a user's situational context).

Pirolli and Card (1999) proposed *Information Foraging Theory* (IFT) as an adaptation to ecological theories of resource-foraging. Such approaches include *optimal foraging theory*

(Charnov, 1976), which suggests that foraging is not random. Rather, it is optimised, in the case of animals, to aid survival. As such, Pirolli and Card (1999, p. 643) outline the basic hypothesis of the IFT as follows: "when feasible, natural information systems evolve toward stable states that maximize gains of valuable information per unit cost [...] cognitive systems engaged in information foraging will exhibit such adaptive tendencies". On this basis, they argue that people modify their information foraging strategies or the structure of their environments to maximise their intake of subjectively valuable information. The structure of the interface with information sources determines the costs (resource and opportunity) associated with different information foraging strategies. Therefore, a particular strategy, media multitasking for instance, is superior if it yields more useful information per unit cost. Before considering media multitasking from this perspective, it is necessary to acknowledge the following caveat offered by Pirolli and Card (1999, p. 645) — "the use of optimization models should not be taken as a hypothesis that human behavior is classically rational, with perfect information and infinite computational resources. A more successful hypothesis about humans is that they exhibit bounded rationality". This proviso reflects Simon (1955)'s notion of bounded rationality, and the subsequent satisficing that occurs.

Pirolli and Card (1999) describe how, within optimal foraging theory, patch models consider foraging situations in which resources are grouped in a limited quantity, separated from other patches. When foraging within a patch a forager is faced with the choice of either continuing in-patch or moving to another. There exists a point at which the expected gains associated with remaining in a patch diminish to the extent that the expected gains associated with moving to a new patch are greater. Applying this model to information foraging they propose that the task environment of an 'information forager' is patchy — information exists across numerous sources and locations. Similarly, they note that, as is the case in ecological models, people face decisions about when to remain in-patch, and when to search for new patches of information. Commenting on this analogy Gazzaley and Rosen (2016, p. 16) indicate that, as is often the case with food patches, mediated information patches, such as SNSs or instant messaging conversations, also exhibit diminishing returns over time. They suggest that this occurs either as a result of the available novel information becoming depleted or through boredom.

To consider information-seeking behaviour in the context of patchy information sources Pirolli and Card (1999) adopted Charnov (1976)'s *Marginal Value Theorem* (MVT). The MVT models consumption in situations where resource patches yield diminishing returns over time. Pirolli and Card (1999)'s interpretation of the MVT is depicted in Figure 3.1.

The left side of the model depicts the costs associated with moving to a new source. The right side reflects the benefits of remaining at the current source. The within-patch gain function g reflects the cumulative consumption of resources over time (information in this instance), and is related to the specific nature of the resource patch. For instance, *Facebook*, as an information source would have a different g than instant messaging. As the benefits of remaining in a specific patch decrease over time, the curve flattens. The tangent to the intake curve R^* reflects the average rate of gain, which increases with decreases in the costs associated with moving between patches, and improvements in g. The *optimal time to remain in source* t^* is represented by the intersection of these two curves. As Gazzaley and Rosen (2016) suggest, this model can be employed as a lens, at a conceptual level, to guide considerations of media multitasking.

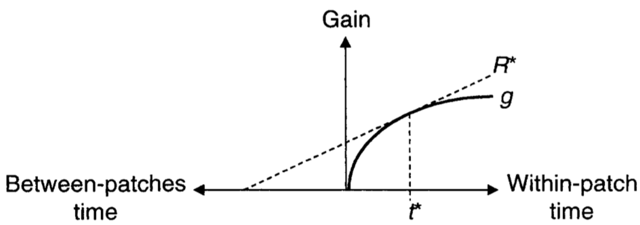

Figure 3.1: A graphical representation of the MVT describing the cost-benefit relationship of foraging in a patchy environment, as depicted in Pirolli and Card (1999).

Gazzaley and Rosen (2016) use this theory to consider the antecedents to media multitasking. For the left-side they note that shifts occur as a result of decreases in the expected transit time between information sources, and suggest that this results from an increase in the *accessibility* of new information patches. They base this position on media's ability to provide rapid access to new information (e.g., switching from one browser-tab to another). On the right side of the model the authors provide two factors which influence the *perceived* benefits of remaining in a patch, reducing the optimal time to remain in source, increasing the rate at which switches occur —*boredom* and *anxiety.* As is the case with accessibility, they propose that increases in boredom and anxiety occur as a result of media interactions. To follow, each of these factors is considered.

3.2.2.1 Boredom

Boredom, as described in Section 2.3, arises due to a number of factors, including (i) a barrier to the performance of a desired activity; (ii) the performance of undesired activities; (iii) an inability to sustain attentional allocation; (iv) a general proclivity towards boredom; and (v) a lack of challenge associated with the performance of undesired activities (Cheyne *et al.*, 2006; Adler and Benbunan-Fich, 2013). Gazzaley and Rosen (2016) argue that, in comparison to the stimulating nature of media, non-mediated environments do not provide the stimulation necessary to sustain attentional allocation. Therefore, people turn to media as an antidote to the apparent boredom this initiates. This position is supported by a number of studies considering the role of boredom in media multitasking (e.g. Annan-coultas, 2012; Yeykelis *et al.*, 2014; Lepp *et al.*, 2015; Parry, 2017). For instance, in a survey study McCoy (2013) found that 55% of respondents (n = 777) indicated that 'fighting boredom' was a benefit of media multitasking. Likewise, in a focus group study Parry (2017) found that boredom in academic contexts triggered media multitasking. Extending Adler and Benbunan-Fich (2013), this can be understood in relation to self-regulation theory. When bored or disengaged, individuals self-regulate, switching attention to tasks associated with other concurrent goals.

Yeykelis *et al.* (2014) investigated media multitasking in personal environments, fitting 12 students with wrist sensors measuring arousal levels through galvanic skin responses (GSR). Additionally, screenshots of the participants' computers were captured every five seconds. It was found that, on average, switches occurred every 19 seconds. Interestingly, the GSR data showed that arousal began to rise 12 seconds prior to a switch. Upon investigating whether this anticipatory increase in arousal held for different content types the authors found that, when switching from work activities to entertainment activities, a significant arousal effect was present. In contrast, when switching from entertainment activities to work activities no anticipatory effect was found. While the authors did not associate this outcome with boredom, Gazzaley and Rosen (2016) interpret it to indicate that shifts from less arousing or, in their interpretation, boring activities to more stimulating activities are preceded by increased levels of anticipatory arousal. Yeykelis *et al.* (2014, p. 186) did, however, interpret this outcome to indicate that, when engaged in non-arousing or boring activities, individuals are in, what they term, a 'hunting state', searching for more stimulating activities.

Gazzaley and Rosen (2016) offer two explanations for relationships between boredom and media multitasking: short time scale reward cycles and intermittent reinforcement. Both involve the concept of reinforcement, relating the rewarding nature of media multitasking to increased boredom. For the first explanation, studies indicate that the shorter the time between reinforcements, the stronger the drive to perform the required action and gain the associated reward (see Deci *et al.*, 1999, for a review). Gazzaley and Rosen (2016) suggest that, with media, text messaging for instance, the time between exposures to rewarding information is short. As such, media multitasking becomes self-reinforcing. To illustrate this Gazzaley and Rosen (2016, p. 168) outline a cyclical relationship between boredom and media multitasking: boredom induces rewarding task switching, which increases boredom in situations which are not stimulating, implying a flattening of the within patch gain function, decreasing the optimal time in a resource, resulting in a shorter time between switches, which in turn contributes to boredom. As a second explanation for the relationship between boredom and media multitasking, Gazzaley and Rosen (2016) consider Skinner's concept of intermittent reinforcement. When behaviour is reinforced on a variable schedule it is more resistant to extinction (Ferster and Skinner, 2015, p. 326). Gazzaley and Rosen (2016) propose that the reinforcement offered by media use occurs in such a manner. Consider, for instance, notifications or alerts. They may be useful or desired (a reward), or they may be uninteresting, irrelevant or undesired. Another example of this intermittent reinforcement is the 'feed' nature of SNSs. Such services —*Twitter* or *Facebook* for instance— provide a stream of information, some of which is engaging, some of which is not. While not all posts provide rewarding engagement, when browsing these feeds, there exists the possibility that a post may be interesting, relevant or important, providing the desired reward. Tristan Harris, a design ethicist and technology commentator, suggests that, in some cases, this is by design (Harris, 2016). Again, as is the case with their previous explanation, Gazzaley and Rosen (2016) suggest that this cycle promotes media multitasking, with previous rewarding instances giving rise to subsequent instances of task-switching.

3.2.2.2 Anxiety

As with boredom, Gazzaley and Rosen (2016) propose that anxiety impacts the right-side of the MVT, decreasing the time between switches. As discussed in Section 2.1, media provide access to rewarding *social* information. This has prompted consideration of a specific form of anxiety —the *fear of missing out* (FoMo), or the "pervasive apprehension that others might be having rewarding experiences from which one is absent" (Przybylski *et al.*, 2013, p. 1841). This phenomenon is characterised by a desire to stay continually connected with the activities of one's social connections. As Przybylski *et al.* (2013) note, it is generally not possible to participate in all possible social experiences. Consequently, people 'miss out' on a subset of potentially rewarding experiences. They argue, therefore, that use of SNSs becomes increasingly attractive. Through the acquisition of social information a degree of vicarious participation can be achieved. Rosen *et al.* (2013*b*) investigated relationships between media use and a number of psychological disorders, including anxiety. Following analysis of a survey of adults aged 18 to 65 ($n = 1335$), they found that younger generations (those born since 1980) reported more media-related anxiety than those in older generations. The highest prevalence of anxiety was found to relate to an inability to check text-messages, with an inability to check social media following. Moreover, they found that symptoms of obsessive compulsive disorder were predicted by media-anxiety, media use, and task-switching frequency. Commenting on this, the authors postulate that the need to stay connected and the anxiety relating to missing out on information or experiences fosters an 'obsession' to check media.

In seeking to explain why information foraging is related to anxiety, Gazzaley and Rosen (2016, p. 174) suggest that, because media enable ubiquitous, frequent, and rich communication, expectations about desired levels of connectivity have increased. Consequently, such expectations produce anxiety related to a fear of missing out on social experiences, important or not. Moreover, it is suggested that media are seen to offer an antidote to this fear, enabling vicarious sharing in experiences. As such, the authors argue that, to gain access to this information and quell their anxiety, people seek out frequent media engagement through media multitasking.

3.2.2.3 Accessibility

While boredom and anxiety impact the right side of the MVT, the third factor, accessibility, is theorised to impact the left side (Gazzaley and Rosen, 2016). With increases in the accessibility of information, through media, the expected time to move from one source to another is decreased, increasing the frequency of shifts. Gazzaley and Rosen (2016, p. 176) note two aspects of accessibility that impact media multitasking. First, accessibility refers to the ease with which people can access media. Second, it refers to the ease with which media themselves initiate engagement. Consider, for instance, notifications, calls, popup messages, or hyperlinks. The authors suggest that these triggers serve to, firstly, initiate media use and, secondly, remind people how accessible a particular medium is, thereby decreasing the expected transit time to this medium. In this way, they note how media can prompt shifts from one information source to another, even prior to satisfactory engagement or information intake with the first source. Notifications for instance, serve as triggers, indicating, exogenously, that there may be something more interesting, entertaining, or useful available through another medium.

With relevance to the accessibility of media, recent nation-level surveys indicate that, in developed countries, over 95% of people own a mobile phone of some sort, with 77% owning a smartphone (Pew Research Center, 2017). This rate increases to 98% when considering those typically within the age-range of students (18-24 years, Nielsen, 2016). While the penetration rate in developing countries is not at the same level, it has increased from 21% in 2013, to 37% in 2015 (Poushter, 2016). In South Africa, specifically, smartphone ownership is at 37% for the total population, and 46% for those between the ages of 18 and 34 (Poushter, 2016). Interestingly, this survey found a 54% increase in smartphone ownership amongst those with a higher level of education in South Africa. This outcome is supported by an earlier survey conducted at a single higher education institution in South Africa which found that 99% of respondents owned, or had owned a mobile device recently (North *et al.*, 2014). Collectively, these studies indicate that, for students, access to mobile devices is especially prevalent. Mobile devices, as media artefacts, present particular affordances to their users. Coupled with mobile connectivity, this enables students to access a profusion of other media artefacts —SNSs or instant messaging platforms for instance— at any time, and any location. In addition to the increased ubiquity of media, increased accessibility occurs as a result of media's hypertextuality. Many media artefacts —web-browsers, mobile phones, laptops for instance— afford users the ability to switch to other activities —changing tabs, opening new windows or applications, for instance. The accessibility of task-switching is facilitated by the manner of operation engendered by the affordances of such media.

3.2.3 Situations and Norms

Given the accessibility of media, it follows that media use occurs in increasingly diverse situations and contexts. Consequently, Zhang and Zhang (2012) argue that, in addition to the personal dimensions outlined previously, there exists a situational dimension to media multitasking. The notion that situation, along with cognition, determines actions is termed the *situated action* approach. Actions are influenced by the material and social circumstances in which they take place (Suchman, 1987, p. 50). Importantly, in addition to physical factors, situations are also characterised by interpersonal, normative factors (Goffman, 1963). The RAA and SCT, discussed in Section 2.4, incorporate this notion into their behavioural models. Ito and Okabe (2005) indicate that behaviour with media results from situations in which technological affordances interact with social norms.

In *'No sense of place'*, Meyrowitz (1986) proposes that media alter the nature of situated behaviour. Following a review of Goffman (1963)'s theories of social situation, he suggests that situated action theories fail to account for the manner in which media cross the boundaries between situations and contexts previously considered to be distinct. In particular, he demonstrates how media imply a disconnect between location and social interaction. As such, the connection between physical location and social location is broken. Accordingly, Meyrowitz (1986)'s primary insight is that social situations characterised by media use are themselves influenced by factors outside of the physical boundaries of a particular context or situation. Ito and Okabe (2005) propose the concept of 'technosocial situations' to account for the conventional understanding of situations as interpersonal settings, as espoused in situated action theories, and the technologically mediated nature of social orders suggested by Meyrowitz (1986).

Zhang and Zhang (2012) propose a model integrating the UGT and the technosocial situations approach. While specifically targeting computer-based multitasking, this model holds value for considering the role of situations for media multitasking in general. The model indicates that this behaviour is influenced by both personal psychologies (needs and gratifications) as well as situational eco-systemic factors. The first factor, needs and their ensuing gratifications, has been discussed in Section 3.2.1, and extended with the consideration of the notion of information foraging and the implications of the MVT. The second factor, situations, as defined in Zhang and Zhang's model has three dimensions: (i) the physical locations in which media use takes place; (ii) the particular media available in these locations; and (iii) the social relationships and behavioural norms present in these locations. The authors assessed this model by means of a survey of both high-school pupils ($n = 31$) and university students ($n = 203$), finding that physical environments such as study rooms or public spaces were associated with media multitasking for interaction purposes. As expected, work environments were associated with work-related media multitasking. Importantly, however, media multitasking was found to be associated with all five social environments considered (alone, with family, with colleagues/classmates, and with strangers).

As discussed previously, Zhang and Zhang (2012)'s findings in relation to personal factors suggest that different gratifications predict different types of media multitasking. Their findings in relation to situations suggest that, in addition to these factors, physical, technical and social contexts influence the nature of media multitasking. In particular, technological constraints moderate media multitasking and, irrespective of their nature, social environments positively influence media multitasking. In finding that both gratifications and situations predict media multitasking their integrated model is supported. This theory of technosocial situations is compatible with the information foraging explanation of media multitasking behaviour —implicitly aspects of technosocial situations are incorporated into the concepts of boredom, anxiety and, particularly, accessibility.

Zhang and Zhang (2012) suggest that social norms have a greater influence on behaviour than needs. Perceptions of normalcy are related to social and peer-group norms and are developed through observations of attitudes and behaviours (Kallgren *et al.*, 2000). There exists two categories of norms: injunctive norms, which specify "what people approve and disapprove within the culture and motivate action by promising social sanctions for normative or counternormative conduct", and descriptive norms, which specify "what most people do in a particular situation, and they motivate action by informing people of what is generally seen as effective or adaptive behavior there" (Reno *et al.*, 1993, p. 104). Such norms are, accordingly, integral to both a reasoned action and a social cognitive approach to understanding behaviour. Xu *et al.* (2016, p. 245) propose that media multitasking motivated by either cognitive needs or social needs, relates to descriptive norms. In contrast, they argue that media multitasking motivated by entertainment needs relates to both descriptive and injunctive norms. Parry (2017) conducted a focus-group study considering students' beliefs about media multitasking, finding that, in both personal and academic settings, media multitasking is perceived to be normal and socially accepted. Similarly, following a survey-based study Hammer *et al.* (2010) suggest that a 'mobile culture', legitimising media multitasking, is present in university classrooms. Such outcomes, indicating that media use in conjunction with other activities (media multitasking) has become normal behaviour for students in both academic and non-academic contexts, have been supported in a number of other studies (e.g. Annan-coultas, 2012; Leysens *et al.*, 2016; Xu *et al.*, 2016; le Roux and Parry, 2017*b*).

3.2.4 Conclusions

Building on the studies reviewed in this chapter, those of the previous chapter, and extending Zhang and Zhang (2012)'s model of computer multitasking to media multitasking in general, a high-level model of determinants for media multitasking behaviour is proposed as an integrative summary of the literature considered. The model, depicted in Figure 3.2, contends that media multitasking results from both subjective and situational factors. While Zhang and Zhang (2012) considered subjective factors to relate to an individual's needs and gratifications, on the basis of the theories of behaviour considered in Chapter 2 and findings from a number of related studies (e.g., Wang and Tchernev, 2012; Sanbonmatsu *et al.*, 2013; Carrier *et al.*, 2015; Kononova and Chiang, 2015, amongst others), it is proposed that, in addition to needs and gratifications, such subjective factors include the affective, cognitive, motivational, and attitudinal characteristics of an individual. Importantly, studies indicate that deficiencies in self-control, a key component of self-regulation, are associated with increased levels of media multitasking (Sanbonmatsu *et al.*, 2013; Magen, 2017; Szumowska *et al.*, 2018). For needs, media multitasking is, primarily, seen to be driven by needs to attain information subjectively deemed to be gratifying (Zhang and Zhang, 2012; Wang and Tchernev, 2012; Hwang *et al.*, 2014). While it has been argued that media multitasking occurs simply because it is emotionally gratifying (Chinchanachokchai *et al.*, 2015), Wang and Tchernev (2012) found that emotional gratification occurs as a side-effect of media multitasking. The goal-directed, information seeking nature of media interaction is adopted as a theoretical point of departure by information foraging theories in proposing that, from an evolutionary perspective, media multitasking is optimal to satisfy an innate drive to seek information. Acknowledging this, Gazzaley and Rosen (2016) proposed three factors which underlie media multitasking —boredom, anxiety, and accessibility.

As in Zhang and Zhang (2012)'s model for computer multitasking, the integrative model for media multitasking considers a situation to be characterised by three factors: the physical environment, the social environment, and the technological environment. The physical environment refers to the characteristics of the present physical location. These characteristics influence the type of activities engaged in, but not necessarily the extent of media multitasking. The social environment includes both those present and the descriptive norms for behaviour in the situation. Norms are particularly key to media multitasking, legitimising the behaviour. The technological environment refers to the artefacts present in a situation. This determines which affordances are available to be enacted and, consequently, whether media multitasking is feasible. In particular, affordances enabling the rapid switching between various devices or services and, specifically, increases in accessibility, are seen to be notable drivers of media multitasking.

These factors —subjective and situational— do not occur in isolation. Rather, they influence each other. For instance, personal needs for engagement (contributing to boredom) may be affected by the nature of a physical environment. Or, alternatively, one's present

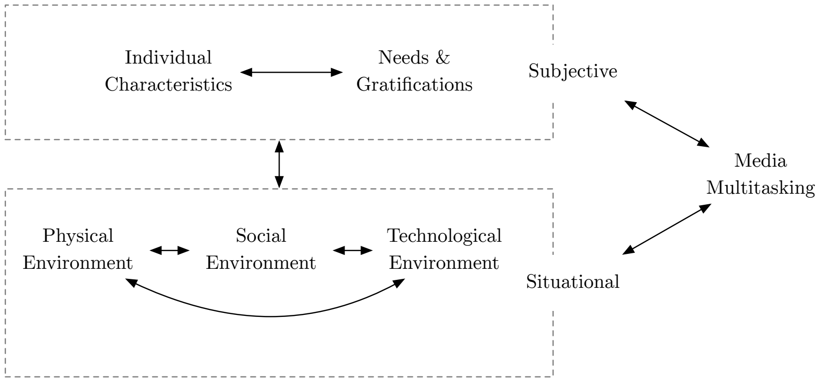

Figure 3.2: Integrative Model of Media Multitasking

social environment may be determined, in part, by various individual characteristics. Finally, in-line with Gazzaley and Rosen (2016)'s interpretations, media multitasking behaviour itself reciprocally influences the subjective and situational factors discussed. Moreover, as Wang and Tchernev (2012) propose, media multitasking is self-reinforcing and, as supported by other studies (e.g., Aagaard, 2015; Parry, 2017), habitual.

As a basis, this model accepts the goal-directed nature of multitasking. Specifically, it is proposed that gratifying informational needs constitutes a key goal for media use. Such goals may, however, be in conflict with other concurrent goals. A number of researchers, consequently, frame media multitasking as the result of a conflict in goals and deficiencies in the ability to regulate behaviour in relation to these goals (Ralph *et al.*, 2015; Gazzaley and Rosen, 2016; Reinecke *et al.*, 2016; Hoffmann *et al.*, 2017; van Koningsbruggen *et al.*, 2018). The present engagement, information, or value offered by a primary task (mediated or non-mediated) is compared to that offered by a secondary mediated task. While both tasks may be associated with various goals, in a given situation, facilitated by the affordances of the media present, through media multitasking, one goal may temporarily supplant another. This is supported by Szumowska *et al.* (2018) who indicate that media multitasking occurs with a greater frequency for those low in self-regulation ability.

Considering this integrative model in relation to Michie *et al.* (2011)'s COM-B model it is proposed that the subjective factors can represent the motivations for the behaviour while the situational factors, as a whole, represent the opportunity construct. Affordances, in providing the technological capacity for the behaviour to occur, represent the capability construct. This comparison is, of course, imperfect. It does, however, present a useful means to relate various factors identified as driving media multitasking to a more general theory of human behaviour. Given Michie *et al.* (2011)'s assertion that any consideration of behavioural change techniques should be underpinned by a comprehensive model of factors that influence the behaviour, the integrative model presented here is regarded to be useful for this purpose. However, it is important to note that, given the nature of the preceding review, this model should not be considered a comprehensive causal summary of all factors driving media multitasking in all situations. Rather, it is presented as an integrative summary of the literature considered. While this integration is inherently useful in its own right, it is also useful when considering both the implications of media multitasking, as well as strategies for addressing any potential implications associated with this behaviour. The various factors identified may hold implications for the nature and consequences of frequent media multitasking. For instance, there may exist individual differences in susceptibility, needs, strategies for attention, self-regulation, anxiety or thresholds for boredom. Similarly, different affordances may not only impact the nature of media multitasking, but also how such behaviour may come to effect cognitive outcomes. Additionally, given the primary objectives of this study, this model focuses attention on a set of factors which may be key to the feasibility of any intervention targeting such behaviour.

3.3 Summary

In this chapter the patterns and drivers of media multitasking for a student population were considered. As an initial point of departure a working definition for media multitasking as the *simultaneous engagement with one medium along with other media or non-media activities*, was provided. Next, it was established that the standard approach to measuring media multitasking involves determining the total amount of time for which media are used, as well as the amount of media used simultaneously with various primary media. Following this, the extent to which students media multitask was considered. From this brief investigation it was shown that, for students, media are used extensively throughout their everyday lives, across numerous contexts. Moreover, for this population, a majority of media use involves multitasking to some extent. Finally, having established the prevalence of this behaviour, the factors underlying media multitasking were considered. Upon considering this behaviour through the lens of the UGT and a technosocial view of behaviour, it was shown that media multitasking occurs as a result of the interplay between various subjective and situational factors.

Chapter 4

Media Multitasking And Cognitive Control

The previous chapter established that, for students, media use is characterised by multitasking. As noted in Section 2.1, McLuhan (1964) emphasises how different media extend the senses in different ways, enabling certain patterns of interaction, while preventing others. In the same way Lin (2009) suggests that the pattern of engagement engendered by hypertextual, interactive media —media multitasking— holds the potential to produce significant outcomes for emotional, cognitive and social functioning. Likewise, in their consideration of the impact of cultural inventions on neural functioning, Dehaene and Cohen (2007) suggest that the acquisition of new tools or behavioural patterns can reshape neural networks, impacting both cognition and behaviour. Similarly, Dux *et al.* (2009) provide evidence indicating that repeated behaviours, media multitasking for instance, impact the manner in which information is processed. Lin (2009) argues that increased media multitasking may impact cognitive control, leading to different styles of information processing and attentional distributions. Heavy media multitaskers may come to adopt a broader style of attentional distribution, achieve superior task-switching abilities, or become more distractible as a result of their extensive task-switching.

In this chapter studies concerning associations between media multitasking and cognitive control are considered to establish the state of research in this regard and, additionally, to provide the motivation for the development of a targeted behavioural intervention. This commences with an overview of the first study to investigate associations between media multitasking and cognitive control. Thereafter, subsequent studies are considered chronologically before an overall evaluation is presented.

4.1 Seminal Study: Ophir *et al.* (2009)

Ophir *et al.* (2009) conducted the first study investigating relationships between media multitasking and cognitive control. Specifically, they addressed whether: *breadth-biased media consumption behaviour is mirrored by breadth-bias in cognitive control.* At the time there existed no standard measure for media multitasking. Therefore, as discussed in Section 3.1.1, they developed the media-use questionnaire (MUQ) and the media multitasking index (MMI) to classify individuals as either heavy or light media multitaskers (HMMs are one standard deviation (SD) above the mean score, and LMMs are one SD below). While there are shortcomings in this methodology (discussed in Section 3.1.1 and later in this chapter), the MMI has become the most common measure for media multitasking. Once the participants were classified as either LMMs or HMMs their MMI scores were compared to seven standard measures of cognitive control: two task-switching paradigms, a Stroop task, a stop-signal task, an AX-continuous-performance task (CPT) with and without distractors, an n-back task with two levels of memory load, and a change-detection task, with and without distractors.

For the filtering of environmental distractions, Ophir *et al.* (2009) found that, while LMMs were unaffected by distractors, HMMs' performance was negatively impacted by the presence of distractors, in both the change-detection and AX-CPT tasks. For the filtering of irrelevant memory representations HMMs displayed a greater increase in false alarms from two-back to three-back assessments than was the case for LMMs. The authors suggest that this implies that HMMs are more susceptible to interference from familiar items stored in working memory (WM). Importantly, for both the filtering and the n-back tasks, these differences only emerged at higher cognitive loads. For task switching, HMMs showed slower response times (RTs) and larger switch costs than was the case for LMMs. These outcomes were not moderated by individual differences for SAT scores, need for cognition, creativity, or Big Five personality traits.

Ophir *et al.* (2009) interpreted their findings to indicate that those who frequently engage in media multitasking approach information processing activities differently than those who abstain from extensive media multitasking. They propose, accordingly, that the breadth-biased media consumption characterising media multitasking is mirrored in the breadth-biased cognitive control of such individuals. In this way, they suggest that HMMs have a greater tendency for bottom-up attentional control. HMMs are less adept at filtering out irrelevant environmental stimuli, less likely to suppress irrelevant mental representations in memory, and are less effective at inhibiting irrelevant task sets.

4.2 Subsequent Research in This Domain

Given Ophir *et al.* (2009)'s findings, Cain and Mitroff (2011) investigated whether this pattern arises due to attentional or memory related associations with media multitasking by isolating attentional processes through the use of a singleton distractor task with low WM demands. Participants were classified as either HMMs (upper quartile, $n = 21$, MMI > 5.36) or LMMs (lower quartile, $n = 21$, MMI < 3.18) on the basis of their responses to the MUQ. The authors found that, in contrast to LMMs, HMMs attended to irrelevant distractors in the task. This finding is consistent with the notion that HMMs adopt a broader distribution of attention and has been supported by findings indicating that HMMs are better at splitting their visual focal attention (Yap and Lim, 2013), and that they display greater processing of irrelevant visual stimuli (Lui and Wong, 2012). Cain and Mitroff (2011, p. 1190) indicate that variations in attentional mechanisms, and not WM processes, are likely to contribute to the diminished attentional performance of HMMs. The authors offer two interpretations of their findings. First, they suggest that frequent media multitasking may broaden HMMs' attentional filters, reducing their ability to inhibit extraneous stimuli. This was first suggested by Lin (2009) in a commentary published alongside Ophir *et al.* (2009)'s report. Second, they suggest that those who display greater difficulties with filtering irrelevant information may choose to engage in a greater degree of media multitasking and, as a consequence, make up a larger proportion of the HMM population.

Minear *et al.* (2013) considered Ophir *et al.* (2009)'s finding that HMMs performed worse at tasks requiring the integration of multiple stimuli, noting that subsequent work has primarily investigated this relationship from an attentional paradigm. In response, they conducted three studies assessing associations between media multitasking and WM, fluid intelligence, and task-switching. In the first, participants were classified as HMMs ($n = 33$, MMI > 5.36) or LMMs ($n = 36$, MMI < 3.18) using the MUQ. Differing from Ophir *et al.* (2009), these groups were based on the cut-off points used by Cain and Mitroff (2011). This implies that the relative level of media multitasking considered differed from previous studies. Minear *et al.* (2013) found that media multitasking was positively associated with impulsivity and, correspondingly, negatively associated with self-control. For performance-based assays they found a difference between LMMs and HMMs for fluid intelligence but not for reading span or task-switching. The latter result is particularly interesting given that they employed the same task-switching measure as Ophir *et al.* (2009), with different outcomes. The survey data, however, indicate that media multitasking is associated with impulsivity. The authors, accordingly, propose that pre-existing cognitive differences may underly media multitasking preferences. Replicating their first study, in a second study Minear *et al.* (2013) again found a difference between HMMs ($n = 27$) and LMMs ($n = 30$) for fluid intelligence. In their third study they assessed differences in attention through the attention network task (ANT), resolution of WM interference (recent probes task), and task switching. No differences between HMMs ($n = 27$) and LMMs ($n = 26$) were found. The authors suggest that this may have resulted from the tasks used. In comparison with Cain and Mitroff (2011)'s use of a singleton distractor task, the ANT prevents the use of particular attentional strategies. Likewise, in comparison with Ophir *et al.* (2009)'s use of the n-back task, the recent probes task assesses WM differently. Commenting on the failure to replicate Ophir *et al.* (2009)'s findings across their three studies the authors suggest that this may have occurred due to differences in how HMMs and LMMs were defined, population-level factors, and cognitive load. Ophir *et al.* (2009) found group differences under higher cognitive load, an aspect that was not manipulated in their study. The proposed effects may only occur under greater cognitive load.

Alzahabi and Becker (2013) investigated associations between task-switching, dual-tasking, and media multitasking in two studies. In the first, participants ($n = 23$ HMMs, 23 LMMs) performed two sets of behavioural trials, a task-switching block (number-letter task), and a dual-task block (number-only tasks interspersed with letter-only tasks, followed by a 'both' condition). In contrast to Ophir *et al.* (2009), HMMs displayed significantly better task-switching performance than LMMs. Moreover, no evidence of a relationship between media multitasking and dual-task performance was found. The authors interpret their findings to suggest that, through frequent media multitasking, HMMs improved their task-switching abilities. This does not necessarily apply to dual-task situations. Media multitaskers have become efficient at sequential multitasking, but not parallel multitasking. This interpretation is supported by the finding that HMMs displayed faster RTs in the switch trials, with decreased switch costs. This is inconsistent with Ophir *et al.* (2009)'s finding of slower RTs in repeat trials for HMMs. When considering the inconstancies between these two studies, it is necessary to note the methodological differences. Alzahabi and Becker (2013) presented the cue and stimulus simultaneously, whereas Ophir *et al.* (2009) allowed a gap between cue and stimulus. Additionally, the response options differed. In the former study bivalent response options (two-buttons) were used, whereas the latter used univalent responses (four-buttons). Univalent responding limits the possibility of response congruency, potentially improving RTs. Alzahabi and

Becker (2013) conducted a second study to investigate whether these differences could explain the inconsistent results. Participants ($n = 15$ HMMs, 15 LMMs) completed the task-switching task, as specified by Ophir *et al.* (2009). Despite identical methodologies, Ophir *et al.*'s findings were unable to be replicated. HMMs displayed faster RTs than LMMs, indicating a superior task-switching ability.

Along with the MMI Baumgartner *et al.* (2014) collected self-report data for WM, inhibition, and shifting (through the behavioural rating inventory of executive function, BRIEF), as well as performance-based assays of WM (digit Span test), inhibition (Eriksen flanker task), and shifting (dots-triangles task) from a sample of adolescents ($n = 523$). The authors found that media multitasking correlated with self-reported WM, inhibition, shifting, performance-based WM and inhibition, but not performance-based shifting. Through three separate regression analyses it was found that media multitasking predicted self-reported WM, inhibition and shifting, but not performance-based assays of these functions. This pattern indicates that those who frequently engage in media multitasking report more problems in their everyday lives associated with shifting between tasks and inhibiting extraneous stimuli but, at a functional level, their abilities to switch or inhibit irrelevant stimuli remain unaffected. The generalisability of these findings is, however, limited by the population targeted —adolescents between the ages of 11 and 15. Due to ongoing cognitive development during adolescence (Blakemore and Choudhury, 2006), it is difficult to extrapolate from such a population to university students (typically between 18 and 24 years old). A second caveat relates to the discrepancy between self-reported and performance-based assays of cognitive control. Toplak *et al.* (2013) indicates that there tends to be no association between these two paradigms. While not related, each assesses different aspects of cognitive control. Self-report measures consider everyday, behavioural aspects of cognitive control —the extent to which goals are accomplished in real-world situations (Toplak *et al.*, 2013). In contrast, performance-based tasks assess the processing efficiency of an executive function in an isolated context. There is, however, much debate on this issue. Barkley and Fischer (2011) for instance, suggest that self-report measures offer a greater level of ecological validity, with more accurate predictions of real-world cognitive impairments in the course of everyday activities. In contrast, Snyder *et al.* (2015) suggest that self-report measures are problematic due to the interplay between contextual factors and executive processes.

Further considering associations with everyday executive functioning, Ralph *et al.* (2014) investigated relationships between media multitasking, as indicated by the MMI, and self-reported attentional functioning along three dimensions: lapses of attention, attention-related errors, and mind wandering. For the first dimension three scales were used: the Mindful Attention Awareness Scale-lapses Only (MAAS-LO), the Attention-related Cognitive Errors Scale (ARCES), and the Memory Failures Scale (MFS). For the third, both the spontaneous and the deliberate mind wandering questionnaires (MW-S & MW-D) were used and, to consider attention switching, subjective measures of attentional switching and distractibility (AC-S & AC-D) were used. The authors found that media multitasking was positively related[1] to self-reports of attentional failures for both the MAAS-LO and the ARCES. Similarly, a positive correlation between media multitasking and both spontaneous and deliberate mind wandering was found. No correlations between media multitasking and attentional control for switching or distractibility were found.

On the basis of these findings Ralph *et al.* (2014) propose a causal model in support of the *deficit-producing hypothesis*, postulating that, through repeated media multitasking, endogenous control of attention may become weakened. Corresponding with Lin (2009)'s commentary on Ophir *et al.* (2009)'s findings, and Cain and Mitroff (2011, p. 1190)'s suggestion that "consistent practice with consuming multiple media has led to a broadening of HMMs' attentional filters", this model supports findings indicating attentional deficits associated with increased media multitasking (e.g., Ophir *et al.*, 2009; Cain and Mitroff, 2011; Sanbonmatsu *et al.*, 2013). Ralph *et al.* (2014) contend, however, that the relationship may be the opposite to what their model describes —those with deficits in aspects of cognitive control may be drawn to media multitasking, a *self-selection hypothesis*. Additionally, Ralph *et al.* (2014) note that, while performance-based tasks have provided inconsistent evidence for a relationship between media multitasking and cognition, self-report measures have been more consistent in indicating an association with attentional failures in everyday life. Moreover, they suggest that while ostensibly isolating a particular executive function, the links between performance-based assays and 'real-world' performance are often tenuous and subtle. For instance, switch costs are measured in the hundreds of milliseconds. In contrast, both Ralph *et al.* (2014) and Baumgartner *et al.* (2014) indicate that, at a *subjective* level, increased incidences of attentional failures are associated with increased media multitasking.

Subsequently, Ralph *et al.* (2015) investigated media multitasking and sustained attention with three performance-based tasks: the metronome response task (MRT), the sustained-attention-to-response task (SART), and a vigilance task (a modified SART). The authors posited that media multitasking is associated with a deficit "in one's ability to sustain the focus of attention on a single task over time" (p. 39). Their first study considered

[1] With these scales a higher score represents a greater tendency for attentional failures.

associations between media multitasking and performance on the MRT. Participants (n = 77) were classified as either HMMs or LMMs with the MMI.[2] Increased media multitasking was associated with increased variability on the MRT, an indication of poorer performance. In their second study (n = 83) the authors tested whether this would generalise to another measure of sustained attention, the SART. In contrast to study one, no associations between media multitasking and performance measures of the SART were found. As a result of these inconsistencies Ralph *et al.* (2015) conducted a third study involving the use of two online samples testing, firstly, the outcome of study one (n = 174) and, secondly, the outcome of study two (n = 152). After controlling for concurrent media multitasking, these assessments replicated their earlier results —media multitasking correlated with response variability in the MRT but not with the SART. In seeking to understand why media multitasking might correlate with one measure of sustained attention and not another, the authors note that these measures are only moderately correlated with each other. Media multitasking may be associated with a task-specific aspect of one measure, but not sustained attention in general. In their fourth study they considered associations between media multitasking and a third measure of sustained attention, the vigilance task. Following another online sampling procedure (n = 130), no associations with media multitasking were found. Considering all four studies Ralph *et al.* (2015, p. 399) conclude that, on the basis of their data, there is no relation between media multitasking and a deficit in sustained attention. They attribute the relationship observed for the MRT to specific aspects of the measure. The results of this series of studies differ to those reported in their earlier paper. The authors propose that such differences exist as a result of how HMMs approach tasks outside of a laboratory setting. They suggest that HMMs 'allow' themselves to become more distracted in the course of their everyday lives but, when in a controlled laboratory setting, they do not interrupt themselves, sustaining attention to the tasks.

Using the same tasks as Ophir *et al.* (2009) Cardoso-Leite *et al.* (2016) considered the effects of media multitasking on cognitive control. Participants ($n = 60$) were classified as HMMs, LMMs or intermediate multitaskers (IMMs) through the MUQ. The researchers used the same boundary values as Ophir *et al.* (2009) to classify the participants (MMI $<$ 2.86 for LMMs and $>$ 5.90 for HMMs), despite a different mean value in their study (M = $3.98, SD = 1.99$). Participants completed three questionnaires: the Adult ADHD Self-Report Scale (ASRS), the Cognitive Failures Questionnaire (CFQ), and the Work and Family Orientation Questionnaire (WOFO). No difference between HMMs and LMMs

[2] The authors did not disclose the size of these samples, nor how they were computed.

for any of the measures was found. Across all of the performance-based assays HMMs performed worse than LMMs. In the AX-CPT the pattern observed differed from that reported by Ophir *et al.* (2009). In the earlier study HMMs' performance differed only when distractors were added to the task. In the latter, there was no specific impairment in the presence of distractors —HMMs' performance was worse across the entire task. In the filter task the researchers found that HMMs performed worse than both IMMs and LMMs. In contrast, for the n-back and task-switching tasks, no significant differences were found.

Cain *et al.* (2016) assessed relationships between media multitasking and WM. As with Baumgartner *et al.* (2014), they considered a sample of adolescents (12.8 to 16.5 years old). WM was assessed through three tasks (the count span task, the n-back task, and the WM filtering task). Additionally, participants performed the Coding and Symbol Search subtests from the Wechsler Intelligence Scale for Children to assess cognitive processing speed. Media multitasking was found to correlate negatively with performance in the count span task and the n-back task, but not WM filtering or cognitive processing speed. Cain *et al.* (2016) note that their findings are consistent with Ophir *et al.*'s despite population and task differences. They do, however, suggest that these imply differences in the mechanisms underlying the relationships found. Ophir *et al.* (2009) interpreted their results to indicate that HMMs have a deficit in inhibitory control, allowing impulsive responses to irrelevant exogenous stimuli. Cain *et al.* (2016), in contrast, interpret their findings to suggest that performance suffers due to improper maintenance of representations in WM. Additionally, they found no association between media multitasking and WM filtering, whereas Ophir *et al.* (2009) found media multitasking to be negatively associated with WM filtering. The authors suggest that this results from differences in filtering load, with their task requiring a much lower load than the former. Finally, they suggest that their data indicating that those who habitually media multitask are also those least able to effectively multitask, supports the notion that differences in underlying cognitive abilities may drive tendencies to media multitask.

Moisala *et al.* (2016) considered associations between media multitasking and attention-related task performance. Participants ($n = 149$) performed tasks assessing, firstly, their attention in the presence of distractors and, secondly, the division of attention between tasks. The distracted attention condition involved performing a sentence congruence judgment task in either auditory or visual modalities in the presence of irrelevant inputs in the other modality, while the divided attention condition involved performing both tasks in parallel. During both conditions participants' brain activity was recorded through event-related fMRI. Participants were classified as either HMMs or LMMs[3] using a modified version of the MUQ. Moisala *et al.* (2016) calculated an index for the absolute time spent media multitasking (MMT), arguing that this is more appropriate. They did, however, calculate an MMI for comparative purposes. No associations between either measures and divided attention performance were found. This supports Alzahabi and Becker (2013)'s suggestion that frequent media multitasking does not lead to improvements in dual-tasking ability. In observing this the authors note that performance-based assays of dual-tasking ability do not correspond with everyday dual-tasking situations and, typically, force participants to adopt a serial rather than parallel mode of processing. For distracted attention Moisala *et al.* (2016) found an effect of MMT on performance with a greater MMT associated with more incorrect responses. No effect of MMI on performance was found. This suggests that the effect of time media multitasking is greater than the time-weighted sum of media combinations represented by the MMI. For neural activation, Moisala *et al.* (2016) found that, during the distracted attention condition, activation of right prefrontal regions was associated with the MMT. No correlations were found with the MMT for undistracted and divided attention conditions. These regions have been associated with attentional and inhibitory control (Miller and Cohen, 2001). This suggests that, for those who spend more time media multitasking, increased cognitive effort is required under distracted conditions. As with all of the correlational research in this domain this finding can be interpreted in both directions. Regardless, these findings indicate that there is an association between media multitasking and reduced attentional functioning and that, at a neural level, this relationship is reflected in right prefrontal regions during tasks requiring divided attention.

Uncapher *et al.* (2016) considered relationships between media multitasking and WM, categorising participants ($n = 139$) as either HMMs ($n = 36$), or LMMs ($n = 36$) using the MUQ. Additionally, the authors used inventories for impulsivity (BIS) and ADHD, along with two WM tasks (rectangles and objects) and two recognition memory tasks (target objects and distractor objects). Media multitasking was found to correlate positively with impulsivity and ADHD. In both WM tasks HMMs performed worse than LMMs, irrespective of the presence of external distractors. Uncapher *et al.* (2016) interpret this to indicate a reduction in the precision of task-representations encoded in WM for HMMs. Taken together, these findings support the notion that increased media multitasking is associated with a broader distribution of attention. The authors suggest that this broader distribution, combined with higher levels of attentional impulsivity, may

[3]The authors did not specify the size of these samples.

alter filtering strategies, permitting goal-irrelevant stimuli to compete with goal-relevant stimuli, diminishing the precision of, and capacity for, relevant-representations in WM.

Ralph and Smilek (2017) considered associations between media multitasking and a single WM paradigm, the n-back task. Three previous studies have compared media multitasking with this task (Ophir *et al.*, 2009; Cardoso-Leite *et al.*, 2016; Cain *et al.*, 2016), with each producing different outcomes. Ralph and Smilek (2017) endeavoured to resolve these inconsistencies through, firstly, using a larger sample and, secondly, treating media multitasking as a continuous construct rather than the dichotomous construct considered previously. Participants ($n = 317$) completed two media use questionnaires and 2-back and 3-back assessments. The first MUQ corresponds to the measure used by Ophir *et al.* (2009). The second included fewer items and, rather than specifying total use-hours per week, as is the case in the original MUQ, required participants to indicate use-hours on an average day. Ralph and Smilek (2017) found that, after controlling for age, both indices positively correlated with 2-back hits, but not 3-back hits, suggesting an effect of cognitive load on performance. Moreover, both indices correlated positively with a greater proportion of omitted trials, for both conditions. This indicates that, irrespective of how media multitasking was classified, those who media multitask more, were more disengaged during the tasks. Previous studies considering n-back performance in relation to media multitasking have failed to report any associations with trial omissions. When controlling for omissions, media multitasking was associated with an increase in false alarms, but not with hits. While supporting Ophir *et al.* (2009)'s findings, this result is incongruent with Cain *et al.* (2016)'s finding of a relationship between media multitasking and hits. For comparative purposes the authors considered their findings in the same manner as these studies, ignoring omissions. In this second analysis, as shown in Cain *et al.* (2016), they found correlations between media multitasking and hits. As Cain *et al.* (2016) did not report omissions in their trial, it is unknown whether this outcome accounts for their findings. In considering the implications of their findings the authors suggest that, rather than representing a cognitive deficit or inability to ignore distracting stimuli amongst heavy media multitaskers, their findings may indicate an association between media multitasking and a particular *attentional strategy.* This would suggest that increased media multitasking is associated with a greater propensity to disengage from ongoing tasks. Previously Ralph *et al.* (2015) indicated that HMMs may 'allow' themselves to become more distracted in the course of their everyday lives.

Wiradhany and Nieuwenstein (2017) conducted two studies attempting to replicate Ophir *et al.* (2009)'s findings. In the first, participants were classified as either HMMs ($n = 13$)

or LMMs ($n = 10$) and performed four tasks (change detection, n-back, AX-CPT, and task-switching) conducted in the manner described by Ophir *et al.*, with one exception. For the AX-CPT the condition without distractors was excluded. Wiradhany and Nieuwenstein (2017) adopted these four tasks to assess the replicability of what they identified as Ophir *et al.*'s seven core findings. Only three statistically significant associations were found. In the task switching paradigm HMMs indicated larger switch costs and slower RTs than LMMs while, in the AX-CPT, HMMs were slower than LMMs in responding to BX probes. While these effects were reproduced, no significant difference between the groups for false alarms in the n-back task, RTs on repeat trials in the task switching paradigm, AX trials in the AX-CPT, or vulnerability to distraction in the change-detection task were found. Wiradhany and Nieuwenstein (2017) performed a Bayes factor (BF) analysis to quantify the extent to which the findings support the existence of the targeted effects. Only one of the three significant effects, higher switch costs in HMMs, was shown to be supported by strong evidence. The two remaining significant effects produced BFs indicating an anecdotal level of evidence. Interestingly, however, only one of the four nonsignificant effects produced a BF indicating evidence stronger than anecdotal for the null hypothesis (i.e. the absence of an interaction effect for media multitasking group in the change detection task). Consequently, this replication was largely inconclusive —only two of the seven effects produced evidence either confirming or disconfirming Ophir *et al.* (2009)'s effects. With a mean MMI of 6.80, higher than most previous studies, the researchers proposed that this may account for the outcomes observed.[4] Additionally, the small sample size considered hampers the extent to which robust interpretation of the outcomes can be provided.

Wiradhany and Nieuwenstein (2017) conducted a second study to address the possibility that the MMI scores in their first were affected by demographic factors. A sample of Dutch students participated in this second study, producing a mean MMI of 3.80. This is in-line with those reported in previous studies. 19 HMMs and 11 LMMs completed the same procedures as in the first study. It is important to note that 10 participants were removed from the AX-CPT, leaving a very small sample of 14 HMMs and only six LMMs. Only two comparisons produced significant outcomes corresponding to Ophir *et al.*'s. In the AX-CPT HMMs were slower than LMMs in AX trials and, in the task switching trials, their overall time was slower than LMMs' times. In contrast, for the change detection and n-back tasks no differences between HMMs and LMMs were found. From the BF analysis the authors found that only the difference in AX trials was supported

[4] The authors note that Indonesians have been shown to have a tendency to select extreme answers.

by moderately strong evidence. The significant difference in the switch trials, as well as the five non-significant effects were all shown to be backed by anecdotal evidence only. Given these outcomes, and those of the first, the replications were largely inconclusive.

Following these studies Wiradhany and Nieuwenstein (2017) conducted a meta analysis of research considering associations between media multitasking and performance-based assays of cognitive control. They did not consider self-reported indications of cognitive performance or other related outcomes. The authors included results reported in 12 articles in their meta-analysis.[5] Additionally, they included the effect sizes found in their first two studies. Using a random-effects model they calculated a weighted overall effect size for the relationship between media multitasking and cognitive control, as represented by these studies. This model indicates a small but significant association between media multitasking and impaired cognitive control, as measured in performance-based assays ($d = .17$, $p < .01$). Extending this analysis, Wiradhany and Nieuwenstein (2017) found there to be no moderating effect of firstly, different types of distraction, secondly, different populations and, thirdly, different statistical approaches. In considering whether the outcomes of their meta-analysis were affected by small-study effects Wiradhany and Nieuwenstein (2017) determined that the distribution of effects across the studies is asymmetrical. Studies with small sample sizes indicating a negative relationship with cognitive control dominate the sample. Consequently, they propose that there exists a degree of reporting bias in the literature. After statistically accounting for this bias the ostensibly significant relationship between media multitasking and cognitive control represented by their model became nonsignificant.

4.3 Conclusions

Ophir *et al.* (2009) first considered a possible relationship between media multitasking and cognitive control and, on the basis of their findings, proposed that those who multitask more, as represented by a higher MMI score, have a greater tendency for bottom-up attentional control and a bias toward exploratory information processing. Subsequently, numerous studies have considered possible relationships between media multitasking and cognitive control. Evidence supporting this relationship has been mixed, with some studies confirming aspects of this association (e.g. Cain and Mitroff, 2011; Lui and Wong,

[5]Ophir *et al.* (2009), Cain and Mitroff (2011), Alzahabi and Becker (2013), Minear *et al.* (2013), Baumgartner *et al.* (2014), Cardoso-Leite *et al.* (2016), Ralph *et al.* (2015), Cain *et al.* (2016), Gorman and Green (2016), Moisala *et al.* (2016), Uncapher *et al.* (2016), Ralph and Smilek (2017).

2012; Sanbonmatsu *et al.*, 2013; Minear *et al.*, 2013; Yap and Lim, 2013; Baumgartner *et al.*, 2014; Ralph *et al.*, 2014; Cain *et al.*, 2016; Moisala *et al.*, 2016), while, in contrast, others do not (e.g. Alzahabi and Becker, 2013; Minear *et al.*, 2013; Baumgartner *et al.*, 2014; Ralph *et al.*, 2014; Cardoso-Leite *et al.*, 2016; Ralph *et al.*, 2015; Uncapher *et al.*, 2016; Magen, 2017; Murphy *et al.*, 2017; Wiradhany and Nieuwenstein, 2017). Studies in this domain have largely adopted correlational designs. As such, inferences about the causality of any relationship between media multitasking and cognitive control are limited. To establish whether there is a relationship between media multitasking and cognitive control and, in particular, if increased media multitasking diminishes cognitive control further experimental, longitudinal research is required. Nevertheless, on the basis of findings produced in their respective studies researchers have outlined various hypotheses for potential relationships between media multitasking and cognitive control.

Ophir *et al.* (2009) proposed the *breadth-biased hypothesis*, postulating that HMMs have a greater tendency for bottom-up attentional control and a bias toward exploratory information processing. This hypothesis does not express a direction of causality. Rather, it describes the pattern of performance observed in their study. Ophir *et al.* (2009, p. 15585) note that media multitasking can be associated with a breadth-biased approach to attention either because repeated media multitasking 'encourages' HMMs to operate in such a manner, or such a bias can emerge as a result of underlying individual differences. These alternatives describe two possible directions of causality between media multitasking and cognitive control. One possibility, the *deficit-producing hypothesis*, as described by Ralph *et al.* (2014), postulates that through repeated outsourcing of control to mediated, exogenous stimuli, endogenous control of attention becomes weakened.

In contrast, individual differences may drive media multitasking. These differences extend beyond media multitasking and, consequently, affect performance. Ralph *et al.* (2015)'s *strategic hypothesis* postulates that individual differences in media multitasking are indicative of general strategies for behaviour. HMMs report increased instances of attentional failures, not because of deficits in cognitive control but, rather, they adopt an attentional strategy permitting themselves to become distracted (Ralph *et al.*, 2018). While such a strategy may be reflected in self-reported measures of attentional failures, it may not manifest in laboratory settings. Ralph *et al.* (2015) suggest that, when HMMs are required to adopt a particular attentional strategy in assessments they do so, sustaining attention as needed. Ralph and Smilek (2017) argue that individual differences in thresholds of engagement may explain this strategic choice. Moreover, Yeykelis *et al.* (2014) found that the act of switching between media is arousing in itself. Baumgartner *et al.* (2017*b*) suggest that those who frequently engage in media multitasking may become habituated to such elevated arousal levels and, accordingly, adopt a strategy to achieve commensurate arousal when not engaged. Another possibility indicated by Szumowska *et al.* (2018), is individual differences in self-regulation ability. These authors found that self-regulation moderated the effects of media multitasking on performance. In a related manner, Schutten *et al.* (2017) found that HMMs adopted a more intuitive mode of decision making than LMMs and, on this basis, suggest that HMMs favour short-term gratification. Finally, there is the *self-selection hypothesis*, which proposes that individuals with deficits in the filtering components of cognitive control may be drawn to media multitasking (Cain and Mitroff, 2011; Ralph *et al.*, 2014). Observed deficits in cognitive performance occur not as a result of media multitasking but, rather, those who already exhibit such deficits are more likely to be HMMs.

All of these hypotheses presuppose the existence of a relationship in some form between media multitasking and cognitive control. Moreover, they are not mutually exclusive — the cognitive control of those who are biased to, or choose to adopt particular attentional strategies, may be further impacted by their media multitasking. However, at this stage, given the disparate findings in this domain, the true nature of such a relationship, if any, remains uncertain. In seeking to understand these hypotheses and the relationship between media multitasking and cognitive control it is necessary to question why findings in this regard are so inconsistent. In the following sections these findings are considered in aggregate to elucidate the current state of research in this domain. Following this, consideration is given to methodological factors potentially accounting for these findings.

4.3.1 Outcomes Across Measurement Paradigms

Associations between media multitasking and aspects of cognitive control have primarily been considered along two lines: performance based assays of cognitive control and self-reported assessments of everyday executive functioning. In this sub-section the patterns of findings produced through these two approaches are briefly considered. Table 4.1 summarises key findings for self-report assessments and, following this, Table 4.2 summarises findings reported in performance-based studies. Thereafter, the implications of such measures for evaluations of possible relationships between media multitasking and cognitive control are considered.

Considering the findings presented in Table 4.1, it is evident that there are inconsistencies in outcomes produced through such measures. Nonetheless, 15 of the 20 assessments

Table 4.1: Summary of self-reported findings

Study	Measure	Outcome
Working memory		
Baumgartner *et al.* (2014)	BRIEF WM subscale	Correlation with decreased WM
Ralph *et al.* (2014)	MFS	No correlation
Magen (2017)	BRIEF WM subscale	Correlation with decreased WM
Shifting/Flexibility		
Baumgartner *et al.* (2014)	BRIEF Shifting subscale	Correlation with decreased shifting
Magen (2017)	BRIEF Shifting subscale	No correlation
Inhibition/Filtering		
Baumgartner *et al.* (2014)	BRIEF inhibition subscale	Correlation with decreased inhibition
Magen (2017)	BRIEF Inhibition subscale	No correlation
Attentional Control		
Ralph *et al.* (2014)	MAAS-LO	Predicted attentional failures
	ARCES	Predicted attentional failures
	MW-S & MW-D	Predicted mind wandering
	AC-S & AC-D	No correlation
Other Measures		
Minear *et al.* (2013)	Impulsivity: BIS	Correlation with impulsivity
	Self-Control: BSCS	Negative Correlation with self-control
	Impulsivity: BIS	HMMs reported higher motor impulsivity
Sanbonmatsu *et al.* (2013)	Impulsivity: BIS	Correlation with impulsivity
	Disinhibition: SSS	Correlation with disinhibition
Cardoso-Leite *et al.* (2016)	Cognitive failures: CFQ	No difference between groups
Uncapher *et al.* (2016)	Impulsivity: BIS	Correlation with impulsivity
Schutten *et al.* (2017)	Impulsivity: BIS	Correlation with impulsivity
Hadlington and Murphy (2018)	Cognitive failures: CFQ	More cognitive failures for HMMs

of everyday executive functioning indicate a significant negative association with media multitasking. Additionally, while five studies produced non-significant outcomes no study reported a positive correlation between media multitasking and any measure for everyday executive functioning. Taken together, while small in size, and often considered in isolation, the overall pattern of results produced on the basis of these studies indicates that those who media multitask more perceive themselves to be more distractible in everyday life, to a greater extent than those who refrain from frequent media multitasking.

As is evident in Table 4.2 considerations of relationships between media multitasking and cognitive control through performance-based assays have produced particularly inconsistent outcomes, with many studies failing to replicate Ophir *et al.* (2009)'s findings. As a result of the complex nature of many of the tasks used in these studies it is typically difficult to compare outcomes from one study to another (Snyder *et al.*, 2015). Moreover, it is acknowledged that a simple tallying of results does not indicate, at a meta-level, the existence of an effect. However, what can be deduced from such a table, is the general pattern of results emerging from these studies. In the table, for each measure, the main effect (ME) of media multitasking group-comparisons or correlational analyses is reported. Seven of the fourteen measures of WM performance indicate a

Table 4.2: Summary of performance-based findings

Study	N	Measure	Outcome
Working memory			
Ophir *et al.* (2009)	15 HMMs, 15 LMMs	N-back (2- and 3-back)	Group*load interaction; HMMs worse on 3-back
Minear *et al.* (2013)	33 HMMs, 36 LMMs	Automated Reading Span	no ME of group
Baumgartner *et al.* (2014)	523 total	Digit-span	No correlation
Cardoso-Leite *et al.* (2016)	12 HMMs, 20 LMMs	N-back (2- and 3-back)	ME of group: HMMs worse
Cain *et al.* (2016)	73 total	Count span Task	Negative correlation
	73 total	Count span Task	Negative correlation
	73 total	WM Filtering Task	No correlation
Uncapher *et al.* (2016)	36 HMMs, 36 LMMs	Change detection task (objects)	ME of group: HMMs lower
	36 HMMs, 36 LMMs	Change detection task (rectangles)	ME of group: HMMs lower
Ralph and Smilek (2017)	265 total	N-back (2- and 3-back)	correlation with false alarms and omissions
Wiradhany and Nieuwenstein (2017)	13 HMMs, 10 LMMs	N-back (2- and 3-back)	no ME of group
	6 HMMs, 14 LMMs	N-back (2- and 3-back)	no ME of group
Seddon *et al.* (2018)	112 total	Backwards Corsi block task	No correlation
	112 total	Backwards Digit-span	No correlation
Shifting/Flexibility			
Ophir *et al.* (2009)	15 HMMs, 15 LMMs	Number-letter (task-switching variant)	ME of group: HMMs greater switch cost
	19 HMMs, 22 LMMs	Stop-signal task	no ME of group
Minear *et al.* (2013)	33 HMMs, 36 LMMs	Number-letter (task-switching)	no ME of group
	27 HMMs, 26 LMMs	Number-letter (predictable switches)	no ME of group
Alzahabi and Becker (2013)	23 HMMs, 23 LMMs	Number-letter (task-switching)	ME of group: HMMs better
	23 HMMs, 23 LMMs	Number-letter (dual-task)	no ME of group
	15 HMMs, 15 LMMs	Number-letter (task-switching)	ME of group: HMMs better
Baumgartner *et al.* (2014)	523 total	Dots-triangles task	No correlation
Cardoso-Leite *et al.* (2016)	12 HMMs, 20 LMMs	Number-letter (dual-task)	no ME of group
Gorman and Green (2016)	22 HMMs, 20 LMMs	Number-letter (task-switching)	ME of group: HMMs worse
Wiradhany and Nieuwenstein (2017)	13 HMMs, 10 LMMs	Number-letter (task-switching)	ME of group: HMMs worse
	14 HMMs, 6 LMMs	Number-letter (task-switching)	ME of group: HMMs worse
Seddon *et al.* (2018)	112 total	Wisconsin Card Sorting task	No correlation
	112 total	Trail making task	No correlation
	112 total	Phonetic fluency task	No correlation

Table 4.2 continued from previous page

Study	N	Measure	Outcome
	112 total	Semantic fluency task	No correlation
Inhibition/Filtering			
Ophir *et al.* (2009)	15 HMMs, 15 LMMs	AX-CPT (without distractors)	no ME of group
	15 HMMs, 15 LMMs	AX-CPT (with distractors)	ME of group: HMMs worse
	19 HMMs, 22 LMMs	Change detection task	ME of group: HMMs worse
Cain and Mitroff (2011)	21 HMMs, 21 LMMs	Singleton distractor task	ME of group: HMMs worse
Lui and Wong (2012)	10 HMMS, 9 LMMs	Visual search (pip-and-pop)	ME of group: HMMs process irrelevant stimuli
Baumgartner *et al.* (2014)	523 total	Flanker Task	No correlation
Cardoso-Leite *et al.* (2016)	12 HMMs, 20 LMMs	AX-CPT (with distractors)	ME of group: HMMs less efficient
	12 HMMs, 20 LMMs	AX-CPT (without distractors)	ME of group: HMMs worse
	12HMMs, 20 LMMs	Change detection task	ME of group: HMMs lower
Gorman and Green (2016)	22 HMMs, 20 LMMs	Change detection Task	ME of group: HMMs less efficient
Murphy *et al.* (2017)	28 HMMs, 28 LMMs	Flanker Task	no ME of group
	28 HMMs, 28 LMMs	Go/No-Go Task	no ME of group
Wiradhany and Nieuwenstein (2017)	13 HMMs, 10 LMMs	AX-CPT (with distractors)	ME of group: HMMs slower
	14 HMMs, 6 LMMs	AX-CPT (with distractors)	ME of group: HMMs slower
	13 HMMs, 10 LMMs	Change detection task	no ME of group
	15 HMMs, 6 LMMs	Change detection task	no ME of group
Seddon *et al.* (2018)	112 total	Flanker Task	No correlation
	112 total	Flanker Task	No correlation
	112 total	Go/No-Go Task	No correlation
	112 total	Stop-Signal task	No correlation
Attentional Control			
Yap and Lim (2013)	33 HMMs, 33 LMMs	Attention distribution paradigm	ME of group: HMMs' split, LMMs' focus
Ralph *et al.* (2015)	73 total	MRT	correlation with increased variability
	82 total	SART	No correlation
	146 total	MRT	correlation with increased variability
	143 total	SART	No correlation
	109 total	SART-vigilance	No correlation
Moisala *et al.* (2016)	149 total	Sentence congruence judgment (divided)	No correlation
	149 total	Sentence congruence judgment (distracted)	correlation with decreased performance

negative relationship between media multitasking and aspects of WM, while seven show no relationship and no studies report evidence of a positive relationship with WM. For cognitive flexibility three outcomes show that heavier media multitasking is associated with improved shifting outcomes, four with diminished performance, and ten indicate no association. Of the four cognitive control processes assessed in the literature these are the only to report a positive relationship with media multitasking. For inhibition 10 of the 20 outcomes indicate diminished performance for HMMs, and 10 indicate no effect. Finally, for attentional control, four assessments indicate a negative relationship with media multitasking, while four found no association.

While the nature of the relationship between media multitasking and cognitive control remains unresolved, evidence at this stage points to a small negative association. An important distinction, however, is the difference between self-reported and performance-based findings. The pattern of results produced on the basis of self-report measures indicates that heavy media multitasking is associated with diminished everyday executive functioning. In performance-based assays the general trend is less clear, with some studies indicating a negative relationship, some finding no evidence of a relationship, and others indicating a positive relationship. Together these outcomes suggest that, in everyday life, those who frequently media multitask experience diminished cognitive functioning and, as indicated by the disparate results in laboratory assessments, and the goal-related nature of multitasking, this reduction may be associated with behavioural goals.

4.3.2 Methodological Factors

Before providing a final evaluation of the current state of knowledge on the relationship between media multitasking and cognition, it is necessary to briefly consider the implications of a number of methodological factors present in research in this domain.

4.3.2.1 Paradigmatic Implications

Research in this domain has produced varied outcomes. In particular, the general pattern of findings produced on the basis of self-reports of everyday executive functioning differs from that indicated by laboratory assessments. A number of researchers have commented on the distinction between these two measures. Lin (2009, p. 15521), for instance, notes that "what happens in lab experiments does not often represent a complete picture of what happens in real life [...] the distractions in experiments are not necessarily distractions in real life". Outside of artificial laboratory settings decisions about what is a primary task and what is a distraction, or when switching should occur, can all affect cognitive control and task-switching performance. Ralph *et al.* (2014) suggest that the links between performance-based measures and 'real-world' performance are often tenuous. This assertion is supported by a recent review indicating that self-reported and performance-based assays of cognitive functioning do not correlate (Toplak *et al.*, 2013).

Performance-based assessments are administered in controlled conditions where performance is measured for accuracy or response times. In contrast, self-report assessments are designed to provide an indication of performance on tasks requiring cognitive control in everyday life (Gioia *et al.*, 2015). Toplak *et al.* (2013) contend that, while related, these measures consider cognitive functioning at different levels. Performance-based assessments focus on the underlying information processing mechanisms of cognitive control, at a functional level. Self-reported, reflective assessments relate to goals, beliefs and reflections on action in context. They argue that, only at the reflective level do "issues of optimal decision making come into play" (p. 137). Performance, therefore, is grounded in context and is related to prevailing goals. They argue that performance-based measures, in their assessments of functional efficiency, ignore the role of goals in directing behaviour and cognitive control. Toplak *et al.* (2013) support this assertion in quoting Salthouse *et al.* (2003, p. 569): "the role of executive functioning may also be rather limited in many laboratory tasks because much of the organisation or structure of the tasks is provided by the experimenter and does not need to be discovered or created by the research participant". Finally, the authors note that this distinction is characteristic of the distinction between *typical* performance situations and *optimal* performance situations. As typical performance situations are unconstrained by requirements to maximise performance, evaluations of performance in such situations assess goal prioritisation and the extent to which behaviour requiring cognitive control *typically* corresponds to these goals. The latter, however, are constrained, in that participants are required to maximise performance within the bounds of a given task, irrespective of their personal goals.

Given ongoing psychometric debates surrounding these measures, it is not within the scope of this dissertation to assess their validity as indications of cognitive functioning. What is important, however, are implications for research in this domain. Irrespective of their validity as measures of cognitive control at a functional level, self-report measures capture the extent to which behaviour in context *typically* corresponds to goals. Given the variety of situations in which media multitasking occurs, such measures provide a valuable indication of situated action and reflections on combined everyday executive functioning. More research seeking to understand the differential outcomes extending from these measurement paradigms is required. Of importance is understanding the role of goals in driving media multitasking and the extent to which assessments capture this.

4.3.2.2 Small Sample Sizes

As Wiradhany and Nieuwenstein (2017) note, a key factor characterising studies in this domain is the reliance on small sample sizes. In Ophir *et al.* (2009)'s early study the outcomes of only 30 participants were compared. This trend continued with similarly small samples characterising subsequent studies: 36 in Minear *et al.* (2013), 23 in Alzahabi and Becker (2013), 36 in Uncapher *et al.* (2016), 28 in Murphy *et al.* (2017). Similarly, in studies where the sample size differed across the groups the trend proceeded. For instance, in their second study Wiradhany and Nieuwenstein (2017), considered 14 LMMs and six HMMs. As noted previously, Ralph and Smilek (2017) suggest that, in such studies, effect sizes can be overestimated and spurious. The reliance on small samples, across measurement paradigms, jeopardises the determination of the true relationship between media multitasking and cognitive control. Further research, with larger samples more adequately powered to statistically determine the nature of any relationship is required.

4.3.2.3 The Measurement of Media Multitasking

Studies have used either the MMI, as described by Ophir *et al.* (2009), or modified versions of this index. As discussed in Section 3.1.1 there are a number of shortcomings to the MMI as a measure of media multitasking. Baumgartner *et al.* (2017*a*) note that, as a relative measure, MMI scores cannot be interpreted as representing an absolute amount of simultaneous media use. While the formula accounts for each primary medium's hours of use, this is nullified by dividing the overall score by the total use hours. An MMI score is therefore *the amount of simultaneous media use relative to overall media use.* A shortcoming with this calculation, as noted by Wiradhany and Nieuwenstein (2017, p. 20), is that "a person who spends only 1 hour per day using his laptop while watching television can have the same MMI as a person who does this 16 hours per day". Consider an individual who always multitasks when they use media, but only uses media infrequently, and an individual who extensively uses media, but rarely multitasks. The first individual will receive a higher MMI score than the second, despite a similar amount of multitasking. Arguing that time spent media multitasking may be more important, Moisala *et al.* (2016) produced an index for the absolute time spent media multitasking.

The calculation of the MMI has also been discussed as a shortcoming. Wilmer *et al.* (2017) argue that the matrix-structure, where each primary medium is considered in relation to a number of secondary media, regards all media as equal. The MMI increases by the same amount regardless of the type of media, the attentional demands of a task or combination of tasks. As an example, they note how 'playing video games' and 'listening to music' are regarded as equivalent activities, despite their different cognitive demands. Additionally, they contend that 'playing video games' while 'reading print media' presents a different cognitive demand than 'listening to music' while 'instant messaging'. Such combinations have an equivalent effect on an MMI score. Moreover, an individual who extensively participates in one combination, 'instant messages' while 'browsing' for instance, but not other categories, will receive a low MMI. The MMI does not reflect extensive task-switching resulting from a single, highly performed, activity. As Moisala *et al.* (2016) note, such shortcomings are indicative of the manner in which the MUQ considers media multitasking as specific primary and secondary task combinations. While in some instances this may reflect how media are used, in others it may not. Everyday media multitasking consists of a combination of task-switching, divided attention, and serialised dual-tasking (Moisala *et al.*, 2016).

These shortcomings present in the dominant measure of media multitasking may have affected findings produced on its basis. If the MMI is not a valid representation of media multitasking, in terms of time spent media multitasking or the frequency of task-switching, the validity of findings indicating potential relationships with cognitive control, in any direction, is brought into question. However, despite its flaws, the measure does produce an indication of media multitasking relative to overall media use which, nonetheless is useful for comparative purposes. While alternative measures have been proposed, Baumgartner *et al.* (2017*a*)'s MMI-S or Moisala *et al.* (2016)'s MMT for example, they suffer from many of the same shortcomings as the MMI. Baumgartner *et al.* (2017*a*), for instance, designed the MMI-S to decrease the time taken to collect and classify an individual's media multitasking, not necessarily to produce a more accurate assessment. Only presenting a subset of media combinations implies that the measure is, by definition, an inaccurate reflection of an individual's media multitasking.

4.3.2.4 The Extreme Groups Approach

Extending from the use of the MMI is the adoption of an *extreme-groups* approach to considering possible relationships between media multitasking and cognitive control. The performance of HMMs' has been compared with that of LMMs. Ralph (2017, p. 21) notes, however, that, across studies considering media multitasking, "researchers have consistently found that there is no bimodal distribution of heavy media multitaskers and light media multitaskers" —MMI scores are relatively normally distributed. Ralph (2017, p. 22) contends that "there is no clear reason why one ought to discard data from individuals whose scores fall in the middle portion of the distribution when one could examine the entire distribution". Only three studies, Cardoso-Leite *et al.* (2016), Murphy *et al.* (2017) and Hadlington and Murphy (2018), consider comparisons for those falling between the arbitrary classifications of light and heavy media multitaskers. Other studies have conducted comparisons between the entire sample and various outcome measures (e.g. Baumgartner *et al.*, 2014; Cain *et al.*, 2016). In the extreme-groups approach studies adopted different notions for what constitutes a heavy or a light media multitasker. Some researchers, for instance Ophir *et al.* (2009), Cardoso-Leite *et al.* (2016), or Alzahabi and Becker (2013), took HMMs to have an MMI score one SD or more above the mean and LMMs to be one SD or more below the mean. In contrast, other researchers, for instance Minear *et al.* (2013) or Yap and Lim (2013), divided the sample in half, taking the top 50% of scores to be HMMs and the bottom 50% to be LMMs. Murphy *et al.* (2017) divided their sample into tertiles, with HMMs being those in the top third of the sample.

The extreme groups approach regards all within a particular group as equal in terms of media multitasking. However, as a result of the normal distribution of MMI scores, those within each group —LMM or HMM— display a diversity of scores. Commenting on this characteristic Ralph (2017) notes that in many studies in this domain (e.g. Ophir *et al.*, 2009; Minear *et al.*, 2013; Cardoso-Leite *et al.*, 2016), the range of MMI scores falling between the upper bound of LMM scores and the lower bound of HMM scores is smaller than the range of scores for a particular extreme group. This outcome, resulting from the normal distribution of MMI scores, combined with the small sample sizes typical of research in this domain, implies that the scores for both extreme groups are skewed —higher for HMMs and lower for LMMs. While some studies account for this by eliminating outliers from their comparisons (e.g. Alzahabi and Becker, 2013), a majority of those considered have not. This skewing of scores has implications for the determination of potential relationships with media multitasking, in terms of both direction and magnitude, and thus presents as a possible explanation for the inconsistencies reported.

4.3.3 Conclusion

Since Ophir *et al.* (2009) numerous studies have considered associations between media multitasking and cognitive control. Research in this domain is characterised by inconsistent and divergent findings. Despite this, the emergent trend, while small, is indicative of a negative relationship between increased levels of media multitasking and cognitive control (Uncapher and Wagner, 2018). This position is supported by Uncapher *et al.* (2017, p. 63) in their evaluation of the state of research in this domain, who note that, despite the inconsistencies the "weight of the evidence overall points to HMMs demonstrating reduced performance in a number of cognitive domains relative to LMMs". Given the nature of research in this domain, the existence of any relationship is still entirely correlational. At present there exist two broad conjectures about this relationship. On the one hand underlying individual differences may drive media multitasking, and, these differences, rather than media multitasking, explain diminished performance on assessments of cognitive control. On the other hand, media multitasking may lead to changes in the operation of cognitive control. While both conjectures hold interesting value for future research, empirical evidence is weak, inconsistent and based on small sample sizes, with a number of methodological and conceptual factors hindering progress in this regard. To further understand the nature of associations between media multitasking and cognitive control further research adopting experimental and longitudinal designs is required. Moreover, despite the heterogeneity of outcomes and assessments, further meta-analyses of all assessments, across methodological paradigms, is required. Notwithstanding the methodological and conceptual shortcomings of research in this regard, as Uncapher and Wagner (2018, p. 9890) conclude, overall "the weight of current evidence shows that in some contexts heavier media multitaskers underperform relative to lighter media multitaskers in a number of cognitive domains".

4.4 Summary

This chapter presented an examination of research considering associations between media multitasking and cognitive control. While there are challenges present in research in this domain, and many outcomes are weak and inconsistent, the general pattern of results suggests that media multitasking is associated with a broader distribution of attention and increased processing of irrelevant stimuli. In particular, this relationship is more consistent in self-reports of everyday executive functioning than in performance-based assessments. This distinction is suggestive of strategic level differences when it comes to media multitasking and cognitive control. Moreover, it is indicative of the importance of goals for any consideration of effects associated with media multitasking.

Part II

Media Multitasking and Cognitive Control: A Systematic Review of Interventions

Chapter 5

Systematic Review Methodology

The literature reviewed in Part I of this dissertation indicate that, while there is certainly more research required to elucidate the relationship between media multitasking and cognitive functioning, such behaviour is, for some individuals, associated with a broader distribution of attention, increased processing of irrelevant stimuli, and interference. Given the absence of causal research in this regard, a number of interpretations accounting for such outcomes exist. Whether effects are due to individual differences at either a 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 settings.

In response, researchers have proposed a number of interventions targeting the possible effects associated with high levels of media multitasking. Such responses generally fall into two categories: 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. Examples of such techniques include education, meditation, physical exercise, and cognitive exercise. 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., Thornton *et al.*, 2014; Kushlev *et al.*, 2016), little authoritative work has been completed to substantiate their effectiveness. Consequently, in a presentation outlining key questions facing this domain, Wagner (2015) indicated a need for determining the remedial efficacy of interventions targeting media multitasking. Moreover, he notes that such investigations will, in part, contribute towards addressing the issue of causality between media multitasking and cognitive control. Similarly, in an overview of the state of research in this regard, Uncapher *et al.* (2017) call for studies investigating interventions targeting the effects of media multitasking. Uncapher and Wagner (2018) reiterate these calls in a subsequent review of research concerning the cognitive and neural profiles of media multitaskers.

In this part of the dissertation, to address the first objective of the study, the execution of a systematic review is reported. Systematic reviews have been acknowledged as suitable for considering the effects and nature of behavioural interventions (Littell *et al.*, 2008). Through the systematic assessment of existing interventions a number of important contributions can be made. First, a review enables an evaluation of the state of research concerning such interventions, with regards to techniques employed, quality of evidence, and efficacy. Second, as research in this domain is spread across a number of different fields from *Information Science* to *Psychology*, integrating findings from these fields is a necessary and desirable outcome. Finally, such a review serves to inform the development of a specific intervention targeting media multitasking amongst university students. To summarise, the objectives for this review are to:

- *Determine the nature of behavioural 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 have an effect on outcomes associated with cognitive control.*
- *Identify the factors that are associated with successful intervention implementation.*
- *Identify gaps in research in this regard to provide guidelines for future studies.*
- *Inform the development of an intervention targeting media multitasking amongst university students.*

In this chapter the systematic review methodology is outlined. While the heterogeneity in situational and individual factors surrounding both media multitasking and cognitive control make the provision of a comprehensive theory of change problematic, the first section outlines a number of relevant factors generally considered to underly changes in cognitive control. Subsequently, to delineate the scope of the review, the eligibility criteria are described, followed by the search strategy and the data management and analysis procedures. As a consequence of the heterogeneity of study objectives and eligibility criteria, meta-analysis of the data was not conducted. Rather, a systematic process of narrative synthesis was performed. In Chapter 6 the results of this review are presented.

5.1 Theory of Change

Before relevant interventions can be reviewed it is necessary to outline what Weiss (1998) refers to as the *theory of change*. This involves considering why, at a theoretical level, interventions might be successful. To achieve this the mutability of cognitive control is briefly revisited before evidence from a number of approaches to improving cognitive control is considered. The purpose of this is to provide evidence for what Gazzaley and Rosen (2016) term *reasonable hypotheses* about the underlying mechanisms and efficacy of changing behaviour to enhance cognitive control.

As noted in Chapter 2.2, cognitive control is not fixed, it is mutable. Changes in behaviour can alter the activation patterns of neural networks associated with cognitive control (Dehaene and Cohen, 2007; Dux *et al.*, 2009). This is termed *neuroplasticity*. While the brain is drawn toward homeostasis, coupled with *cognitive reserve* (Stern, 2013), neuroplasticity "allows the nerve cells in the brain to adjust their activities in response to new situations or to changes in the environment" (Taupin, 2006, p. 12). Consequently, neural networks regularly activated as a result of their involvement with frequently performed actions are strengthened, while those rarely used are diminished (Pantev *et al.*, 1998; Maguire *et al.*, 2000).

Building on the notion of neuroplasticity, a theory of neural reorganisation postulates that, through task-specific training, performance on tasks requiring cognitive control can be improved by shifting processing from neural networks involved in cognitive control to task- or process-specific networks (Dux *et al.*, 2009, p. 2). Behaviour becomes more intuitive and less deliberative. As an example of this, training with dual tasks has been shown to reduce the switch costs associated with multitasking (e.g. Van Selst *et al.*, 1999; Dux *et al.*, 2009). While the shifting of processing to more intuitive modes does not indicate improvements in cognitive control, it does indicate that performance in behaviours requiring cognitive control can be improved. A key issue in this regard is the *transfer of learning.* This occurs when training in one domain provides benefits beyond the domain in question (Barnett and Ceci, 2002). Woodworth and Thorndike (1901) postulated that transfer of learning operates as a function of domain commonality —the closer two domains are to each other, the more likely it is that training in one will benefit performance in the other. Since its publication this theory has received much empirical support (e.g. Knecht, 2003; Sala and Gobet, 2016).

While transfer of learning implies limitations to the generalisability of domain-specific training, researchers have argued that training domain-general abilities, cognitive control for instance, can generalise across domains (Taatgen, 2016). Again, this adopts neuroplasticity as a fundamental principle. Training leads to neural network adaptions, which, it is theorised, account for improvements in cognitive control (Karbach and Schubert, 2013). Studies have shown that cognitive control can be improved either through the training of specific cognitive tasks (e.g., n-back tasks; Klingberg, 2010) or through engaging in cognitively demanding tasks (e.g., playing chess; Burgoyne *et al.*, 2016). Similarly, video games, as a form of cognitive training, have also been shown to enhance cognitive control (Anguera *et al.*, 2013). Research in this area, however, is still in its infancy. Kelly *et al.* (2014) note that the impact of cognitive training on everyday cognitive functioning, and the transfer and maintenance of training effects require further investigation. Despite mixed evidence in this regard, results from some studies suggest that improvements in cognitive control are, to some extent, possible.

For multitasking, it has been argued that, just as media multitasking may bias towards a broader distribution of attention, interventions promoting single-tasking and focused attention may counteract such biases (Gorman and Green, 2016; Irwin, 2017). The mechanisms through which such tasks are theorised to impact cognitive control are the same as those theorised to account for the adverse effects associated with frequent media multitasking. The effect is, however, in the opposite direction. Through practice at inhibiting interruptions (self or external), or repeated instances of single-tasking (adopting a narrow focus of attention), the proclivity towards a broader distribution of cognitive control is shifted in favour of a narrower distribution. Studies demonstrate, for example, that mindfulness practices can produce improvements in cognitive control (Jha *et al.*, 2007; Lutz *et al.*, 2008). The theory of change in this instance is multifaceted. First, through practice at inhibiting distractions the ability to sustain attention when confronted with potentially distracting stimuli is improved. Second, through focused attention training, metacognition of self-interruption tendencies is enhanced. Finally, through repeated instances of single-tasking, the proclivity to attend to tasks in succession, rather than concurrently, is strengthened. Examples of such interventions include: increasing metacognition of the effects of media multitasking, reducing the frequency of media-related switches, reducing the amount of media-use, restricting media use to segmented time periods, mindfulness training, or reducing media accessibility (Gazzaley and Rosen, 2016). These interventions avoid the challenge of transfer effects — through repeated practice at single-tasking neural networks associated with distraction inhibition and attention-distribution in relation to media use are specifically targeted.

To conclude, while more work is required, the accumulation of evidence thus far provides a signal that cognitive control can be improved through either targeted or general interventions. While not all interventions targeting cognitive control have been successful, research concerning neuroplasticity, task-performance, and multitasking suggests that improvements can be achieved through changes in behaviour.

5.2 Eligibility Criteria

An initial criterion requiring clarification is the unit of analysis considered in the review. While many adopt reports as their units of analysis, this introduces a bias toward studies which have produced multiple reports. Consequently, in this review the study was used as the unit of analysis. Littell *et al.* (2008, p. 67) define a study as an "investigation that produces one or more reports on a sample that does not overlap with other samples". Extending this, building on the *Cochrane Collaboration guidelines for systematic reviews* (Higgins and Green, 2008), Littell *et al.* (2008) outline a framework for eligibility criteria consisting of four categories: *populations, interventions, comparisons, and outcomes* (PICO). In the following sections criteria for each of these categories are outlined.

5.2.1 Populations

Eligible studies should have considered individuals as their units of analysis. No restrictions in terms of gender, race, socioeconomic status, or location were placed on the participants in these studies. While the current study primarily concerns media multitasking in the context of a student population, it is argued that, through considering studies targeting a broader population, an understanding of the full range of interventions applied can be achieved. Two exclusion criteria were specified. First, studies targeting the elderly, children or those in early adolescence were not eligible for inclusion. Due to ongoing neurodevelopmental changes during childhood and late-adulthood (McAvinue *et al.*, 2012), such studies may produce results valid for one population, but not for others. Second, studies explicitly targeting populations exhibiting neurodevelopmental disorders (e.g., ADHD), attention-related disorders, or those considering populations exhibiting clinical symptoms (e.g., brain injuries associated with executive dysfunction) were excluded from the review. Such populations, it is argued, do not reflect normal brain function and exhibit altered cognitive processes. Consequently, the efficacy of interventions assessed on such populations is not generalisable to nonclinical populations.

5.2.2 Interventions

Eligible studies should have considered *behavioural change* interventions. Such interventions are defined as "coordinated sets of activities designed to change specified behaviour patterns" (Michie *et al.*, 2011, p. 1). In this case, these behavioural patterns relate to media multitasking. While this review considers media multitasking and associated cognitive effects, interventions targeting such outcomes may not have directly targeted media multitasking. Rather, eligible interventions should have either targeted media multitasking, or they should have targeted related behaviours, beliefs, attitudes, or experiences. Alternatively, eligible interventions should have targeted the behaviour of individuals whose level of media multitasking is known. The key aspect characterising eligible interventions is that they aimed to modify behaviour with the intention of affecting outcomes associated with cognitive control. As one of the primary purposes of this review is to identify relevant interventions, the specific techniques, durations, or activities characterising these interventions cannot be specified a priori. Including such a heterogenous set of interventions is appropriate given the objectives of the review. Other forms of intervention, for instance psychiatric or pharmaceutical, were excluded.

5.2.3 Comparisons

Eligible studies should have adopted the following study designs: randomised, quasi-randomised, and non-randomised control trial, within-subjects experiment, post-only, or pre/post assessment. Specifically, the performance of participants in a treatment group must have been compared with that of either a control group or a comparison group that received an alternative treatment. In the case of within-subjects designs, performance under treatment conditions should have been compared with performance under control or normal conditions.

5.2.4 Outcomes

Intervention efficacy should have been assessed by means of relevant measures of cognitive control. Given the prevalence of both standardised performance-based and self-report scales, assessments for either of these two outcome categories were eligible for inclusion. While it is acknowledged that standardised instruments provide a greater degree of validity than non-standardised instruments, Higgins and Green (2006) recommend including all reported outcomes potentially relevant to a problem. Consequently, related non-standardised measures assessing functional or reflective aspects of cognitive control were eligible for inclusion. Such measures include functional assessments of distractibility, performance on tasks requiring focused, sustained or shifted attention, or performance on tasks requiring the combined operation of the executive functions, as well as self-reports or qualitative assessments of attention or performance.

5.2.5 Miscellaneous Criteria

In addition to the aforementioned criteria, three miscellaneous criteria were specified. First, while Higgins and Green (2006) caution against language restrictions, Littell *et al.* (2008) note that the application of language criteria should be based on the available personnel for the review. Consequently, eligible studies must have been reported in either *English* or *Afrikaans*. Second, while some systematic reviews place restrictions on publication type, researchers considering biases in systematic reviews suggest that a review should not adopt publication status as a criterion for inclusion (Rothstein *et al.*, 2006). Therefore, both published and unpublished studies were eligible for inclusion. The latter category refers to what is typically called *grey* literature.[1] The final criterion described the time frame for the study. Given the role of the *World Wide Web* in characterising media, its release to the public in 1991 was one option for a lower bound. Another option was 2006, the year in which the term 'media multitasking' was first used in research literature (by Foehr, 2006). A third option was 2009, the year Ophir

[1] Grey literature refers to literature not produced for commercial publication, not widely distributed, not bibliographically consistent, not peer-reviewed and, typically, difficult to find (Tillett and Newbold, 2006). This category includes unpublished dissertations, abstracts, and technical reports.

et al. conducted the first study considering associations between media multitasking and cognition. Given these options, a compromise was found in adopting the middle option, 2006, as a lower time bound. The date of sample construction (February 2018) was adopted as an upper bound. To summarise, studies were included in this review if they:

1. Considered nonclinical individuals who are not children, adolescents or the elderly.
2. Investigated behavioural change interventions targeting either media multitasking, or related behaviours, beliefs, attitudes, or experiences.
3. Adopted study designs comparing outcomes under treatment conditions to normal conditions, either between subjects or within-subjects.
4. Measured cognitive control outcomes through self report measures, laboratory assessments, or measures of performance relying on executive functioning.
5. Are reported in English or Afrikaans.
6. Are either peer reviewed or, in the case of grey literature, un-reviewed.
7. Were published between January 2006 and February 2018.

5.3 Search Strategy

Having established the eligibility criteria for inclusion in this review a sample of eligible studies was required. A convenience sample is insufficient to provide a representative sample of all eligible studies. Consequently, a systematic strategy for locating eligible studies was developed. In this section this strategy is described, beginning with electronic databases of academic material. Next, the procedure used for selectively 'hand-searching' relevant journals is outlined, followed by a strategy for the acquisition of 'grey' literature. Finally, a reference list search strategy is described. The outcomes of these procedures are reported in Chapter 6 in accordance with the *Preferred Reporting Items for Systematic Reviews and Meta-Analysis* (PRISMA) guidelines (Liberati *et al.*, 2009).

5.3.1 Electronic Database Search Strategy

The first phase in the acquisition of a sample involved the development of a search strategy targeting bibliographic databases. Littell *et al.* (2008) note that, because there is only a partial overlap in the content covered by such databases, multiple databases should be targeted to ensure comprehensive coverage. Consequently, four sources were selected. *PsycINFO* was selected on the basis of its relevance to this review, while *Web of Science* (WoS), *Scopus*, and *Academic Search Premier* (ASP) were selected based on the breadth of material they cover. While there is a substantial overlap in coverage between WoS and Scopus, differences exist with regards to both the nature and depth of content covered. Moreover, there are gaps in their combined coverage. Consequently, a third multidisciplinary database was necessary. On the basis of the relevance of its coverage ASP was selected for this purpose. While two-thirds of the content covered by ASP appears in either WoS or Scopus, a third (over 1 000 journals) appear in ASP only. Finally, in addition to these multidisciplinary databases, a fourth, specifically targeting psychological studies, was required. PsycINFO provides access to over 4 million records within the psychological sciences (American Psychological Association, 2017). In targeting these four bibliographic databases it is argued that, in the aid of developing a representative sample, an adequate degree of coverage was achieved.

These databases may be queried through the provision of search strings consisting of keywords and Boolean operators. In this study a generic search string was created, which, dependent on the requirements of each database, was adjusted as necessary. This string consisted of four clauses each containing terms, separated by the OR operator, related to a particular PICO category. The search was then narrowed by combining these categories with the AND operator. This design implies that, for a result to be returned, it must have contained at least one term from each category. The first category covered the concept media and related synonyms, the second related to behaviour, including synonyms for the word 'multitasking', the third covered concepts relating to cognitive outcomes, and the fourth referred to interventions and changes in these outcomes. Additionally, the search was constrained to the target time period, languages and applied only to the title and abstract fields. The full search strings are available in Appendix A.

5.3.2 Targeted Journal Search Strategy

The second method through which studies were acquired involved 'hand-searching' selected sources for eligible studies. Upon considering the publication location of the studies reviewed in Chapter 4, three journals were selected for this purpose: *Computers in Human Behavior*, *Journal of Experimental Psychology: Human Perception and Performance*, and *Attention, Perception, & Psychophysics*. In addition to selection based on the relevance of their coverage, these three were selected because, unlike other possibilities, they publish studies adopting experimental and intervention-based designs. Of the three selected only Computers in Human Behavior specifically focuses on behaviour in relation to technological artefacts. The other two cover research broadly concerning attention, cognitive control, and performance. They do, however, cover studies considering these factors in relation to media-use. It is argued, therefore, that through targeting these journals, the likelihood of missing potentially relevant material was reduced.

5.3.3 Grey Literature Search Strategy

The third phase involved locating grey literature. As noted previously, grey literature refers to literature not produced for commercial publication, not widely distributed, not peer-reviewed and, typically, difficult to find (Tillett and Newbold, 2006). Theses, dissertations, and non-indexed conference proceedings are common examples of such literature. As this category is especially broad, in line with Littell *et al.* (2008)'s prescriptions, two collections were searched: *ProQuest Dissertations & Theses Global* and the *Association for Information Systems (AIS) Electronic Library conference database*. The first contains over 2.4 million records and indexes dissertations and theses from universities in North America, Europe and Asia. The latter was selected because it indexes conference proceedings for the major global IS conferences. Three other organisations were considered, the *American Psychological Association*, the *British Psychological Society*, and the *International Communication Association*. Repositories produced by these organisations are, however, indexed by the electronic databases considered in the review.

5.3.4 Reference List Search Strategy

The final phase involved a process of 'reference harvesting'. Webster and Watson (2002) suggest that this should involve both forward and backward searches from the sources already located. Backward searching involves identifying the reports cited in a body of work already in possession, whereas forward searching involves identifying reports which cite those in this corpus. Once the outputs of the first three phases had been screened for eligibility, those remaining were considered for this purpose. For each of these reports a search of their reference lists was conducted, along with a search for articles in which they are cited using the *Google Scholar* search engine.

5.4 Data Extraction and Management Procedures

The results of the electronic database searches (bibliographic information and abstracts) were downloaded into reference management software (Zotero). This corpus was then supplemented with the outputs of the remaining search procedures. Following this, any duplicates were removed. Next, the sample of studies was screened against the eligibility criteria for inclusion in the review. First, the titles and abstracts of all reports were considered and, following this, the full-texts were assessed for eligibility. If ambiguities remained about the eligibility of a study, input was sought from an external reviewer within the same academic department. If agreement could not be reached, a third reviewer from a different department was consulted. The specific details and outputs of these procedures are presented in Chapter 6. Two categories of data were extracted from studies. First, for efficacy, details of the intervention, the participants, the outcomes, and the study design were extracted. Second, for implementation, further details of the intervention, the context in which it was introduced and the factors identified as impacting implementation were extracted. As with study selection, one reviewer extracted the data and, where necessary, input from an external reviewer was sought. The form used to guide the extraction of relevant data is available in Appendix B.

5.5 Data Analysis Procedures

Given the heterogeneity of study objectives, interventions, comparisons, and outcomes considered in this review, meta-analysis was not conducted. A narrative synthesis methodology was adopted. As a means of analysing the outputs of systematic search procedures, this method refers to a process where a textual approach to synthesis is adopted. Popay *et al.* (2006, p. 5) note that such a method is particularly well suited to reviews where implementation details and effectiveness are areas of concern. In view of the objectives of the review, the purpose of this analysis was to determine the nature, efficacy, and implementation details of the interventions assessed. In accordance with Popay *et al.* (2006), during preliminary analysis, the extracted data were categorised on the basis of the nature of the intervention to facilitate detailed analysis of implementation patterns and intervention designs. For this purpose the *behaviour change wheel* (BCW) proposed by Michie *et al.* (2011) was adopted. Within this framework seven categories of policies, nine intervention functions, and six sources of behaviour are described. Definitions for the policy categories and intervention functions are provided in Table 5.1 (the sources of

Table 5.1: Behaviour change wheel intervention function and policy category definitions

Interventions	Definition
Education	Increasing knowledge or understanding
Persuasion	Using communication to stimulate action
Incentivisation	Creating expectation of reward
Coercion	Creating expectation of punishment or cost
Training	Imparting skills
Restriction	Rules to reduce the opportunity to engage in the target behaviour
Environmental restructuring	Changing the physical or social content
Modelling	Providing an example for people to aspire to or imitate
Enablement	Increasing means/reducing barriers to increase capability or opportunity
Policies	Definition
Communication	Using print, electronic, telephonic or broadcast media
Guidelines	Creating documents that recommend or mandate practice
Fiscal	Using the tax system to reduce or increase the financial cost
Regulation	Establishing rules or principles of behaviour
Legislation	Making or changing laws
Environmental/social planning	Designing and/or controlling physical or social environments
Service provision	Delivering a service

behaviour were described in Section 2.4). Next, analysis focused on considering patterns in the implementation processes reported. For intervention efficacy analysis concerned outcomes for both behaviour and cognitive control. Following this, the analysis focused on individual differences identified in the primary studies as well as the identification of factors impacting intervention implementation. Finally, the methodological quality of the primary studies included in the sample was appraised.

5.6 Summary

This chapter began by considering calls for research into interventions addressing potential effects of media multitasking. On the back of these calls, to address the first research objective of this study, a systematic review was adopted as a method for evaluating such research. In this chapter the methodology for the review was outlined, commencing with a theory of change and the inclusion criteria. Next, the strategy for acquiring a sample of studies was described, followed by the procedures for extracting and managing the data. Finally, this methodological description concluded with an explanation of the data analysis procedures. The next chapter presents the outcomes of the systematic review.

Chapter 6

Review Findings and Conclusions

In this chapter the findings of the systematic review are presented. This begins with an overview of the search results and sample. Next, the narrative synthesis is presented in six sections. First, a categorisation of the interventions is provided, followed by an examination of patterns in intervention implementation and a consideration of intervention efficacy. Next, analysis of individual differences is described, followed by a consideration of factors impacting intervention implementation, and an appraisal of methodological quality. The chapter concludes with a discussion of these findings.

6.1 Search Results

The search produced 2792 results (PsychINFO $n = 205$, WoS $n = 889$, Scopus $n = 1411$, ASP $n = 266$, and 21 from other sources). After duplicates ($n = 597$) were discarded the titles and abstracts of the remaining results ($n = 2195$) were screened. Upon excluding ineligible records ($n = 2166$) the full-texts of the remaining reports ($n = 29$) were considered. This process was conducted in consultation with an external reviewer. Ineligible records ($n = 19$) were excluded on the basis of the PICO criteria. Appendix C provides bibliographic details for these records along with reasons for exclusion. These screening procedures produced a sample ($n = 10$) upon which forward and backward searches were applied. The final sample, supplemented by the outcomes of these searches ($n = 2$), was then established ($n = 12$). Figure 6.1 summarises this process.

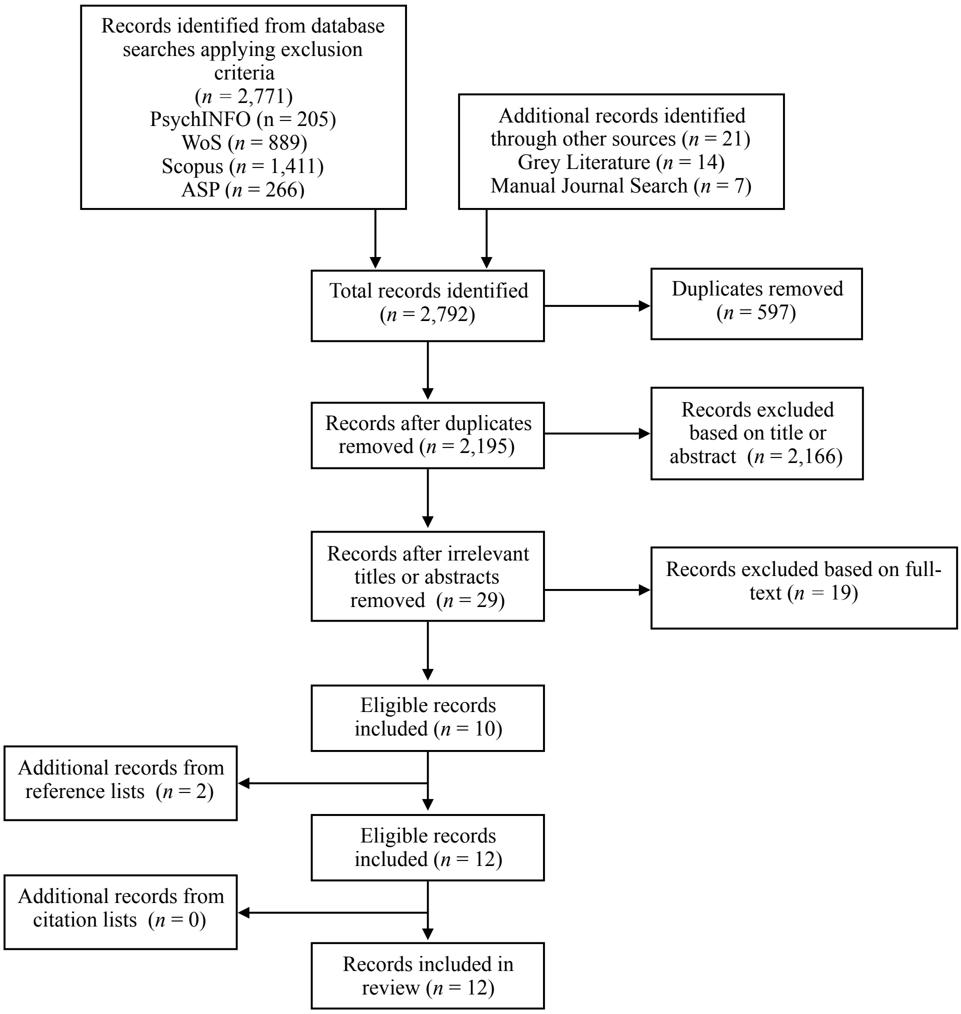

Figure 6.1: A PRISMA flowchart for study inclusion

6.2 Included Studies

From the 12 records identified, 15 studies were included in the review. Hartanto and Yang (2016), Whittaker *et al.* (2016), and Yildirim (2017) each reported two studies in their reports. The bibliographic details for the sample are available in Appendix C. Each study is identified by a unique ID (ST-x). Seven of these studies are published in peer-reviewed conference proceedings, five are published in peer-reviewed journal articles, and three appear in PhD theses. While studies conducted between the beginning of 2006 and February 2018 were eligible for inclusion, the first report included was published in 2012. As shown in Figure 6.2, a majority of studies included were published in 2016, while four were published in 2017 and, at the time of review, none were published in 2018.

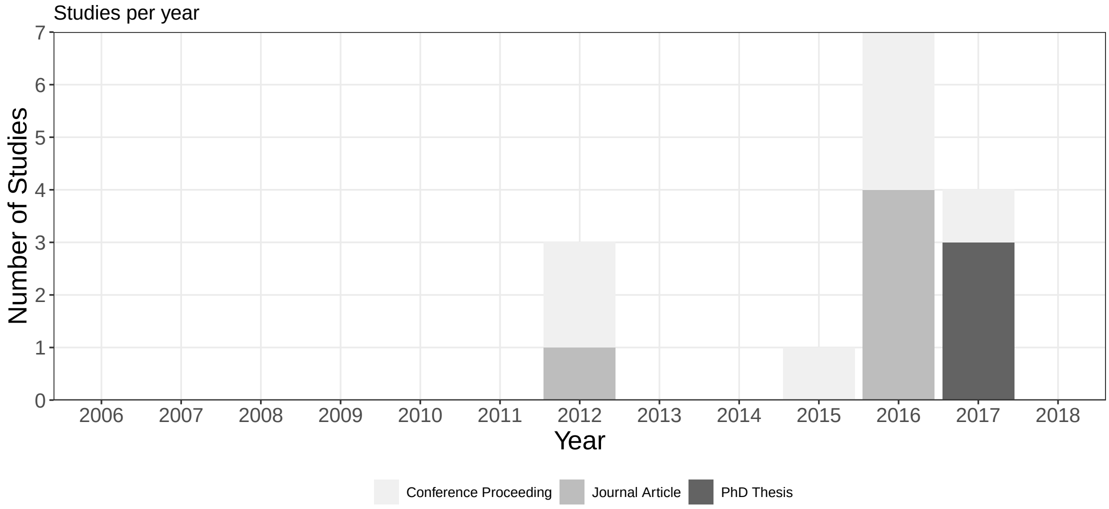

Figure 6.2: Studies included in the systematic review for each year considered.

Table 6.1 presents a summary of the sample providing the ID, reference, type, study design, and an overview of the sample considered.[1] Across the sample two study designs were adopted —between-subjects (eight studies) and within-subjects (seven studies). 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 *et al.*, 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). In contrast, Levy *et al.* (2012, ST-8) considered workers employed in human-resources 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 of these studies involved participants who worked in an office environment in the United States (Mark *et al.*, 2012, 2017; Pielot and Rello, 2016, ST-9, ST-10, ST-11). Finally, 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 considered a sample

[1]Many of these reports provide information on other studies or other samples. Only the information pertaining to the study in question is presented in this table.

Table 6.1: Summary of studies included in the review

ID	Reference	Type	Study Design	Sample
ST-1	Adler *et al.* (2015)	CP	Between-subjects	66 students (US; 30 F, 36 M)
ST-2	Gorman and Green (2016)	JA	Within-subjects	42 students (US; 29 F, 13 M)
ST-3	Hartanto and Yang (2016)	JA	Between-subjects	86 students (SG)[a]
ST-4	Hartanto and Yang (2016)	JA	Between-subjects	66 students (SG; 38 F, 32 M)
ST-5	Irwin (2017)	T	Between-subjects	38 students (US; 29 F, 9 M)
ST-6	Jeuris and Bardram (2016)	JA	Within-subjects	16 computer users (DK; 4 F, 12 M)
ST-7	Ie *et al.* (2012)	JA	Between-subjects	75 computer users (US; 45 F, 30 M)
ST-8	Levy *et al.* (2012)	CP	Between-subjects	39 human resources workers (US; 39 F)
ST-9	Mark *et al.* (2012)	CP	Within-subjects	13 information workers (US; 6 F, 7 M)
ST-10	Mark *et al.* (2017)	CP	Within-subjects	31 information workers (US; 14 F, 17 M)
ST-11	Pielot and Rello (2016)	CP	Within-subjects	30 white-collar workers (US; 14 F, 16 M)
ST-12	Whittaker *et al.* (2016)	CP	Within-subjects	17 office workers (5 F, 12 M)[b] & 44 students (32 F, 12 M)[b]
ST-13	Whittaker *et al.* (2016)	CP	Within-subjects	57 students (39 F, 18 M)[b]
ST-14	Yildirim (2017)	T	Between-subjects	177 students (US; 95 F, 82 M)
ST-15	Yildirim (2017)	T	Between-subjects	44 students (US; 44 F, 6 M)

Note. Type: CP = conference proceedings, JA = journal article, and T = PhD thesis. Sample: US = United States of America, SG = Singapore, DK = Denmark. Gender: F = Female, M = Male.
[a] The authors do not supply information on the gender make up of this sample.
[b] The authors do not specify the country for this 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. No study has involved a sample of participants from a developing country. Finally, across the 15 studies, the mean sample size is 56.07 ($SD = 39.49$).

6.3 Data Analysis and Synthesis

The outcomes of the three-stage synthesis procedure are presented in six sections. First, studies are categorised based on intervention type. Second, patterns in the implementation and assessment procedures are considered. Next, the efficacy of the interventions in terms of both behaviour change and cognitive outcomes is described. Thereafter, analysis concerns individual differences present in the outcomes, followed by a consideration of factors affecting the implementation of the interventions. Finally, the last section concerns an assessment of the quality of evidence presented in the studies.

Table 6.2: Summary of Intervention descriptions, categories and durations

ID	Intervention	Category	BCW[c]	Duration[a]
ST-1	Pop-up reminders to stay on task	Awareness	Persuasion	Brief
ST-2	Mindfulness exercises	Mindfulness	Training	Brief
ST-3	Smartphone separation	Restriction	Restriction	Brief
ST-4	Smartphone separation	Restriction	Restriction	Brief
ST-5	Media diet	Restriction	Restriction[b]	Long-term
ST-6	Virtual workspaces for each task	Restriction	Restriction	Brief
ST-7	Mindfulness exercises	Mindfulness	Training	Brief
ST-8	Mindfulness training	Mindfulness	Training	Long-term
ST-9	All email blocked	Restriction	Restriction	Short-term
ST-10	Blocking of off-task websites	Restriction	Restriction	Long-term
ST-11	Smartphone separation	Restriction	Restriction	Short-term
ST-12	Awareness of recent media activity	Awareness	Education	Short-term
ST-13	Awareness of recent media activity	Awareness	Education	Short-term
ST-14	Mindfulness exercises	Mindfulness	Training	Brief
ST-15	Mindfulness exercises	Mindfulness	Training	Brief

[a] For duration an intervention was classified as brief if it took place in a single session, typically less than an hour. Short-term refers to interventions taking place during a single week, and long-term 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 and education as secondary components.
[c] Behaviour change wheel function as described by Michie *et al.* (2011).

6.3.1 Categorisation of Interventions

After considering the 15 interventions three categories —*awareness* (three studies), *restriction* (seven studies), and *mindfulness* (five studies)— were produced. Additionally, the function of each intervention was classed according to the BCW framework and its duration. Table 6.2 presents a summary of these categorisations. To follow, a description of the interventions within each intervention category is provided.

6.3.1.1 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 off-task media use (Adler *et al.*, 2015). Operating on the motivation aspect of the COM-B model, these reminders aimed to reduce motivations to switch and increase motivations to remain on task. Whittaker *et al.* (2016) assessed two awareness interventions exemplifying the education function. In ST-12 an application tracked and constantly displayed participants' computer-based activity across different applications for a period of two days. In ST-13, in addition to automatic tracking, a subset of participants used a diary to log their activity for set intervals throughout the 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 increase metacognition of media multitasking and, as a consequence, alter the frequency of this behaviour and bring about changes in focus.

6.3.1.2 Restriction Interventions

Seven studies considered interventions in which access to media was restricted either through separation from a device or through the blocking 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 media was intended to reduce media multitasking behaviour and increase instances of single-tasking with media. Restriction interventions target the opportunity construct of the COM-B model. In this instance, the physical opportunities to engage in media multitasking were restricted.

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 all 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'. Through a structured procedure participants created specific plans for restricting their media use. These plans involved, firstly, a target of reducing use by at least one hour per day and, secondly, a series of 'if-then' statements guiding behaviour with media. Additionally, the intervention incorporated an awareness aspect, with participants tracking their media use three times a day. As an alternate treatment half of the participants ($n = 19$) tracked their behaviour, without restricting it. Acknowledging that the intervention did not explicitly target media multitasking, Irwin (2017) proposes that such behaviour would, however, have been affected by the intervention. This is confirmed by media multitasking data collected during the study.

6.3.1.3 Mindfulness Interventions

Mindfulness has variously been understood as a mental state, a trait, and a practice (Brown *et al.*, 2007). Creswell (2017, p. 495) describes mindfulness as a process of "openly attending, with awareness, to one's present moment experience". Mindfulness interventions, accordingly, aim to cultivate greater attention to and awareness of one's current state, empowering an individual to enact greater control over their actions (Langer, 1989). Such interventions function through the training construct of the BCW framework. Mindfulness practices strengthen psychological capabilities to abstain from multitasking, support the development of automatic motivation to engage in focused media use and, when faced with opportunities (physical or social), enable individuals to consider their actions in light of their goals. Five studies in this review applied mindfulness practices to media multitasking. Four considered brief interventions involving short mindfulness exercises and one assessed a long-term intervention in which participants received training in mindfulness practices. A 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. In three of these studies individuals were selected on the basis of their media multitasking tendencies (e.g. Gorman and Green, 2016; Yildirim, 2017, ST-2, ST-14, ST-15). While Levy *et al.* (2012) and Ie *et al.* (2012) did not consider media multitasking tendencies, their interventions considered performance associated with media multitasking situations.

Ie *et al.* (2012) assessed two brief mindfulness interventions (low and high mindfulness exercises). For both, participants engaged with a series of text-based exercises for a 20-minute period. The low mindfulness exercises targeted the development of focus, whereas the high mindfulness exercises targeted increasing mindful flexibility. Both Gorman and Green (2016) and Yildirim (2017, ST-14, ST-15) employed brief mindfulness 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 with an instructor for a period of eight weeks. Additionally, participants were provided with exercises to practice in their own time. The training primarily concerned fostering a greater ability to voluntarily focus attention, as well as the ability to endogenously shift attention when required.

6.3.2 Patterns in Implementation Processes

Before considering intervention efficacy it is necessary to briefly consider patterns in their implementation. These patterns relate to intervention duration, pre-screening procedures, media multitasking measurement, assessment timing, and follow-up procedures. Of the 15 interventions considered eight (one awareness, four mindfulness, three restriction) were classified as brief having taken place during a single experimental session, four (two awareness, two restriction) were classified as short-term having taken place during a single week, and three (two restriction, one mindfulness) were classified as long-term having occurred over a period longer than a week. Only two studies made use of pre-screening methodologies. Irwin (2017) administered a survey consisting of eight different instruments (assessing aspects of executive functioning and behaviour with media) to a sample of students ($n = 313$). Students were eligible to participate if they reported at least one hour of habitual media use in a typical day. Gorman and Green (2016) administered the MUQ to a large sample of students ($n = 1683$). Only those considered to be LMMs or HMMs were selected to participate in the experimental procedures. While not used for pre-screening purposes, three other studies used the standard MUQ (e.g., Ie *et al.*, 2012; Yildirim, 2017, ST-7, ST-14, ST-15). Five of the 15 studies adopted designs in which both baseline and post-intervention measures were gathered. The rest only considered post-intervention measures. Only two studies conducted any form of post-study follow-up. Irwin (2017) required participants to complete the pre-screening survey a week after the final study measures, and Pielot and Rello (2016) contacted participants two years after the intervention to inquire about long-term behavioural changes.

6.3.3 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. It is necessary to acknowledge that, for some studies, the primary outcome concerned changes in behaviour. In such studies outcomes relating to cognitive control were secondary. In other studies primary outcomes concerned mitigating possible effects of media use or bringing about changes in cognitive control or related performance. Given the differences in outcomes reported and measures employed, 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 (Equation 6.1; Cohen, 1988).

$$d = \frac{M_1 - M_2}{\sqrt{\frac{(n_1-1)SD_1^2+(n_2-1)SD_2^2}{n_1+n_2-2}}} \tag{6.1}$$

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 (Equation 6.2; Lakens, 2013).

$$d = \frac{M_1 - M_2}{\frac{SD_1+SD_2}{2}} \tag{6.2}$$

Where possible the SMD was calculated from reported sample sizes, means and SDs. If these were not reported, F-statistics or t-statistics 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 SDs. 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 the measurement scales used. To follow, for each intervention category, efficacy in terms of behaviour changes and cognitive outcomes is considered.

6.3.3.1 Awareness Interventions

All three studies assessing awareness interventions considered behavioural and cognitive outcomes. While media use was measured through automatic tracking, outcomes related to cognitive control (e.g., focus-based performance, focused attention and multitasking ability) were assessed through custom measures, quizzes or interviews. A summary of the outcomes considered, measures used, and effect sizes found is presented in Table 6.3.

Adler *et al.* (2015) found that reminders to return to a primary task did not reduce switches between browser tabs. Rather, they found the opposite —the number of switches

Table 6.3: Outcomes, measures and effect sizes for awareness interventions

ID	Outcome	Measure	Effect Size[a] [95% CI]
ST-1	Performance	Multiple choice quiz	*ns*
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	*ns*
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, and attitudes were considered.
[c] It was not possible to calculate the effect size based on the provided information.

was higher for the reminder group ($M = 13.43$) than for the control group ($M = 6.61$).[2] Despite this, their 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 (ST-12) suggests that increasing metacognition of media multitasking is associated with behaviour changes. In ST-12 Whittaker *et al.* (2016) found that their sample used 12.18 applications per 30-minute interval. They argued, therefore, that this behaviour could be characterised as multitasking. For behaviour change, awareness of application usage reduced use across all applications by 28%, an effect size of $d = 0.59$. Specifically, awareness reduced time spent browsing by 21%, using social media by 44%, and email by 30%. The change in use-time for work-related applications (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. Awareness of media multitasking served to clarify goals, motivating participants to remain on-task.

In ST-13 Whittaker *et al.* (2016) replicated the behaviour-change results, finding that awareness reduced the total time spent using all media ($d = 0.37$). Again, awareness reduced social media use ($d = 0.76$) and email ($d = 0.77$), while not reducing use of applications associated with productivity. For cognitive control, awareness of media use negatively affected participants' personal strategies for remaining on task, had no effect on time-on-task, but positively affected perceptions of multitasking abilities. Following the intervention participants completed an open-ended survey on their experience. Participants in both conditions reported that an awareness of their media use supported

[2] The authors did not report the standard deviations for these means.

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 on a computer. Whether such results hold across other media is at this stage unknown. These findings indicate that improving metacognition of media multitasking can empower individuals to regulate their behaviour and enable them to 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.

6.3.3.2 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 behaviour were assessed through automatic and manual procedures. Mark *et al.* (2017) used software to track participants' behaviour on their computers, while Pielot and Rello (2016) conducted semi-structured interviews, and Irwin (2017) considered post-experiment estimates, experience-sampling data, and pre- and post-measures of media multitasking. For cognitive control outcomes 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 6.4.

Table 6.4: 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	*ns*
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	*ns*
ST-5	Attention	ANT - alerting	*ns*
ST-5	Attention	ANT - orienting	*ns*
ST-5	Self-Control	BSCS	*ns*
ST-5	Attention	ARCES	*ns*
ST-6	Task Productivity	Computer-based task-related	ns
ST-6	Task Accuracy	Computer-based task-related	ns
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). Insufficient data was provided in the original source to calculate confidence intervals.

In the first of the three studies reporting on behaviour change outcomes Mark *et al.* (2012) found that, when email was restricted, the 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 time allocated to each window when email was restricted ($d = -1.51$) and decreased the frequency of switches between windows ($d = 1.85$). 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 than when they were not. The effect size of this change, however, was low ($d = 0.31$). Despite this, reports of turning on a device to check for missed notifications increased when notifications were restricted. Again, the effect size was low ($d = 0.37$). While these two findings are seemingly contradictory, the effect sizes suggest low practical significance.

Irwin (2017) evaluated participants' media use through a number of measures. First, from post-intervention estimates it was shown that, on a scale from zero (not at all) to ten (completely) for success at restricting media, the mean score for the media diet condition was 7.11 ($SD = 1.59$). 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 during the intervention. For media multitasking, while there was no effect of condition, the effect of time was large ($d = 1.40$). This implies that participants in both conditions reported reductions in their media multitasking. Without the presence of a control group it is difficult to determine 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 relevant outcomes 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).

For performance-based outcomes Jeuris and Bardram (2016) found no 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). 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 an effect of condition for both RT and accuracy ($d = -0.54$ and $d = 0.58$). Irwin (2017) used the attention network test, a measure that isolates alerting, orienting and executive attention functions to assess cognitive outcomes. For both conditions there was no 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 study period. 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 an effect of time, with performance for both conditions improving following the intervention. In particular, RTs 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 through two self-report scales, finding no effect on self-control. 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 immersion[3] ($d = 0.51$) 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.* (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, participants felt that they could remain 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 using 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. For media multitasking, where measured, restricting media use was associated with decreases in switches recorded and media multitasking tendencies. To further understand this relationship more research is required. Emphasis should be placed on understanding failures to change behaviour.

For cognitive control, for self-report measures, four of the six outcomes indicate improvements in attention, focus, or productivity, while two indicate no change as a result of restriction. For performance-based outcomes the findings are more nuanced. While four indicate that restriction impaired executive functioning, the intervention in this case was conducted over a single 20-minute session in a lab-based setting. In contrast, the re-

[3]Focused 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).

maining studies were conducted in the course of participants' everyday activities. While this contributed to ecological validity, 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. 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 (qualitative or quantitative) 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 may affect attentional strategies.

6.3.3.3 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 duration (eight 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, and 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 custom tasks). A summary of the outcomes considered, measures used, and effect sizes produced is presented in Table 6.5.

For the brief mindfulness exercises, with the exception of mind wandering, all outcomes were assessed by means of performance-based measures. Through a custom measure Ie

Table 6.5: Outcomes, measures and effect sizes for mindfulness interventions

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

et al. (2012) found no effect of mindfulness on multitasking performance. In contrast, Gorman and Green (2016) assessed efficacy through six standard measures of cognitive control. No effect was found for cognitive flexibility or inhibitory control as measured by the filter task, the task switching task and the Flanker task. While the specific outcomes for the three remaining assessments were not reported, Gorman 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 effect of a 10-minute mindfulness intervention on mind wandering, working memory, or test performance. In a follow-up Yildirim (2017, ST-15) again found no effect on mind wandering or sustained attention. 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 used a custom, quasi-naturalistic test in which a number of typical computer-related tasks were performed under conditions of distraction. No effect on test completion time or time per activity was found. While there was no effect for completion time, a 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, as with the other intervention categories, relationships between mindfulness interventions and cognitive control outcomes are inconclusive. With the exception of Gorman and Green (2016), brief mindfulness interventions have 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 if this extends to behaviour outside of laboratory conditions, and if this affects cognitive control.

6.3.4 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. With five studies explicitly measuring media multitasking, it was the primary factor considered across the sample. Other factors include gender, anxiety, polychronicity and participant type. Despite the commonalities in study designs and intervention types considered, no clear pattern in analyses or effects is evident in the sample.

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 *et al.*'s MMI-S (Irwin, 2017, ST-5). Gorman and Green (2016) found a moderating effect of media multitasking on intervention efficacy for attention-related outcomes ($d = 0.66$) but not for WM 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 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 moderating effect of media multitasking on intervention efficacy. In ST-15 and ST-5, while media multitasking was assessed, moderation analyses were not conducted.

In addition to media multitasking a number of other factors were considered. Adler *et al.* (2015), for instance, found that gender influenced the effect of awareness. While females performed 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 *et al.*, 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 that of students. Despite this, no performance difference was found. Across the remainder of the sample no other relevant individual differences were reported.

6.3.5 Factors Impacting Implementation

Across the categories a number of factors facilitating implementation were identified. First, only two studies conducted any form of pre-screening for participation. Irwin (2017), for instance, specifically targeted participants who indicated an availability to participate in the study. While such measures introduce a degree of selection bias, it can be argued that targeting participants motivated to participate facilitated implementation. In all three long-term interventions recruitment focused on availability and willingness to participate in the intervention procedures. Another factor facilitating implementation was participants' familiarity with the intervention procedures. Irwin (2017) conducted a series of training sessions focusing on the tracking and reporting procedures. While not training participants, a number of studies targeted participants familiar with aspects of the intervention procedures (e.g., Jeuris and Bardram, 2016; Pielot and Rello, 2016). A third facilitating factor was the use of personalisation in intervention implementation. Mark *et al.* (2017) required participants to augment a starter list of websites with sites they frequently interrupted themselves with. Similarly, Irwin (2017) asked participants to develop personal implementation plans. In both cases, personalisation enhanced the relevance of the intervention to the participants. Finally, the implementation of interventions *in situ* constitutes a fourth factor in this regard. Such designs enabled participants to engage in the intervention procedures in the course of their everyday lives.

While the use of *in situ* methods can be regarded as a factor facilitating successful implementation, it can, however, also be regarded as a hindrance to implementation. A number of studies reported issues controlling for factors outside of the experimental conditions. In particular, the nature of work engaged in, adherence to the intervention, and the degree to which behaviour could be changed were all reported as factors hindering implementation. A second hindrance related to the instruments of the intervention. A number of the interventions relied on various software applications or tools. While some experienced no issues, in other cases implementation was hindered by technical failures (e.g. Adler *et al.*, 2015; Whittaker *et al.*, 2016). Another factor hindering implementation was participant non-compliance (Hartanto and Yang, 2016; Gorman and Green, 2016). In some cases participants were not prepared to perform the required tasks, whereas in others, while prepared, they did not have the necessary media with them. A major hindrance reported across a number of studies was the impact of the intervention on participants' everyday lives. In such cases, potential participants were either reticent to participate or their participation was curtailed. While the targeted outcomes were, arguably, positive, the changes in behaviour required of participants may have contributed to difficulties in recruitment and heightened attrition rates. Across the sample two key dimensions—timing and effort— characterise this factor. Irwin (2017, p. 59), for instance, reports that nine participants withdrew from the study after indicating that participation would be "too burdensome". In some studies, sample construction was affected by the duration of the study. Levy *et al.* (2012), for instance, selected participants based on their availability for the training sessions. Similarly, both Jeuris and Bardram (2016) and Pielot and Rello (2016) were required to change the timing and location of the intervention.

6.3.6 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 quality assessment tools each of the 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. NHLBI-1 assesses bias using 14 criteria, while NHLBI-2 uses 12 criteria. These criteria are available in Appendix D. While studies were rated for each criterion, the purpose is not to produce an evaluation through the tallying of scores. Rather, these tools are designed to guide the assessment of quality through a systematic evaluation process. Following assessment, studies are 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

Table 6.6: 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'.

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 6.6.

Of the 15 studies assessed, four were rated as poor, five as fair, and six as good. 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 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 with no control or comparison groups. While such designs can control for high variances between groups before assessment, internal validity is threatened due to external confounding variables (especially for *in situ* experiments), and time-related factors such as testing effects, order effects or statistical regression (Shadish *et al.*, 2005). Moreover, as indicated, studies failing to assess key outcomes before the implementation of an intervention were limited to a maximum rating of fair. No study assessing an awareness intervention received a good rating, while three studies assessing mindfulness or restriction interventions received good ratings.

While study designs and implementation 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 and 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. It is acknowledged that, given the nature of the behavioural interventions employed, it would not necessarily 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 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. 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.

6.4 Conclusions

Despite the importance of attention management in the face of increasingly mediated personal, social and work environments, there is 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. Building on recent calls (e.g., Wagner, 2015; Uncapher *et al.*, 2017), to address the first research objective of this study, this systematic review aimed to consider the current body of evidence and, on this basis, determine, firstly, the nature of interventions employed, secondly, the efficacy of these interventions in terms of both behaviour change and changes in outcomes related to cognitive control and, finally, to identify the factors affecting implementation.

The systematic search identified 12 studies assessing 15 distinct interventions in three categories —restriction, awareness, and mindfulness. Of the methods proposed by Gazzaley and Rosen (2016) only increasing metacognition, limiting the accessibility of media and abstinence from media use have been employed. The other suggestions —decreasing boredom and reducing media-related anxiety— have not been assessed. In general, while interventions have targeted accessibility, psychological capabilities, metacognition, and media affordances, the role of individual needs or situations has been ignored in intervention development. Only a single study (e.g., Irwin, 2017) explicitly considered individual intentions for behaviour with media. As suggested in Section 5.1, 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. Additionally, 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 sustainability of any interventions in this regard is unknown.

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. In self-regulation theory (see 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. Restriction of media use or restriction of particular activities decreased recorded switches between media and led to perceptions of decreases in 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 affected such outcomes and others did not. Importantly, 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. When considering these differences, it is necessary to acknowledge possible biases present in such measures (Lilienfeld *et al.*, 2014). Additionally, as discussed previously, there is a difference in level of assessment between these two measurement approaches. Toplak *et al.* (2013) explains that self-report measures consider cognitive functioning at a reflective level, whereas performance-based measures concern functional or efficient operation. While both provide useful accounts of cognitive functioning, they hold different implications for relationships found on their basis. At a functional level, performance-based measures provide an indication of the efficiency with which information processing mechanisms operate. Such cognitive mechanisms are central to behavioural control and optimal performance. A key difference between these approaches is the importance of goals. While performance-based measures neglect the influence of rational goal pursuit on performance, reflective measures concern beliefs about action in context and the extent to which an individual perceives their behaviour to correspond to their goals (Stanovich, 2011; Toplak *et al.*, 2013).

At a functional level, in terms of information-processing efficiency, 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 affect perceptions of distractibility, focus, control over action, and performance. Of course, this implies that, in terms of the efficiency with which cognitive control mechanisms operate, these interventions are not effective. Behaviour and performance, *in-situ*, however, rely on more than simply the efficiency of cognitive control. Action and performance, whether reasoned or habitual, relate to goals and intentions. Consequently, it is argued that, rather than affecting the functional efficiency of information processing mechanisms, the primary effect of these interventions is a strategic one. These interventions 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.

This assessment corresponds to the 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 may promote 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 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 note, however, that, just as Ralph (2017) suggests, differences between HMMs and LMMs in terms of self-report measures of everyday executive functioning are not necessarily representative of media multitasking-related effects. Rather, such effects are indicative of different approaches to behaviour in the course of everyday life. Similarly, with regards to interventions, self-reports of improved performance and focus are indicative of changes in behavioural and attention-related strategies and not necessarily changes in cognitive control. Despite this, as Ralph (2017) notes, it is typically difficult to separate ability and strategy choices. It can be argued, however, that the outcomes of this review indicate, to a limited extent, that changing behavioural strategies (an intervention) affects actions which, in turn, affect performance, irrespective of the effect on cognitive control abilities.

In addition to the above assessment, it is argued that a key aspect present in all three intervention categories is metacognition. Whether through restricting behaviour with media, practicing mindfulness, or explicitly providing information on media use, cognition of behaviour with media and related attentional outcomes is enhanced. This argument corresponds to Rosen *et al.* (2013*a*)'s suggestion that strategies enhancing metacognition of behaviour, through self-regulation, will enhance task performance. In terms of the three categories, 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 or behavioural strategy.

Finally, in addition to the nature and effect of interventions employed, this review considered a number of factors affecting intervention implementation and risk of bias. Factors considered to facilitate implementation included: pre-screening participations, the selection of motivated participants who are familiar or trained in the procedures of the intervention, customisation of interventions, and the use of in situ contexts. Factors identified as hindering implementation included the possible burden of the interventions on participants, the timing and effort required to adhere to the intervention, the duration of the intervention, technical errors related to artefacts of the intervention and factors in participants' environments outside of experimental control. In terms of risk of bias, 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 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 multitasking 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, it is argued that the following gaps in terms of research focus are present in the current body of work. While some studies have targeted particular activities or stimuli, others have targeted media use in general. There is, however, an *absence of research explicitly targeting media multitasking behaviour and related outcomes*. 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 situation (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).

Another aspect missing from current intervention investigations is a consideration of the *motivations for media multitasking*. As noted in Chapter 3 there are a number of drivers of media multitasking behaviour. In particular, media multitasking intentions, driven by individual and situational factors, moderated by particular affordances, may hold a differential effect on intervention efficacy and implementation. 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 effects, interventions are likely to be more relevant and have a greater effect on such a population. Additionally, it has been shown that the potential burden of an intervention poses a barrier to participation. Before assessing intervention efficacy on a general population, studies should target individuals who already hold an intrinsic motivation to reduce their media multitasking or improve their ability to selectively allocate attention when faced with mediated work or study environments. This does, of course, introduce an element of selection bias and, therefore, such studies should be considerate of this possibility.

Finally, while different intervention types have been assessed, the specific *causal mechanisms underlying these interventions has not explicitly been investigated.* 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 include the use of adequate control procedures, successful manipulations of media multitasking behaviour, and longitudinal study designs. Additionally, given the need to consider long-term changes in media multitasking behaviour, studies have yet to explicitly consider the duration of intervention required to identify the presence of an effect and, if found, the sustainability of such effects.

6.5 Summary

In this chapter, to address the first research objective, the findings of the systematic literature review were presented. This presentation commenced with an overview of the search results and selection procedure. Following this, an overview of the included sample of studies was provided. Data analysis was conducted by means of a narrative synthesis of findings. The outcomes of this analysis were presented in six sections. First, interventions were categorised on the basis of the BCW framework. Second, patterns in the implementation of these interventions were examined. Third, the efficacy of these interventions in terms of behaviour change and effects on cognitive control or related performance was considered. This was followed by a consideration of individual differences and factors affecting intervention implementation. The synthesis concluded with a consideration of the quality of evidence reviewed. Finally, these results were discussed and, extending from key shortcomings and gaps identified, recommendations for future work were provided.

Part III

Intervention Feasibility Assessment

Chapter 7

Intervention Development and Assessment Design

The literature reviewed in Part I of this dissertation indicate that, given the affordances and gratifications offered by media, for some individuals, media multitasking is associated with a broader distribution of attention and increased processing of irrelevant stimuli. Building on this, Part II reported a systematic review of research concerning behavioural interventions targeting improvements in cognitive control or performance in relation to media multitasking. While some interventions have been effective for some individuals, there remains much uncertainty with regards to the nature, efficacy and feasibility of such interventions. Despite these inconclusive findings, in agreement with Rosen *et al.* (2013*a*), it was suggested that interventions promoting metacognition of behaviour, through self-regulation, may enhance performance and executive functioning.

In the third part of the dissertation, building on Parts I and II, to address the second research objective, the design, execution and results of an assessment of a media multitasking-related intervention are reported. In this chapter the intervention and the methodology adopted for its assessment are outlined, after which Chapter 8 presents the results of the investigation. Informed by the outcomes of the first research objective and the literature considered in Part I, the chapter commences with a description of the development and nature of the intervention, followed by the research questions posed for its assessment. Thereafter, an overview of the research design is provided. This is followed by a description of the population and the setting within which the study was conducted. Next, the instruments and procedures for data collection and analysis are described in detail. Where necessary, hypotheses are provided for key study outcomes.

7.1 Intervention Development and Description

Informed by the outcomes of the first research objective and the theoretical foundation established in Chapter 2 a media multitasking intervention, targeting improvements in cognitive control and everyday executive functioning, was developed. Beginning with a description of the theory of change this section outlines the details of this intervention.

7.1.1 Theory of Change

To outline a theory of change and guide the development of the intervention in question, three propositions are described. It is important to note that, in contrast to an axiomatic view of propositions, these propositions are understood in accordance with the definition provided by Cooper and Schindler (2014, p. 58) —"a statement about observable phenomena (concepts) that may be judged as true or false". Designating such propositions relational statements, Reynolds (2015, p. 77) describes them as "logically and theoretically valid statements that explain relations between concepts under consideration". In contrast to hypotheses, which are propositions formulated for empirical testing (Cooper and Schindler, 2014), these relational statements are specified to provide a theory describing the proposed mechanism through which the intervention affects cognitive control. While the purpose is not to empirically test these propositions, in the course of evaluating the hypotheses provided in Section 7.6.3, these propositions will come to be evaluated, for the specific setting, population and intervention in question.

As with previous interventions, the theory of change held, as its basis, the value of single-tasking for promoting a narrower distribution of attention (Bavelier *et al.*, 2012; Gorman and Green, 2016; Irwin, 2017; Rothbart and Posner, 2015). In particular, noting Adler and Benbunan-Fich (2013)'s typology integrating theories of self-regulation and 'psychological flow', it was proposed that the promotion of single tasking would support the achievement of a 'flow state' with respect to ongoing tasks. As Hoffman and Novak (1996) note, in such a state irrelevant stimuli are more likely to be inhibited. Following a review of studies considering multitasking and attention, Rothbart and Posner (2015) note, in particular, that training can alter neural networks, and practice in tasks requiring singular focus can lead to improved everyday attentional performance. On this basis, it is argued that, through practice at inhibiting media-related interruptions (self or external), the tendency to adopt a broader distribution of attention can be shifted in favour of a narrower distribution. This argument forms the first proposition of the study (P_1).

Increasing the frequency and extent of single-tasking will promote a narrower distribution of attention which, through the transfer of learning, will effect cognitive control and improve attentional performance in everyday life.

As noted previously, media multitasking can be understood to result from a form of goal conflict (Ralph *et al.*, 2015; van Koningsbruggen *et al.*, 2018). The present engagement, information, or value offered by a primary task is compared to that offered by a secondary mediated task. While both may be associated with various goals, in a given situation, facilitated by the affordances of the media present, through media multitasking, one goal may supplant another. Szumowska *et al.* (2018, p. 191) note that, for media multitasking, restrictions on task-switching may not present as an optimal solution. They propose, rather, that the adjustment of performance strategies, in particular single-tasking versus multitasking, based on goal-alignment, through self-regulation, may present as a more effective approach. Extending this, just as Adler and Benbunan-Fich (2013) argue that, through self-regulation, individuals multitask to optimise their experiences to achieve other goals when not engaged or stimulated by a primary task, supported by a number of previous studies (e.g., Baumeister *et al.*, 2007; Moskowitz, 2012; Rosen *et al.*, 2013*a*; Meier *et al.*, 2016), it is argued that an intervention supporting processes of goal-oriented self-regulation can contribute positively to the enactment of single-tasking. This notion is represented by the second proposition of the study (P_2):

Goal-oriented self-regulation will facilitate the enactment of single-tasking.

Taking P_1 and P_2 together, a third proposition is advanced:

An intervention supporting goal-oriented self-regulation will facilitate the enactment of single-tasking and, consequently, promote a narrower distribution of attention, leading to changes in cognitive control and everyday executive functioning (P_3).

7.1.2 Intervention Description

Given the theory of change, an intervention, grounded in self-regulation theory, was developed to support single-tasking and the reduction of media multitasking. In relation to the model of media multitasking proposed in Chapter 3, the intervention primarily targets *individual factors*. However, to a lesser extent, aspects of the technological and social environment, as *situational factors*, are targeted. Additionally, the intervention can be understood to primarily function through restriction and awareness. Consequently, in relation to the BCW framework the restriction and enablement functions were adopted to target all four components of behaviour described in the COM-B model. In this subsection the development and nature of the intervention is described. Prior to this, the selection of self-regulation as a theoretical framework is briefly motivated.

While the role of self-regulation as a determinant of media multitasking has been highlighted throughout this dissertation, four motivations, in particular, support the adoption of this theory as a theoretical framework for the intervention. First, as highlighted in Chapter 2, the self-regulation of behaviour is theorised to be central to multitasking and self-interruption and, as concluded in Chapter 3, the convergence of evidence, at this stage, indicates that self-regulation influences media multitasking (Reinecke *et al.*, 2018; Szumowska *et al.*, 2018). Second, as indicated in Chapter 6, metacognition of media use holds potential for changing such behaviour. Theories of self-regulation emphasise metacognition, through monitoring, as a key component of behavioural regulation in the aid of pro-actively attaining desired outcomes (Zimmerman, 2008). Third, researchers have argued the value of self-regulation as a means of reducing media-related self-interruption and multitasking (e.g., Rosen *et al.*, 2013*a*; Flanigan and Kiewra, 2017; Parry and le Roux, 2019*b*; Szumowska *et al.*, 2018). Specifically, Adler and Benbunan-Fich (2013) contend that self-regulation can support the inhibition of self-interruptions, increasing instances of single-tasking. Moreover, Szumowska *et al.* (2018, p. 191) argue that improvements in self-regulation "should counteract the tendency of frequent media multitasking to engage in switches between tasks". Finally, given the goal-directed nature of media multitasking and the manner in which self-regulation theory focuses on the goals directing behaviour, such a theory provides an appropriate framework for an intervention targeting the promotion of single-tasking in relation to media multitasking.

To support the effective self-regulation of media multitasking it was necessary to design an intervention which facilitated, firstly, goal setting, secondly, monitoring of behaviour in relation to these goals and, thirdly, responding to bring behaviour in-line with the goals. While some previous studies have considered interventions indiscriminately targeting all media use (e.g., Irwin, 2017), others have targeted use of a single artefact (e.g., Hartanto and Yang, 2016). In this study it was decided to specifically target media multitasking involving the use of a smartphone. For the target population a majority of media use and, as a consequence, media multitasking, involves the use of such devices (Nielsen, 2016; Poushter, 2016; Pew Research Center, 2017). Bornman (2014) notes that, in many African countries, mobile phone ownership is over 90%. This percentage rises to over 90% when considering university students in South Africa (North *et al.*, 2014).

Behaviour change is complex and, as Michie *et al.* (2011) note, often unsuccessful. Moreover, efforts at improving self-regulation are often ineffective (Baumeister and Heatherton, 1996). As has been illustrated in a number of domains plans are necessary to achieve success at self-regulation. Specifically, Klimmt *et al.* (2018, p. 18) note that "abstaining from media use and communication access is now an action that requires intentions, planning, and specific arrangements". Therefore, to support effective self-regulation of media multitasking the intervention involved the use of a pre-built mobile application —*Forest*.[1] This application, available on both Android and iOS platforms[2], enables users to track their phone usage as represented by the session duration and number of screen-unlocks. Additionally, it enables users to adopt the *Pomodoro Technique*[3] to managing their smartphone use. Use of such applications in social science research is not without precedent (Elhai *et al.*, 2017; Rozgonjuk *et al.*, 2018). Additionally, as Chokalingam *et al.* (2018) indicate, for students in South Africa, use of such applications is uncommon. The intervention involved using the application to support the self-regulation necessary for facilitating single-tasking. To follow, the details of the intervention are outlined.

Smartphone Usage Goals: Based on usage statistics reported in previous studies participants were set a target of a *maximum of one and a half hours (90-minutes) of smartphone usage per day.* While there is a large scope for individual differences, across a number of studies employing experience sampling, diary tracking, self-reported, automatically monitored, and observational methods, it has emerged that, on average, individuals use media for approximately nine hours per day (Voorveld and van der Goot, 2013; Magen, 2017). While there is much variance across studies and individuals, between 30% and 80% of this use involves multitasking (Jeong and Fishbein, 2007; Rideout *et al.*, 2010). For smartphone use while, again, there is variance, studies indicate that students typically use these devices for more than three hours per day (Rosen, 2016). For South Africans aged 16 to 64, on average, three hours, 17 minutes per day is spent accessing the internet with a mobile phone (Kemp, 2018). In terms of multitasking, Deng *et al.* (2018) found that such use typically involves over 100 switches between applications. Therefore, it is argued that the usage goal would, on average, require participants to reduce their

[1]See `https://www.forestapp.cc/` for more information about this application.

[2]While it is freely available on the Android platform, the iOS version requires a once-off fee. For this reason, this study required participants to be Android users.

[3]A timer is used to separate tasks into set, uninterrupted intervals (Cirillo, 2006).

media use and, consequently, the total switches involving media. Importantly, while the target may have required reductions in media use, the focus was not on the amount of time or extent of the reduction in use. Rather, the purpose of the target was to guide the self-regulation of behaviour with media in accordance with the pre-specified goal. To support participants in meeting this target and provide them with an awareness of their media use, the *Forest* application provides a dashboard displaying total use per day.

Monitoring of Smartphone Usage: Building on this first component, the second aspect of the intervention involved the self-monitoring of smartphone usage. While previous studies have relied on the provision of reminders, diary logging, or constantly displayed metrics, in this study monitoring of behaviour was supported through the aforementioned dashboard displayed by the *Forest* application. In this way, while constantly available, participants were able to monitor their media use at their own leisure. In contrast to unsupported attempts to improve self-regulation, providing participants with accurate reports on their behaviour, it was argued, would support them in monitoring their own behaviour. As with previous interventions promoting awareness of media use and multitasking, metacognition was a key target of this aspect of the intervention. The specific behavioural strategies to change, however, were left to the participants' discretion. Additionally, participants were required to submit a report of this dashboard to the primary researcher each day. This report provided data on the number of screen-unlocks and the time of day and number of minutes for which the smartphone was used. Figure **??** provides an indication of the phone-usage report.

Operating for goal-alignment While awareness may in-itself be a useful method of behaviour change, in self-regulation theory, the primary purpose of monitoring is the evaluation of current actions and, on this basis, responding as necessary. In this case, responses could be issued in one of two ways. First, as indicated by their usage reports, participants could, themselves, operate and bring their behaviour in-line with the target. Second, supported by the *Forest* application, participants were instructed to initiate set periods of time for which they wished not to use their smartphones. Using the pomodoro timer provided by the application participants were supported in bringing their behaviour in-line with the target. In the language of the application these sessions are termed 'planting a tree' and are run for a self-determined period of time. If the participant was successful at meeting their goal the tree 'grew' and, if they were not, the tree 'died'. Along with the previous report, the participants submitted a report on their 'forest' each day to the primary researcher. This indicated, firstly, the number of restrictions initiated and, secondly, for how many the participant was successful at meeting their goal.

Figure 7.1: Screen capture of the phone usage dashboard displayed by *Forest*.

The intervention was implemented for a period of 28 days. As Irwin (2017) notes, and as discussed in Chapter 6, the duration required to identify an effect, if any, remains unknown. While some studies have shown effects of behaviour change or cognitive training on outcomes for cognitive control in periods as short as a single session (e.g., Josefsson *et al.*, 2014; Jaeggi *et al.*, 2014), others have shown effects after periods of three to four weeks (e.g., Nouchi *et al.*, 2012; Anguera *et al.*, 2013), and yet others have found effects after eight weeks or longer (e.g., Jha *et al.*, 2007). Additionally, as noted in Chapter 6, a majority of studies in this regard are brief in nature (occurring in a single session). Of the 15 studies reviewed only three took place for a period longer than a week. Given the disparate and, arguably, ineffectual results indicated in these studies, it was decided to implement the intervention for a longer duration. The chosen duration corresponds to Kushlev *et al.* (2016)'s suggestion that interventions involving reductions in media use be implemented for at least a month. As Webb and Bain (2011) note, compliance to intervention procedures is a key challenge facing intervention studies conducted in situ. Moreover, as noted in Chapter 6, adherence to intervention procedures has negatively affected the implementation of previous interventions in this regard. To promote adherence participants were provided with a financial incentive commensurate to their success at achieving the usage target. While the provision of financial incentives may support adherence, it is acknowledged that they may also have introduced biases into the study.

7.2 Research Questions

Extending from the second research objective of the study, to guide the intervention feasibility assessment, a single primary research question was posed:

RQ1: *Is a self-regulation based intervention a feasible approach to improving the cognitive control of students who are heavy media multitaskers?*

To address this question, in relation to the appropriate areas of focus for feasibility assessments identified by Bowen *et al.* (2010, p. 8), secondary research questions were posed. Of the eight dimensions identified, four are relevant for this study:[4]

- *Demand:* The extent to which the intervention is likely to be used.
- *Implementation:* The extent to which the intervention can be implemented as proposed.
- *Acceptability:* The recipients' reaction to the intervention.
- *Limited-efficacy testing:* The extent to which the intervention produces the targeted outcomes.

For each dimension Bowen *et al.* (2010) identify core outcomes of interest. For demand, outcomes include: recipients' perceptions of positive or negative effects, their application of the intervention procedures, and their intentions to continue with the intervention. For implementation, outcomes include: the recipients' degree of execution, success or failure of execution, and the resources needed for implementation. For acceptability, outcomes include: understanding recipients' intentions to continue with the intervention, and perceptions of appropriateness and satisfaction. Finally, for limited-efficacy testing, outcomes include: testing intended effects and deriving effect size estimates. Extending from these areas of focus, specific secondary research questions were posed:

RQ1.1a: *Amongst the target population, is a self-regulation based intervention requiring reduced media use likely to be used?*

[4]The remaining dimensions include practicality, adaption, integration, and expansion. Practicality has been excluded because it concerns the cost-effectiveness, the role of administrators, and other constraints on the intervention outside of the scope of this study. The remaining dimensions have been excluded as they refer to the assessment of existing interventions applied to new populations or contexts.

RQ1.1b: *What is the pattern of media use exhibited by those executing the intervention?*

RQ1.2a: *What are the factors that facilitate the implementation of the intervention?*

RQ1.2b: *What are the factors that hinder the implementation of the intervention?*

RQ1.3: *How do executors of the intervention react to the intervention?*

RQ1.4: *Is an intervention requiring heavy media multitaskers to reduce their media use, through self-regulation, effective at improving cognitive control ability?*

7.3 Overview of Research Design

To address the second research objective and the primary and secondary research questions that followed, a study involving three high-level phases (a pre-screening survey, an experimental assessment, and an interview follow-up) was conducted. The second phase was, itself, comprised of three stages: the baseline assessment, the intervention period, and the post-intervention assessment. This section provides a brief overview of each of the phases, with details provided in the subsequent sections. Figure 7.2 presents a diagrammatic representation of the study, while Table 7.1 presents an overview of the instruments for each phase. As noted in Chapter 1, in accordance with Venkatesh *et al.* (2013), the research design can be characterised as mixed methods, involving the sequential collection of complementary quantitative and qualitative data.

In phase one, through an online self-administered survey, a sample of eligible participants was identified and selected. Following this, phase two involved the use of a between-subjects pre/post experimental design to assess the effects of the intervention on measures of performance-based cognitive control and everyday executive functioning. In accordance with prescriptions for intervention evaluation (Webb and Bain, 2011, p. 208), this methodology is widely used for intervention assessment in general and, as was demonstrated in Chapter 6, in this domain. Bowen *et al.* (2010, p. 4) note that, for assessments of feasibility, experiments provide a time- and cost-effective means of assessing intervention efficacy. At the outset this phase involved the random allocation of participants into either an intervention or a control group. Babbie (2012, p. 274) explains that, in social science experiments "control groups guard against not only the effects of the experiments themselves but also the effects of any events outside the laboratory during the experiments". Both groups underwent a series of tests enabling the

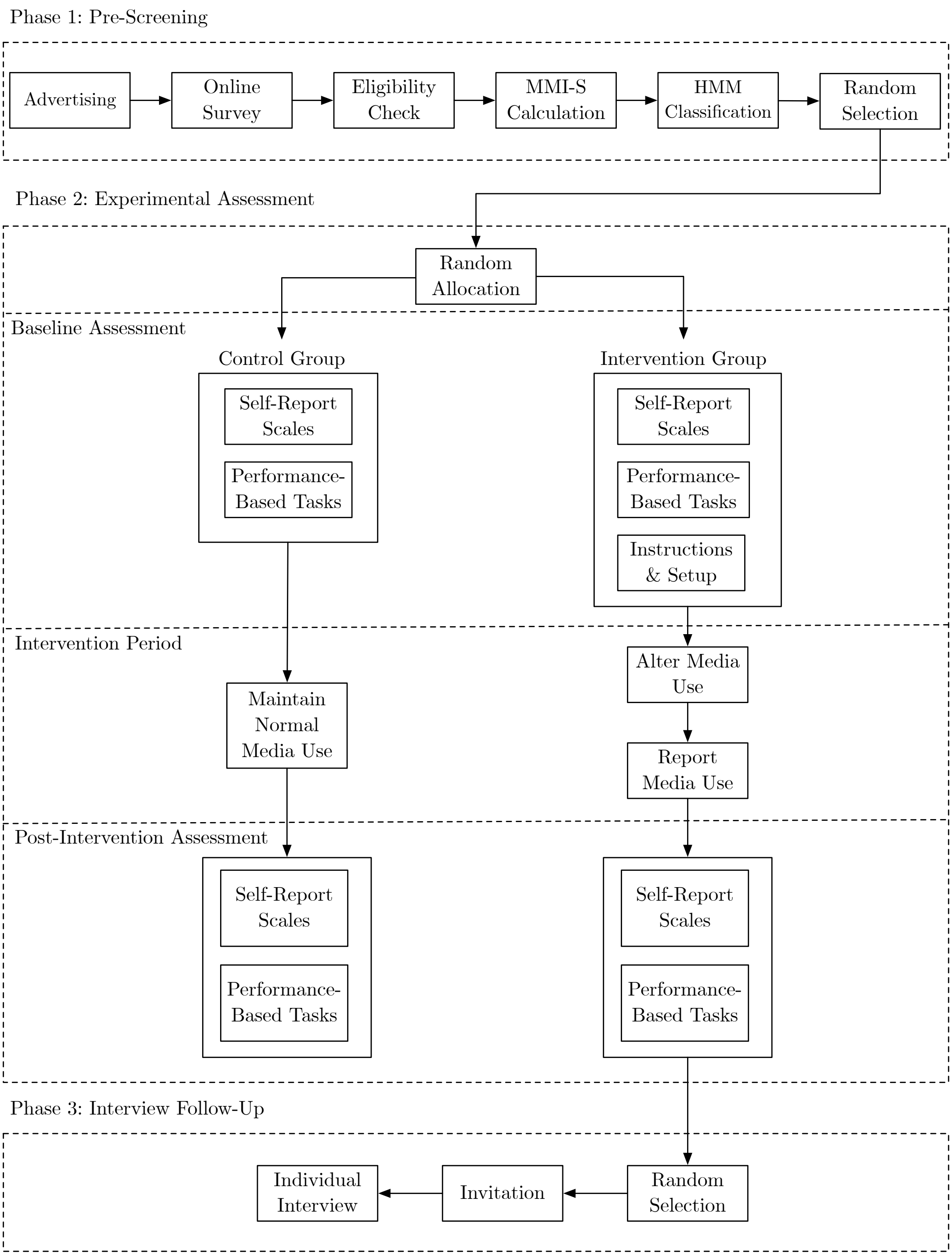

Figure 7.2: Diagrammatic representation of the three-phase empirical investigation.

Table 7.1: Overview of instruments employed and measures gathered across the study.

Pre-screening	Baseline	Intervention	Post-intervention	Interview
Self-Reported	*Self-Reported*	*Tracked*	*Self-Reported*	Interview guide
Eligibility	MAAS-LO	Daily Unlocks	MAAS-LO	
Demographics	ARCES	Daily Usage	ARCES	
MMI-S	MW-S & MW-D	Restriction Sessions	MW-S & MW-D	
	AC-S & AC-D		AC-S & AC-D	
	BSCS		BSCS	
	IPS		IPS	
	Performance-Based		*Performance-Based*	
	Flanker		Flanker	
	N-Back		N-Back	
	SART		SART	
	Number-Letter		Number-Letter	

establishment of baseline measures for cognitive control and everyday executive functioning. This was followed by an intervention period where those in the intervention group altered their behaviour in accordance with the intervention, while those in the control group maintained their normal behaviour. Throughout this period data on compliance with and execution of the intervention were collected. As Bowen *et al.* (2010, p. 3) notes, "gathering data on estimated use or by actually documenting the use of selected intervention activities in a defined intervention population or setting" enables the assessment of intervention demand. The phase concluded with a post-intervention assessment, where the same measures acquired at the baseline were re-assessed to enable comparisons before and after the intervention. In phase three a subset of participants from the intervention group were individually interviewed. As Mouton (1996) suggests, the qualitative data produced in these interviews enables the investigation of factors (demand, implementation and acceptability) not considered in the experimental assessment.

7.4 Population and Setting

The study was conducted in the context of a large residential university in South Africa, with the target population defined as university students who self-reported as heavy media multitaskers (HMMs). This population is characterised by two key aspects: their status as students and their media multitasking tendencies. In relation to previous research in this domain both of these characteristics provide appropriate bounds for delineating a suitable population. First, a majority of studies concerning media multitasking and related beliefs, behaviour, effects, and interventions consider student populations. Second, HMMs were targeted on the basis of the outcomes of the systematic review reported in Chapter 6. Because such individuals engage in media multitasking to a greater extent and, arguably, are more likely to experience possible negative effects, interventions are likely to be more relevant and have a greater effect on such a population. As shown in previous studies, in terms of media use patterns and effects, students at this institution are comparable to global norms (le Roux and Parry, 2017*a*,*b*). Since these traits of the target population are not unique to students at this institution, generalisation is possible. Given this target population, and the needs and constraints of the study, an individual was eligible if, at the time of the pre-screening, he/she:

1. Was a student at the institution where the study was conducted.
2. Was an HMM (as indicated by a media multitasking index).
3. Owned and used an *Android* smartphone.[5]
4. Was willing to participate in a 28-day behaviour-change intervention study.
5. Used the *WhatsApp* instant messaging service.[6]
6. Did not use focus-management mobile applications.[7]
7. Did not use psychostimulants (e.g., *Ritalin, Concerta, Adderall*) in the month prior to the study period, nor intended to during the study period.
8. Had not had any previous diagnoses for neurodevelopmental disorders (e.g., ADHD).

7.5 Phase 1: Pre-Screening

The first phase of the study involved a survey to identify and select a sample of eligible students to participate in the study. This screening was conducted through an online self-administered questionnaire covering demographics, eligibility, and media multitasking tendencies. Requests for participation in the study outlined the details of all three phases. As noted in Chapter 6, a number of studies reported participants withdrawing due to the burden of participation. Therefore, in providing this information at this stage,

[5]This criterion was specified on the basis of the instrumentation required for the intervention and the restrictions placed on other mobile operating systems.

[6]This popular service was used to communicate with the participants.

[7]This criterion was specified on the basis of the nature of the intervention proposed in this study.

participants were asked to provide informed consent to the full study and volunteered their participation with full knowledge of the procedures. This may have presented an impediment to achieving a representative sample. However, in terms of adhering to ethical research practices, such steps were entirely necessary. Additionally, it is argued that providing such information at this stage minimised attrition during the subsequent procedures. To follow, the materials and procedures for this phase are outlined.

7.5.1 Pre-Screening Materials and Procedure

Students were recruited to participate in the study through three methods, including: the placement of posters and flyers around the main campus of the institution, and both email and in-person announcements in six undergraduate courses (combined enrolment of 3000 students across five faculties). Potential participants were directed to a survey hosted on the institution's implementation of the *Checkbox* platform. The survey contained three sections. The first provided respondents with details of the study and outlined the expectations of participants. To enable the invitation of eligible participants to phase two, respondents were required to provide their contact details in the form of an email address. The second section concerned demographic details and was used to determine eligibility and representativeness. Using the MMI-S, the third section concerned respondents' media multitasking tendencies. As a shorter variant of the MMI this measure has been utilised in a number of recent studies in this domain (e.g., Baumgartner *et al.*, 2017*b*; Irwin, 2017; Szumowska *et al.*, 2018). To follow, given its important role in the selection of participants, the MMI-S is described.

The **Media Multitasking Index-Short** (MMI-S) is calculated on the basis of the Media Multitasking Measure-Short (MMM-S), as well as a media use questionnaire (MUQ). As discussed in Chapter 3, these measures were developed as modifications to the measures produced by Ophir *et al.* (2009). The MMM-S considers media multitasking across three primary activities (watching TV, using social networking sites, and sending messages via phone or computer) and four secondary activities (the three primary activities and listening to music). In the same way Baumgartner *et al.* (2017*a*) amended the original measure to increase the relevance to their target population (adolescents), in this study, the 'watching TV' item was amended to include a broader scope for possible video-related media use (e.g., online-streaming or computer-based video). Consequently, this item was represented as 'watching video content'. Full representations of the MMM-S and MUQ are provided in Appendix E. For each of the secondary items respondents indicated, on a scale from one (*never*) to four (*very often*), how often they engage simultaneously with each of the primary items. For media use, through a 6-point Likert scale ranging from one (*not at all*) to six (*3 hours or more*), participants indicated how long they used each primary medium on an average day. To calculate the MMI-S these indications were combined using the formula (Equation 3.1) specified by Ophir *et al.* (2009).

It is necessary to note that, as with the original MMI, this measure only includes combinations in which both activities involve media use. While a broader definition for media multitasking is adopted in this study, given the need for comparability and the validation conducted on this scale (e.g., Baumgartner *et al.*, 2017*a*,*b*) it is, nonetheless, considered to be suitable for the purpose of determining participants' media multitasking tendencies. Additionally, as discussed previously, there are limitations to assessing media multitasking in this manner. Despite these, this measure still provides an outcome indicative of the level of media multitasking relative to media use, suitable for selection purposes. No correlational analyses with cognitive processes were planned.

7.5.2 Participant Selection

To determine the sample size for phase two an a priori power analysis was conducted using G*Power version 3.1.9.3 (Faul *et al.*, 2007). This enables the determination of the smallest sample size required to detect an effect with a pre-specified level of confidence (Cohen, 1988). Sample size is calculated as a function of the required power level ($1-\beta$), where β represents the probability of committing a Type II error, the pre-specified significance level α (which represents the probability of committing a Type I error), and the population effect size. The effect sizes found in the studies reviewed in Chapter 6 were used for this purpose. While these varied, and many were non-significant, an average effect size of $f = .35$ was calculated. It is important to note that, while an a priori power analysis is recommended, such analyses are often fraught with uncertainty (Noordzij *et al.*, 2010). Additionally, as Bowen *et al.* (2010) note, a key outcome of feasibility studies is the production of effect size estimates upon which accurate sample size calculations may be based. A power analysis for an analysis of covariance (ANCOVA) was conducted with the effect size set at .35, power at .80, α at .05, number of groups at two (intervention and control), and number of covariates at one. This indicated that a sample size of 67 was required. An equal allocation ratio was adopted, implying two groups of 34 participants.[8] This intended sample size is larger than the average number of participants considered in the studies reviewed in Chapter 6 ($M = 56.07$, $SD = 39.49$). It is, however, within the range of sample sizes Arain *et al.* (2010) identified in a review of feasibility studies. Despite this, given the uncertainty surrounding prior effect sizes, a larger sample size may be necessary in full intervention evaluations.

To produce a sample a purposive approach was adopted. This involved selecting participants on the basis of their characteristics (Babbie, 2012, p. 128). In this case, from those who completed the pre-screening survey, participants were selected based on their media multitasking tendencies. Sampling was conducted in two stages. First, those whose MMI-S scores fell within the upper two-thirds of all scores were classified as HMMs. Next, individuals from this pool were randomly selected to receive invitations to participate in phase two of the study. As noted in Section 6.3.5, a major hindrance to studies in this regard is the potential burden interventions place on participants. Therefore, sampling was, to some extent, based on self-selection. As Irwin (2017, p. 58) notes, this is not necessarily undesirable. As discussed in Section 6.4, because HMMs engage in media multitasking to a greater extent and, arguably, are more likely to experience possible negative effects, interventions are likely to have a greater effect on such a population. While it is acknowledged that such sampling techniques introduced a degree of bias into the sample, it is argued that, firstly, the nature of the sample is in accordance with the research questions and target population, secondly, such a sample potentially addresses a number of factors necessary for research in this regard and, finally, the random selection and allocation from this sample limits the effect of any other selection biases.

7.6 Phase 2: Experimental Assessment

Following the pre-screening procedures phase two involved assessing the intervention with an experimental design. In this section the instruments and procedures adopted in this assessment are described, followed by the specification of a number of hypotheses for intervention efficacy. Finally, the last sub-section describes the manner in which the data were analysed to test the hypotheses and assess aspects of intervention feasibility.

[8] It is acknowledged that a greater hedge for attrition is recommended. In this study, however, the total sample size was constrained by available resources. Section 8.1.3 presents an overview of the flow of participation and the sample considered.

7.6.1 Instruments

In the experimental assessment two measurement paradigms were adopted, self-report and performance-based. This approach enabled intervention assessment to take place at both a reflective and a functional level. Given the current discrepancies in the literature concerning relationships between media multitasking and cognitive control across these paradigms, considering outcomes from both perspectives will, in addition to providing a more nuanced assessment of intervention efficacy, enable the advancement of knowledge in this regard. Such an approach is congruent with previous studies in this domain (e.g., Irwin, 2017; Yildirim, 2017). Prior to the study, all measures, from both paradigms, were piloted with a group of seven students from the target population. This enabled, firstly, the refinement of the timing, instructions, and presentation of the measures and, secondly, the testing of the automated data collection procedures and programs used. To follow, the specific measures adopted from each paradigm are explained in detail.

7.6.1.1 Self-report Measures

To assess everyday executive functioning seven self-report scales were employed. While there are overlaps in coverage for various aspects of executive functioning, each scale focuses analysis on different features of the construct. In previous studies in this domain such measures have frequently been used in conjunction with each other (e.g., Ralph *et al.*, 2014; Irwin, 2017). Additionally, given the associations between media use, self-regulation and procrastination (Reinecke *et al.*, 2016; Meier *et al.*, 2016), an additional scale was used to assess procrastination. All scales used are in the public domain and did not require permission for use. To follow, a description of each scale is provided with complete representations available in Appendix E.

The **Attention Related Cognitive Errors Scale** (ARCES), developed by Cheyne *et al.* (2006) and updated by Carriere *et al.* (2008), is a 12-item scale designed to assess the frequency of everyday performance errors associated with lapses in sustained attention. Participants provide responses to statements such as “I begin one task and get distracted into doing something else” and “I make mistakes because I am doing one thing and thinking about another” through 5-point Likert scales ranging from one (*never*) to five (*very often*). A score is produced by averaging all 12 items, with a higher score representing greater self-reported failures of attention.

The **Mindful Attention Awareness Scale - Lapses Only** (MAAS-LO; Carriere *et al.*, 2008), an adapted version of the 15-item MAAS (Brown and Ryan, 2003), is a 12-item scale designed to assess the frequency with which an individual experiences lapses in their attention in the course of their everyday life. Specifically, it concerns the frequency of mindless or absent-minded behaviour assessed through items such as "I find myself doing things without paying attention" and "It seems I am 'running on automatic', without much awareness of what I'm doing". For each of the 12-items responses are provided on a 6-point Likert scale ranging from one (*almost never*) to six (*almost always*). In contrast to the original version, as Cheyne *et al.* (2006) suggest, scores are not reversed. Therefore, with a minimum score of one and a maximum of six, higher ratings indicate a greater frequency of attentional lapses.

The **Attentional Control: Switching and Distractibility** (AC-S and AC-D; Carriere *et al.*, 2013) scales assess tendencies to become distracted or difficulties shifting attention between stimuli. Each scale consists of four items, with responses provided through 5-point Likert scales ranging from one (*almost never*) to five (*always*). For each scale scores are independently averaged, with higher scores representing a greater degree of distractibility or a greater difficulty in switching attention between tasks. Items presented in the AC-S include: "it takes me a while to get really involved in a new task" and "after being interrupted, I have a hard time shifting my attention back to what I was doing before". Items presented in the AC-D include "while I am working hard on something, I still get distracted by events around me" and "when I am reading or studying, I am easily distracted if there are people talking in the same room". For the AC-S, it is acknowledged that it could be argued theoretically that the intervention may either increase or decrease difficulties switching attention between tasks (i.e., either improve or weaken shifting ability). High levels of task-switching, through media multitasking, may improve shifting abilities and, therefore, reductions in media multitasking may reduce perceptions of switching ability. In contrast, it can be argued that increases in single-tasking and an adoption of a narrower distribution of attention will improve cognitive control ability in general which, as a consequence, will support perceptions of improved shifting due to improvements in cognitive flexibility. In Section 7.6.3 specific hypotheses are formulated to capture the proposed effect of the intervention and, in Section 9.2.2, the discussion of the findings considers the varying directionality of possible effects.

The **Spontaneous and Deliberate Mind-wandering** (MW-S and MW-D) scales were developed by Carriere *et al.* (2013) to assess tendencies to engage in intentional (MW-D) and unintentional (MW-S) mind-wandering. Each scale consists of four items, with responses provided through 5-point Likert scales ranging from one (*almost never*) to five (*very often*). Items presented in the MW-D include: "I allow my thoughts to wander on purpose" and "I find mind-wandering is a good way to cope with boredom". In the MW-S items include: "I find my mind wandering spontaneously", and "I mind-wander even when I'm supposed to be doing something else". Responses are independently averaged, with higher values reflecting a greater tendency to engage in intentional or unintentional mind wandering. Assessing mind wandering is relevant to this study given the associations between this construct and attentional strategies. Carriere *et al.* (2013) assert that mind wandering can either arise as a result of a deliberate choice to direct attention away from a primary task or it can occur spontaneously without deliberate intentions. They support this by referencing Giambra (1995, p. 2), who states that "task-unrelated thoughts may occupy awareness because they capture our attention—an uncontrolled shift—or because we have deliberately shifted our attention to them—a controlled shift".

The **Brief Self-control Scale** (BSCS; Tangney *et al.*, 2004) is a 13-item self-report measure of self-control developed as a short variant of a longer 36-item scale. Through 5-point Likert scales ranging from one (*not at all like me*) to five (*completely like me*) responses are provided for items such as "I often act without thinking through all the alternatives", and "I am able to work effectively toward long-term goals". To produce a score items one, six, eight and eleven are summed, while the remaining items are reversed scored and then added to this sum. This total is then averaged, with a higher score representing greater self-control. As Maloney *et al.* (2012) indicate, the BSCS is useful for predicting self-reported affective and behavioural outcomes associated with behavioural and attentional control.

The **Irrational Procrastination Scale** (IPS; Steel, 2002) is a nine-item self-report scale designed to assess trait procrastination. This scale is consistent with the notion that procrastination runs counter to behavioural goals and, therefore, can be understood in the context of self-regulation failure. Through 5-point Likert scales ranging from one (*not true of me*) to five (*true of me*) responses are provided for items such as "I put things off so long that my well-being or efficiency unnecessarily suffers" and "I delay tasks beyond what is reasonable". To produce a score items two, five, and eight are reverse scored and then summed with the remaining six items. This total is then averaged to produce a score ranging from one to five. A higher score indicates greater trait procrastination.

7.6.1.2 Performance-based Measures

To assess cognitive control from a performance-based perspective four tasks were employed: The *n-back task*, the *Eriksen Flanker task*, the *Sustained attention to response task*, and the *Number-letter task-switching task*. All four were constructed using *PsyToolKit* (Stoet, 2010, 2017) and implemented online. The tasks were run on a 21.5-inch Apple iMac with OS X 10.13.5, a 3.1Ghz Intel Core i7 processor, and 16 GB of RAM. Stimuli were displayed on the built-in display at a resolution of 1920x1080. Participants were seated approximately 55cm from this screen and issued responses through an 'Apple Wired Keyboard with Numeric Keypad'. The Internet connection was provided by the *Tertiary Education and Research Network of South Africa* (TENET) and, as indicated by a speed test, the download speed was 698.64 Mbps, the upload speed was 588.93 Mbps, and the latency was 2ms. Each task required approximately 10-minutes and, for each participant, their order of presentation was randomised. While online implementations of such tasks are becomingly increasingly common, it is acknowledged that reaction times may be affected. Researchers have shown, however, that distributions of reaction times and sensitivity to experimental manipulations do not significantly differ across online or offline methods (de Leeuw and Motz, 2016; Hilbig, 2016). Schubert *et al.* (2013) note, importantly, that interpretation of absolute latencies should be conducted with caution, and suggest that analysis should primarily focus on mean reaction times. To follow, the nature and implementation of these tasks is described.

The **n-back Task** is widely used to assess WM. In this task a sequence of stimuli (letters of the alphabet) are displayed one at a time. For each item, participants indicate, with a key press, whether it matches an item presented n items back in the sequence (Sweet, 2011). This task assesses the ability to monitor and update multiple representations in WM (Miyake *et al.*, 2000). Performance is assessed under two conditions: two-back and three-back. Representing different cognitive loads, these conditions are run in separate blocks of trials. In the two-back condition participants indicate if the displayed item corresponds to the item displayed two items previously and, in the three-back (representing a greater cognitive load), participants indicate if the item corresponds to the item displayed three items back. While other variants exist, in this domain, studies have primarily used these variants (e.g., Ophir *et al.*, 2009; Cain *et al.*, 2016; Ralph and Smilek, 2017; Wiradhany and Nieuwenstein, 2017). Across cognitive loads, three indices assess performance. *Hits* represent the proportion of target trials correctly identified as targets. *False alarms* represent the proportion of non-target trials incorrectly identified as targets. *Omissions* represent the proportion of trials for which no response is provided.

Participants were presented with a series of letters displayed in white in the centre of a black screen. Each letter was displayed for 500ms. These items were selected from a set of eight phonologically distinct letters —B, F, K, H, M, Q, R, and X— used by Ralph and Smilek (2017) and provided by Kane *et al.* (2007). For each trial, participants were instructed to indicate, as quickly and as accurately as possible, through a key press (M for 'match' and N for 'non-match'), whether the current letter matched the letter n items back —a target. Non-targets represented instances where the current letter did not match the letter presented n items back. Prior to commencing the task participants performed a practice block of 15 trials for each condition. Following this, participants performed four blocks of 48 trials (alternating between two- and three-back conditions). Within each block each letter appeared six times (five as a non-target and once as a target). Each block was separated by a rest period of 12 seconds. Following this, instructions indicated whether the following block required correctly identifying a match two or three items back. Figure 7.3 depicts example trial sequences for both conditions.

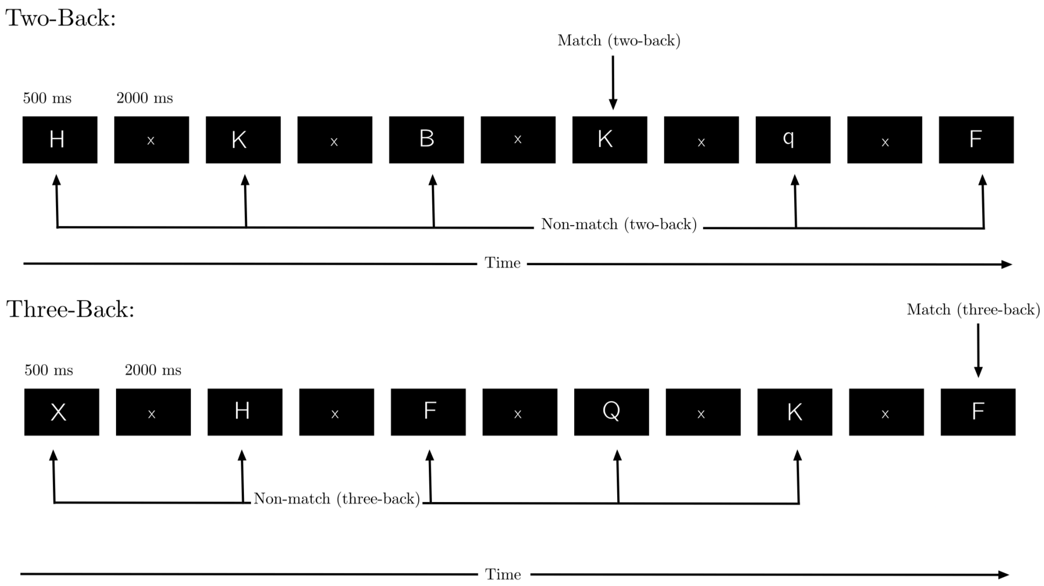

Figure 7.3: Example sequences for the two- and three-back conditions.

To assess cognitive inhibition, as in other studies (e.g., Baumgartner *et al.*, 2014; Gorman and Green, 2016), an adapted version of the **Eriksen Flanker task** (Eriksen and Eriksen, 1974; Ridderinkhof and van der Molen, 1995) was used. In its original form stimuli were presented as letters. In recent variants stimuli are presented as arrows. In each trial five stimuli are presented in a horizontal line in the centre of the screen. Participants react, through a key press, to a target stimulus presented in the middle of four distractor stimuli. Participants indicate in which direction (either left or right) the target arrow is pointing by pressing a response key ('q' for left and 'p' for right). The stimuli flanking the target can either point in the same direction as the target (congruent flankers: $\rightarrow \rightarrow \rightarrow \rightarrow \rightarrow$), or point in the opposite direction to the target (incongruent flankers: $\rightarrow \rightarrow \leftarrow \rightarrow \rightarrow$). Throughout the task these conditions are randomly interspersed. Results are computed by calculating the average RT for congruent and incongruent conditions and, on this basis, calculating a ratio of the two —the flanker congruency effect. A higher ratio (incongruent/congruent) indicates more problems with inhibiting irrelevant information. Additionally, response accuracy is considered through an inverse efficiency score (IES=RT/proportion correct). Integrating both accuracy and RTs, a lower score indicates greater task efficiency (Townsend and Ashby, 1983; Murphy *et al.*, 2017). In this study, a practice block of 30 trials (15 congruent and 15 incongruent) with error feedback was presented to participants. This was followed by a test block of 140 trials (70 congruent and 70 incongruent) without error feedback. For each trial participants had 2500ms to respond. Once a response was provided the current set of stimuli disappeared and, after 1000ms, new stimuli were displayed. Participants were informed that speed and accuracy were of equal importance in the task.

The **Sustained Attention to Response Task** (SART; Robertson *et al.*, 1997) is a Go/No-Go style continuous performance task designed to assess the ability to sustain attention to a dull but demanding task. It involves responding, through key presses, to frequently presented non-targets (Go-stimuli) as quickly as possible, while withholding such responses to less frequently presented targets (No-Go stimuli). Stimuli are presented for a short duration followed by a masking stimulus presented for a longer duration. Each trial consists of the presentation of a single digit (1 to 9) in the centre of the screen, followed by a mask (a 29mm diameter ring with a diagonal cross in the centre). Both the digits and the mask are presented in white on a black background. Two indices assess aspects of sustained attention. First, *SART errors* (No-Go errors) represent failures to refrain from responding to No-Go stimuli —a drift of attention from the primary task. Second, *RT variability* to Go stimuli represents fluctuations in attentional allocation. RT variability is calculated as the standard deviation for non-target RTs divided by the mean RT. In this study, each digit presented to participants was displayed for 250 ms followed by a 900 ms mask. Of the digits displayed digit '3' was the No-Go digit. Participants were instructed to respond by pressing the 'space bar' whenever the displayed digit was not a '3' and, whenever a '3' was displayed, to withhold their response. Furthermore, participants were informed that speed and accuracy were of equal importance in this task. Prior to commencing the task participants completed 18 practice trials (containing two No-Go digits). The SART was divided into seven blocks of 60 trials, with each block containing 54 non-targets (Go) and six targets (No-Go). These targets were randomly dispersed within each block (see Figure 7.4). As Robertson *et al.* (1997, p. 749) recommend, each digit was presented in one of five randomly allocated font sizes (8, 72, 94, 100, or 120).

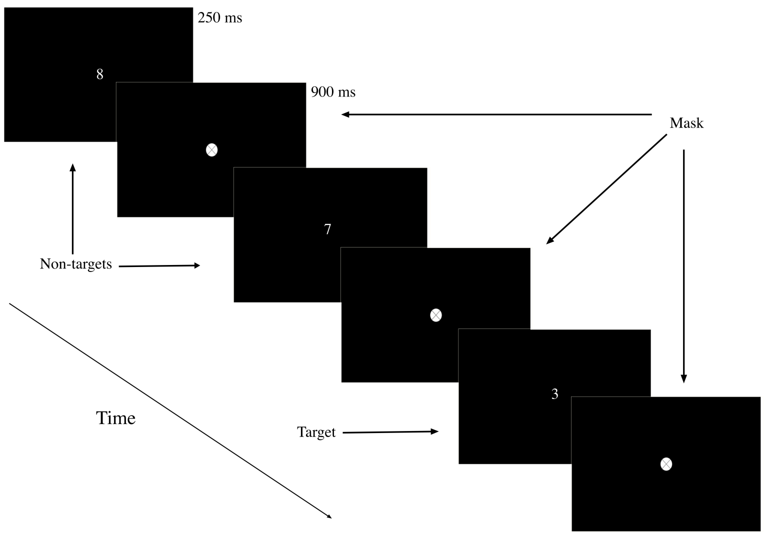

Figure 7.4: Example of three possible SART trials.

To assess shifting aspects of cognitive flexibility, as in previous studies (e.g., Ophir *et al.*, 2009; Alzahabi and Becker, 2013; Gorman and Green, 2016), the **Number-Letter task-switching paradigm** (Rogers and Monsell, 1995) was used. In this task participants are required to keep multiple task sets active in WM and, across trials, switch among these task sets. Specifically, in Rogers and Monsell (1995)'s alternating runs approach participants perform two trials of task A, followed by two trials of task B, and then switch back to task A. Therefore, on every second trial a switch occurs. These tasks may appear as either repeat trials (the next trial is the same as the current trial) or switch trials (the next trial differs from the current trial). Switch costs are calculated as the difference in mean RT between switch trials and repeat trials for correct responses. In this study, each trial consisted of a grid displayed as in Figure 7.5. Within each quadrant of the grid letter-number pairs (e.g., "B2" or "E7") were displayed one at a time. Possible letters were drawn from a set of vowels (A, E, I, U) and consonants (G, K, M, R). Possible numbers were drawn from a set of even numbers (2, 4, 6, 8) and a set of odd numbers (3, 5, 7, 9). If the letter-number pair appeared in the top two quadrants participants performed a classification task with the letter (ignoring the number). If the letter-number pair appeared in the bottom two quadrants participants performed a classification task with the number (ignoring the letter). For both tasks responses were provided through key presses. The letter task involved classifying the displayed letter as either a consonant ('B') or a vowel ('N'). The number task involved classifying the displayed number as either even ('N') or odd ('B'). As with the other paradigms in this study, participants were informed that speed and accuracy were of equal importance. Prior to commencing the task participants performed three practice blocks of 20 trials each (one of just letter classification, one of just number classification, and one of both), with feedback. Following this, participants performed four blocks of 60 trials each, without error feedback. The sequence of trials was randomly allocated.

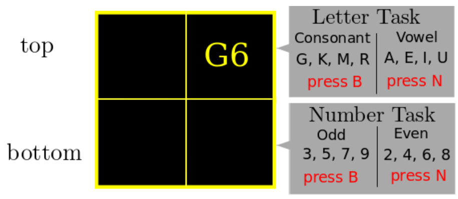

Figure 7.5: Trial grid with example stimuli and options for the number and letter tasks.

7.6.2 Procedure

As depicted in Figure 7.2, the experimental assessment involved three stages: the baseline assessment, the intervention period, and the post-intervention assessment. Prior to the baseline assessment participants were randomly allocated to either the control or intervention group. Such a between-subjects design safeguards, to some extent, against possible biases emerging due to demand characteristics (Orne, 2009). Participants in both groups were then invited to separate sessions in which they received briefings on the study procedures. All instructions and communication followed a standard script.

Additionally, participants followed a standard set of written instructions during these sessions. Moreover, in both assessments, the testing procedures were automated, with all instructions, tasks and questions following a set sequence. The purpose of this was to minimise any researcher biases or differences between the groups. During their respective sessions, isolated from other people, participants completed the baseline assessments. These procedures, administered in the presence of a registered psychologist, involved, firstly, the performance-based tasks and, following this, the self-report scales. For those in the intervention group, instructions for the intervention period were provided. This involved installing and configuring the *Forest* application, and training in its use.

During the period between the assessments those in the control group were instructed to maintain their normal patterns of media use, with no emphasis placed on self-regulation or single-tasking with media. Conversely, during this period, those in the intervention group were instructed to carry out the aforementioned intervention procedures. This involved attempting to meet the smartphone usage goal, monitoring and reporting on smartphone usage, and operating to remain on-task when the goal was not achieved. Throughout this period, members of the intervention group submitted reports on their media use and media-restriction sessions with the primary researcher on a daily basis. The 28-day intervention period included two sub-periods. The first 19 days fell during normal term time, while the next nine days fell during the spring vacation. Following the intervention period the same assessment sessions as conducted during the baseline were conducted again. Participants were known only through a unique identifier and no knowledge of group-assignment was available at the post-intervention assessment.

7.6.3 Hypotheses

In accordance with the hypothetico-deductive model of scientific enquiry, to guide the assessment of this intervention, two categories of hypotheses were proposed. These hypotheses were pre-registered with the *Open Science Framework* (OSF) prior to data collection and are available at: `https://osf.io/xy45e/`. Supporting ongoing efforts to ensure data analysis and reporting are conducted openly and with integrity, this pre-registration enables a distinction to be made between confirmatory and exploratory analysis (Elisabeth *et al.*, 2016; van 't Veer and Giner-Sorolla, 2016).

7.6.3.1 Intervention effects on self-reported everyday executive functioning.

It was expected that, in comparison to the control group, those in the intervention group would experience general improvements in their everyday executive functioning. In this regard, in relation to the relevant instruments, seven hypotheses were formulated. Following the intervention period, those in the intervention group will indicate a greater degree of mindfulness as represented by higher MAAS-LO scores ($H1_a$) and more self-control as represented by higher BSCS scores ($H1_b$) compared to those in the control group. Additionally, following the intervention period, in comparison to the control group, those in the intervention group will report fewer attention-related errors, as represented by lower ARCES scores ($H1_c$), less difficulty shifting attention as represented by lower AC-S scores ($H1_d$), less difficulty inhibiting distractions as represented by lower AC-D scores ($H1_e$), less spontaneous mind wandering as represented by lower MW-S scores ($H1_f$) and, finally, less deliberate mind wandering as represented by lower MW-D scores ($H1_g$).

7.6.3.2 Intervention effects on performance-based cognitive control.

It was expected that, in contrast to the control group, those in the intervention group would experience improvements in their performance-based cognitive control. Therefore, in relation to the relevant instruments, four hypotheses were formulated. Following the intervention period, in comparison with the control group, those in the intervention group will demonstrate greater working memory performance, as indicated for each of the indices in the n-back task ($H2_a$), improved filtering of irrelevant information, as indicated for each of the indices in the Eriksen Flanker task ($H2_b$), a larger capacity to sustain attention, as indicated by the indices in the sustained attention to response task ($H2_c$) and, finally, better shifting performance, as indicated for each of the indices in the number-letter task-switching task ($H2_d$).

7.6.4 Analysis Procedures

Data analysis was conducted in six stages, the outcomes of which are presented in Chapter 8. The first four stages were primarily descriptive in nature. In stage one the pre-screening data were analysed to provide a descriptive account of the sample from which the experimental groups were selected. Second, the data gathered during the baseline assessment were analysed to describe the baseline outcomes and determine differences between the groups. The third stage concerned the analysis of the data produced by the intervention group during the intervention period. This analysis served two purposes. First, it functioned as an adherence check, with analysis considering the participants' success or failure at adhering to the intervention. Second, it enabled the description of the pattern of media use over the time period. This is an important step necessary for understanding the feasibility of an application-supported intervention targeting self-regulation and single-tasking. The fourth stage, the analysis of the post-intervention assessment data, mirrored that of the second stage.

Following the descriptive analysis, the fifth stage adopted a confirmatory framework. Data from the baseline and post-intervention assessments were analysed to test each of the hypotheses provided. This informed the assessment of intervention efficacy. Two approaches to analysis were adopted. First, to isolate any effect of the intervention a per-protocol analysis was conducted. In this initial process of confirmatory analysis data from any participants who withdrew or failed to adhere to the intervention were removed. Consequently, this analysis only concerned the outcomes of participants who adhered to the trial protocol. As Montori and Guyatt (2001) note, if conducted in isolation, per-protocol analysis can bias the testing of hypotheses. Removing these participants undermines any protection from selection biases that randomisation affords (Altman, 1990). Given the limitations to this first analysis approach, to minimise biases resulting from noncompliance, non-adherence, attrition or withdrawal, an intention-to-treat (ITT) approach was also adopted. In such an approach data from all participants irrespective of their completion of the trial are considered (Montori and Guyatt, 2001). Gupta (2011) notes that this maintains the baseline equivalence of the experimental groups produced by random allocation. The "last value carried forward" procedure for missing observations, as recommended by Montori and Guyatt (2001) was adopted.

Hypothesis tests were conducted through ANCOVA statistical procedures. Such tests enable the evaluation of whether the group means from the post-intervention assessments (as dependent variables) differed across the two experimental groups (as independent variables), while controlling for participants' baseline scores (as covariates). Statistically corresponding to a generalised linear model, ANCOVA distinguishes between the variance in post-intervention group means explained by group membership, by baseline scores, and by the residual variance in the model (Huck and McLean, 1975). Covarying for baseline scores supports the analysis in two ways. First, while randomisation aimed to reduce any pre-intervention differences between the groups, residual random differences may have occurred. Accounting for such differences isolates the effect of the intervention on any post-intervention mean differences. Second, it accounts for variation in post-intervention means occurring due to individual differences in performance across the assessments. Because the overall error variance in the model is reduced, an ANCOVA presents a means of testing the hypotheses under question with greater statistical power (Breukelen, 2006; Borm *et al.*, 2007; Field *et al.*, 2012; Egbewale *et al.*, 2014). In particular, in studies where group assignment occurs through randomisation, Breukelen (2006) advocates ANCOVA analyses over repeated measures ANOVA procedures. The final stage of quantitative analysis involved a brief process of exploratory analysis, with no prior hypotheses specified. Following recent findings by Reinecke *et al.* (2018), the effect of the intervention on procrastination tendencies, was assessed.

7.7 Phase 3: Interview Follow-up

Phase three involved a follow-up procedure in the form of individual semi-structured interviews. These interviews were conducted by the primary researcher to understand participants' experiences during the intervention phase. Specifically, such procedures enabled participants from the intervention group to reflect on how they implemented the intervention and how it affected their media use, and behaviour. In this section the procedures, instruments and analysis paradigm adopted for the interviews are outlined.

7.7.1 Procedures

Following the post-intervention assessment 10 participants from the intervention group were randomly selected and invited for an individual semi-structured interview occurring in the following week. If an invitation was declined another participant was randomly selected from those remaining. For a relatively homogeneous sample, Guest *et al.* (2006) argue that 10 interviews should produce sufficient data to reach a point of saturation in terms of the reporting of new themes. Each interview, lasting between 30 and 60 minutes, was audio-recorded to enable subsequent analysis. The interviews were semi-structured, based around a question guide and followed the same general pattern.

7.7.2 Instruments

To provide structure and consistency to the interviews a question-guide was developed. Additionally, on the basis of responses provided by the interviewees, more specific prompts or queries were provided. The question guide (available in Appendix F) focused discussion on the following aspects of the participants' experiences:

1. Media use prior to commencing the study.
2. Expectations for the study.
3. Initial impressions and experiences of the intervention.
4. Experiences with meeting the target, in terms of:
    a) Obstructions to goal achievement.
    b) Enablers of goal achievement.
5. Perceptions of the intervention, in terms of:
    a) Attitudes to media use and media multitasking.
    b) Concentration, focus, and productivity.
6. Intentions to maintain or modify the intervention.

7.7.3 Analysis Procedures

To analyse the interview data a *Thematic Analysis* approach was adopted. Thematic analysis, as described by Braun and Clarke (2006), presents a method for identifying, analysing and reporting patterns present in qualitative data. Such patterns, termed themes, enable the clustering of recurring ideas, interpretations, and experiences around a central concept (Connelly and Peltzer, 2016). As the objective of the interview phase was to gain a comprehensive understanding of the participants' experiences, driven by both the overarching research questions, a deductive approach (see Boyatzis, 1998) to analysis was followed. Given the focus on the reality of the participants, a constructionist epistemology was adopted. The language participants used to recount their experiences was considered to be, largely, reflective of the reality experienced and the associated meanings attached to such experiences (Braun and Clarke, 2006). Meaning and experience are seen to be subjective and socially constructed. As Braun and Clarke (2006) suggest, themes were initially produced at a semantic level and, as the analysis progressed, the interpretation of the significance and implications of the themes imply that the data were, subsequently considered at a latent level.

The thematic analysis proceeded through six stages (the outcomes of which are provided in Chapter 8). In accordance with Braun and Clarke (2006), the first step involved the transcription of the audio-recordings into a textual format to be analysed through the RQDA R package (Huang, 2016). The second stage involved a process of coding. Codes, as defined by Boyatzis (1998, p. 63), represent "the most basic segment, or element, of the raw data or information that can be assessed in a meaningful way regarding the phenomenon". Codes are used to identify and cluster aspects of the data which may form the basis of themes. To guide the analysis a set of a priori codes (provided in Table 8.10 in Chapter 8) were developed on the basis of the research questions posed in the study. Following this, a process of open coding was conducted to further classify aspects of the data. Patterns in the codes were then identified as preliminary themes. The associated data were then reviewed to refine, combine or eliminate the themes. The resulting themes were compared to the transcriptions to assess the extent to which they reflect the experiences and interpretations recounted during the interviews. The penultimate stage involved specifying, in detail, the nature of each theme through a process of narrative definition. Finally, the sixth stage required identifying how the resulting themes enable the provision of a descriptive account of the participants' experiences. This involved, firstly, the selection of relevant data extracts and, secondly, the arrangement of these extracts in a manner conveying the narrative of the data.

7.8 Ethical Considerations

Prior to conducting any of the aforementioned procedures clearance was received from the relevant boards for ethical research standards. Additionally, as students were involved in this study, institutional permission was acquired. Despite the relatively low-risk of emotional or physical harm presented by the study procedures, a number of ethical challenges existed. Of particular relevance, were challenges associated with the monitoring of personal media use. A number of methods were employed to mitigate this challenge. First, participants' involvement in the study was entirely voluntary and conducted in full knowledge of the study procedures. Second, the option to withdraw from the study at any time was communicated throughout. Third, all media use data were reported by the participants themselves and not collected automatically. Fourth, no personally-identifiable information will be made publicly available. Finally, if, in the course of the study, it arose that a participant reported problems relating to the assessment procedures or the nature of the intervention, steps were taken to responsibly manage such situations.

7.9 Summary

Commencing with an overview of the research design this chapter described the method through which the second research objective of the study was addressed. At a high level Figure 7.2 provided a diagrammatic representation of the study and Table 7.1 provided an overview of the instruments used. A key aspect of this chapter was the description of the intervention to be assessed. The intervention was described as an application-supported behavioural intervention facilitating single-tasking and the reduction of smartphone-based media multitasking through the self-regulation of smartphone use. To assess the feasibility of this intervention a three-part design, consisting of a pre-screening phase, a pre/post experiment and an interview follow-up, was described. To outline the measures gathered in these assessments the details of the self-report, performance-based, and interview instruments were described. Additionally, to guide the assessment of efficacy, 11 hypotheses were specified.

Chapter 8

Analysis and Results

In this chapter, for each of the study phases, the analysis of the data collected and the results thereof are reported. In the first two sections, where applicable, results are reported in accordance with the *Consolidated Standards of Reporting Trials* (CONSORT) statement (Schulz *et al.*, 2010). In Section 8.1, through the description of the sample considered and the processes of selection and allocation, the outcomes of the pre-screening phase are presented. Next, in Section 8.2, the analysis of the data collected during the experimental assessment is reported. First, to provide an overview of intervention adherence, demand, and implementation, the participants' media use is described. Following this, the self-report and performance-based data before and after the intervention period are considered. Finally, the last section of the chapter reports the thematic analysis of the qualitative data collected during the post-intervention interviews.

8.1 Pre-Screening Outcomes

Over the two-week pre-screening period 202 complete and 25 incomplete responses were received (a completion rate of 88.90%). Incomplete responses were removed for all subsequent analyses. In the following sub-sections the characteristics and eligibility of the pre-screening sample are described. Following this, in Section 8.1.3 the calculation of the MMI-S is reported and, on this basis, the processes of sample selection and allocation to experimental groups are described.

8.1.1 Pre-Screening Sample Description

The sample considered in the pre-screening phase was broadly representative of the targeted university population. Respondents ranged from 18 to 37 years old and had a mean age of 20.45 years ($SD = 2.16$). Respondents were predominantly female, with 133 (65.84%) identifying as female, 68 (33.66%) identifying as male, and one (0.50%) choosing not to specify their gender. Consequently, relative to the target population, the sample slightly over-represented females. For population group, 98 (48.51%) respondents indicated White, 56 (27.72%) Coloured, 44 (21.78%) African/Black, and the remaining four (1.98%) respondents indicated 'Other'. While all participants could speak English, the sample was characterised by a variety of first languages spoken, with 115 (56.93%) predominantly speaking English, 50 (24.75%) Afrikaans, 19 (9.41%) Xhosa, four (1.98%) Zulu, nine (4.46%) other African languages, and five (2.48%) other European languages. Respondents' tertiary education experience ranged from a single year-in-progress to 10 years ($M = 1.98$, $SD = 1.44$). Specifically, 99 (49.01%) respondents were in their first year of study, 56 (27.72%) in their second year of study, 24 (11.88%) in their third year of study, and the remaining 23 (11.39%) had been studying for more than three years.

8.1.2 Pre-Screening Sample Eligibility

While respondents were informed of the eligibility criteria prior to the survey, as an eligibility check, questions were asked in relation to each criterion. Table 8.1 summarises the outcomes for these items. If a respondent answered 'no' for items 1, 2, or 3, or 'yes' for items 4, 5, 6, or 7 they were considered ineligible and excluded from further analysis. Of the 202 respondents who completed the survey, 42 (20.79%) were excluded based on their responses to these items, leaving a sample of $n = 160$ for the remaining procedures.

8.1.3 Study Participants

Having screened all respondents for eligibility, the next step involved selecting, firstly, an experimental sample and, secondly, allocating individuals within this sample to either a control or intervention group. In the following sub-sections the selection and allocation processes are outlined, followed by a description of the two experimental groups.

Table 8.1: Summary of responses to the eligibility questions.

Item	Criterion	Yes (n)	%	No (n)	%
1[a]	Student at Stellenbosch University	202	100.00	0	0.00
2[a]	Use the Android Mobile Operating System	172	85.15	30	14.85
3[a]	Use WhatsApp	202	100.00	0	0.00
4[b]	Use focus management applications	9	4.45	193	95.55
5[b]	Used psychostimulants	4	1.98	198	98.02
6[b]	Intended to use psychostimulants	7	3.47	195	96.53
7[b]	Diagnosed with an attention-related condition	5	2.48	197	97.52

[a] Respondents who indicated 'no' were excluded from any further procedures.
[b] Respondents who indicated 'yes' were excluded from any further procedures.

8.1.3.1 Participant Selection and Allocation

For all eligible respondents an MMI-S was calculated using Equation 3.1. Ranging from 0.00 to 3.00, the mean MMI-S was 1.84 ($SD = 0.65$). The MMI-S demonstrated good internal consistency ($Cronbach's\ alpha = 0.84$) and was marginally skewed to the left ($skewness = -0.28$). As with Baumgartner *et al.* (2017*a*), there was a moderate association between media use (represented by hours per day for the three primary media) and MMI-S ($r = 0.62, p < .01$).

To classify respondents based on their media multitasking tendencies the distribution of MMI-S scores was divided into terciles (T). With a mean of 1.10 ($SD = 0.35$), those whose scores fell in T_1 (MMI-S $<$ 1.50) were classified as LMMs ($n = 53$). The remaining respondents ($n = 107$) whose MMI-S scores fell in T_2 (1.50 $<$ MMI-S $<$ 2.17) and T_3 (MMI-S $>$ 2.17) were classified as HMMs ($M = 2.20$, $SD = 0.41$) relative to this sample. In accordance with the pre-specified eligibility criteria those classified as LMMs were considered ineligible for selection. With a mean age of 20.45 ($SD = 2.16$) the sample of eligible respondents included 73 (68.22%) females and 34 (31.78%) males. From this sample of 107 eligible respondents 68 individuals (44 female, 24 male) were randomly selected to receive invitations to participate in the second phase of the study (leaving 39 unselected). A random sequence was generated using the *randomizr* R package (Coppock *et al.*, 2018). Of the 68 participants initially selected and invited to participate, one declined participation, and seven did not respond. To make up the targeted sample size an additional eight participants were randomly selected from the remaining 39 potential participants. From this final sample, participants were randomly allocated to either an intervention group or a control group. Block randomisation of $size = 2$ was used to ensure equal sample sizes ($n = 34$) across the two conditions (an equal allocation ratio).

Table 8.2: Characteristics of the two experimental groups.

Group	MMI-S	Age	Study Year	Gender		Population Group			
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	M	F	A	W	C	O
Intervention ($n = 34$)	2.26 (0.42)	20.3 (1.47)	1.79 (0.98)	12	22	11	9	13	1
Control ($n = 34$)	2.21 (0.39)	20.4 (1.31)	2.12 (1.32)	8	26	9	13	11	1
Overall ($n = 68$)	*2.23 (0.40)*	*20.3 (1.39)*	*1.96 (1.16)*	*20*	*48*	*20*	*22*	*24*	*2*

Note. For gender: M = male, F = female. For population group: A = African/Black, W = White, C = Coloured, O = Other.

8.1.3.2 Experimental Groups

The random selection and allocation methods endeavoured to reduce any differences between the groups prior to the intervention. Table 8.2 summarises the characteristics of these groups before the baseline assessment. Notably, the sample include more females (70.58%) than males (29.42%). Three population groups (African/Black, White, and Coloured) were relatively evenly represented, while no members of the Asian/Indian population group participated. On average, participants had completed at least one year of university and were 20.32 ($SD = 1.39$) years old. Prior to the assessment no significant differences between the two groups existed.

8.1.3.3 Participant Flow

Figure 8.1 depicts the flow of participants through the study procedures. As noted, the selection process resulted in 31 eligible participants not being selected. Of the 68 participants allocated to the experimental groups, 62 participated in the baseline assessment. Six participants (five in the intervention group and one from the control group) withdrew from the study during the baseline procedure. Consequently, the experimental sample for which an intention to treat (ITT) was specified consisted of 62 individuals, with 29 in the intervention group and 33 in the control group. After the baseline sessions, in the intervention period, two further members of the intervention group withdrew from the study. These withdrawals occurred in the first week of the intervention period. Consequently, while they were considered in the ITT analysis, they were removed from the per-protocol analysis. Additionally, as they did not provide any usage data, these participants were not considered in this analysis. All 27 remaining participants in the intervention group attempted to adhere to the required behaviour changes over the course of the intervention period and attended the post-intervention assessment. One participant in the control group withdrew from the study during the intervention period. Unfortunately for the

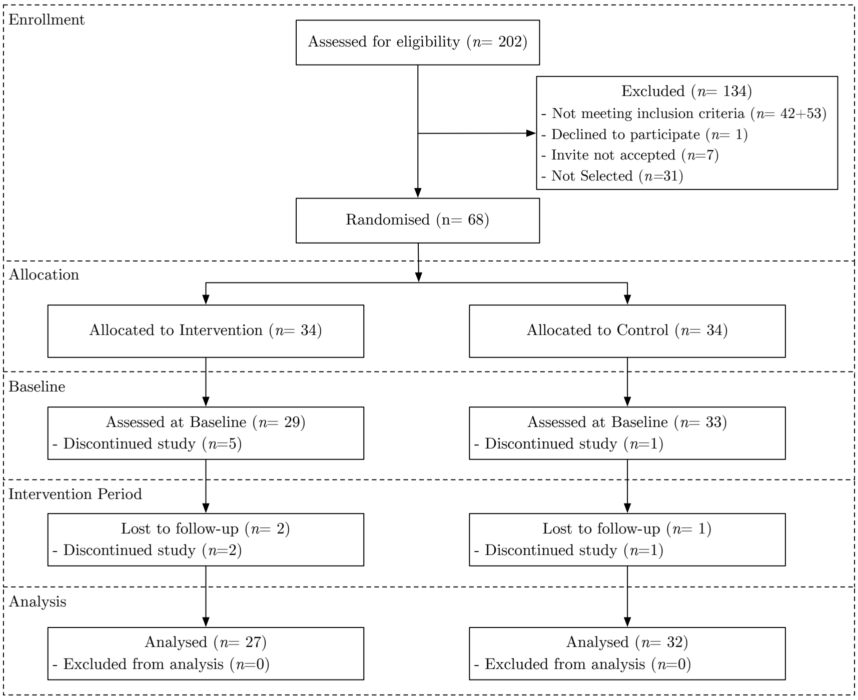

Figure 8.1: CONSORT flow diagram of participation in the experimental assessment.

assessment of feasibility, as they were not required to provide reasons for withdrawal, all three of these participants did not divulge their motivations for withdrawing. After these withdrawals, the final sample considered in the per-protocol analysis included 27 participants in the intervention group and 32 in the control group.

8.2 Experimental Assessment Analysis And Results

The analysis of the experimental assessment is presented in two sub-sections. In the first, findings concerning the intervention groups' media and application usage are presented and, in the second, statistical comparisons of everyday executive functioning and cognitive control before and after the intervention period are reported.

8.2.1 Intervention Adherence, Media And Application Usage

Throughout the intervention period three indicators of behaviour were collected from the participants in the intervention group: the total amount and time of daily phone use, the number of daily phone unlocks, and the number and nature of phone-restriction sessions. These measures provide an indication of intervention adherence and, to address RQ 1.1b, present a means of describing the participants' behaviour and experiences with the intervention. In the following sub-sections the analysis of the data gathered for each of these indicators is briefly reported.

8.2.1.1 Mobile Application Implementation Issues

Participants were asked to use a mobile application to support them in their self-regulation. While a majority of participants reported no issues with the application, in a few instances difficulties were acknowledged. Given the central role of the application in the support of the participants' efforts to self-regulate their media multitasking, acknowledging these difficulties is key for considering the feasibility of the intervention as proposed.

In the course of the first two days of the intervention-period four participants (14.81% of those in the intervention group) reported that the application was not correctly tracking their smartphone usage. For instance, one participant reported the following:

> *I seem to be having a few problems with the app. Despite having followed the setup instructions precisely, it does not seem to be tracking my phone usage. I've tried turning the phone usage tracker on and off and on again, tried making sure that my phone doesn't shut the app down in the background to conserve battery. The only thing I haven't done is reinstall the app in its entirety. I have been regulating my phone usage by myself, however.*

Similarly, a different participant reported the following:

> *I tried to send you yesterday's report but I think something went wrong because it says I've been on my phone for only 1 minute.*

Despite extensive troubleshooting these four participants were unable to receive reports on their daily usage through the application. All four did, however, wish to continue regulating their media use without the support of the application. For instance, one of these participants reported the following on day 20 of the intervention period:

> *The phone management has been going really well! I've been trying to use my phone as little as possible during the day and have been making an effort to single task when approaching my day-to-day activities.*

As these participants continued the self-regulation of their smartphone usage, focusing on single-tasking, they were retained in the analysis of the intervention group. They were, however, excluded from all analyses of the usage data. As was evident by the daily usage reports, no other participants experienced these difficulties with the application.

A further issue encountered during the course of the intervention period was experienced by only one participant. On two occasions they reported their usage spiking to over 60-minutes per hour for 20 hours. The participant reported the issue immediately on both occasions. For instance, the following message (along with a screen-capture) was received on day 14 of the intervention period:

> *Could you help/give advice please! Something is seriously wrong with the app today. This is impossible. I don't know what happened or what to do.*

The participant was instructed to restart their phone and clear the application's cache. This resolved the problem. It was again experienced on day 27 of the intervention period. The data from this participant for these two days were removed from the usage analysis.

While complete explanations for these malfunctions are not available, device-compatibility provides a key factor affecting the implementation dimension of feasibility. If an individual's device is not compatible with an application supporting self-regulation, whether this is due to an operating system error, settings mismatches, device faults, restrictions, or application errors, the implementation of such an intervention is hindered.

Another issue encountered during the intervention period, unrelated to technical malfunctions or incompatibilities, was the unfortunate theft of one participants' phone. Two days after the phone was stolen the following message was received from the participant:

> *Unfortunately my phone was stolen on Friday. I am temporarily using a different cellphone and this number until my previous number is sorted out in the week. I have downloaded the forest app and have used it today. Unfortunately Friday and Saturday's data will be unobtainable and I am very sorry for that.*

The data from these two days for this participant were not available to be considered. This incident presents a further indication of a class of factors that may hinder the implementation of an application-supported intervention. The unintentional loss or theft of a device can obstruct, firstly continuity of behaviour, secondly, support of self-regulation and, thirdly, consistency of data. While such factors are, of course, outside of the control of participants, experimenters or those who may wish to apply an intervention, their deleterious effects are worth noting, regardless.

8.2.1.2 Daily Phone Usage

Figure 8.2 depicts the mean daily phone usage over the 28-day intervention period. In the usage figures in this section a smoothed trendline is illustrated (as a dashed line), with the band indicating the 95% CI for the trend.[1] In Figure 8.2 the red dotted line at the 90th-intercept represents the daily usage target. Over the 28-day period, on average, participants used their devices for less than this targeted maximum ($M = 59.37$, $SD = 15.76$). The lowest average usage ($M = 34.85$, $SD = 20.58$) was recorded for day 19, the Friday before vacation, while the highest average ($M = 88.75$, $SD = 65.42$) was recorded for day eight, the second Monday of the intervention period. An independent samples t-test indicated that there was no significant difference between the mean for weekdays (57.17, SD=16.60) and weekends (59.18, $SD = 12.00$). The first 19 days of the intervention period fell during term time, while the next nine days fell during vacation. As indicated by an independent samples t-test, there was a significant difference in the average smartphone usage between term time ($M = 62.79$, $SD = 13.95$) and vacation ($M = 47.11$, $SD = 12.50$), with participants using their smartphones more in term time than in vacation ($t(17.52) = 2.99, p < .01, d = 1.16$). While the trendline supports the interpretation of this difference, it is evident in Figure 8.2 that there was considerable variation in the daily mean smartphone usage over the course of the 28-day period.

To consider participants' adherence to the specified usage target, and the degree to which the target was surpassed, the participants whose usage exceeded the target each day were isolated. On average, the target was exceeded by 2.7 participants ($SD = 1.5$) per day (10.9% of participants). The target was met by all participants on only three days (19, 23, 26), with the largest proportion of participants missing the target on day 11 (24%). As is evident in Table 8.3, the number of participants missing the target decreased over the course of the intervention-period. During the first 19 days (term time) an average of

[1] The locally weighed smoothing LOESS polynomial regression approach was adopted.

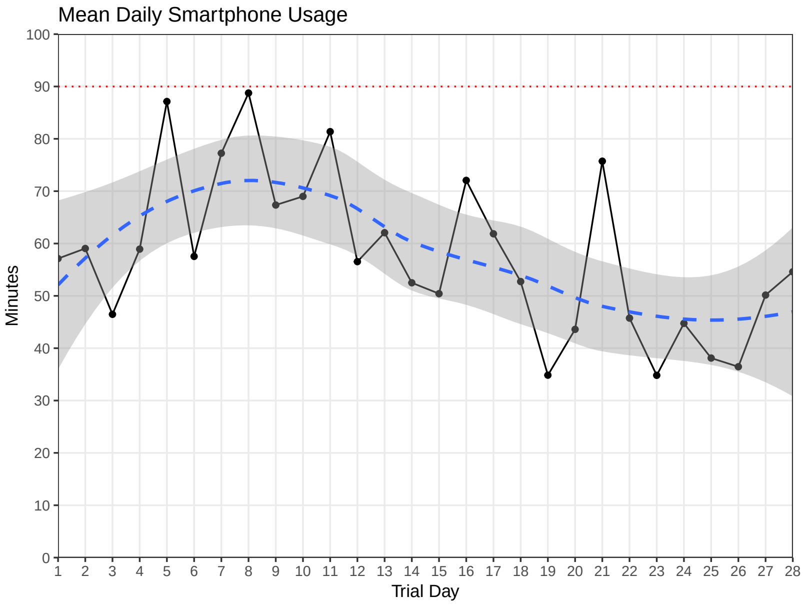

Figure 8.2: Daily smartphone usage for each of the 28 days of the intervention period.

3.05 ($SD = 1.54$) participants missed the target per day. During the vacation time (the next 9 days) an average of 1.11 participants ($SD = 0.93$) missed the target. The table further summarises the degree to which the target was missed, presenting both the mean and median minutes over the target, as well as the least and highest amount by which the target was surpassed. While the mean indicates that, on days where use exceeded the target, the target was breached by 35.2 minutes on average ($SD = 28.2$), given the outliers indicated in the *max* column, the median presents a more useful indication of the degree to which the target was exceeded. Considering this, on average, the target was exceeded by 15.9 minutes ($SD = 15.2$). To further understand this behaviour, the usage patterns for the individuals who exceeded the target were considered. Of the 27 participants in the intervention group, 15 reported usage greater than the target more than once, five only surpassed the target once and 12 (44.44%) always remained under the target. The median number of times a participant missed the target was 1.00. Two participants exceeded the target on 50% or more of the days in the intervention-period (16 days and 14 days respectively). For these participants, the mean daily usage was 108.86 minutes ($SD = 34.77$).

Considering the time of day for which this usage occurred, as represented in Figure 8.3, it is evident that smartphone usage peaked in the middle and end of the day. Over the course of a 24-hour day participants used their devices for a mean of 2.43 minutes ($SD =$

Table 8.3: Summary of smartphone usage target outcomes.

Day	Over	Amount Over			
	n	*M* (*SD*)	Median	Min	Max
1	3	9.33 (6.11)	8.0	4	16
2	4	25.50 (13.30)	24.0	12	42
3	1	5.00 (*na*)	5.0	5	5
4	2	22.50 (6.36)	22.5	18	27
5	3	121.00 (91.20)	134.0	24	205
6	2	43.50 (26.16)	43.5	25	62
7	5	63.60 (86.08)	22.0	5	209
8	5	77.80 (50.31)	71.0	13	154
9	3	64.33 (45.37)	46.0	31	116
10	3	77.33 (11.72)	82.0	64	86
11	6	38.50 (37.00)	20.5	7	92
12	2	47.00 (31.11)	47.0	25	69
13	4	42.75 (44.04)	31.5	4	104
14	3	25.33 (17.50)	25.0	8	43
15	1	7.00 (*na*)	7.0	7	7
16	5	36.00 (34.44)	45.0	2	83
17	3	15.33 (15.28)	12.0	2	32
18	3	22.00 (30.41)	7.0	2	57
19	0	*na*	*na*	*na*	*na*
20	1	13.00 (*na*)	13.0	13	13
21	3	70.67 (58.53)	53.0	23	136
22	1	27.00 (*na*)	27.0	27	27
23	0	*na*	*na*	*na*	*na*
24	1	25.00 (*na*)	25.0	25	25
25	1	5.00 (*na*)	5.0	5	5
26	0	*na*	*na*	*na*	*na*
27	1	45.00 (*na*)	45.0	45	45
28	2	21.00 (28.28)	21.0	1	41
M (*SD*)	*10.9 (6.0)*	*35.2 (28.2)*	*15.9 (15.2)*	*68.0 (15.2)*	*158.0 (58.5)*

1.51) per hour. When considering waking hours (between 06:00 and 00:00), the mean increases to 3.25 minutes per hour ($SD = 0.88$). To further understand participants' usage the 24-hour day was divided into three time periods: *early* (representing the hours between 00:00 and 08:00), *middle* (representing the hours between 08:00 and 16:00), and *late* (representing the hours between 16:00 and 00:00). An ANOVA indicated that the effect of day-time was large ($F(2, 21) = 52.67, p < .001, \eta_p^2 = 0.83$). Post hoc analyses using the *Holm-Bonferroni* adjustment indicated that usage was significantly higher in the middle ($M = 3.40$, $SD = 0.66$, $p < .001$) and late ($M = 3.37$, $SD = 0.79$, $p < .001$) periods, in comparison to the early period ($M = 0.52$, $SD = 0.44$). No significant difference between middle and late was present. However, as indicated by the dashed trend line in Figure 8.3, usage increased over the course of the day, peaking in the middle of the day and declining before a rise again at the end of the day.

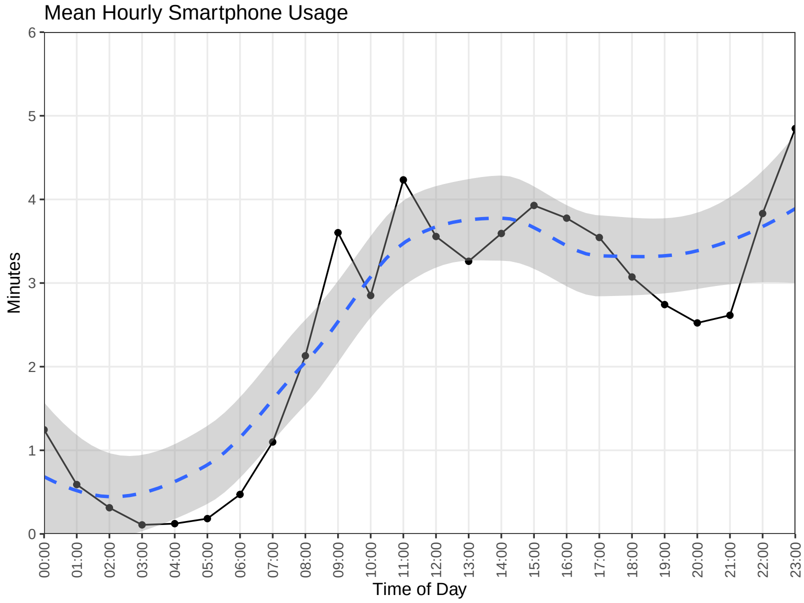

Figure 8.3: Hourly smartphone usage over the course of a 24-hour day during the intervention period.

The mean number of daily unlocks was 24.35 ($SD = 5.97$). Combining this with the usage data this implies a mean of 2.35-minutes of use per screen-unlock. As would be expected, daily screen-unlocks were associated with daily usage time ($r = 0.51, p < .05$). Figure 8.4 depicts the number of daily phone unlocks across the intervention period. As indicated by an independent samples t-test, the difference in usage between term ($M = 26.45$, $SD = 26.66$) and vacation (19.61, $SD = 20.53$) time was significant ($t(255.50) = 2.72, p < 0.01, d = .27$), with greater usage during term time. While no significant difference in overall usage between weekends and weekdays was found, the difference in screen unlocks between weekends ($M = 20.28$, $SD = 4.11$) and weekdays (25.98, $SD = 5.89$) was statistically significant ($t(18.58) = 2.91, p < .01, d = 1.04$).

8.2.1.3 Restriction Sessions

In addition to phone usage, participants shared reports on their use of the application's restriction session feature. The intervention did not explicitly require the use of this feature. Rather, in emphasising self-regulation, it was described as an option for operating to ensure goal-adherence. As is evident in Table 8.4, few participants used the feature. Of the 25 participants considered in this analysis 11 (44.0%) used the feature

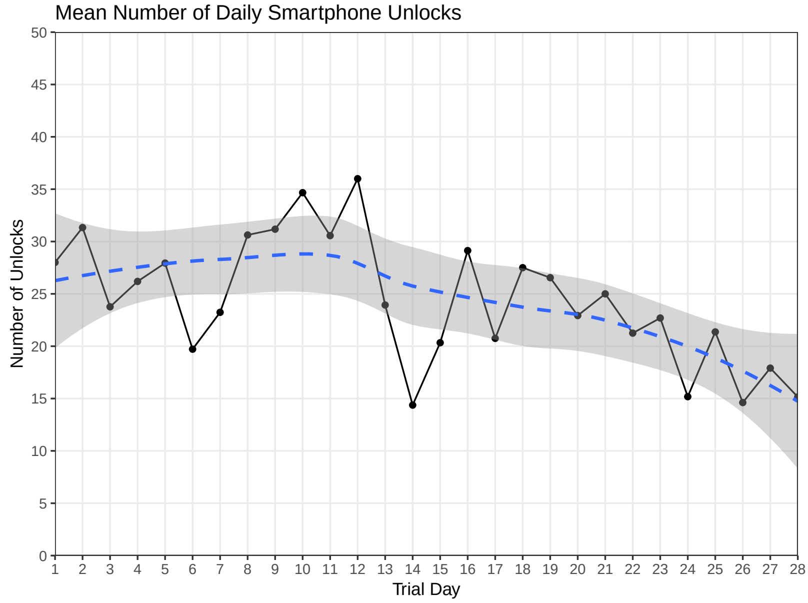

Figure 8.4: Daily smartphone unlocks for each of the 28 days of the intervention period.

at least once, with only two (8.0%) using it for more than 50% of the days considered. It is evident, therefore, that a majority of participants chose not to use this feature as a component of their self-regulation. For those who did use the feature, on average, it was used on 7.82 days ($SD = 6.54$), with two participants using it on only a single day and one participant using it on 21 days. Overall, 342 sessions were initiated, with 335 successful (97.95%). It is acknowledged that there exists the possibility of reporting bias in this regard, with participants reticent to disclose failed restriction sessions. For all participants, the mean number of sessions initiated was 13.68 ($SD = 39.64$). However, as indicated by the SD and the range of 194, this distribution is highly skewed ($skewness = 3.78$). Considering only those who used the feature, the mean number of sessions moves to 31.09 ($SD = 56.36$). This figure is affected by an outlier who used the feature 194 times ($M = 6.93$ per day). Consequently, the median presents a more useful summary of this behaviour. For those who used the restriction feature the median number of restriction sessions was 8.00.

Table 8.4 summarises the restriction sessions. Due to the low number of participants using the feature and the skewed distribution characterising this use, the median time restricted per day is reported. Additionally, the number of restriction sessions for which the goal was achieved (GA) and not achieved (GNA) are reported, along with the minimum and maximum time restricted and the IQR for this duration. A mean of 3.1 ($SD = 2.2$)

Table 8.4: Use of the restriction feature over the intervention period.

Day	Users	GA	GNA	Time Restricted			
	n	n	n	*Median*	*Min*	*Max*	*IQR*
1	9	29	0	45.00	25	300	110.00
2	6	27	0	50.00	20	435	222.50
3	6	23	0	40.00	20	455	76.25
4	6	15	1	52.50	40	139	60.00
5	3	9	0	100.00	40	110	35.00
6	2	11	0	172.50	45	300	127.50
7	4	14	1	85.00	20	235	106.25
8	4	9	0	70.00	25	120	61.25
9	3	3	0	35.00	25	45	10.00
10	4	14	1	55.00	30	299	82.25
11	4	9	0	67.50	25	100	53.75
12	3	21	0	120.00	30	500	237.50
13	3	4	0	45.00	30	58	14.00
14	5	18	0	72.00	45	240	70.00
15	4	12	0	52.50	15	238	89.50
16	3	32	3	90.00	45	743	349.00
17	5	15	0	50.00	30	300	30.00
18	3	8	0	100.00	45	120	37.50
19	2	13	1	201.50	60	343	141.50
20	1	4	0	120.00	120	120	0.00
21	0	0	0	0.00	*na*	*na*	*na*
22	1	21	0	517.00	517	517	0.00
23	1	8	0	240.00	240	240	0.00
24	1	8	0	240.00	240	240	0.00
25	0	0	0	0.00	*na*	*na*	*na*
26	1	2	0	60.00	60	60	0.00
27	0	0	0	0.00	*na*	*na*	*na*
28	2	6	0	90.00	60	120	30.00
M (SD)	3.1 (2.2)	11.96 (8.85)	0.3 (0.7)	110.8 (183.4)	73.7 (110.0)	255.1 (171.8)	77.8 (85.8)

Note GA = goal achieved and GNA = goal not achieved. Time restricted represents minutes.

participants used the restriction feature per day for 11.96 successful sessions (SD = 8.85). As indicated in Table 8.4, the number of participants using the feature decreased over the intervention period. Considering the four weeks of the intervention-period this trend becomes clear. In the first week 128 restriction sessions were completed (M = 18.29, SD = 7.98), in the second 78 were completed (M = 11.14, SD = 6.82), in the third 84 were completed (M = 12.00, SD = 10.28) and, in the fourth week only 45 sessions were completed (M = 6.43, SD = 7.30). For those who restricted their media use, the mean number of minutes restricted per session was 31.81 (SD = 7.93), and the median number of minutes restricted per participant per day was 60.

8.2.2 Comparisons Before and After The Intervention Period

To test the hypotheses specified in Section 7.6.3 data collected for the two experimental groups for both measurement paradigms during the baseline and post-intervention assessments were compared. The results of these comparisons are reported in two sub-sections. In Section 8.2.2.1, the data collected by means of the self-report scales are analysed and, in Section 8.2.2.2, the data collected with the performance-based tasks are analysed. Data analysis was conducted in *RStudio* using the R statistical programming language version 3.5.0. As noted in Section 7.5.2, a pre-specified significance level of $\alpha = 0.05$ was adopted for the null-hypothesis tests.[2] Additionally, given the discrepancies between the sample considered at baseline and the sample considered after the intervention period, both per-protocol ($n = 27$ intervention group; $n = 32$ control group) and ITT ($n = 29$ intervention group; $n = 33$ control group) analyses were conducted. The "last value carried forward" procedure for missing observations, as recommended by Montori and Guyatt (2001) was adopted to account for the participants who withdrew.

As noted in Section 7.6.4, hypothesis tests were conducted by means of ANCOVA statistical procedures, a form of general linear model.[3] A key assumption in such analyses is the independence of the factor-levels in the independent variable. This assumption was addressed through the study design (participants were randomly assigned to the experimental groups and no participant was in multiple groups). Any differences between the groups at baseline for the various assessments (used as covariates in the model) are artefacts of the randomisation (Keppel and Wickens, 2004). Additionally, in such analyses, the residuals of the model (the differences between the observations and the modelled values; Maxwell *et al.*, 1985) should be approximately normally distributed for each category of the independent variable. ANCOVA are, however, quite robust to violations of normality, with minimal effects on significance or power (Glass *et al.*, 1969; Olejnik and Algina, 1984). No assumption of normality is specified for the covariate or dependent variable(s). However, the relationship between the covariate and the dependent variable should be linear, at each level of the independent variable (for each group). Consequently, there should be homogeneity of regression slopes (Huitema, 2011). Additionally, ANCOVA assume homogeneity of variances (homoscedasticity) for the dependent variable. For each group and at all levels of the baseline outcomes there should be homogenous variances in the post-intervention outcomes. Finally, because the sample sizes of the two groups were unequal, *Type III Sums of Squares* were used for the ANCOVA.

[2] As is explained in Section 8.2.2.2 an adjustment is made to this α-level for each family of performance-based tasks.

[3] As a form of multiple regression, an ANCOVA is a linear model with one continuous covariate and one or more categorical predictor variables.

8.2.2.1 Self-report Scales

Seven hypotheses for the effect of the intervention on aspects of self-reported everyday executive functioning were specified. In the following sub-section, through the analysis of the data collected for each of the scales, these hypotheses are tested. Additionally, while no a priori hypothesis was specified, data for irrational procrastination were collected before and after the intervention and comparisons are reported here. This sub-section begins with the descriptive analysis of the data for all eight measures at both assessments. Thereafter, for each scale, analyses are reported.

Table 8.5 provides a summary of the outcomes for both groups for both assessments. Additionally, the table presents a combined summary of the outcomes for these assessments across both groups. While the analyses in the subsequent sections will consider both per-protocol and ITT samples, the summary is only provided for the data actually gathered at the second assessment. Consequently, it is a summary of the per-protocol outcomes. While allocation randomisation aimed to reduce any differences between the groups at baseline, separate independent-samples t-tests were conducted to compare the baseline outcomes for the control and intervention groups. No significant differences between the groups were found, indicating independence. Additionally, for both assessment sessions all self-report data were approximately normally distributed ($-0.37 < skewness < 0.66$). Considering the values presented in Table 8.5, it should be noted that, with the exception of the BSCS, a decrease from the baseline to the post-intervention assessment was hypothesised (for the BSCS an increase was hypothesised).

Pearson correlation coefficients among the scales were calculated and are presented in Table G.1 in Appendix G. All correlation coefficients, where significant, were moderate to large. Given the directions of the scales, as would be expected, the BSCS scores for both assessments were negatively correlated with the scores for all of the other scales. Of importance for the present analysis, baseline scores for each scale correlated with the relevant post-intervention scores. Consequently, the baseline scores are an appropriate covariate for the ANCOVA procedures. Additionally, internal consistency for each scale at each measurement period was assessed and is also reported in Table G.1. All scales demonstrated good internal consistency for the sample considered.

To test $H1_c$ and assess the effect of the intervention on **attention related cognitive errors (ARCES)** two separate ANCOVA were conducted. As depicted in Figure 8.5 ARCES outcomes for both groups decreased from the baseline (control: $M = 3.26$, $SD = 0.58$; intervention: $M = 3.28$, $SD = 0.60$) to the post-intervention assess-

Table 8.5: Summary of self-report measures from the baseline and post-intervention assessments for those who remained in the study.

Scale	Intervention Group		Control Group		Combined	
	Baseline	Post	Baseline	Post	Baseline	Post
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
ARCES[a]	3.28 (0.60)	2.94 (0.60)	3.26 (0.52)	3.15 (0.58)	3.27 (0.56)	3.05 (0.59)
MAAS-LO[b]	3.61 (0.61)	3.67 (0.62)	3.49 (0.72)	3.54 (0.78)	3.55 (0.67)	3.60 (0.70)
AC-S[a]	2.84 (0.81)	2.94 (0.89)	2.95 (1.13)	2.59 (1.09)	2.86 (0.98)	2.75 (1.01)
AC-D[a]	2.72 (0.84)	2.33 (0.79)	2.69 (1.01)	2.66 (1.02)	2.70 (0.93)	2.51 (0.93)
MW-S[a]	3.64 (0.82)	3.52 (0.98)	3.86 (0.99)	3.91 (0.87)	3.76 (0.92)	3.73 (0.93)
MW-D[a]	3.47 (0.83)	3.29 (1.06)	3.49 (0.91)	3.52 (0.87)	3.48 (0.87)	3.42 (0.96)
BSCS[a]	3.00 (0.57)	3.10 (0.42)	2.80 (0.63)	2.84 (0.55)	2.89 (0.61)	2.96 (0.51)
IPS[a]	3.15 (0.49)	3.16 (0.38)	3.20 (0.49)	3.17 (0.50)	3.17 (0.49)	3.17 (0.44)

[a] Scores range from 1 to 5, with a higher score representing greater failures of attention for ARCES, a greater degree of distractibility (AC-D) or a greater difficulty in switching attention between tasks (AC-S), a greater tendency to engage in intentional (MW-D) or unintentional mind wandering (MW-S), greater self-control (BSCS), or greater trait procrastination (IPS).
[b] Scores range from 1 to 6, with a higher score indicating a greater frequency of attentional lapses.

ment (control: $M = 3.15$, $SD = 0.56$; intervention: $M = 2.94$, $SD = 0.60$). As confirmed by *Levene's test*, the outcome variances were homogenous. Confirming the homogeneity of the regression slopes, the interaction between the baseline scores and the experimental group was not significant. There was no main effect of experimental group on post-intervention ARCES outcomes after controlling for baseline outcomes ($F(1, 56) = 1.86, p = .18, \eta_p^2 = .032$). The baseline scores were, however, a large and significant predictor of post-intervention values ($F(1, 56) = 50.73, p < .001, \eta_p^2 = .48$). For the ITT analysis, again, no main effect of experimental group on post-intervention ARCES outcomes after controlling for the baseline values was found ($F(1, 59) = 0.91, p = .34, \eta_p^2 = .015$).[4] Consequently, across both analyses, $H1_c$ was not supported.

Mindful Attentional Awareness Lapses (MAAS-LO) outcomes for both groups at both assessments are depicted in Figure 8.6. To test $H1_a$, and assess the effect of the intervention on lapses of mindful attentional awareness, two separate ANCOVA were conducted. First, to isolate any effect of the intervention, a per-protocol analysis was conducted. Next, to minimise biases resulting from withdrawal, an ITT analysis followed. As indicated in Figure 8.6, the MAAS-LO outcomes for both the control and the intervention groups increased from the baseline (control: $M = 3.49$, $SD = 0.72$; intervention: $M = 3.61$, $SD = 0.61$) to the post-intervention assessment (control:

[4] All other ANCOVA assumptions held true for this analysis.

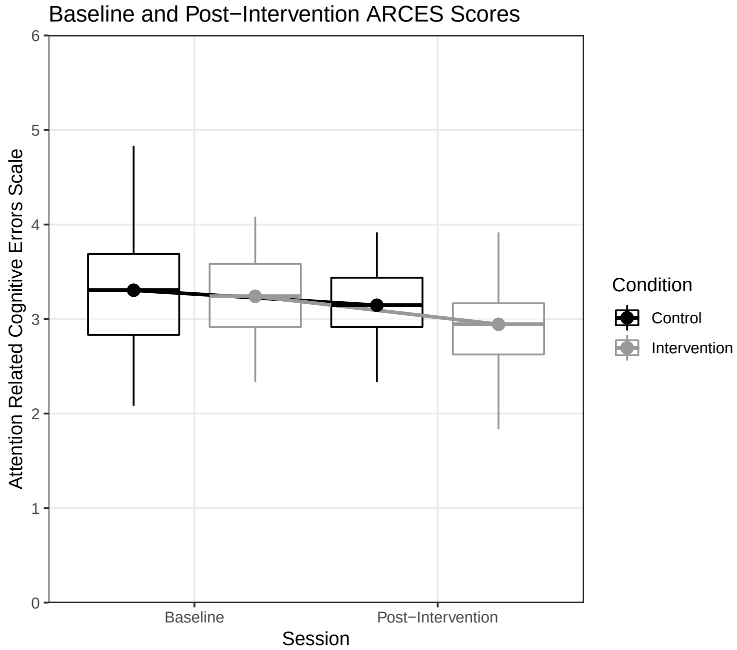

Figure 8.5: Per-protocol ARCES outcomes before and after the intervention period.

$M = 3.54$, $SD = 0.78$; intervention: $M = 3.67$, $SD = 0.62$). *Levene's test* indicated homogenous variances for the outcome across the study groups, satisfying this assumption. Confirming the homogeneity of the regression slopes, the interaction between the baseline scores and the experimental group was not significant. No main effect of experimental group on post-intervention MAAS-LO outcomes after controlling for baseline outcomes was found ($F(1, 56) = 0.159, p = .69, \eta_p^2 = .003$). The baseline scores were, however, a large and significant predictor of post-intervention outcomes ($F(1, 56) = 26.33, p < .001, \eta_p^2 = .320$). Accounting for all participants, the outcomes were analysed on an ITT basis and, as with the per-protocol analysis, no main effect of experimental group on post-intervention MAAS-LO scores after controlling for baseline scores was found ($F(1, 59) = 0.18, p = .67, \eta_p^2 = .003$).[5] Consequently, across both analyses, $H1_a$ was not supported.

For **self-control (BSCS)**, Figure 8.7 presents the outcomes for both groups at the baseline and post-intervention assessments. To determine if $H1_b$ held, and assess the effect of the intervention on self-control, two separate ANCOVA were conducted. For the per-protocol analysis the BSCS scores for both groups improved from baseline (control: $M = 2.80$, $SD = 0.63$; intervention: $M = 3.00$, $SD = 0.57$) to post-intervention

[5] All other ANCOVA assumptions held true for this analysis.

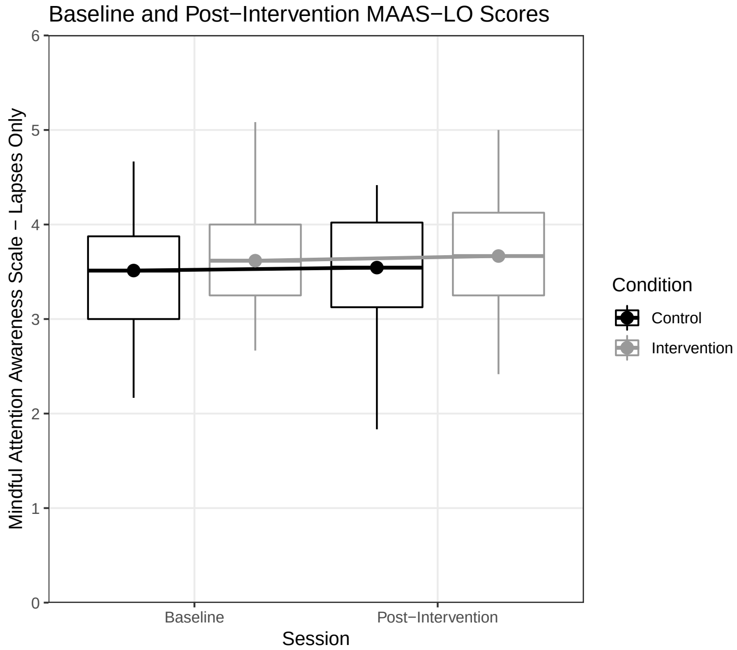

Figure 8.6: Per-protocol MAAS-LO outcomes before and after the intervention period.

assessment (control: $M = 2.84$, $SD = 0.55$; intervention: $M = 3.10$, $SD = 2.84$). *Levene's test* indicated homogenous outcome variances and, confirming the homogeneity of the regression slopes, the interaction between the baseline scores and the experimental group was not significant. No main effect of experimental group on post-intervention BSCS outcomes after controlling for baseline BSCS scores was found ($F(1, 56) = 0.99, p = .32, \eta_p^2 = .017$). Baseline scores were, however, a significant predictor of post-intervention outcomes ($F(1, 56) = 92.14, p < .001, \eta_p^2 = .622$). As was the case with the per-protocol analysis, no main effect of experimental group on post-intervention BSCS outcomes after controlling for baseline scores was found ($F(1, 59) = 0.44, p = .51, \eta_p^2 = .007$) in the ITT analysis.[6] Consequently, across both analyses, $H1_b$ was not supported.

To test $H1_d$, and assess the effect of the intervention on **attentional switching (AC-S)**, two separate ANCOVA were conducted. As indicated in Figure 8.8, for the per-protocol sample, outcomes for those in the intervention group increased slightly from baseline ($M = 2.84$, $SD = 0.81$) to post-intervention assessment ($M = 2.94$, $SD = 0.89$), while decreasing slightly from baseline ($M = 2.95$, $SD = 1.13$) to post-intervention assessment ($M = 2.59$, $SD = 1.09$) for the control group. *Levene's test* confirmed that the variances for the outcome were homogenous. Confirming the homogeneity of the

[6] All other ANCOVA assumptions held true for this analysis.

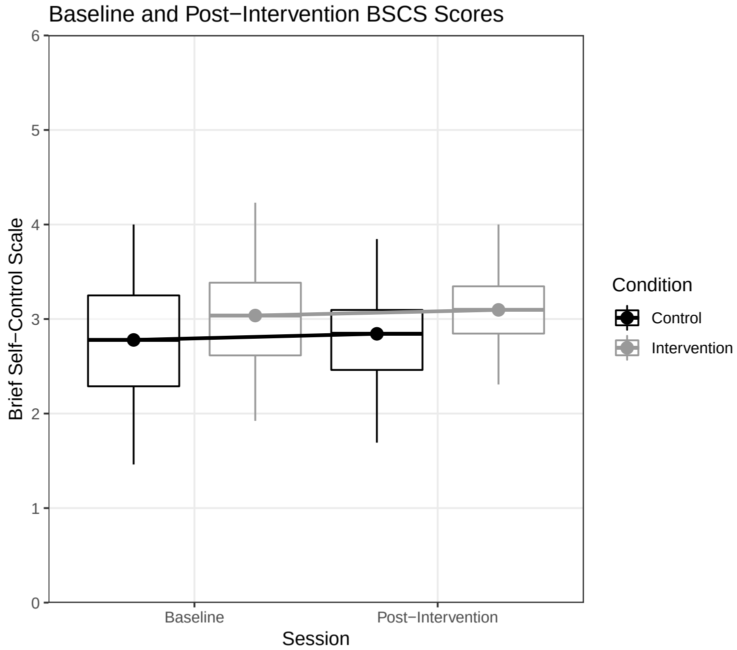

Figure 8.7: Per-protocol BSCS outcomes before and after the intervention period.

regression slopes, the interaction between the baseline scores and the experimental group was not significant. A main effect of experimental group on post-intervention AC-S scores after controlling for baseline scores was found ($F(1,56) = 5.30, p < .05, \eta_p^2 = .086$). While the effect size was small, controlling for the baseline, those in the intervention group reported greater difficulty shifting attention than those in the control group after the intervention period. Consequently, $H1_d$ was not supported. Additionally, the baseline values were found to be a large and significant predictor of post-intervention outcomes ($F(1,56) = 63.00, p < .001, \eta_p^2 = .529$). The ITT analysis corroborated the per-protocol analysis, finding a main effect of experimental group on post-intervention AC-S after controlling for baseline outcomes ($F(1,59) = 5.20, p < .05, \eta_p^2 = .081$).[7]

To test $H1_e$, and ascertain the effect of the intervention on **distractibility (AC-D)** two separate one-way ANCOVA were conducted. For the per-protocol analysis, as indicated in Figure 8.9, the AC-D scores for both groups decreased from the baseline (control: M = 2.69, SD = 1.01; intervention: M = 2.72, SD = 0.84) to the post-intervention assessment (control: M = 2.66, SD = 1.02; intervention: M = 2.33, SD = 0.79). The improvement for the intervention group was greater than that of the control group. *Levene's test* confirmed that the variances for the outcome were homogenous across

[7] All other ANCOVA assumptions held true for this analysis.

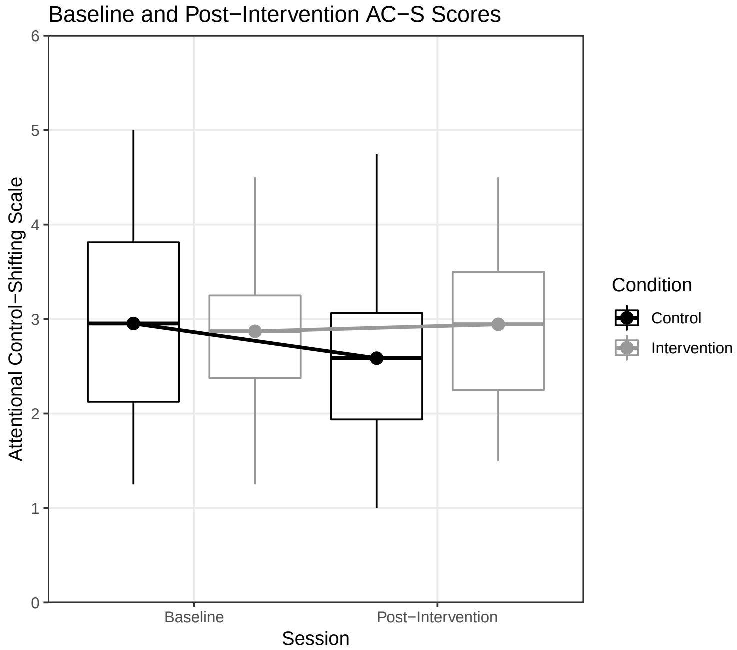

Figure 8.8: Per-protocol AC-S outcomes before and after the intervention period.

the groups and the non-significance of the interaction between the baseline scores and the experimental group confirmed the homogeneity of the regression slopes. Despite the change in scores following the intervention-period, the ANCOVA indicated no main effect of experimental group on post-intervention AC-D values after controlling for baseline outcomes ($F(1, 56) = 3.34, p = .07, \eta_p^2 = .056$). $H1_e$, consequently, was not confirmed. The baseline scores were, however, a significant predictor of post-intervention scores ($F(1, 56) = 40.40, p < .001, \eta_p^2 = .419$). This analysis was followed by the ITT analysis which, again, found there to be no main effect of experimental group on post-intervention AC-D scores after controlling for baseline scores ($F(1, 59) = 3.15, p = .08, \eta_p^2 = .051$).[8]

To test $H1_f$, and assess the effect of the intervention on **spontaneous mind-wandering (MW-S)** two separate ANCOVA were conducted. For the per-protocol analysis, Figure 8.10 depicts the outcomes for both groups. For the intervention group MW-S outcomes decreased from baseline (M = 3.64, SD = 0.82) to post-intervention assessment (M = 3.52, SD = 0.98), while increasing from baseline (M = 3.86, SD = 0.99) to post-intervention assessment (M = 3.91, SD = 0.87) for the control group. *Levene's test* confirmed the outcome variance homogeneity, while the non-significance of the interaction between the baseline scores and the experimental group confirmed the homogeneity of

[8] All other ANCOVA assumptions held true for this analysis.

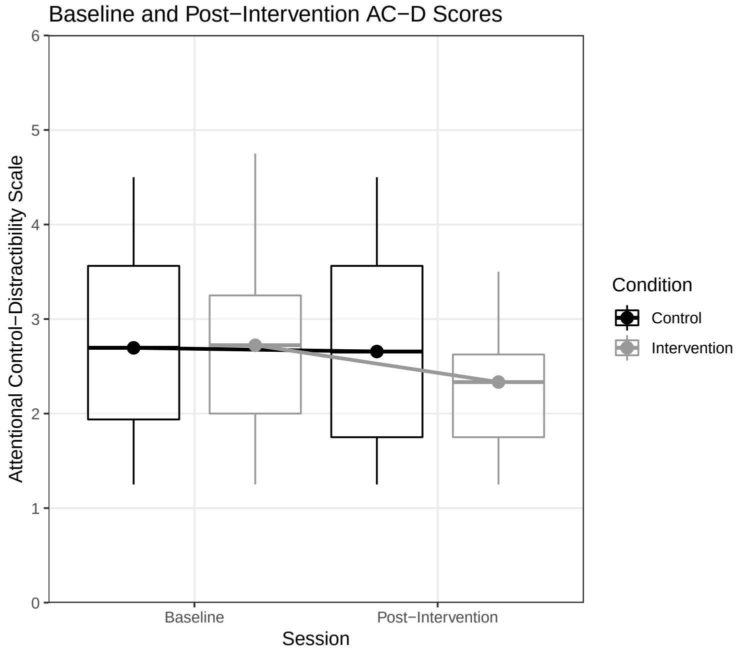

Figure 8.9: Per-protocol AC-D outcomes before and after the intervention period.

the regression slopes. No main effect of experimental group on post-intervention MW-S outcomes after controlling for the baseline was found ($F(1, 56) = 1.66, p = .20, \eta_p^2 = .029$). Consequently, $H1_f$ was not supported. The baseline scores were shown to be a significant predictor of post-intervention outcomes ($F(1, 56) = 91.81, < 0.001, \eta_p^2 = .621$). In the same manner as the per-protocol analysis, in the ITT analysis, no main effect of experimental group on post-intervention MW-S outcomes after controlling for the baseline was found ($F(1, 59) = 1.66, p = .20, \eta_p^2 = .029$).[9]

To test $H1_g$, and determine the effect of the intervention on **deliberate mind-wandering (MW-D)** two separate ANCOVA were conducted. For the per-protocol analysis, as depicted in Figure 8.11, deliberate mind-wandering for the intervention group decreased from the baseline ($M = 3.47$, $SD = 0.83$) to the post-intervention assessment ($M = 3.29$, $SD = 1.06$), while MW-D outcomes for the control group increased from the baseline ($M = 3.49$, $SD = 0.91$) to the post-intervention assessment ($M = 3.52$, $SD = 0.87$). *Levene's test* confirmed the homogeneity of the outcome variances for both groups. The interaction between the baseline scores and the experimental group was not significant, confirming the homogeneity of the regression slopes. Despite the change in scores, no main effect of experimental group on post-intervention MW-D outcomes after control-

[9] All other ANCOVA assumptions held true for this analysis.

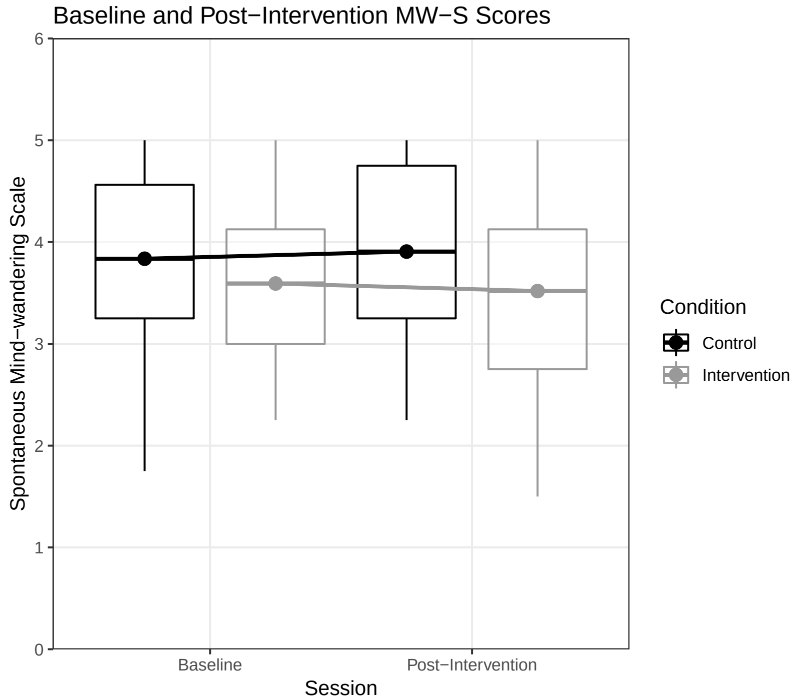

Figure 8.10: Per-protocol MW-S outcomes before and after the intervention period.

ling for baseline outcomes was found ($F(1, 56) = 0.95, p = .33, \eta_p^2 = .017$). On this basis, $H1_g$ was not supported. The baseline MW-D did, however, significantly predict post-intervention outcomes ($F(1, 56) = 81.63, p < .001, \eta_p^2 = .593$). The same pattern of change in MW-D outcomes was observed for the ITT analysis. Similarly, no main effect of experimental group on post-intervention MW-D outcomes after controlling for the baseline was found ($F(1, 59) = 0.81, p = .37, \eta_p^2 = .014$).[10]

Finally, following this confirmatory analysis, the effect of the intervention on **irrational procrastination (IPS)** was considered. No explicit a priori hypothesis for an effect of the intervention on procrastination was provided, implying that the analysis was exploratory. Figure 8.12 depicts the procrastination outcomes for both groups at both assessments. As confirmed by an independent samples t-test, no differences were found between the groups at baseline. Moreover, as indicated by an ANCOVA, no main effect of group on post-intervention outcomes for procrastination (after accounting for baseline values) was found ($F(1, 56) = 0.17, p = 0.68, \eta_p^2 = 0.003$).[11]

[10]All other ANCOVA assumptions held true for this analysis.

[11]This exploratory analysis was only conducted on a per-protocol basis. Additionally, as with all previous analyses, all assumptions for the ANCOVA were satisfied.

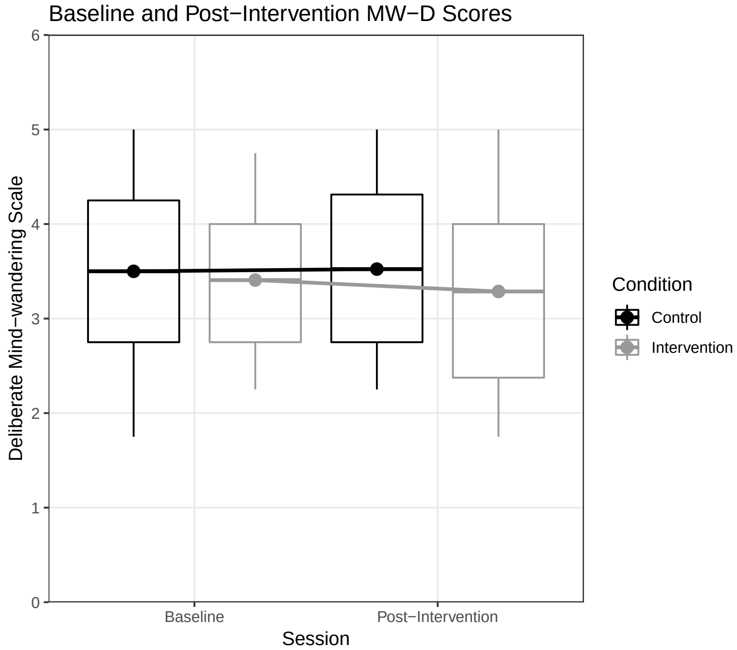

Figure 8.11: Per-protocol MW-D outcomes before and after the intervention period.

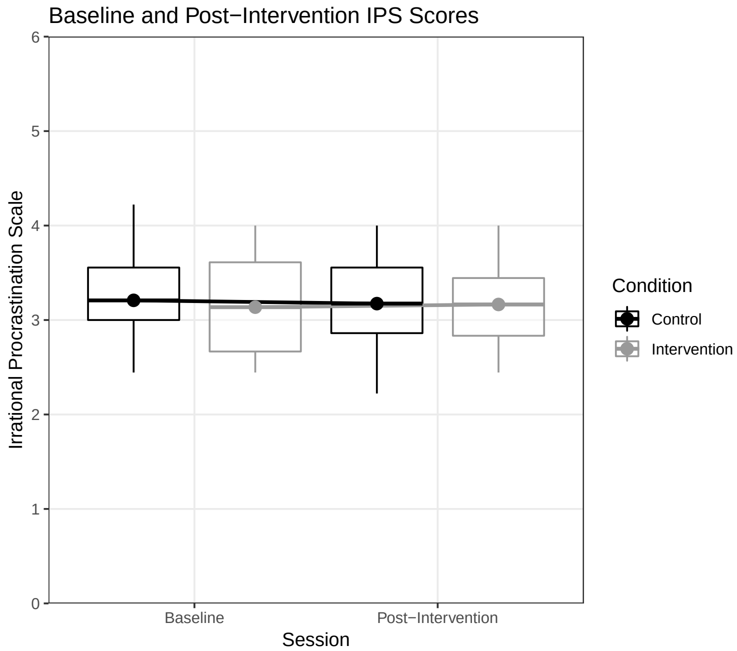

Figure 8.12: Per-protocol IPS outcomes before and after the intervention period.

8.2.2.2 Performance-Based Assessments

In the following sub-section, through analysis of the data collected for each of the performance-based tasks, the hypotheses for the effect of the intervention on aspects of cognitive control are evaluated. As noted previously, a pre-specified significance level of $\alpha = 0.05$ was adopted for all hypothesis tests. Additionally, for each task, where multiple metrics were considered, a separate *Holm-Bonferroni* adjustment was made to this significance level. Consequently, as in previous studies in this regard (e.g., Ralph *et al.*, 2014), results are described at both an unadjusted level of significance and at the more conservative, adjusted level of significance where necessary. For tasks involving RTs, to minimise the effect of outlying RTs due to aberrant key presses, as is necessary in ANCOVA, a winsorizing method (Tabachnick and Fiddell, 1996) was applied. As was the case in Murphy *et al.* (2017), RTs three or more SDs from the mean for each participant were adjusted to this cut-off value. To follow, for each task, the data collected at each assessment are described before testing the specific hypotheses with separate ANCOVA. Importantly, while multiple metrics are provided for each task, only certain metrics (indicated in the respective sections) are considered in the hypothesis testing.

Working Memory (N-back task) was assessed by three metrics: *hits* (H), *false alarms* (FA), and *omissions* (O) at two cognitive loads (2-back and 3-back). As metrics of WM performance, hits and false alarms are of primary interest. Table 8.6 provides a description of these metrics, at each cognitive load and assessment. In this analysis, data from three participants were removed due to significantly aberrant responses (false alarms 5 SDs above the mean). These outcomes indicate a misunderstanding of the task. To consider the within-subject effect of cognitive load on these metrics, separate paired t-tests were conducted. There was a significant but negligible effect of cognitive load on hits ($t(5663) = 6.50, p < .001, d = .08$) and false alarms ($t(5663) = 5.42, p < .001, d = .07$), such that, at a higher cognitive load, participants made less hits and false alarms. There was no effect of cognitive load on omissions. These outcomes are commensurate with Ralph (2017). As indicated by separate independent-samples t-tests, at baseline, no significant differences between the groups were present.

Hits, representing the proportion of targets correctly identified as targets, were considered at two cognitive loads. As indicated in Table 8.6 and depicted in Figure 8.13, for the 2-back, changes for both groups from the baseline (control: $M = 0.73$, $SD = 0.13$; intervention: $M = 0.65$, $SD = 0.20$) to the post-intervention assessment (control: $M = 0.72$, $SD = 0.15$; intervention: $M = 0.64$, $SD = 0.22$) were negligible. Similarly, at

Table 8.6: N-back metrics at both assessments for each group and overall.

Load	Metric	Intervention Group		Control Group		Combined	
		Baseline	Post	Baseline	Post	Baseline	Post
		M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
2-Back	*H*	0.65 (0.20)	0.64 (0.22)	0.73 (0.13)	0.72 (0.15)	0.69 (0.17)	0.68 (0.19)
	FA	0.20 (0.07)	0.17 (0.06)	0.21 (0.07)	0.17 (0.06)	0.21 (0.07)	0.17 (0.06)
	O	0.03 (0.04)	0.01 (0.01)	0.02 (0.02)	0.01 (0.01)	0.02 (0.03)	0.01 (0.01)
3-Back	*H*	0.48 (0.20)	0.48 (0.22)	0.50 (0.19)	0.50 (0.22)	0.49 (0.20)	0.49 (0.22)
	FA	0.13 (0.06)	0.13 (0.08)	0.13 (0.07)	0.11 (0.06)	0.13 (0.06)	0.12 (0.07)
	O	0.02 (0.02)	0.02 (0.05)	0.02 (0.02)	0.01 (0.01)	0.02 (0.02)	0.01 (0.03)

Note. For metric: H = Hits, FA = False Alarms, and O = Omissions.

3-back, while the SDs of the outcomes differed, the mean proportion, for both groups, at baseline (control: $M = 0.50$, $SD = 0.19$; intervention: $M = 0.48$, $SD = 0.20$) and post-intervention assessment (control: $M = 0.50$, $SD = 0.22$; intervention: $M = 0.48$, $SD = 0.22$) did not. Nonetheless, four separate ANCOVA were conducted (one for per-protocol and ITT at each cognitive load) to determine the effect of study group on post-intervention hits, after accounting for baseline hits. At both the 2-back and 3-back cognitive loads the homogeneity of outcome variances for both groups was confirmed by *Levene's test*. For the 3-back task the homogeneity of regression slopes was confirmed by testing the interaction term for 3-back hits at baseline and the group. For the 2-back task, however, the interaction term was significant ($F(1, 52) = 5.49, p < .05$). Therefore, because the homogeneity of regression slopes assumption was violated, for the 2-back hits analysis, an ANCOVA model was not appropriate. To account for this interaction a multiple regression model was produced.

For 3-back hits, after accounting for the baseline, the ANCOVA indicated there to be no main effect of group ($F(1, 53) = 0.079, p = .78, \eta_p^2 = .001$). Baseline hits were, however, a significant predictor of post-intervention hits ($F(1, 53) = 17.04, p < .001, \eta_p^2 = .243$). For 2-back hits a significant regression equation was found ($F(3, 52) = 10.32, p < .001$), with an R^2 of 0.37. It was found that baseline hits ($\beta_1 = 0.52, p < .001$), group ($\beta_2 = -0.22, p < .05$), and the interaction between baseline and group ($\beta_3 = 0.30, p < .05$) were all significant predictors of post-intervention 2-back hits. Considering the coefficient for group, it is evident that post-intervention hits, for those in the intervention group, were predicted to be 0.22 lower than for those in the control group. Despite this, a greater change in post-intervention hits was attributable to baseline outcomes (0.52). Moreover, as indicated by the interaction coefficient in the model, for those in the control group, hits were, on average 0.08 greater than those in the intervention group,

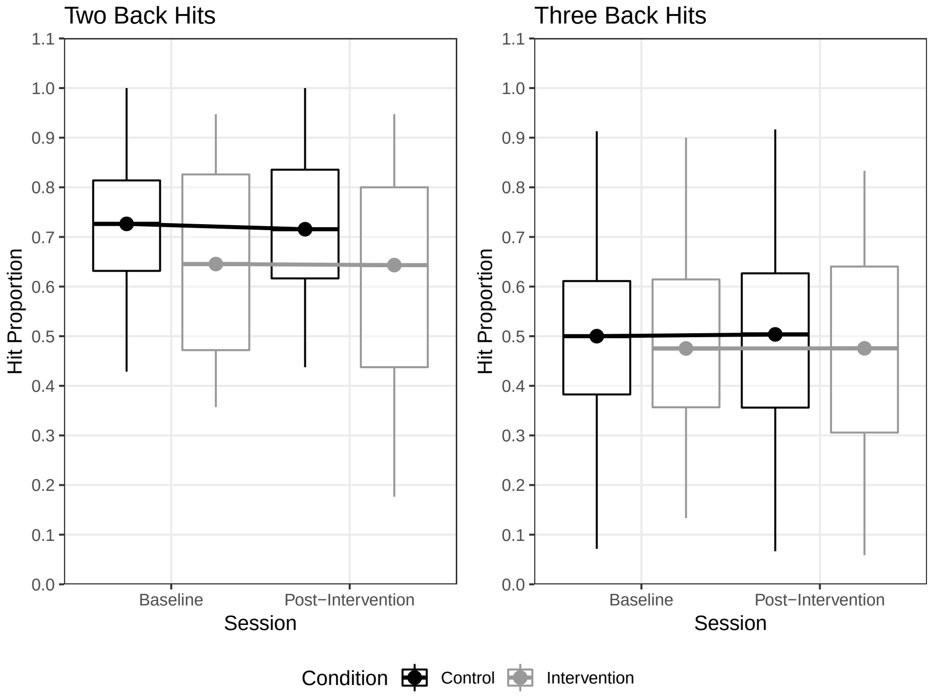

Figure 8.13: Two back and three back hits before and after the intervention period.

at both assessments ($\beta_3 + \beta_2$). Despite the significant effect of group in this regard (on both baseline and post-intervention assessments), because of the increased likelihood of family-wise errors, the *Holm-Bonferroni* adjustment was applied to the group outcome for the 2-back condition. Consequently, following this adjustment the effect was no longer significant ($p = .08$). Overall, the outcomes for hits do not support $H2_a$. Following this, the ITT analysis further indicated no significant effect of group on hits at either 2-back ($F(1,56) = 0.49, p = .62, \eta_p^2 = .017$) or 3-back ($F(1,56) = 0.05, p = .95, \eta_p^2 = .002$).[12]

As with hits, false alarms were considered at two cognitive loads. As indicated in Figure 8.14, at 2-back, false alarms for both groups were greater at baseline (control: $M = 0.21$, $SD = 0.07$; intervention: $M = 0.20$, $SD = 0.07$) than at the post-intervention assessment (control: $M = 0.17$, $SD = 0.06$; intervention: $M = 0.17$, $SD = 0.06$). At 3-back, on average, scores were the same at both assessments for the intervention group (baseline: $M = 0.13$, $SD = 0.06$: post-intervention: $M = 0.13$, $SD = 0.07$) and, for the control group, greater at baseline ($M = 0.13$, $SD = 0.07$) than at the post-intervention assessment ($M = 0.11$, $SD = 0.06$). For both cognitive loads *Levene's test* confirmed the homogeneity of variances. Similarly, the non-significance of the interac-

[12]In the ITT analysis all relevant assumptions for the analysis held true.

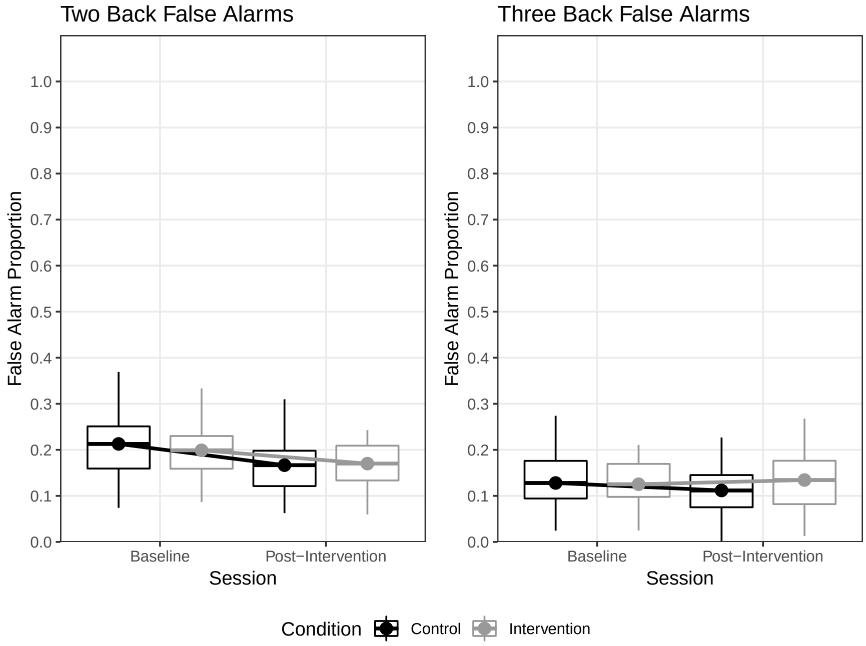

Figure 8.14: Two and three back false alarms before and after the intervention period.

tion term confirmed the homogeneity of the regression slopes for both assessments. In the 2-back condition, after controlling for baseline outcomes, no main effect of group on post-intervention false alarms was found (($F(1,53) = 0.07, p = .79, \eta_p^2 = .001$). Moreover, baseline outcomes for false alarms were not a significant predictor of post-intervention false alarms ($F(1,53) = 0.53, p = .47, \eta_p^2 = .010$). As was the case in the 2-back condition, no main effect of group on post-intervention false alarms was found in the 3-back condition ($F(1,53) = 1.62, p = .21, \eta_p^2 = .030$). Similarly, no effect of baseline false alarms on post-intervention false alarms in the 3-back condition was found ($F(1,53) = 1.26, p = .27, \eta_p^2 = .023$). Considering these outcomes in conjunction with the outcomes for hit proportions, $H2_a$ cannot be confirmed. Additionally, after analysing the false alarm data from an ITT perspective, no effect of group on post-intervention false alarms for either 2-back ($F(1,56) = 0.26, p = .77, \eta_p^2 = .009$) or 3-back ($F(1,56) = 1.13, p = .33, \eta_p^2 = .039$) conditions was found.[13]

Cognitive Inhibition was assessed with the **Flanker task** through two metrics: the flanker congruency effect (FCE) and the response accuracy represented by an inverse efficiency score (IES). As Murphy *et al.* (2017) note, when considering RTs, only correct responses are included. Table 8.7 presents a summary of these metrics. Additionally,

[13] All other relevant assumptions for the analysis held true.

while the overall IES and RT ratio are of interest, the IES and RTs for both congruent and incongruent trials are also presented in this table. For the RTs the winsorizing procedure resulted in the replacement of 2.33% of trials at baseline and 2.21% at the post-intervention assessment. In addition to this, data for five participants for this task were removed from the analysis due to notably aberrant responses (an overall error-rate five SDs greater than the mean and RTs close to the maximum possible). For the RT data, three separate independent-samples t-tests were conducted to compare the baseline outcomes for the groups. While significant differences existed between the groups at baseline for congruent RTs ($t(73.86) = -2.34, p < .05$), no significant differences existed for incongruent RTs or the overall FCE. For IES data, only the difference for incongruent trials were statistically significant at baseline ($t(54.15) = -2.47, p < .05$).

Figure 8.15 depicts the key outcomes of interest for the per-protocol analysis. As is evident, for both groups, changes in the FCE were negligible. *Levene's test* confirmed the homogeneity of the outcome variances for both groups, while the non-significance of the interaction between the baseline and the group confirmed the homogeneity of the regression slopes. As would be expected given the outcomes provided in Table 8.7 no main effect of experimental group on post-intervention FCEs, after controlling for baseline FCEs, was found ($F(1, 51) = 0.12, p = .72, \eta_p^2 = .002$). Baseline FCEs were, however, a significant predictor of post-intervention outcomes ($F(1, 51) = 21.28, p < .001, \eta_p^2 = .294$). This outcome was supported when the analysis was conducted on an ITT basis (main effect of group: $F(1, 54) = 0.31, p = .73, \eta_p^2 = .012$).[14]

For the IESs, both groups indicated greater efficiency in the post-intervention assessment (control: $M = 524.05\ ms$, $SD = 41.61$; intervention: $M = 577.51\ ms$, $SD = 107.51$) than in the baseline assessment (control: $M = 561.78\ ms$, $SD = 71.43$; intervention: $M = 591.91\ ms$, $SD = 93.44$). *Levene's test* indicated significant heterogeneity of the outcome variances ($F(1, 52) = 6.08, p < .05$). To correct for this heteroscedasticity, as recommended by MacKinnon and White (1985) and Long and Ervin (2000), the ANCOVA tests were based on a heteroscedasticity consistent covariance matrix (HCCM). Specifically, given the sample size, the HC3 estimator, proposed by MacKinnon and White (1985) and supported by Davidson and MacKinnon (1993), was employed. The interaction between the baseline outcome and the group confirmed the homogeneity of the regression slopes. No main effect of experimental group on post-intervention IESs, after controlling for baseline IESs, was found ($F(1, 51) = 3.47, p = .068, \eta_p^2 = .081$). As with FCEs, the baseline IESs were a significant predictor of post-intervention IESs

[14] All other relevant assumptions for the analysis held true.

Table 8.7: Flanker metrics at both assessments for each group and overall.

Metric	Intervention Group		Control Group		Combined	
	Baseline	Post	Baseline	Post	Baseline	Post
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Congruent RT	619.34 (85.99)	578.60 (74.59)	583.84 (63.14)	543.64 (42.92)	598.30 (75.00)	557.88 (60.15)
Incongruent RT	534.91 (88.86)	505.04 (69.01)	506.72 (68.74)	474.07 (48.85)	518.20 (78.42)	486.68 (59.60)
FCE	0.86 (0.05)	0.87 (0.05)	0.87 (0.05)	0.87 (0.05)	0.86 (0.05)	0.87 (0.05)
Congruent IES	676.73 (169.00)	614.36 (77.25)	612.07 (63.33)	583.81 (48.00)	639.11 (123.03)	596.25 (62.93)
Incongruent IES	537.04 (92.07)	513.89 (69.28)	512.92 (71.82)	479.75 (48.87)	522.75 (81.15)	493.66 (59.97)
Overall IES	591.91 (93.44)	577.51 (107.51)	561.78 (71.43)	524.05 (41.61)	574.06 (81.65)	545.83 (79.35)

Note. For metric: FCE = Flanker congruency effect; IES = Inverse efficiency score.

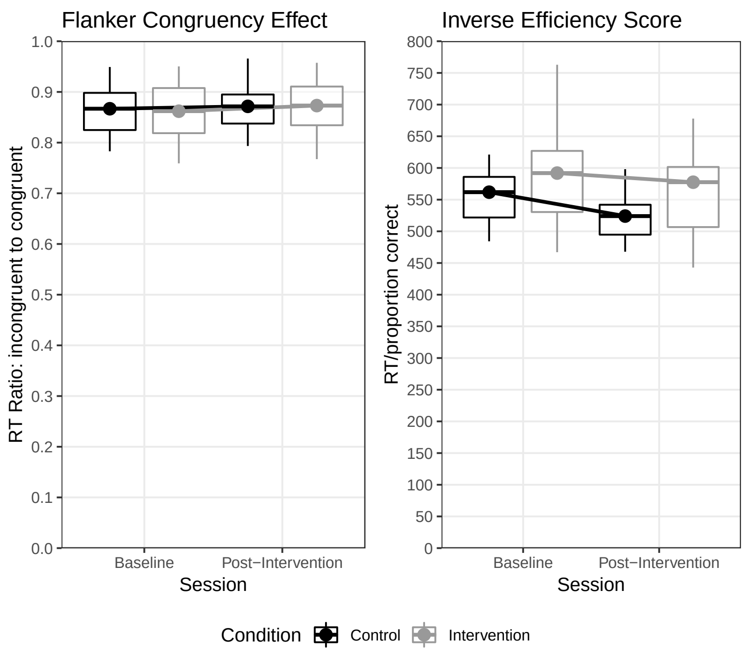

Figure 8.15: FCE and IES before and after the intervention period.

$(F(1,51) = 25.46, p < .001, \eta_p^2 = .225)$. Given the absence of support for both metrics under consideration (IES and FCE), $H2_b$ was not confirmed. This analysis was followed by the ITT analysis. As with the per-protocol analysis, *Levene's test* indicated significant heterogeneity of the outcome variances. Therefore, the ANCOVA tests were also based on a HCCM. Corroborating the per protocol analysis, the ITT analysis found no main effect of group on post-intervention IESs $(F(1,54) = 2.04, p = .14, \eta_P^2 = .071)$.[15]

Sustained Attention (SART) was assessed by two metrics, each with two components:

[15] All other relevant assumptions for the analysis held true.

Table 8.8: SART metrics at both assessments for each group and overall.

Metric	Intervention Group		Control Group		Combined	
	Baseline	Post	Baseline	Post	Baseline	Post
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
SART errors	22.5 (7.60)	24.0 (6.38)	21.3 (8.16)	23.0 (8.02)	21.87 (7.86)	23.47 (7.27)
Error proportion	0.54 (0.18)	0.57 (0.15)	0.51 (0.19)	0.55 (0.19)	0.52 (0.19)	0.56 (0.17)
Go RT	324 (27.3)	308.52 (27.85)	317 (35.5)	304.98 (40.15)	320.37 (31.84)	306.60 (34.82)
Go RT variability	0.19 (0.07)	0.23 (0.09)	0.19 (0.08)	0.23 (0.12)	0.19 (0.07)	0.23 (0.10)

SART errors (absolute number and proportion) and *RT to Go stimuli* (mean RT and RT variability). Of primary interest are RT variability and error proportion. Table 8.8 provides a description of these metrics, at each assessment stage, for each group and overall. Considering the error proportions, it is evident that participants in both groups at both assessments made errors on approximately 50% of 'Go' trials, indicating drifts of attention from the primary task in these trials. This outcome corresponds with previous studies in this regard (e.g., Cheyne *et al.*, 2006; Ralph, 2014). Correlational analyses at baseline indicated that SART errors were positively associated with RT variability ($r = .72, p < .001$) and negatively associated with mean RT to go stimuli ($r = -0.72, p < .001$), outcomes commensurate with previous studies (e.g., Yildirim, 2017; Seli *et al.*, 2013; Ralph, 2014). Separate independent-samples t-tests indicated that there were no significant differences between the groups at baseline for any of the metrics. At baseline, the distribution of SART errors (and error proportions) was approximately symmetrical ($skewness = -0.31$). While the distribution of RTs to Go stimuli was moderately skewed ($skewness = -0.74$), the manipulation of these scores necessary for calculating the RT variability (the SD for non-target RTs divided by the mean RT) implied that the distribution of RT variability was substantially skewed ($skewness = 1.68$).

Considering those who completed the study (the per-protocol analysis), as is evident in Figure 8.16, for both SART error proportions and Go RT variability outcomes worsened from the baseline to the post-intervention assessment for both experimental groups. The differences, however, were small. The error proportions at both assessments were lower for those in the control group (baseline: $M = 0.51$, $SD = 0.19$; post-intervention: $M = 0.55$, $SD = 0.19$) than for those in the intervention group (baseline: $M = 0.54$, $SD = 0.18$; post-intervention: $M = 0.57$, $SD = 0.15$). In contrast, the variability of RTs to 'Go' stimuli was the same for both experimental groups at both the baseline (control: $M = 0.19$, $SD = 0.08$; intervention: $M = 0.19$, $SD = 0.07$) and post-intervention assessments (control: $M = 0.23$, $SD = 0.12$; intervention: $M = 0.23$,

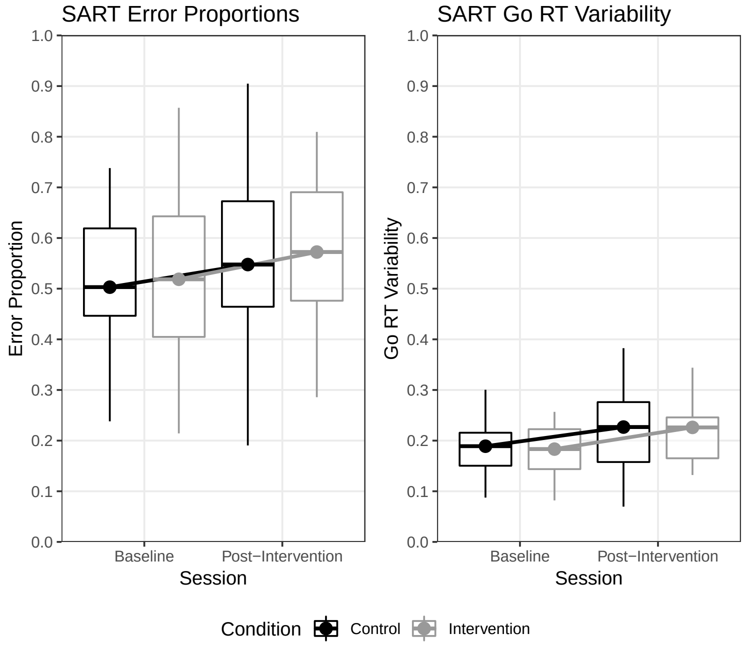

Figure 8.16: SART error proportions and Go RT variability before and after the intervention period.

$SD = 0.09$). *Levene's test* confirmed the homogeneity of the outcome variances for both groups for both error proportions and Go RT variability. Similarly, for both metrics the non-significance of the interaction between the baseline scores and the experimental group confirmed the homogeneity of the regression slopes. Finally, as would be expected given the equivalence in the change for both outcomes, after controlling for baseline outcomes, no main effect of experimental group on post-intervention error proportions ($F(1, 56) = 0.19, p = .67, \eta_p^2 = 0.003$) or Go RT variability ($F(1, 56) = 0.04, p = .83, \eta_p^2 = .001$) was found. Consequently, H2$_c$ was not confirmed. For both metrics, the baseline outcomes were significant predictors of post-intervention outcomes (Go RT variability: $F(1, 56) = 36.79, p < 0.001, \eta_p^2 = 0.397$; Error proportions: $F(1, 56) = 30.86, p =< 0.001, \eta_p^2 = .355$). Extending the per-protocol analysis, for both error proportions (main effect of group: $F(1, 57) = 0.18, p = .67, \eta_p^2 = .003$) and go RT variability (main effect of group: $F(1, 57) = 0.12, p = .89, \eta_p^2 = .004$), the ITT analysis confirmed the outcome.[16]

Cognitive Flexibility (Number letter task) was assessed with a single metric, the *switch cost*. As in previous studies (e.g., Ophir *et al.*, 2009; Wiradhany and Nieuwenstein, 2017), switch costs were calculated as the difference in mean RT between switch trials

[16]All other relevant assumptions for the analysis held true.

Table 8.9: Number-letter task metrics at both assessments for each group and overall.

Metric	Intervention Group		Control Group		Combined	
	Baseline	Post	Baseline	Post	Baseline	Post
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Accuracy						
Task-switch	0.88 (0.08)	0.88 (0.12)	0.91 (0.11)	0.93 (0.4)	0.90 (0.10)	0.91 (0.09)
Task-repeat	0.94 (0.06)	0.92 (0.12)	0.94 (0.10)	0.97 (0.02)	0.94 (0.09)	0.95 (0.08)
Overall	0.91 (0.07)	0.90 (0.12)	0.92 (0.10)	0.95 (0.03)	0.92 (0.08)	0.93 (0.09)
Response Time						
Task-switch	1197.80 (286.60)	885.95 (200.38)	971.55 (275.17)	862.65 (184.31)	1075.40 (300.45)	873.31 (190.51)
Task-repeat	898.53 (222.04)	709.81 (121.04)	730.29 (167.46)	665.45 (88.78)	807.51 (210.44)	685.75 (106.19)
Switch Costs	299.27 (217.82)	176.14 (128.06)	241.26 (149.06)	197.20 (140.16)	267.89 (184.53)	187.56 (134.03)

and repeat trials, with a larger value representing a greater impact from switching.[17] For the RTs the winsorizing procedure resulted in the replacement of 3.71% of trials at baseline and 2.93% of trials at the post-intervention assessment. For the analysis of RTs only correct responses were considered. Therefore, response accuracy is also reported. These outcomes, along with RTs for each condition, for both assessment sessions and groups are summarised in Table 8.9. All accuracy data are reported as the proportion of correct responses and, as is evident in Table 8.9, on average participants were accurate in at least 90% of the trials. While participants were generally accurate, as is to be expected with the number-letter task, the RTs differed significantly between task-repeat and task-switch trials ($t(107.45) = -5.70, p < .001, d = -1.03$), with greater RTs in switch trials at both assessment sessions. Additionally, at baseline, for both task-switch ($t(56.56) = -3.13, p < 0.01, d = -.81$) and task-repeat ($t(49.60) = -3.29, p < 0.01, d = -0.87$) conditions there was a significant difference in the mean RT between the two experimental groups. However, for the primary metric of interest, the switch cost, no statistically significant difference between the groups existed at baseline.

For the per-protocol analysis, as depicted in Figure 8.17, the switch costs for both groups decreased from the baseline (control: $M = 241.26$, $SD = 149.06$; intervention: $M = 299.27$, $SD = 217.82$) to the post-intervention assessment (control: $M = 197.20$, $SD = 140.16$; intervention: $M = 176.14$, $SD = 128.06$). On average, the decrease in switch costs was greater in the intervention group ($123.13\,ms$) than in the control group ($44.12\,ms$). To determine if the difference between the control group and the interven-

[17] Negative values (as represented in Figure 8.17) are indicative of instances where the mean RT for repeat trials was greater than that of switch trials. This was the case for only two individuals in the baseline assessment.

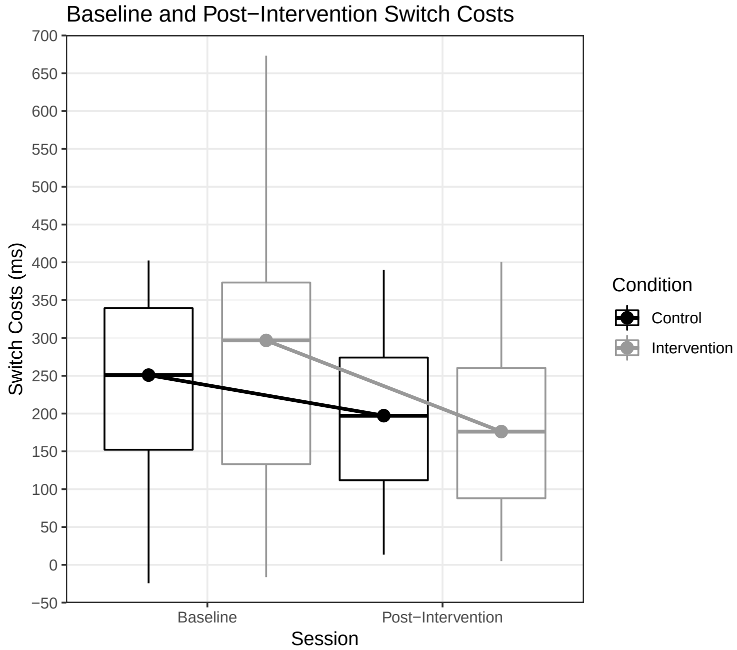

Figure 8.17: Switch costs (in ms) before and after the intervention period.

tion group on post-intervention switch costs, controlling for baseline switch costs, was statistically significant, a one-way ANCOVA was conducted. *Levene's test* confirmed the homogeneity of the outcome variances for both groups and the non-significance of the interaction between the baseline scores and the experimental group confirmed the homogeneity of the regression slopes. Despite the difference in magnitude of the change in switch costs, no main effect of experimental group on post-intervention switch costs after controlling for baseline outcomes was found ($F(1, 56) = 1.59, p = .21, \eta_p^2 = .028$). On this basis, $H2_d$ was not supported. Baseline scores were, however, a significant predictor of post-intervention outcomes ($F(1, 56) = 20.86, p < .001, \eta_p^2 = .271$). These outcomes were further confirmed when the analysis was conducted on an ITT basis (main effect of group: $F(1, 58) = 1.50, p = .23, \eta_p^2 = .049$).[18]

8.3 Interview Follow-Up Analysis

To provide further insight into the participants' experiences a series of semi-structured interviews were conducted. Ten participants from the intervention group were randomly

[18] All other relevant assumptions for the analysis held true.

selected to receive an invite to attend the interviews. Two participants declined the invite and were replaced by two more. The final sample included three males and seven females and were, on average, in their second year of study. As described in Section 7.7.3, a thematic analysis procedure was adopted to synthesise the resultant corpus. The first stage in the analysis involved transcribing the audio-recordings into a textual format. All questions, prompts and participant-responses were transcribed verbatim into separate text-files to be analysed with RQDA. Through the application of the a priori codes described in Table 8.10, the second stage of analysis involved assigning descriptive codes to relevant aspects of the corpus. Following the a priori coding, a second stage of open coding was conducted to further classify emergent aspects of the data. Table 8.10 provides a summary of the final codes applied in the analysis. Having coded the dataset the third phase involved identifying patterns present in these codes. Related codes were clustered together and considered along with the relevant text extracts. Thereafter, the fourth phase involved reviewing these themes and the associated data extractions to refine the descriptive account represented by the various themes. The purpose of these analyses was, in part, to address aspects of the second research objective of the study. In particular, such qualitative techniques enabled a number of aspects of intervention feasibility to be assessed, including: demand, implementation, and acceptability.

8.3.1 Prominent Themes Pertinent To Intervention Feasibility

In the following sub-section key themes characterising participants' experiences and interpretations are defined and described. To support the description of the narrative of the themes, where applicable, relevant excerpts from the interviews are provided as examples of statements characteristic of the theme.

8.3.1.1 Pervasive Media Multitasking as a Mode of Existence

Participants' media use prior to the intervention was characterised by pervasive multitasking. This is not unexpected given the nature of the target populations' interactions with media (le Roux and Parry, 2017*b*). For the participants, the phone was seen to be their primary connection to the world and, in comparison to studying, attending to lectures, or interacting with people around them, this connection, through various SNSs (especially *Facebook* and *Instagram*) and instant messaging services (e.g., *Whatsapp*),

Table 8.10: Final codes for the thematic analysis of the follow-up interviews.

#	Code	Description
A priori codes		
1	MOT	Motivations for regulating media multitasking
2	CON	Continuance of aspects of the intervention
3	STR	Strategies adopted to self-regulate media multitasking
4	POS	Positive effects associated with the intervention
5	NEG	Negative effects associated with the intervention
6	SUP	Factors supporting self-regulation of media multitasking
7	OBS	Factors obstructing self-regulation of media multitasking
8	DEG	Degree of execution of the intervention
9	SUC	Successful implementation of the intervention
10	FAI	Failure to implement the intervention
11	RES	Resources required to implement the intervention
12	REA	Reactions to the intervention
13	SAT	Satisfaction with the intervention
14	EFF	Perceptions of intervention efficacy
A posteriori codes		
15	AWA	Awareness of behaviour with media
16	TYP	Type of media restricted
17	WHY	Reason for restricting particular media or behaviour
18	OTH	The other activities in-place of simultaneous media use
19	OPE	Instances of operating on behaviour
20	APP	Use of application (Forest) features
21	CHA	Change over time
22	DIF	Aspects of the intervention that were difficult to enact
23	AME	Recommendations of amendments to the intervention
24	TIM	Use/structuring of time
25	GOA	Alignment between behaviour and goals
26	END	Endorsement of aspects of the intervention to others
27	GOC	Instances of goal-conflict in relation to media
28	OVE	Overall evaluation of the intervention
29	BAT	Response batching strategy
30	ACC	Alter accessibility of device strategy
31	BLO	Time blocking of media use strategy
32	UND	Underestimation of effort required
33	PRI	Prior intervention attempts
34	PRM	Prior media use patterns
35	IMP	Assessment of impact of prior behaviour with media
36	SIF	Situational factor
37	INF	individual factor
38	AFF	Affordance of medium
39	NOR	Normative factor
40	ABS	The absence of a negative effect associated with the intervention

was simultaneously a source of entertainment, communication and information, and a driver of goal-conflict, interference and procrastination.

> *I used it from the moment I was in lectures until the end of the day. Even when I was studying or doing work I would be on my phone, a lot of multitasking.* (Participant-2)

> *I was that person in lectures that can get distracted quite easily. So, if I see something on my phone and I am getting bored in the lecture then I would pick up my phone and quickly look at something. I would be on a news article for example. Then I would read something on Chrome and then I would go over to some social media. So yeah, I would say I multitasked quite a bit.* (Participant-1)

In some cases, this behaviour was seen to be automatic or habitual. Without prior deliberation or consideration of goals or intentions participants would initiate media multitasking, irrespective of the present setting or task.

> *It was very uncontrolled and like whenever I would get a text I would answer it immediately.* (Participant-3)

> *If I was sitting in lectures or busy trying to study. Of course, the phone is very interesting. So, there wasn't really a set structure to how I used my phone, it was just kind of all the time. If you get bored, you don't even think about it and just pick it up.* (Participant-7)

Despite the frequency with which they media multitasked, the participants were not ignorant of the potential consequences of their behaviour. Simultaneous use of media was seen to break concentration, divert attention away from present tasks and, in many cases, lead to unplanned, prolonged instances of procrastination. These outcomes were seen to have a negative effect on academic performance and study goals. Such behavioural patterns have previously been associated with failures of self-regulation (Reinecke *et al.*, 2016; Hoffmann *et al.*, 2017). Engagement with media is seen to gratify short term needs (for entertainment, information, or affect-regulation), while more distal goals are neglected. This supports the indication that media multitasking can be understood as a form of goal conflict.

> *The break in concentration from the lecture is really, like I don't think it helped at all. I feel like you totally lose track of what is going on and it was definitely bad.* (Participant-1)

> *I am like oh well, I am on my phone anyway. I didn't pay attention to twenty minutes of the lecture, might as well carry on. What's the use of paying attention to the next twenty minutes of the lecture. Then I just procrastinate. I am in my final year now so I actually have to graduate. My marks were dropping a bit because I am on my phone so much and I couldn't focus as much on my work as I constantly get distracted by my phone.* (Participant-10)

In addition to associations with procrastination, lapses in concentration, and misallocation of time, the participants appreciated how their media multitasking influenced the nature of their social interactions.

> *Any breaks that I would have, whether I was in [the computer lab], or sitting with my friends, even interacting with people, I would be on my phone. Which is really rude and I know that. But, the phone is almost an addictive device that connects you to the rest of the world.* (Participant-9)

This awareness of how media multitasking affected their studies and their social interactions, for many participants, motivated their participation in the study and their continued efforts to self-regulate their media multitasking during the study period.

> *Mainly I wanted to get my time on my phone under control and bring it down a bit. The money was a nice incentive. But I wasn't in the study for the money, I actually wanted to see if I could manage my phone usage.* (Participant-10)

> *Something to keep you accountable, to actually track what you are doing. That is probably the main reason.* (Participant-1)

In addition to viewing the intervention as an opportunity to change their behaviour with media, participants saw it as a challenge and were motivated to participate and regulate their media multitasking by a desire to push themselves to take control of their behaviour and, potentially, contribute positively to their academic goals.

> *Even when I was studying or doing work I would be on my phone, a lot of multitasking. Actually, it's a bad habit that I can't actually study without being on my phone. I wanted to challenge myself. I wanted to see if I could do this.* (Participant-2)

8.3.1.2 Deficient Cognition of Behaviour With Media

Participants' cognisance of the duration and frequency with which they media multitask was poor prior to the study. Moreover, their metacognition of their self-interruption tendencies and the extent to which they multitask was limited. Despite the acknowledgements of their continuous use of their phones in conjunction with other activities, when provided with time-specific data on their own media usage patterns, the participants realised that their insight into their behaviour with media was flawed.

> *It really made me realise how much I use my phone. Because, I would use it all the time. I think scrolling through everything takes a lot of time without you even realising it. I knew I was on it a lot, but I didn't want to know. I didn't realise how much I am actually on my phone when I do other things.* (Participant-7)

> *I saw the patterns of how I used my device. Especially in the first week. The first day scared me. I think it was about two or three hours. I was like: 'no, this is really bad'.* (Participant-2)

Participants were unaware of, firstly, the extent of the duration spent using their phones and, secondly, how frequently this use occurred in conjunction with other activities. Consequently, they were surprised when confronted with their own usage patterns.

> *I was surprised by how much and when I was actually using my phone. So, it was really interesting to see how much I multitask. I didn't realise it until now, but it is quite insane. So that is why my focus isn't where it should be.* (Participant-3)

> *I was quite surprised. Because, when you are on your phone, you don't realise it. You think I am just going to be five minutes on your phone, then you check*

> *the time and it was actually closer to 20 minutes. It was quite worrying how quickly time passes when you are on your phone. You don't really notice it, so it was nice to see that on the app.* (Participant-10)

As a consequence of their poor metacognition, participants underestimated the effort required to regulate their media multitasking. Prior to the commencement of the intervention period, in relation to their present understanding of their behaviour, the 90-minute target and reduction in multitasking was seen to be an easy goal to achieve. However, in retrospect, the participants realised that they underestimated, firstly, how much they multitasked and, secondly, the difficulty of self-regulating their behaviour.

> *I thought it was going to be easy money because I didn't think I was on my phone that much. And then, yoh.. it's not what I thought.* (Participant-4)

> *I still struggled with the 90 minutes. But I think I more struggled with the single tasking. I didn't think I would as much as I did.* (Participant-7)

8.3.1.3 The Intervention Engendered Greater Cognisance of Behaviour

In relation to the BCW framework, as a component of the intervention, the awareness of media use patterns was intended to enable participants to change their behaviour. Consequently, as expected, the intervention was understood by the participants to engender a greater awareness of, firstly, their behaviour with media, secondly, their allocation of their time in relation to their goals and, thirdly, the effects that their behavioural choices have for their cognitive functioning and goals. While awareness of behaviour was employed as a behaviour change technique, the participants viewed the improvements in the awareness of their behaviour as key outcomes of the intervention.

> *I think being a part of this made me aware of just how much I am using my phone and also just how much I am missing of everyday life by being on my phone.* (Participant-10)

> *I am definitely more aware of phone use and how it affects you more than you think and how you can only do one thing at a time.* (Participant-3)

A greater awareness of media use and media multitasking tendencies emerged as key drivers of behavioural change. The awareness engendered by the intervention enabled participants to consider whether their behavioural patterns aligned with their goals or intentions and, on this basis, operate to bring their behaviour in-line with their intentions.

> *Being aware of how much I am on my phone made me actively try to restrict it more.* (Participant-10)

> *Being aware of your behaviour makes you want to change it.* (Participant-5)

Both the duration of time spent on a phone and the overlap between this usage and other activities was seen to interfere with attainment of other goals (academic and social). In particular, an awareness of behaviour with media led participants to consider how they allocated their time and attention, and how these allocation strategies aligned with their goals. Moreover, in considering their behavioural patterns, participants reported being more mindful of their goals themselves.

> *I think it was more just like making myself more aware of my actions and what is normal for me. And what is normal for me is probably not that healthy to just constantly rely on my phone. I think the awareness thing was one of the big benefits, just to actually keep track of what I am doing. I just realised that the phone was just connected to how I was using my time. I think the study did make me aware of how often I used it during in-between things, like in-between studying or in-between lectures.* (Participant-8)

> *The big thing was being aware of how and when I was using my phone. I would rather use that time to spend it either with friends drinking coffee or just working.* (Participant-3)

While the intervention on a whole was seen to engender a greater cognisance of behaviour with media and tendencies for the allocation of time and attention, participants noted the value of the reports on their media use patterns provided by the application. The tracking was seen to support them in the monitoring of their behaviour and, on this basis, evaluating how their behaviour corresponded to both the intervention target and their own behavioural goals.

> *You can see how long you have been on for each hour. You can then think about what you were doing then. Then you know you can just cut back on that.* (Participant-1)

> *When I first downloaded the app, on the first day I saw that by the end I had been on my phone for over three hours and I thought back over the day and it was just two minutes here, two minutes there all throughout the day. It was so weird to me. I thought about all of the times I should've just left my phone.* (Participant-4)

> *I used the app to check my use a lot. I got very conscious of it.* (Participant-5)

8.3.1.4 Structuring of Time as an Approach to Self-Regulating Media Multitasking

While the intervention specified a target and the use of the application, the approaches adopted to ensure goal adherence were left to the participants. Consequently, a wide variety of self-regulation strategies were adopted. Across these strategies, however, an explicit consideration of how their available time was structured emerged as a common theme. Extending from the cognisance of their behaviour participants endeavoured to use their time in a constructive manner.

> *I just realised that the phone was just connected to how I was using my time now. So I would try to plan my time better so that I have things to do, so that I am doing something specific and not just being lazy. That this is study time, this is dinner time and stuff like that. I think during this study I was more aware of my schedule and my time.* (Participant-8)

The use of time-blocking is a key example of a strategy adopted to achieve a more optimal alignment between their behaviour with media and their goals. Participants would set aside specific times for different activities. Specifically, participants reported spending time on their phones in the morning upon waking up and then, throughout the day prioritising studying and concentrating in class, only using their phones during lunch and again at the end of the day. In this way, as required in the intervention, participants aimed to reduce the extent to which they multitasked with their phones, using it outside of times when they were occupied by other activities. While a small minority of participants used the restriction feature to support their time-blocking, most participants did not use any mobile application or device-features to facilitate it. Rather, it seems that the participants relied on willpower to support their time-blocking strategy.

> *I would kind of try and limit my phone usage to certain windows of time.* (Participant-1)

> *I set specific times of the day that I was going to be on my phone. So I set up a timetable and said in the mornings when I wake up I am going to be on my phone for 15 minutes check for the day and then during lunch time half an hour and then after dinner another half an hour or the remainder of the time I had.* (Participant-10)

> *I would wake up in the morning and use it for like ten minutes and then stop. Then, during the day, I would limit it and try find other ways to distract myself. I would make sure to only use my phone for about 30 minutes during the day so that during the night when I was done, I could have an hour to use my phone.* (Participant-6)

In a similar manner, another strategy adopted to structure the use of their time with the phone and the extent to which this use occurred in conjunction with other activities was the batching of responses to incoming messages. Participants would delay responding to incoming messages until they had completed a present task and, upon completion, respond to all of the messages received in a single batch. In this way, rather than responding to individual messages in a piecemeal manner, participants aimed to maintain their single-tasking and abstain from externally driven interruptions. Again, no indication was made that any applications or settings were used to facilitate this batching.

> *I think my main strategy was to, say for example, if I did go on my phone, I would answer multiple messages at once, like a batch. I would wait quite a long time and then respond to a whole lot of messages at once.* (Participant-1)

> *Individual conversations I would try and delay it until I could single task and actually reply. So, I would wait until five or six messages had accumulated and then reply to them all and then put my phone away.* (Participant-9)

Another strategy adopted by participants corresponds to Gazzaley and Rosen (2016)'s suggestion that limiting the accessibility of media will facilitate single-tasking. Participants reported placing their phones in locations that were either outside of their direct line-of-sight or required effort to move to and access. Additionally, as a further aspect of reducing the accessibility of their devices, some participants indicated that they would switch their phones off while in class or studying. This was the only form of device-level accessibility reported. Rather than using restriction applications, device-level settings, or other manipulations of affordances, the participants elected to alter their physical proximity to their devices when aiming to work uninterrupted. While those who switched off their devices were unable to perceive any incoming notifications, those who simply altered their proximity to their device by moving it out of their immediate reach or direct line of sight were still able to perceive vibrations or other auditory notifications. In this way, while out of sight, the device was not completely out of mind and, as Cheever *et al.* (2014) found, individuals still experience effects associated with the removal of their device. Cheever *et al.* (2014) investigated associations with anxiety and not attention but, regardless, the possibility remains that this "backdoor" exists. Despite removing the device and the physical possibility of engaging with it, perceiving notifications and allocating attention to thinking about their potential content may, itself, have presented as a distraction to some, undermining their single-tasking intentions.

> *In class time I would switch off my phone put it somewhere and then focus on the lecture.* (Participant-10)

> *With the single tasking I would try and actually just leave my phone in a different room to me. Because then, when I thought about checking it, I would think where is it and that would remind me that I am trying not to check it.* (Participant-7)

> *I just put it in my drawer and closed the drawer while studying, and if it vibrated I would just let it go.* (Participant-6)

In relation to strategic choices, a number of relevant sub-themes pertaining to the use of the prescribed application emerged. Primarily, as intended, the participants used the application as a means to understand their own media use behaviour. Consequently, through the provision of to-the-minute information on media use, the application contributed to the enhancement of the participants' cognisance of their behaviour. The participants compared the application to other health and fitness related applications they used and felt that, without the availability of such information, they would struggle to effectively regulate their behaviour.

> *If you just have to cut back yourself I think you are going to not always achieve your goal for each day. So for me, I think having an app or just some record of how long you have been on your phone is useful.* (Participant-1)

> *You need something to help you. My phone also tracks my steps and stuff and you need something to help you keep to your goal. If something is motivating you can do it better. So I planted trees to help me.* (Participant-4)

> *It helped make you aware and that's why I liked the app.* (Participant-7)

Extending from this, and in relation to the perception of a greater awareness of media use patterns, participants understood that, without an application, they could deceive themselves about their behaviour and the extent to which they multitasked. Additionally, in providing information on behavioural patterns, the application supported participants in operating to remain aligned to their goals.

> *I think the app definitely helped a lot. It is good to see how much time you are actually on your phone. I think an app definitely helps so much more than just doing it on your own. If you are doing it on your own you can sort of lie to yourself. But when you actually see the results you know, ok, I am really good at this, or I screwed up today and have to do better tomorrow.* (Participant-10)

While the application was regarded as a useful means of understanding their own behaviour, as indicated by the analysis of the application usage, the restriction feature was not regarded to be universally beneficial. Many participants reported initially using the feature but, as they gained control of their behaviour, curtailed this usage.

> *I used it a lot in the beginning but in the end when I got my phone more under control I didn't grow a forest that much.* (Participant-10)

> *I did a bit in the beginning. I think during the first couple days I did. But not in the last few weeks. I didn't really because I didn't feel like I needed it that much. I felt like I was kind of managing my time well enough.* (Participant-1)

Of those interviewed, only two participants continued their use of the feature throughout the intervention period. These participants used the feature to support their time-blocking, allocating lecture and study periods to restrict their device usage.

> *I did use the tree feature. The planting trees, for lectures mostly. That was beneficial in that I stopped using my phone during lectures, like a lot. Then I also would set my self study times and I would use the tree thing a few times there.* (Participant-8)

> *It did help me focus on studying more. I planted a lot of trees and it was really good to disconnect from all of that. I feel very pressured when people asked me questions, so with planting the tree I could see the message coming in but chose to ignore it because I am growing my tree! You guys can wait for me to grow my tree. It was nice to shut off from people and be like 'sorry I am growing my tree'.* (Participant-5)

8.3.1.5 Intervention Implementation as a Function of Situational Factors

The participants were cognisant that there exists a situational dimension to their actions and that, along with individual needs and affordances, their behaviour with media was influenced by their material and social circumstances. Such an understanding is consistent with the situated action approach and the notion of technosocial situations as espoused by Ito and Okabe (2005). This awareness was expressed in relation to reflections on factors which either hindered or facilitated their media multitasking self-regulation. In this regard, two contradictory patterns emerged. In both, participants considered the ease with which they could regulate their behaviour in relation to the activities characterising their present situation. Specifically, factors such as the presence of others, the degree to which the participants were occupied with their studies, and the time available for leisure activities all affected their implementation of the intervention.

In the first pattern, participants considered it easier to regulate their media multitasking when studying but, when presented with free time, they struggled to regulate their behaviour. During the week participants were able to structure their behaviour around a routine and, when in lectures or studying for assessments, regulated their media multitasking accordingly. This pattern of behaviour followed from a greater awareness of their goals and was seen, in part, to enable a greater alignment between their behaviour and these goals. Participants prioritised their studies and were able to use this as a motivation to abstain from multitasking with their phones. However, in the absence of an academic-goal driven incentive, when socialising or resting on the weekends, participants struggled to regulate their media multitasking.

> *In the third week, luckily for me, there were a lot of tests. So I was just studying. So it was easier when I was studying.* (Participant-6)

> *I think during the week it was a lot easier because you have a routine. When you were studying it was definitely a lot easier. During the weekends when you have a lot more free time it is a lot more difficult. When you go out to places you do end up on your phone quite often without realising it. It is a lot easier when you have to study for something. When you don't have any studies then the time can rack up on the phone.* (Participant-1)

> *When I am busier it was easier to manage my use. When I didn't have anything to do I tended to pick up my phone.When I was busy or had tests I just focused on studying.* (Participant-4)

In contrast, a number of participants reported the opposite. For these participants it was more difficult to regulate their media multitasking when involved in academic tasks while, when in social settings or resting, it was easier to manage their behaviour. In this pattern media multitasking was either induced by boredom with the present situation or, in relation to both academic performance goals and FoMo, anxiety. In relation to Gazzaley and Rosen (2016)'s interpretation of the MVT, both of these factors have frequently been associated with increased instances of media multitasking. Boredom in academic settings has been associated with, firstly, the relative engagement offered by media and, secondly, the value of the task or setting for attaining longer-term goals (Parry, 2017). Additionally, media multitasking while in academic settings may be interpreted as a form of *escapism* from the subjectively aversive nature of these settings for a participant. Students may be stressed, bored or anxious while in academic settings and, when faced with looming deadlines or high workloads, may seek short-term escape from these particularly salient stressors through simultaneous engagement with various readily available media.

> *The times that it was most difficult for me was in the really boring classes when I actually have to pay attention to what they are saying.* (Participant-9)

> *My difficulty was in test periods and when the workload got very intense.* (Participant-5)

> *On weekends and in the holiday it was actually easier. No one was looking for me. I was like 'yay cool!' It was easier.* (Participant-3)

Considering these patterns it is evident that, just as media multitasking is driven, in part, by situational factors, the regulation of media multitasking is also influenced by aspects of the present situation. While there is a degree of incongruence between these patterns, it is evident that, goal-achievement and the alignment between present activities and longer-term goals contributes positively to the self-regulation of media multitasking.

> *I felt less intertwined with social media after a while because I just realised it is not really beneficial to me.* (Participant-6)

> *I can be without my phone and focus more on my work and my degree and my social life. Instagram and Facebook like you don't really need it that much. My friends will understand if I don't talk to them. So it helped me to focus more on my work.* (Participant-10)

8.3.1.6 Intervention Implementation as a Function of Time

Initially participants struggled to regulate their media multitasking, finding the task particularly challenging. However, over time, as they formed new habits, became cognisant of their behaviour, and developed strategies for structuring their time and managing their media use, the task became easier. This corresponds with the declining use of the restriction feature over the intervention period. As participants became accustomed to regulating their media multitasking, their need to rely on the application to maintain the time-blocks declined.

> *The first day was really hard. It was so hard not being on my phone. But then, I adapted on using my phone only after lectures. Like the first week was very difficult, but then you get used to it. Even now, I am rarely on my phone. I have gotten used to it. Even now that I know the period is over, I still try not to use my phone during lectures.* (Participant-2)

> *The first week was so difficult to get all the way down. I was still playing my game like three or four times a day, I was scrolling through Instagram three times a day. I realised at the end of the first day that it was going to be difficult. I was still using it for over three hours. So, I just tried to reduce it by half an hour each day and by the end of the first week I was pretty much set to go for the rest. After the first week it became a lot easier.* (Participant-9)

The easing of the challenge of regulating their media multitasking was associated with the replacement of old habits with new habits. Initially, effort was required to, firstly, disrupt longstanding behavioural patterns and, secondly, establish habits associated with the behaviour necessary for achieving the intervention target. In accordance with Wood and Neal (2007) the goal set in the intervention aided the formation of these habits and, as these patterns became automatic, the effort required diminished.

> *I think during the first week it was a bit difficult to get into but then I reached the target for quite a while so I broke the habit.* (Participant-10)

> *In the beginning it was a bit like: 'oh, because I am not on my phone I am not really part of that'. But then as it went on it was like breaking a habit. I wasn't to bothered by it. After a while I got used to it.* (Participant-1)

> *It was a bit thought-consuming. But I think, as I did it longer, it became part of a habit.* (Participant-3)

8.3.1.7 The Regulation of Media Multitasking as a Means to Produce More Opportunities to Single-task

Extending from the structuring of their time and the various strategies adopted, the intervention was seen to provide the participants with increased instances within which they could single-task. By disconnecting from media engagement, the participants shaped their present situations to create the circumstances within which they could sustain attentional allocation. This was seen to positively affect their studies and social lives. As noted in Section 8.3.1.4, the structuring of time emerged as a key approach to media multitasking self-regulation. For the participants this was understood as both a method and an outcome of the intervention. In considering how they used their time in relation to their goals, the participants were driven to become more disciplined in their behaviour and, as a consequence, delay short-term gratifications typically associated with media use. This outcome was reflected in, firstly, perceptions of reduced procrastination and, secondly, perceptions of improved productivity.

> *I think the main thing was it was actually a positive because you are actually using your time more efficiently cause you are just focusing on one thing at a time.* (Participant-1)

> *I think I was just trying to procrastinate less as well. So I would try to plan my time better so that I have things to do, so that I am doing something specific and not just being lazy. That this is study time, this is dinner time and stuff like that. I think during this study I was more aware of my schedule and my time.* (Participant-8)

> *I saw that I completed my assignments days before I usually completed them, I didn't leave them for the last minute because I was occupied with my phone.* (Participant-10)

Extending from this, the participants realised that, when necessary, they could spend periods of time without using media. In setting aside their need to be continuously connected and disengaging from their phones to allocate attention elsewhere they were able to function without undue consequences for their personal or social or lives.

> *I feel like, in general, it kind of made me realise that you don't actually need your phone with you all the time. In most situations you don't actually need to be on it.* (Participant-1)

> *I realised like, if I am not on social media, it is fine. Nothing big is going to happen. Life goes on.* (Partcipant-6)

The goal-prioritisation and time structuring associated with the intervention was seen to engender more opportunities to single-task and allocate attention to one activity at a time. The participants did not perceive the intervention to have an effect on their capacity to concentrate (i.e., sustain attentional allocation). Rather, it was seen to produce more instances in which they were concentrating. Whether in a lecture or studying on their own, the participants equated not using their phone with the allocation of attention to the task associated with their present situation. In this way, while not necessarily improving their attentional performance, through regulating media multitasking, participants managed their time to produce more opportunities within which to concentrate. This was seen to contribute positively to the attainment of academic goals.

> *Before the study I would be using my phone in class and I would realise that I missed something and then I would be trying to catch up. So then, if I am not using my phone I was concentrating more, obviously. I also was keeping up with what the lecturer was saying. So it wasn't like there was space to fill, because now I was actually concentrating. I think it was more like my focus was just on one task. So I think I was focusing more just single view. Single like focus.* (Participant-8)

> *Before, I would just be there physically but, mentally, I wouldn't be there. I was practically wasting my time. Now, I am just in the moment. And it actually works. If I am not concentrating in class or not being attentive, I would struggle to actually understand the work because I wasn't listening. But then, about three weeks ago we had an essay and I found that since I had been focusing in class more without using my phone, I actually knew what the main concept of the thing was and it made things more easier.* (Participant-2)

> *It showed me to be more invested in my work in class. I could listen more and participate in conversations with my peers and the lecturer. It also allowed me to stop procrastinating with my work, like leaving my phone away in a different place so that I can be able to focus more on what I am studying. So, to just focus on my work.* (Participant-6)

The participants indicated that, in producing a greater number of opportunities within which they were single-tasking, they felt more present in their current situations. Rather than allocating attention to irrelevant thoughts, memories or activities, they were more cognisant of their surroundings and the requirements of their present tasks.

> *In lectures I just was like 'you know what, I want to be in the moment'. I just focused.* (Participant-2)

> *Being more present is a lot more enjoyable than being half focused on one thing and half focused on another thing. Also, in lectures, now I feel I am a lot more focused on one thing. I think with, for example, family times sometimes I used to go on my phone and just reply to a message. Now, I was more involved with my family because I figured I shouldn't actually be on my phone, I am not meant to be on my phone now. So it was helpful to have the goal. You are more involved in everyday activities basically.* (Participant-1)

8.3.1.8 Self-regulation of Media Multitasking as an Impediment to Social Communication

Participants viewed their phones as one of the primary means by which they communicated with their social circle. In adhering to the intervention and regulating their media multitasking the extent to which they were in constant communication reduced. As a consequence, they perceived their overall level of social interaction to be diminished. In particular, many participants indicated that, prior to the intervention period, they would frequently engage in group-chats throughout the day. In prioritising single-tasking and setting time-blocks, they elected to ignore these chats until their present task was completed. While this delaying tactic promoted single-tasking, in some cases, it was considered to induce feelings of FoMo and anxiety because the conversation was continuing without them. Overall, however, this anxiety was considered to be minor in relation to the benefits of achieving a better alignment between goals and behaviour.

> *I told them that I would reply later. I got a lot of FoMo. But also, the fun of the conversation was sometimes gone when you replied later.* (Participant-6)

> *I couldn't participate all the time in group chats because I wanted to try and limit when I was using my phone. So I couldn't respond at the time and conversations would move by and you do miss out I suppose. But it was never*

> *a major issue. I found that you miss out on what is going on, on your phone, on the group chat when lots of messages were coming. Most days I felt fine not replying. Conversations would move by and you do miss out I suppose. But, it was never a major issue, I could see the trend of the conversation later on so, not too bothered about it.* (Participant-1)

8.3.1.9 Experiences of Distraction and Negative Affect Associated with Media Multitasking Self-Regulation

While the intervention was primarily viewed by the participants as beneficial, for some, it induced negative affective responses. In gaining a greater awareness of their behaviour with media, participants felt explicitly attuned to their behaviour and, when not conforming to their goals or the target, felt guilty. Additionally, some participants reported becoming upset when they failed to adequately regulate their behaviour. Furthermore, the effort required to regulate their media multitasking was, for some, a distraction itself.

> *I think during the beginning I got a bit stressed out because I didn't meet the target. I told myself '90 minutes is your max' and when I didn't get it I was upset with myself.* (Participant-10)

> *I felt like it put pressure on me. So, every time I would have thought about the phone and then my focus would be on thinking about the app and thinking about the time that I am using instead of focusing on something in front of me like a lecture. So then I was over thinking it with the forests. How you are trying to not think about your phone but you keep thinking about it. For me it was really hard. Every single time I was on my phone I was thinking that I can't be on my phone.* (Participant-3)

8.3.1.10 Despite Positive Reactions, Limited Intentions to Continue With the Intervention

Overall, participants generally regarded the intervention to have been beneficial for them. In addition to the positive outcomes for goal-alignment, time management, and time to focus, the intervention was seen to provide an opportunity for the participants to learn about themselves. It enabled them to improve their metacognition and to better understand how they behave and how their behaviour can be regulated to be brought in-line with their longer-term goals.

> *I think for me it was just positives that came out of it. There weren't really any negatives. I think it was actually a positive because you are actually using your time more efficiently cause you are just focusing on one thing at a time. I feel like it was one of the best ways to achieve focusing on one thing at a time. Most of our lives nowadays phones are involved no matter what you do. So, if you limit that factor. If you take it away or reduce the time that you are meant to use. It does definitely help you focus on just one thing at a time. It is all constantly on the back of your mind. I feel like taking away that option, the thought of the phone in your head, like effectively remove it from your mind by knowing that you have to limit your usage.* (Participant-1)

> *Overall, it was beneficial. I learned that I could actually do it. I could actually stay without my phone. I could study without my phone. It is such a bad habit that our lives revolve around cellphones and social media.* (Participant-2)

> *It wasn't an easy thing to do, but that doesn't make it negative. I think on the whole it is a good thing. I don't see any negatives from it.* (Participant-7)

Despite this, participants did not intend to continue with the intervention in its present form. Rather, they opted to continue with certain aspects of the intervention, while abandoning others. While participants indicated that they would continue structuring their phone use around their goals and abstain from using when in lectures or studying, they did not intend to continue using the application or adhering to the time limit.

> *I will definitely keep it up. Not necessarily the app. But I will use my discretion when it comes to my phone use.* (Participant-3)

> *I am not sticking a time limit on it. Like I was studying yesterday and I checked my phone twice and I was irritated that I checked it because there was no reason for me to do it. I try and set times for when I will use my phone for a little while and then outside of those times not use it instead of doing it sporadically throughout the day.* (Participant-7)

Another form of limited continuation was expressed in relation to particular situations. Rather than constantly regulating their behaviour, participants indicated that, because it was useful when studying, they would continue to regulate their media multitasking when in lectures or studying, but not in other situations.

> *I think I would use it. But, not all the time. If I am for example knowing that I have to get something done like studying, then I would open this up and make sure that its tracking everything that I am doing. Because then I know that I am not wasting time. So, I will probably will continue managing when I have studies to do.* (Participant-1)

> *I still try not to use my phone during lectures.* (Participant-2)

8.4 Summary

In this chapter, to address the second objective of the study, the analysis and results for each of the study phases comprising the feasibility assessment were reported. First, the sample considered in the pre-screening phase and the selection of two experimental groups was described. Following this, to provide an overview of the participants' experiences during the intervention period, the usage data was analysed. This indicated that, on average, usage remained under the target, was greater during term time than vacation time and, finally, increased over the course of the day, peaking in the middle of the day and declining before a rise again at the end of the day. Additionally, it is evident that a majority of participants chose not to make use of the restriction feature of the application to support their self-regulation. Next, in Section 8.2.2, the data collected for both the self-report and performance based assessments of cognitive control were analysed to test the hypotheses specified in Section 7.6.3. In both the per-protocol and ITT analysis none of the specified hypotheses could be confirmed. Following this, through the description of ten key themes, the thematic analysis of the follow-up interviews was reported.

Part IV

Discussion and Conclusions

Chapter 9

Discussion, Recommendations and Conclusions

The mixed-methods study presented in this dissertation was conducted to investigate interventions targeting media multitasking and the effects thereof. Building on theories of behaviour, cognition, media use, and self-regulation, the study aimed to provide greater insight into the design, nature, and feasibility of interventions targeting media multitasking, provide further insight into the causal dynamics of associations between behaviour with technology and cognitive processes and, in addition, provide insights about behaviour with technology which may hold relevance beyond academic environments for individuals seeking to manage media-related interferences. To this end, two high-level research objectives and various sub-objectives and research questions were specified as follows:

Research Objective 1: *Investigate and review existing behavioural interventions targeting cognitive control outcomes associated with media multitasking.*

- Determine the nature of behavioural 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 have an effect on outcomes associated with cognitive control.
- Identify the factors that are associated with successful intervention implementation.

- Identify gaps in research in this regard to provide guidelines for future studies.
- Inform the development of an intervention targeting media multitasking amongst university students.

Research Objective 2: *Propose, informed by the outcomes of the first research objective, a novel media multitasking intervention targeting cognitive control outcomes associated with media multitasking and assess its feasibility for a student population of heavy media multitaskers.*

- RQ1: *Is a self-regulation based intervention a feasible approach to improving the cognitive control of students who are heavy media multitaskers?*
  - RQ1.1a: Amongst the target population, is a self-regulation based intervention requiring reduced media use likely to be used?
  - RQ1.1b: What is the pattern of media use exhibited by those executing the intervention?
  - RQ1.2a: What are the factors that facilitate the implementation of the intervention?
  - RQ1.2b: What are the factors that hinder the implementation of the intervention?
  - RQ1.3: How do executors of the intervention react to the intervention?
  - RQ1.4: Is an intervention requiring heavy media multitaskers to reduce their media use, through self-regulation, effective at improving cognitive control ability?

This chapter commences with a reflective overview of the entire study. Following this, in relation to the second research objective, the findings of the feasibility assessment are considered by providing, firstly, a summary for each of the applicable feasibility dimensions and, secondly, an overall evaluation of the intervention. Thereafter, the discussion concerns the implications of the findings for the management of interferences associated with media multitasking, associations between media multitasking and cognitive control and, more broadly, Social Informatics research in general. In Section 9.4, limitations present in the current study are acknowledged before recommendations for future research are proposed. Lastly, in Section 9.6 a final conclusion to the study is presented.

9.1 Reflective Overview

To address both of the research objectives the study commenced with the establishment of a theoretical basis for understanding associations between media multitasking and cognitive control. First, *media* were conceptualised as an emergent hierarchy consisting of artefacts, their affordances, the enactment of these affordances, and the culture that this enactment produces. Following this, it was established that *cognitive control* refers to the theorised mechanisms underlying the execution of goal-directed behaviour, and that it involves the execution of limited cognitive or executive functions. Next, to provide a basis for considering media-related interferences, the interference conceptual framework was introduced. In relation to prevailing goals, this framework distinguishes interferences as either internally or externally induced interruptions or distractions. Multitasking, as an interruption, was characterised as the simultaneous execution of multiple tasks associated with different goals. When considering internal interruptions, *Self-regulation Theory* was introduced as a theoretical frame through which goal-directed behaviour could be understood. As a final theoretical consideration, theories of behaviour were reviewed to inform a model of factors considered to influence behaviour. Through reviewing both deliberative and intuitive theories of behaviour, in relation to Michie *et al.* (2011)'s COM-B model, behaviour is understood to arise from the interaction between capabilities, opportunities, motivations and the reciprocal effects of actions themselves.

Building on this theoretical basis, the patterns and drivers of media multitasking were considered. In adopting the uses and gratifications approach, the informational needs associated with media multitasking were observed. Moreover, it was noted that media multitasking is also driven by situational, normative and technological factors. Consequently, an integrative model of media multitasking behaviour was proposed as a descriptive summary of previous research in this regard. This model contends that media multitasking occurs as a result of the confluence of a number of key subjective and situational factors. While not empirically tested in this study, the model, as a summary of previous research, was intended to guide subsequent intervention evaluations.

To consider claims that media multitasking is associated with changes in cognitive control, studies investigating these phenomena were reviewed. It is evident that, while there exists some degree of convergence, research in this domain is characterised by inconsistent findings. Notwithstanding the methodological and conceptual shortcomings of research in this regard, and the possibility of individual differences, as with Ralph *et al.* (2018), Uncapher and Wagner (2018, p. 9890) conclude that, overall "the weight of current evidence shows that in some contexts heavier media multitaskers underperform relative to lighter media multitaskers in a number of cognitive domains". For some individuals, media multitasking is associated with a broader distribution of attention and increased processing of irrelevant stimuli. This evaluation is supported by recent reviews (e.g., van der Schuur *et al.*, 2015; Uncapher *et al.*, 2017). Given the nature of research in this domain, the existence of any relationship is, however, entirely correlational. Consequently, it has been proposed that associations may either be causal (Ralph *et al.*, 2014) or, in contrast, occur due to underlying individual differences (Cain and Mitroff, 2011).

To investigate media multitasking interventions, and address the first research objective, a systematic review was conducted. A detailed discussion of the results of this review is presented in Section 6.4. As noted, there remains a lack of clarity in terms of effects on behaviour and cognitive control. While specific interpretations and implications were discussed, the review concluded, broadly, that more work was required to determine the feasibility and prescriptive value of media multitasking interventions. Notably, in relation to the strategic nature of media multitasking (Ralph *et al.*, 2018) the importance of metacognition and self-regulation were acknowledged. Finally, building on the previous phases, to investigate the proposed intervention and address the second research objective, a feasibility assessment was conducted. The mixed method, pre/post design involved the collection of quantitative data relating to media multitasking, demographics, cognitive control, everyday executive functioning, and intervention-application, as well as qualitative interview data relating to experiences and impressions of the intervention.

9.2 Feasibility Assessment: Summary of Core Findings

To evaluate the feasibility of the proposed intervention, in relation to each of the feasibility dimensions considered, the core findings of the study are discussed. First, in Section 9.2.1 findings pertinent to the implementation dimension are considered (RQ1.2a and RQ1.2b). Next, in Section 9.2.2, RQ1.4 is addressed by discussing the findings pertinent to the efficacy of the intervention. Thereafter, in Section 9.2.3, findings in relation to intervention acceptability and demand are considered (RQ1.1a, RQ1.1b, and RQ1.3). Finally, in Section 9.2.4 an overall evaluation of the intervention is presented.

9.2.1 Intervention Implementation

To consider the implementation dimension of feasibility and address RQ1.2a, RQ1.2b and, in part, RQ1.1b, the usage data and aspects of the follow-up interviews were analysed. This dimension primarily concerns the degree of intervention execution and the participants' success or failure at implementation (Bowen *et al.*, 2010). As in a number of previous studies (Mark *et al.*, 2012; Pielot and Rello, 2016; Irwin, 2017), the present intervention was implemented *in situ*, with participants attempting to change their behaviour in the course of their everyday lives. In addition to contributing to the ecological validity of the intervention (Schmuckler, 2010), this presented the opportunity to identify and understand the factors which either facilitated or hindered intervention execution. Three outcomes extend from this. First, it enables a more nuanced perspective of intervention execution. Second, it provides an opportunity to understand the subjective and situational factors associated with implementing relevant behaviour change interventions and, third, it provides insight into behaviour with technology in general.

Prior to the study participants' media use was characterised by high-levels of multitasking across personal and academic contexts. This finding supports earlier indications that media multitasking is regarded to be normal and ubiquitous for this demographic (le Roux and Parry, 2017*b*). Despite assertions that media multitasking is, in part, goal-directed (van Koningsbruggen *et al.*, 2018), this behaviour was seen to be automatic and in conflict with longer-term academic and social goals. Engagement with media was driven by desires to gratify short term needs while more distal goals were neglected. The ubiquity of media multitasking in the participants' lives implied that, to execute the intervention, behaviour change was required across a variety of situations. As indicated by the usage tracking data, on average, participants achieved the specified target and, as confirmed in the follow-up interviews, changes in behaviour were required to accomplish this. Despite this, there was much variation in the degree to which the target was achieved.

Considering this pattern in conjunction with the finding that the number of participants missing the target, and the degree to which the target was passed, decreased over the intervention period the assertion that the regulation of media multitasking became easier over the intervention period is supported. This suggests that the execution of the intervention required time to be achieved and that, only once participants became cognisant of their behaviour and formed new habits and regulation strategies, could the regulation of media multitasking be realised. For intervention implementation, this holds three implications. First, earlier in the intervention period the intervention was not executed to the full extent, with execution improving over time. Second, behaviour change with media takes time to achieve in real-world situations. Third, if, as proposed in Section 7.1.2, at least a month is required to affect cognitive control, such interventions should be implemented for more than 28 days because time is required for the behavioural changes themselves. In this study, usage peaked at the tenth day, with target-achievement improving from two-weeks into the intervention period. These outcomes suggest that, for *in situ* behavioural interventions with media, at least two-weeks is required for behaviour change in addition to the time needed to achieve other targeted outcomes.

In addition to time, the nature of present situations affected participants' self-regulation. As described in the situated action approach (Ito and Okabe, 2005), behaviour was influenced by the material and social circumstances of the situations the participants experienced. Specifically, factors such as the presence of others, academic activities, and the time available for leisure activities all affected the implementation of the intervention. Two patterns in this regard were reported. Some participants considered it to be easier to regulate their media multitasking when studying, but struggled to regulate their behaviour when presented with free time. In contrast, others considered it to be easier to regulate their media multitasking when in social settings, and found that regulation in academic settings was particularly challenging. In these cases, escapism, through boredom, was proposed as a driver of media multitasking. Despite this apparent incongruence, supporting le Roux and Parry (2019*b*), it is suggested that, in a given situation, the alignment between present activities and longer-term goals contributes positively to the self-regulation of media multitasking. In contrast, when there is a misalignment between a situation and an individual's goals, regulating simultaneous media use to remain on-task is hindered. Moreover, in-line with Ralph *et al.* (2018), these patterns indicate that the extent of media multitasking occurs as a function of the demands of a present task. These different patterns can, potentially, be accounted for by individual differences in thresholds for engagement, informational needs, self-regulation ability, or goal-setting.

As in previous intervention studies (e.g., Adler *et al.*, 2015; Whittaker *et al.*, 2016), in a small number of cases, the instruments of the intervention hindered execution. While malfunctions or incompatibilities with the usage tracking application were isolated and infrequent, they do, nonetheless, merit consideration. For two participants, despite the apparent compatibility of their devices and operating systems, the application failed to track their usage. This hindered their ability to execute the intervention as it was originally proposed. Given the indication that the participants' cognition of the duration and frequency with which they media multitask was limited, it is plausible that, without the provision of data on their behaviour, the degree to which these participants could regulate their media multitasking was limited.

9.2.2 Intervention Efficacy

Intervention efficacy was assessed through comparisons of cognitive control assessments (both performance-based assays and self-report measures) conducted before and after the intervention period for participants in either a control group or an intervention group. In relation to P_3, the intervention endeavoured to produce improvements in attentional performance and changes in cognitive control and everyday executive functioning. Across the 11 preregistered hypotheses, at either a functional or a reflective level, the analysis did not find an effect of the intervention in the hypothesised direction. This suggests that the application-supported self-regulation intervention failed to have the intended effect on participants' cognitive control abilities at a trait level in the specified time frame.

For the self-report measures, seven of the eight assessments produced null outcomes. While the change was marginal, and the difference between the groups was not significant, individuals in both groups reported increased instances of lapses in their attention, improved self-control, fewer instances of attention-related errors, and decreased tendencies to become distracted. Those in the intervention group indicated fewer instances of both spontaneous and deliberate mind-wandering, while those in the control group indicated increases. Although improvements were hypothesised, the null effects observed were, nonetheless, commensurate with outcomes observed in previous uses of the same self-report scales in assessments of media multitasking interventions (e.g., Irwin, 2017; Yildirim, 2017). The only significant effect of group was observed for difficulties shifting attention. The effect size was, however, opposite to the direction hypothesised and small in magnitude. Those in the control group reported less difficulties shifting attention between tasks in the course of their everyday lives than those in the intervention group. While, as a result of the theorised general changes in cognitive control, it was hypothesised that shifting ability would improve, it is acknowledged that, in comparison to the intervention group, the control group were expected to have maintained a high-level of task-switching. Consequently, it may be that, in focusing on single-tasking, those in the intervention group perceived greater difficulties in their abilities to shift between tasks relative to those in the control group who maintained high levels of switching behaviour. However, given the magnitude of the effect size observed, the practical significance of this difference is negligible. It is, nonetheless, relevant to acknowledge that, despite hypothesising general improvements in everyday executive functioning and associated cognitive control processes, the intervention did not explicitly support the switching of attention between tasks. Rather, in emphasising single-tasking, the opposite was supported. Consequently, while only a single study has shown improvements in switching ability associated with media multitasking (Alzahabi and Becker, 2013), subsequent intervention considerations should not discount the possibility that, along with possible changes in cognitive control and improvements in attentional allocation, the ability to switch between tasks may be adversely affected.

In addition to these outcomes, in relation to indications that self-regulation is associated with procrastination (Meier *et al.*, 2016), an exploratory analysis was conducted to determine the effect of the intervention on this behaviour. For both groups, no change was observed. Across all seven hypotheses tested, the effect sizes associated with the intervention were small. This indicates that, at a reflective level, participants did not perceive improvements in their everyday executive functioning associated with regulating their media multitasking. In comparison with previous media multitasking interventions, as evaluated with self-report scales, only four assessments have indicated positive effects (e.g., Mark *et al.*, 2017; Pielot and Rello, 2016; Whittaker *et al.*, 2016), with all but one of these involving custom, unvalidated assessment scales.

The outcomes of the performance-based assays were commensurate with those of the self-report measures. For cognitive flexibility, as indicated by switch-costs in the number-letter task, both groups improved following the intervention period. Conversely, for sustained attention, as indicated by the SART, both groups' performance diminished. For cognitive inhibition, while both groups were more accurate in the Flanker task, the Flanker congruency effect was not affected by the intervention. Similarly, for working memory, no effect was observed in the n-back task. In all cases, the effect sizes associated with the intervention were small. This indicates that, at a functional level, the intervention did not improve participants' cognitive control. Three explanations are provided which, potentially, account for the apparent failure of the intervention to bring about changes in cognitive control. These function, firstly, as interpretations of possible factors contributing to the absence of the hypothesised effects and, secondly, as indications of factors to be considered in the design and implementation of future interventions. In addition to these factors, further possibilities are considered in Section 9.4 when acknowledging the limitations of the present investigation.

First, noting the intervention implementation patterns indicated by both the usage data and the follow-up interviews, the degree of execution may account for the absence of the intended effect. While, on the whole, adherence to the target was achieved and, as the changes in cognisance and self-regulation strategies indicate, participants endeavoured to reduce their media multitasking, because media multitasking itself was not measured throughout, adherence to the intervention may have been poor. The limited use of the restriction feature provides some support for this interpretation. While the participants felt that they changed their behaviour and implemented various strategies to achieve this, this may not have reduced the extent of their media multitasking overall. Consequently, any proposed effects of the intervention would not have occurred.

As a second interpretation, irrespective of execution, the nature of the intervention itself may account for the absence of the intended effect. This does, however, not preclude the possibility that the intervention engendered momentary changes in cognitive control. Gorman and Green (2016) for instance, found that mindfulness exercises produced positive but transient effects on cognitive control. Consequently, it may be that the intervention modified the attentional state of the participants during instances of single-tasking, when restricting their media multitasking without transferring to general improvements in cognitive control. Accordingly, it must be acknowledged that, despite the research supporting the propositions guiding the design of the intervention (e.g., Rothbart and Posner, 2015), the effect of single-tasking on momentary aspects of cognitive control may not transfer to produce trait-level changes in cognitive control. Alternatively, just as associations between frequent media multitasking and cognitive control are inconsistent, associations between single-tasking and changes in cognitive control may also be weak and inconsistent. Finally, in relation to the degree of execution and implementation patterns, while increases in single-tasking may bring about changes in cognitive control, the intervention period of 28 days may have been insufficient for this to occur. A longer duration may be required to account for, firstly, the time required for behaviour changes and, secondly, the time required for changes in cognitive control to take effect.

The assessments of cognitive control provide a third factor potentially accounting for the observed outcomes. For the four tasks used, while associations with media multitasking have been found in some studies (e.g., Ophir *et al.*, 2009; Ralph and Smilek, 2017), no intervention effects have been shown in previous studies. Importantly, such tasks have only been used in assessments of mindfulness-related media multitasking interventions (Gorman and Green, 2016; Yildirim, 2017). Prior to the present assessment, interventions functioning through awareness or restriction have, primarily, been assessed either through other standard tasks (e.g., ANT, OSPAN; Hartanto and Yang, 2016; Irwin, 2017;

Yildirim, 2017), custom tasks (e.g., Whittaker *et al.*, 2016; Jeuris and Bardram, 2016), or interviews (e.g., Mark *et al.*, 2012). Additionally, while the performance-based assays were designed in accordance with previous implementations, the validity of these assessments is, nonetheless, a potential explanation for the findings. Although this possibility exists, the outcomes produced across the various tasks (e.g., RTs, accuracy measures, conditional effects) are, broadly, commensurate with those found in previous studies (e.g., Ralph, 2014; Murphy *et al.*, 2017; Ralph, 2017; Yildirim, 2017). Therefore, it is unlikely that task measurement validity explains the absence of the hypothesised effects.

Extending from this third explanation, in-line with Ralph *et al.* (2015, p. 400), who suggest that "in-the-moment media multitasking is likely to impair one's ability to perform the primary task", it is argued that in-the-moment single-tasking will improve one's ability to perform a primary task. Despite this assertion, given the timing of the assessments used in this study, any momentary effects of single-tasking were not observable. Consequently, while the present intervention was designed to target trait-level media multitasking and affect trait-level cognitive control, further investigation is required to determine the value of the proposed intervention as a means to produce positive outcomes for in-the-moment media multitasking. While the reports provided in the follow-up interviews seem to support the assertion that, when regulating their media multitasking, participants were single-tasking and maintaining the allocation of their attention to the primary task at hand, further statistical evidence is required to determine if this was indeed the case. Moreover, in addition to determining the value of the present or similar interventions for momentary performance, it is worth considering whether interventions *should* target state or trait-level outcomes. While many studies have shown that in-the-moment media multitasking or off-task media use (OTMU) negatively affects performance outcomes (e.g., media use while studying or in a lecture; David *et al.*, 2014; Ravizza *et al.*, 2014; van der Schuur *et al.*, 2015; Parry and le Roux, 2018), it could be that, to address the potential interferences produced by such behaviour targeting momentary effects holds greater value than targeting trait-level effects. Rather than designing interventions to bring about changes in cognitive control at a trait-level, it may be more effective to target individual behaviours or instances of media multitasking and the direct effects associated with such actions rather than general cognitive outcomes.

9.2.3 Intervention Acceptability and Demand

The acceptability and demand dimensions of intervention feasibility, concerning the participants' application of the intervention procedures, reactions to the intervention, perceptions of positive or negative effects, and intentions to continue with the intervention, were addressed by considering prominent themes arising in the interviews.

Prior to the intervention period, the participants' cognisance of their media multitasking was poor. They underestimated, firstly, how much they used their phones and, secondly, how much this use coincided with other activities. This limited metacognition of self-interruption tendencies and cognisance of behaviour with media holds important implications for the interpretation of studies relying on self-reports of media multitasking. Recent studies indicate that, when comparing digital trace data of media use with self-reports, correlations are generally poor (Boase and Ling, 2013; Ellis *et al.*, 2018). The findings in this study, produced on the basis of qualitative data, support this assertion. Additionally, they corroborate suggestions that, over time, media use becomes driven, to a greater extent, by habit and situation than goals or processes of reasoned decision-making (Shaw *et al.*, 2018).

Considering the participants' incredulity at the reports of their behaviour and the subsequent statements in the interviews indicating how frequently they media multitasked, in relation to the *Technology Integration Model* (TIM; Shaw *et al.*, 2018), it is proposed that, while media multitasking may initially be driven by goal-directed decisions, over time, through repeated patterns of covariation between situations and responses, the behaviour becomes habitual and automatic. Therefore, media multitasking can, simultaneously, be considered goal-directed and automatic. Extending from Wood and Neal (2007)'s assertion that habits are the 'residue' of repeated instances of goal-directed action, this interpretation potentially accounts for conflicting findings in previous studies where some find that media multitasking is automatic (e.g., Oulasvirta *et al.*, 2012; Aagaard, 2015; Meier *et al.*, 2016) and others find it to be goal-directed (e.g., Ralph *et al.*, 2015; Wang *et al.*, 2015; van Koningsbruggen *et al.*, 2018). While media multitasking might initially be driven by informational needs or needs to alleviate boredom or anxiety, over time, the behaviour becomes automatic in such situations. This situational interpretation is supported by the finding that media multitasking self-regulation was, itself, differentially affected by situational factors. For some, academic settings presented particular difficulties while, for others, this was not the case. It is argued that, for these individuals, media multitasking in these situations had become habitual, and breaking these habits to override the impulse to media multitask was challenging.

While previous media multitasking interventions have primarily relied on a single behaviour change approach (with the exception of Irwin, 2017), the intervention in this study incorporated elements of awareness and restriction. Extending Rosen *et al.* (2013*a*), this decision was based on the interpretation that metacognition was a key aspect present across the three intervention categories reviewed. In relation to the BCW framework (Michie *et al.*, 2011), awareness of media use was intended to enable participants to change their behaviour. In particular, as a form of monitoring, it was intended, simultaneously, to support self-regulation and to provide a greater cognisance of behaviour and interruption tendencies. Consequently, as expected, in using the application to monitor their behaviour, the participants gained a greater awareness of, firstly, their behaviour with media, secondly, the allocation of their time in relation to their goals and, thirdly, the effects that their behavioural choices have for their attentional functioning and goals. Moreover, in considering their behaviour more explicitly, participants reported being more mindful of their goals themselves. This was seen to be a key outcome of the intervention and led participants to consider the alignment between their behaviour and their goals. Supporting Whittaker *et al.* (2016) this finding indicates that, when provided with indications of how and when they engage with media, people become more cognisant of their time and attention allocation strategies, and consider how their actual behaviour aligns with their intended behaviour.

Whether such an outcome would occur outside of an intervention environment requires further research. It does, however, provide early support for recent implementations of behaviour tracking features across the two most popular mobile operating systems (*iOS Screen Time* and *Android Digital Wellbeing*). Notably, the availability of information on media use was seen to be essential to successfully regulating media multitasking. In the absence of a supporting application participants felt that they could deceive themselves about their behaviour and the extent to which they multitasked. In addition to this, as more platforms provide applications to track and report behaviour, and as adoption of existing applications becomes more widespread, cognisance of media use behaviour will improve. This may, in turn, increase demand for interventions (personal or institutional) targeting media use behaviour (i.e., multitasking or other related behaviours) and possible adverse effects of such behaviours. While such features may support the clarification of goals and enable ongoing monitoring of behaviour, without an explicit goal or intention to manage or restrict media multitasking or other media-related behaviours, such features may not be effective at bringing about changes in behaviour.

Awareness of media use patterns and considerations of the alignment between actual behaviour and intended behaviour were seen by the participants to be key drivers of behavioural change. As in a number of previous interventions, while the restriction target forced a particular strategy to some extent, in general, the changes in behaviour required to operate and bring behaviour in-line with the target, were left to the participants. While this hybrid approach limits the extent to which causality can be attributed to any particular strategy or component of self-regulation, it does, however, enable insights into the nature of and motives for the various self-regulation strategies adopted, both of which are key aspects of the demand dimension of intervention feasibility.

Extending from the greater behavioural cognisance and metacognition of interruption tendencies, to meet the target, three principle strategies were adopted: time-blocking, response-batching, and accessibility-altering. Across these strategies a common element was the explicit consideration of how available time was structured. Participants endeavoured to use their time and attentional resources in a manner that aligned with their goals. This finding supports Whittaker *et al.* (2016) who found that awareness of media use led to reductions in hedonic activities but not work-related utilitarian activities. Moreover, the findings produced in the present study extend Whittaker *et al.* (2016) who only considered awareness of computer-based activities over a period of two days. Additionally, as with Adler *et al.* (2015), Whittaker *et al.* (2016) found the manual logging procedures to be a distraction themselves. In contrast, in the present intervention, participants were able to choose how and when they accessed the reports on their behaviour. No indication was received that this was, itself, a distraction.

Considering the strategies adopted, for time-blocking, goal-alignment manifested through the allocation of specific times for different activities. Primarily, this involved using media outside of academic settings. Additionally, in-line with these time-blocks, participants delayed responding to incoming messages until they had completed a task and, upon completion, respond in a single batch. Support for the value of such an approach as a means of managing the effect of notifications on attention has been provided in a recent presentation by Fitz *et al.* (2018). Another strategy adopted to regulate simultaneous media use was to limit the accessibility of phones during a time-block designated to other activities. In lectures, for instance, participants reported turning their devices off or, in other locations, they would place their phones out of their direct line-of-sight. This strategy supports Parry and le Roux (2019*b*)'s indication that, in academic settings, control over technology presents a viable approach to managing media-related interferences.

While viable, the participants' behaviour suggests that, rather than enacting various affordances, besides turning the device off, they did not use other features or settings to regulate their usage and, rather, relied on will-power. As was evident with the usage data, while the application was useful for understanding behaviour, the restriction feature was not adopted as a key component of the participants' media multitasking self-regulation. Rather, after initially using the feature, a majority opted to structure their time without the explicit assistance of initiating restriction sessions. The reluctance to use application-level features or other operating system features (e.g., 'do not disturb mode', 'airplane mode', disconnecting mobile data, or disabling certain applications) and, instead rely on willpower or other changes, may have occurred either due to an absence of knowledge of the existence of such features, the inability to use such features, or an unwillingness to restrict connectivity in such ways. Chokalingam *et al.* (2018), for instance, indicate that many students are unaware of how specific applications can be used to support self-regulation of smartphone use. Moreover, the centrality of such media in students' lives suggests that, despite goal-alignment and intentions to restrict access, some participants may not have wanted to entirely restrict access to their devices and, in this way, intentionally undermined their efforts at self-regulation. A consequence of this strategy, irrespective of its cause, was the opening of a 'back door' to their devices. In not completely restricting access, participants indicated that they perceived notifications arriving on their nearby phone and allocated attention to considering their potential contents. Consequently, their single-tasking efforts were, in some cases, undermined by the manner in which they implemented their time-blocking strategy.

As discussed in Chapter 6, the re-structuring of time associated with a greater cognisance of switching behaviour and media use patterns can be interpreted as the adoption of an attentional strategy fostering a narrow distribution of attention. It is argued that the adoption of such a strategy, in relation to goals and intentions, was a principal effect of the intervention. In requiring participants to target a goal, monitor their behaviour in relation to this goal and, through whatever means they deemed necessary, operate to adhere to this goal, the intervention promoted the adoption of an attentional strategy emphasising a narrow distribution of attention and the inhibition of interferences to maintain a state of single-tasking. Consequently, given the strategic nature of these changes, as Ralph *et al.* (2015) and Parry and le Roux (2019*a*) argue, indications of improved focus or attentional allocation are indicative of changes in behavioural and attention-related strategies and not necessarily changes in cognitive control. Ralph *et al.* (2018), for instance, indicate that individuals strategically balance the requirements of present tasks with other concerns or needs (e.g., boredom or anxiety). Extending from these instances of single-tasking and in relation to the motivational nature of sustained attention (Oken *et al.*, 2006), it is argued that the participants engaged less in rapid switching between tasks. While this may not have affected their cognitive control abilities, as indicated in the interviews, it aided task-performance and goal-achievement. This supports the distinction suggested between in-the-moment effects and trait-level intervention effects. Considering Ralph *et al.* (2018)'s suggestion, it is argued that, extending from a greater awareness of primary goals, when required by present tasks, the intervention supported the participants' adoption of an in-the-moment attentional strategy fostering a narrow distribution of attention. This strategy did not, however, extend beyond such situations to trait-level changes in cognitive control.

Noting the strategies adopted, it is argued that, while external interruptions were reduced, primarily, the participants endeavoured to reduce the degree to which they interrupted themselves with media. While both imply interference (Clapp and Gazzaley, 2013), as Katidioti *et al.* (2016) show, internal interruptions are more disruptive than external interruptions. In this way, rather than perceiving the intervention to have an effect on their underlying capacity to concentrate, the participants understood the behavioural changes as a means to bring about more opportunities to single-task and allocate attention to one activity at a time. At a functional level, as confirmed by the assessments of cognitive control before and after the intervention, the participants' abilities to sustain attention and inhibit interferences were not improved. Despite this, as the participants reported, the regulation of their media multitasking was seen to enable them to enact changes which brought about more instances in which they were single-tasking and sustaining their attentional allocation to individual tasks. This was regarded to be a positive effect of the intervention. Consequently, it is argued that the self-regulation of media multitasking promoted greater cognisance of goals and associated attentional strategies and, in turn, through the delay of short-term gratifications typically associated with media use, increased instances of goal-oriented single-tasking. This outcome was reflected in perceptions of reduced procrastination and perceptions of improved productivity, both of which were seen to have positive effects on academic and social outcomes. This supports Rosen *et al.* (2013*a*)'s suggestion that strategies enhancing metacognition of behaviour, through self-regulation, will enhance task performance. Additionally, while no evidence of changes in either the functional or reflective assessments were found, in the interviews, participants consistently reported that, in the course of their everyday lives, they perceived themselves to be more mindful of their current situations.

Considering the perceptions of reduced procrastination, it is necessary to note the contradiction in the findings. As indicated by the irrational procrastination scale (Steel, 2002), no effect of the intervention on trait procrastination was found. Importantly, as Svartdal and Steel (2017) show, the scale adopted in this study measures only one component of procrastination —irrational delay— and not habitual or problematic delay. Irrational is interpreted to describe voluntary task-delay "despite expecting to be worse off for the delay" (Steel, 2007, p. 66). In many cases, however, in the short-term, task-delays in the aid of affective regulation are seen to be rational (Reinecke *et al.*, 2018). Moreover, as Svartdal and Steel (2017, p. 9) note, assessments of procrastination are complicated by the inherently subjective nature of procrastination – "delays are only irrational if they are inconsistent with a person's internal preferences". Consequently, while further research is required to elucidate associations between media multitasking, self-regulation, time-management and procrastination, it is suggested that the intervention did not affect irrational task-delay but, as indicated in the interviews, it did have an effect on habitual or problematic components of procrastination.

The participants associated two negative effects with the intervention. First, as the phone was used primarily to communicate with social connections, in regulating their behaviour with the device, the participants' mediated social interactions were affected, with some perceiving greater levels of anxiety related to missing out on conversations (FoMo). This supports Hartanto and Yang (2016)'s indication that incidental smartphone-separation is associated with heightened anxiety. Overall, however, the participants considered this anxiety to be minor in relation to the benefits of achieving a better alignment between goals and behaviour. A second negative effect of the intervention related to negative affective responses. The improvements in behavioural cognisance led participants to feel guilty when their behaviour was regarded to be incongruent with their goals. Furthermore, the effort required to regulate their media multitasking was, for some, a distraction itself. This factor is congruent with previous interventions which have shown that monitoring or awareness of media behaviour can divert attention away from present tasks (e.g., Adler *et al.*, 2015; Whittaker *et al.*, 2016). Despite this, it is believed that, in enabling participants to self-monitor their behaviour, the obtrusiveness of the intervention was reduced in comparison to these previous interventions. Moreover, while monitoring may present as a distraction, it is argued that, over time, such actions may become automatic and, as consequence, present less of an interference. More unobtrusive means of behavioural evaluation, while less distracting, may not provide sufficient impetus to engender goal-alignment and behavioural change.

Considering the effort required for implementation and their subjective evaluations of both the positive and negative effects associated with the intervention, participants did not intend to continue with the intervention as it was proposed to them. Specifically, noting the value for their academic goals, the participants indicated that they would continue to regulate their media multitasking when in academic settings, but not in other situations. Moreover, they indicated that they would maintain structuring their phone use around their goals but, despite the improvement in their awareness of their behaviour, would cease using the application or adhering to the time limit.

9.2.4 Overall Intervention Evaluation

To address RQ1, and provide an evaluation of the feasibility of the media multitasking intervention, the findings for the relevant feasibility dimensions are evaluated. For intervention *implementation*, despite variation in the degree of execution, given the *in situ* assessment, it is concluded that the intervention can be implemented as proposed, with one exception. Considering the participants' behaviour prior to the assessment, the intervention procedures supported participants in changing their behaviour. While there existed situational and temporal effects on implementation, the participants were able to implement the proposed procedures in the course of their everyday lives. Noting the deficiencies in cognition of behaviour with media, it is evident that the availability of a usage tracking mobile application to support media multitasking self-regulation is a key resource required for the implementation of such an intervention. As a change, to account for the time required for behaviour changes to occur, the intervention or similar interventions, should be implemented for a longer duration than 28 days.

For intervention *acceptability*, despite acknowledging positive effects associated with the intervention, only limited intentions to continue with the full intervention were reported. In particular, acknowledging that the intervention supported the alignment of behaviour with goals, participants indicated that they would continue the regulation of their media multitasking when in academic settings, but not in other situations. Additionally, despite the value of the mobile application in enabling the behavioural changes, participants indicated that they would be unlikely to continue with this aspect of the intervention. Consequently, while the intervention was deemed to be appropriate and, for the task of supporting changes in behaviour, satisfactory, such an intervention is unlikely to be used by the target population in its present form.

For intervention *efficacy* the results of both the self-reported and performance-based assessments of cognitive control before and after the intervention indicate that, within the parameters of this study, it can be concluded that mobile-application supported self-regulation, as an intervention targeting media multitasking, did not have a significant or practical effect on cognitive control at a trait level. The intended efficacy of the proposed intervention, therefore, is not supported. Notwithstanding this result, considering the *demand* dimension, the intervention was seen to bring about a greater cognisance of media use patterns and considerations of the alignment between actual behaviour and intended behaviour. These were seen to be key drivers of behavioural change. Additionally, while some acknowledged negative affective and social effects, the intervention was understood to enable behavioural changes which brought about more instances of single-tasking and narrower distributions of attention. This occurred, primarily through three strategies: time-blocking, response-batching, and accessibility-altering. Considering the perceived positive effects of the intervention and its apparent failure to bring about trait-level changes in cognitive control, it is concluded that the intervention enabled participants to structure their time to align more closely with their goals and, in this way, brought about momentary changes in their attentional states. These momentary changes, however, did not transfer to trait-level changes in cognitive control over a 28-day period.

To provide an answer to RQ1, for the implementation and demand dimensions of feasibility the intervention is considered to be feasible for the targeted population. For the acceptability dimension, while the intervention was regarded as appropriate and satisfactory, in its current form, it is unlikely to be adopted by members of the target population. Therefore, for acceptability, the intervention is considered to be partially feasible. For efficacy, the intervention did not produce the intended effect and, therefore, for this dimension, it is not considered to be feasible. Despite this, positive effects were associated with the intervention. On this basis, it is proposed that, while such an intervention is not feasible as a means of improving trait-level cognitive control, it is a feasible approach to bring about increased instances of single-tasking and enable momentary occurrences of narrower attentional states, both of which were seen to have positive effects on academic and social outcomes. Given the nature of the assessments used in this study, future research is required to confirm the validity of this assertion and determine how such an intervention can be designed in a way that is acceptable for the target population.

With regard to the propositions advanced as a theoretical basis for the intended effects of the intervention on cognitive control, the findings presented in this study provide support for P_2 —*promoting goal-oriented self-regulation will facilitate the enactment of* *single-tasking.* P_1 is only partially supported. The behavioural changes and participant perceptions recounted indicate that *increasing the frequency and extent of single-tasking will promote a narrower distribution of attention.* Despite this, as indicated by the reflective assessments of everyday executive functioning, this did not *improve attentional performance in everyday life.* This result, in conjunction with the absence of changes in cognitive control, provides no support for P_3. Increased instances of single-tasking and narrower distributions of attention did not *lead to changes in cognitive control and everyday executive functioning* within a 28-day period.

9.3 Implications of the Study

The outcomes of the present investigation hold a number of important implications for research and practice in a variety of domains. In addition to the specific findings for the research objectives and questions, the results are relevant for research considering the management of interferences associated with media multitasking. Specifically, it is argued that the findings will be of value to inform the development of subsequent interventions targeting aspects of media multitasking related interference. Additionally, there are implications for research considering associations between media multitasking and cognitive control extending from the findings. Finally, there exist a number of outcomes which hold relevance for research in Social Informatics and related fields.

9.3.1 Implications for the Management of Interferences Associated With Media Multitasking

The outcomes of the present investigation hold a number of implications for the management of media multitasking related interferences. Such implications are relevant for research concerning interventions targeting effects associated with media multitasking or media use, and for individuals seeking to manage their behaviour with media through the implementation of personal interventions. While the discussion thus far has considered a number of relevant results, six key implications are highlighted.

The first implication relates to the importance of media behaviour cognisance. Interventions for research, personal, or institutional purposes should include, as a fundamental component, an element of behavioural awareness. Whether this is brought about through a self-accessed mobile application as in this study or, as with the latest *iOS* and *Android* updates, weekly reports, as the present study demonstrates, given the poor cognition in this regard, engendering a greater cognisance of media behaviour is key to behaviour change and goal-alignment. It is argued that this leads to self-motivated behavioural changes. Rather than coercive policies or top-down restriction, the development of a personal understanding of the nature of one's behaviour, goals, and the implications of actions with media for these goals enables the self-regulation of actions in a manner that is goal-aligned and self-motivated. Relating this implication to the BCW framework, media-related behavioural changes are brought about, in part, by the education and enablement intervention functions. Additionally, in relation to the COM-B behaviour model, the findings imply that, for behaviour with media to change, interventions should target the opportunity and motivation dimensions of behaviour. It is argued that, for behaviour change with media to be free of unwarranted enmity, such changes need to be individually motivated and driven by personal decisions about what is appropriate and desirable. Such self-motivated changes, while not necessarily having an effect on cognitive control, through greater goal-alignment, will support performance across personal, professional, academic, and social domains. Moreover, in future behaviour change intervention investigations implemented *in situ*, it is recommended that elements targeting behavioural awareness be implemented prior to the implementation of the intervention itself. In this way, irrespective of the nature of the specific intervention, participants would be motivated to make use of the intervention and adhere to its requirements.

A second closely related implication is the value of a reliable, user-friendly instrument for recording and communicating information on media use patterns. Application-supported behaviour change and goal-alignment has emerged across domains, from fitness (Bort-Roig *et al.*, 2014) and nutrition (Franco *et al.*, 2016), to mental health (Wylde *et al.*, 2017). Collectively, such applications are termed *health tracking technology* (Simpson and Mazzeo, 2017). While no associations with changes in cognitive control were found, the present study demonstrates the value of such approaches for changing behaviour with media. In this regard, a key implication of the present study is the need to consider device compatibility when designing or adopting interventions. This implication is important not only for interventions, but also for any research involving the use of mobile applications to track and record smartphone behaviour. In this study, as in a number of others (e.g., Kim *et al.*, 2017*a*; Ellis *et al.*, 2018), the use of such applications was restricted to particular devices using the *Android* operating system. Despite recent developments in this regard, this implies that the generalisability and applicability of any intervention or management strategy are restricted. Additionally, access to information on behaviour needs to be unobtrusive and accessible at the convenience of the users. No indication was found that self-initiated accessing of such information posed a major distraction or hindrance to participants, whereas more obtrusive reports have been found to be distracting (Adler *et al.*, 2015). As noted, for interventions, a balance needs to be found between completely unobtrusive reporting and more intrusive reporting of behaviour. For instance, weekly reports on media behaviour may be too infrequent to provide the impetus to bring about changes in behaviour while, in contrast, hourly or constantly displayed reports may be too intrusive and distracting to effectively change behaviour without undue affective consequences.

A third implication extending from the present investigation relates to the duration of interventions. The design and implementation of interventions needs to account for the time required for behaviour changes to occur and, in addition, the time required for the intended effect to take place. For *in situ* behavioural interventions with media, the outcomes of this investigation indicate that behavioural changes require, at a minimum, two weeks. This implies that brief or short-term interventions, as a number in this domain have been (Ie *et al.*, 2012; Adler *et al.*, 2015; Gorman and Green, 2016), are unlikely to have sustainable effects at either behavioural, cognitive, or performance levels. Moreover, while changes in behaviour became easier for the participants after two weeks, it is unknown whether such changes could be sustained over a longer period of time.

A fourth implication is that changes in behaviour in the short term do not necessarily imply trait-level changes in cognitive functioning. Adopting a behavioural and attentional strategy promoting single-tasking may support task performance through momentary changes in attentional states. Such changes, however, do not automatically transfer to general changes in cognitive control. Consequently, despite assertions that changes in behavioural patterns can reshape information processing styles (Dux *et al.*, 2009) or that single-tasking can alter neural networks associated with attentional control (Rothbart and Posner, 2015), the results of the present investigation indicate that, for cognitive control, increases in the frequency and extent of single-tasking, in the short-term, do not transfer to general, sustained improvements or changes. Therefore, in the same way that there is no definitive evidence for the deficit-producing hypothesis, there is no definitive evidence that the opposite —the benefit producing effect of single-tasking— holds true. It may be that a longer duration of change is required to produce such outcomes or, as Kelly *et al.* (2014) note, more specific training of cognitive functioning or targeting of single-tasking may be necessary to support the transfer and maintenance of effects.

In relation to the integrative model provided in Section 3.2.4, with relevance to media multitasking interventions, the findings hold a number of implications. The model, proposed as a descriptive summary of previous research considering the drivers of media multitasking, indicates that media multitasking is primarily driven by both situational and subjective factors. While it was noted that affordances are central to the enactment of this behaviour, the findings of the intervention assessment indicate that, more-so than affordances, media multitasking is directed by situational and subjective factors. This suggests that, for interventions, such factors present key elements to be targeted to bring about desired changes. Affordances are understood in relation to the capability aspect of behavioural initiation. For a user the affordances provide the physical or virtual capability to engage in media multitasking. Opportunities and motivations, it is argued, are a function of individual needs and situational factors. Interventions targeting media multitasking capabilities, through media affordances, may be seen to be coercive or forced and, as was evident with the strategies adopted, unlikely to be used. Without targeting the opportunities or motivations, through mechanisms working on subjective or situational factors, media multitasking intentions will be unchanged. This, it is argued, will not lead to sustainable changes in behaviour.

Finally, given associations between in-lecture media use (which has frequently been interpreted as media multitasking) and diminished academic performance (van der Schuur *et al.*, 2015), the findings presented in this study hold implications for the management of interferences associated with media multitasking in academic settings. Whether physically co-located in a lecture, studying in a personal space, or through the blending of technology into personal and shared learning spaces, media are increasingly present in such situations. The findings presented here indicate that behaviour in such settings is largely governed by the alignment between the present setting or task and one's goals. If, for instance, a lecture is seen to be irrelevant to the attainment of academic goals, media multitasking presents as a more attractive alternative with regulation of this off-task behaviour suffering. Extending this, supporting previous studies (Parry, 2017), boredom was frequently reported as a hindrance to the self-regulation of media multitasking. Consequently, for lecturers, student-engagement and active communication of the academic value of a class are key elements to foster.

For self-directed study situations where technology is typically present (Moreno *et al.*, 2012) and media multitasking frequently occurs (Rosen *et al.*, 2013*a*; Calderwood *et al.*, 2014), the findings suggest that an explicit strategy is required to manage potential interferences. Without a strategy —time-blocking or notification-delaying for instance—

students struggle to regulate their media multitasking in these situations and, frequently, performance suffers. While, as demonstrated in this study, such strategies might not improve a student's ability to sustain attentional allocation, they will, however, lead to more instances in which a student is remaining on-task and allocating attention to their academic work, inhibiting media-related interruptions. Considering the deficient cognisance of behaviour with media, prior to the adoption of such strategies, students need to gain a level of awareness of, firstly, their own behaviour and, secondly, the effects this might hold for their academic goals. Whether the role of a university lecturer involves fostering such awareness remains an open question for debate. What is evident, however, is that for students to gain the intended value from academic settings, lectures in particular, a lecturer needs to be cognisant of the competing demands for their students' attention and the manner in which students decide how to allocate their attention.

9.3.2 Implications for Social Informatics Research and Associations Between Media Multitasking and Cognitive Control

A primary outcome of the study, with a broad relevance to media research, is the finding that cognition of behaviour was seen to be poor. This outcome has implications for studies relying on self-reported indications of media behaviour. Whether such assessments concern media use, media multitasking, or other dimensions of media behaviour, the construct validity of such measures is called into question. The participants felt that they underestimated how frequently they used media and how frequently this use coincided with other activities. This finding supports studies indicating weak to null associations between self-reports and objective assessments of media use (Boase and Ling, 2013; Ellis *et al.*, 2018). Noting the widespread use of self-reports across media research, cognisance of this incongruence is necessary. Given the indications presented in this study and the results of these correlational studies, greater emphasis on objectively measuring media behaviour is required. While self-reports certainly provide value, when aiming to measure behaviour, actually measuring behaviour is likely to hold greater validity than reports based on deficient cognition of behavioural patterns. Additionally, given the individual and situational dimensions of media multitasking, as Ellis *et al.* (2018) and Jungselius and Weilenmann (2018) note, conceptualisations of media behaviour and considerations of media effects need to develop to more accurately account for these factors. This is particularly the case with media multitasking where the dominant measure relies on self-reports of instances of media combinations, considers all media to hold equal implications for cognitive load, and ignores concurrent non-media tasks and situations.

As noted, in accordance with the TIM, the qualitative findings indicate that, over time, media use becomes driven, to a greater extent, by habit and situation than by goals. Media multitasking may initially be driven by goal-directed decisions to reduce boredom or anxiety or access information but, through repeated patterns of covariation between situations and responses, the behaviour becomes habitual and automatic. This interpretation accounts for conflicting findings in previous studies where media multitasking has been regarded as either goal-directed or habitual. Moreover, this interpretation suggests that, to understand media behaviour, both intuitive and deliberative conceptions of behaviour are required. Such an interpretation does not stand in contrast to Gazzaley and Rosen (2016) who provided a cyclical interpretation of media multitasking as a function of boredom. Rather, this notion is complemented by the interpretation of media multitasking as a habitual process driven by previous instances of goal-directed action. Adopting the information foraging notion and the MVT discussed in Chapter 3, driven by needs for information and positive affective outcomes, the experiences of relative boredom associated with non-stimulating situations brought about by prior instances of media multitasking produce the impulses to initiate simultaneous engagement with media. Such goal-directed impulses, it is argued, provide the necessary triggers to automatically precipitate media multitasking.

In addition to this proposition, the findings support suggestions that media are frequently used as means to escape from subjectively aversive situations (Smock *et al.*, 2011; Taneja *et al.*, 2015; Meier *et al.*, 2018). In-line with Katz and Foulkes (1962)'s conception of escapism as more than simply a gratification of media use, it is suggested that when bored, stressed, or anxious in relation to present situations, particularly academic situations, students frequently switch between present tasks and various media. As Meier *et al.* (2018, p. 169) note, this can simultaneously lead to expected positive affective outcomes and unintended negative consequences (e.g., procrastination, time displacement effects, or stress; Valkenburg, 2007; Sirois and Pychyl, 2013; Parry, 2017). This form of escapism can be viewed as misregulation, with behavioural regulation efforts targeted at gratifying immediate affective needs rather than bringing behaviour in-line with the potentially more distal awards associated with remaining on task in such situations. Meier *et al.* (2018) reason that, as a consequence of this pattern of behaviour, a cycle of media engagement and spiralling affective outcomes may occur.

Finally, the outcomes are, broadly, in support of the strategic hypothesis for the association between media multitasking and cognitive control. It is proposed that, given the strategic nature of the behavioural changes observed in this study and the indications that this brought about increased instances of single-tasking, individual differences in media multitasking are indicative of general behavioural strategies. Frequent media multitaskers report increased instances of attentional failures, not because of deficits in cognitive control but, rather, as le Roux and Parry (2019*a*) suggest, they adopt an attentional strategy permitting themselves to become distracted. While no indication was found that changes in behavioural strategies over a 28-day period affect cognitive control or everyday executive functioning, it is proposed that, over a longer duration, such changes in behavioural and attentional strategies may be reflected in indications of improved everyday executive functioning, but not trait-level cognitive control. Consequently, while differences exist between HMMs and LMMs, such differences are not caused by media multitasking. Rather, as Baumgartner and Sumter (2017) suggest, such differences are primarily accounted for by individual factors which, along with strategic choices, moderate any effects that frequent multitasking with media might hold for cognitive functioning and task performance. Moreover, associations between media multitasking and diminished task performance are due to switching costs and time diverted away from primary tasks, and not changes or deficits in cognitive control. This interpretation provides support for the present intervention —achieving optimal task-performance in the face of increasingly mediated lives is contingent more-so on strategic choices and goal-alignment than on improvements in cognitive control ability.

9.4 Limitations of the Study

In reflecting on the study there are a number of limitations to acknowledge. A first limitation relates to the population and sample make-up. The study targeted a population of university students who self-reported as heavy media multitaskers. While this population was targeted due to their consideration in a majority of previous media multitasking studies and the indications that such individuals, firstly, engage in media multitasking more frequently and, secondly, are more likely to experience possible negative effects, it is acknowledged that the extent to which the findings can be generalised to non-student, non-HMM populations is potentially hindered by this choice. Additionally, given the study design, the sample was restricted to users of the *Android* operating system. While many previous studies have faced the same restriction, and it is not proposed that such users are fundamentally different to users of other mobile operating systems, such a limitation is nonetheless present in the sample make-up. Given these considerations, and the make up of the sample, it is believed that the outcomes of this study may be extrapolated to the targeted population. However, the extent to which these outcomes may be generalised to other populations is limited. Additionally, while frequently used in such studies, it is acknowledged that a student population holds a number of characteristics which do not necessarily extend to other populations (e.g., adolescents or working age individuals). Consequently, it remains unknown whether the current intervention and feasibility assessment would produce different outcomes for other populations. This is especially the case for working professionals or children where, for the latter, lifestyle and developmental factors may imply changes in implementation and potential effects.

A second limitation relates to the sample sizes considered. While the number of interviews conducted is in-line with prescriptions for qualitative research of this type (Guest *et al.*, 2006), the sample size considered in the final experimental analysis was less than that determined by the a priori power analysis. Despite being larger than the average sample size considered in previous media multitasking intervention studies, and in the range of sample sizes for feasibility studies described by Arain *et al.* (2010), due to non-compliance and attrition-related issues, it is acknowledged that the final sample size may have affected the degree to which statistically significant intervention effects could be determined. In relation to participant-attrition, the data collection techniques limited the extent to which reasons for withdrawal could be elicited. Consequently, the study is unable to account for intervention-related factors in this regard.

The nature and duration of the intervention present a third limitation. The intervention in this study targeted only a single device. While participants indicated that they did not increase their usage and multitasking of other media, their behaviour across other devices was not assessed and is, therefore, unknown. While previous research has shown that a majority of media use for the targeted population involves the use of such devices (Nielsen, 2016; Poushter, 2016; Pew Research Center, 2017), there remains the possibility that media multitasking persisted across other media. In prescribing the behavioural changes for a period of 28-days, and only testing at the end of the intervention period, the study was unable to determine, firstly, if changes occurred earlier in the intervention period or, secondly, what the required time is for changes to occur. Additionally, in only considering behavioural changes over such a period, while insights about short-term changes are available, the long-term sustainability of any changes remains unknown.

A fourth limitation relates to the instruments of the investigation. To assess the participants' media use and provide them with feedback on their behaviour a commercial mobile application was used. Despite the use of such applications in prior studies (Elhai *et al.*, 2017; Rozgonjuk *et al.*, 2018) and the testing conducted in this study, this does, however, present a limitation. The application used was designed and developed for commercial and not research purposes. Therefore, the accuracy and reliability of the application remains a shortcoming. Moreover, while researchers (e.g., Ellis *et al.*, 2018) are developing techniques to automatically receive reports on mobile behaviour, the application used in this study required the participants to share their reports. This potentially affected the reliability of the data received. Furthermore, while the study targeted media multitasking, the usage measures collected primarily concerned use time. Consequently, while participants reported reductions in multitasking, the accuracy of these reports presents a limitation. In addition to the instruments of the intervention, the assessment instruments present limitations. While the instruments adopted were all standard, widely adopted tests of cognitive control and everyday executive functioning, inherently they are limited. Self-report assessments (both the reflective executive functioning assessments and the interviews) are subject to a number of well-known biases, including: selective memory, telescoping, attribution, and exaggeration (Babbie, 2012). Performance-based assays are also subject to biases and limitations, including: ecological validity, demographic and socio-economic differences, and construct-validity.

Finally, a fifth limitation present in the current study is the assumption of a relatively linear association between media use and media multitasking. While previous studies (e.g., Baumgartner *et al.*, 2017*a*) have shown that there exists a moderately strong, positive correlation between media use and media multitasking and, indeed, the same was found in this study, this assumption may still have affected the outcomes of the present study. Baumgartner *et al.* (2017*a*) note that, while these behaviours are closely related there is still a distinction, with not all media use involving multitasking. In designing the present study, based on research indicating that a majority of media use involves task-switching to some extent (Jeong and Fishbein, 2007; Rideout *et al.*, 2010; le Roux and Parry, 2017*b*; Deng *et al.*, 2018), it was proposed that a restrictive target for media use would, by definition, imply a reduction in media multitasking. While the interviewees indicated that, in restricting their media use, they also restricted their media multitasking, objectively, this assumption has not been tested. Consequently, while the results might not have been materially affected by this assumption, the design of the intervention, in particular, was influenced.

9.5 Future Directions

Throughout the dissertation limitations in present approaches have been highlighted. In particular, in Chapter 6, when discussing the outcomes of the systematic review a number of recommendations for future research were described. Additionally, throughout the present discussion limitations and implications of this investigation have been noted. In this section, while many have been implicitly described, extending from these limitations and implications, four recommendations for future research are provided.

9.5.1 Adopt Objective Measures of Media Behaviour

It is recommended that future studies use passive, objective measures of media behaviour when considering possible associations with well-being, cognitive functioning, or task-performance. Whether this is achieved through the use of native operating system features or purpose-built applications, objective assessments of both media use and media multitasking are needed to advance research in this domain. Such approaches will not only support the investigation of associations between media multitasking and cognitive control but, in addition, they will aid assessments of related interventions, behavioural changes, and effects. Moreover, it is also recommended that specific instruments be developed to more accurately assess media multitasking. This is particularly challenging given the subjective nature of media multitasking and the goal and task-related conceptualisations of multitasking itself (Aagaard, 2018). While experience sampling may address these challenges in part, the subjective and obtrusive nature of such techniques is problematic. Future studies should endeavour to objectively assess both media to media and media to non-media multitasking and, through more subjective measures, consider the relevance of such actions for current goals and tasks. In this regard, ethnographic studies may present an interesting approach to understanding situational factors that drive media multitasking.

9.5.2 Implement Interventions for Longer Durations

To account for the time required for both behavioural changes and targeted effects interventions should be implemented for longer durations. It is recommended that, at the least, interventions should be implemented for at least six weeks (to account for the time for behaviour change and intervention effects), with an even longer duration being preferable. Moreover, because the sustainability of any changes or effects are unknown at this stage, it is recommended that studies consider adopting longitudinal designs involving multiple waves of data collection. Failing this, as with Pielot and Rello (2016), it is suggested that studies conduct follow-up procedures after a period of at least six months to assess the sustainability and long-term effect of behavioural changes.

9.5.3 Assess State-Level Effects of Interventions

On the basis of the present assessment, it is proposed that future studies investigate the assertion that self-regulation of media multitasking, supported by feedback from a mobile tracking application, is a feasible approach to produce increased instances of single-tasking and enable momentary occurrences of narrower attentional states. In this regard, Schueller *et al.* (2017) note that, when considering the effects of digital health interventions, it is necessary to distinguish between proximal and distal outcomes. While these authors' comments pertain to a different domain, they hold relevance nonetheless. Future research testing such outcomes will need to assess momentary changes in attentional states in relation to behavioural changes. It is therefore recommended that, in conjunction with objective assessments of behaviour, some form of experience-sampling investigation be conducted to enable ecological momentary assessment. Moreover, to statistically determine the effects of behavioural changes on attentional states, single-tasking or, for that matter, cognitive control, it is recommended that future investigations adopting randomised, controlled designs are conducted on a larger scale, with larger samples and over longer durations.

9.5.4 Design Interventions to Target Individual and Situational Factors

Considering the findings presented in this dissertation, it is recommended that researchers explicitly consider individual (i.e., demographics, motivations, intentions, or gratifications) and situational (i.e., social, work, or home) dimensions of behaviour when designing interventions for behaviour with media. This would entail, as a first step, investigations considering in detail the role that these factors play in shaping media multitasking behaviour. As van der Schuur (2018, p. 147) notes, while such aspects have broadly been investigated in communications research, with media multitasking, consideration of individual differences is limited. The identification of individual and situational dimensions of behaviour could inform the design of interventions drawing on findings from fields as diverse as economics (i.e, the idea of commitment devices[1] from game theory) and game design (i.e., the use of gamification[2] techniques). In particular, it is recommended that, as a form of commitment device, researchers investigate the use of device-level settings or the blocking of applications at certain times of the day as means to regulate behaviour with media. Such approaches can, potentially, address the notion of a 'back door' discussed previously. In such instances where individuals rely simply on willpower to resist the urge to check and use their devices, locking oneself in to a pre-selected plan of action will restrict this possibility and enable effective self-regulation in accordance with longer-term goals. Alternatively, such factors can be accounted for through the gamification of self-control through the social sharing of reports on behaviour or through the targeting of social pressure and social norms (e.g., Parry *et al.*, 2019). Additionally, in accounting for individual differences, goals, motivations, and situations, interventions may involve targeting specific behaviours, devices, motivations, or situations.

9.6 Conclusion

Building on indications that media multitasking is associated with changes in cognitive control and diminished task performance, through addressing two primary research objectives, this study aimed to provide greater insight into the design, nature, and feasibility of interventions targeting aspects of media multitasking and the effects thereof. Following a review of relevant theories and the findings a systematic review of behavioural interventions targeting media multitasking was conducted and published (i.e., Parry and le Roux, 2019*a*). Informed by the outcomes of this review, the findings of previous studies, and the theories and frameworks considered, a behavioural intervention was developed. This intervention involved the application-supported self-regulation of media multitasking. Through an experimental assessment involving the collection of both quantitative and qualitative data, and the testing of 11 preregistered hypotheses, the intervention was found to be partially feasible. While implementation and demand dimensions were feasible, acceptability was only partially feasible, and efficacy was not feasible. Through both functional and reflective assessments no evidence to support the targeted improvements in cognitive control ability were found. Despite this, the intervention was seen to engender increased instances of single-tasking. Consequently, it is proposed that, as

[1] A choice that restricts future choices to those that align with longer-term goals.

[2] Gamification is the application of game-design principles to non-game contexts.

an intervention targeting improvements in cognitive control it is not feasible but, as an intervention targeting alignment between media behaviour and longer-term goals, it is feasible. This assertion and other stated recommendations need to be tested and applied in future investigations of media multitasking interventions.

Notwithstanding the aforementioned limitations, the study findings are of interest because of their relevance for research concerning media multitasking interventions, associations between media multitasking and cognitive control and, more generally, behaviour with technology. Reflecting on the contributions of the study, while many of the findings are particularly nuanced and often lead to more questions than answers, there exist a number of contributions worth highlighting from those discussed throughout the preceding dissertation and chapter. First, the systematic review found that there is a a paucity of research considering behavioural change interventions targeting improvements in cognitive control or performance in relation to media multitasking. In identifying and assessing three categories of intervention —awareness, restriction, and mindfulness— it was found that there remains a distinct lack of clarity in terms of effects of relevant behavioural interventions on behaviour and cognitive control.

Extending from the feasibility assessment, while numerous findings and implications have been discussed throughout this chapter, the following key contributions are provided. First, the qualitative data produced novel support for indications that self-reports of media behaviour are generally inaccurate. It was shown that students' poor cognisance of their behaviour with media leads them to underestimate the extent of their use and how frequently they media multitask. Second, it was shown that behaviour change with media is not immediate and takes time to implement. Following from this, the approach adopted in this study enabled the identification of a number of strategies adopted by students to self-regulate their media multitasking: time-blocking, response-batching, and accessibility-altering. Across these strategies a common element identified was the explicit consideration of how available time was structured. In particular, the intervention was seen to bring about a greater cognisance of media use patterns and considerations of the alignment between actual behaviour and intended behaviour. This was shown to support behaviour change and the self-regulation of media multitasking, increasing instances of goal-oriented single-tasking. Moreover, while the present intervention was found to not to be feasible as a means of improving trait-level cognitive control, it is a feasible approach to bring about increased instances of single-tasking and enable momentary occurrences of narrower attentional states, both of which were seen to have positive effects on academic and social outcomes. In noting this final contribution, the apparent 'null' finding for the effect of the intervention on cognitive control outcomes should be interpreted holistically in the context of the outcomes of a feasibility assessment. Consequently, in addition to the aforementioned contributions, the primary contribution of the study is the identification of refinements to a proposed class of interventions for media multitasking and the proposal of an open question for future researchers:

> *When seeking to manage the potential interferences associated with media multitasking, through the development of associated interventions, should state or trait-level outcomes be targeted?*

To conclude, while many open questions remain, drawing on Fallon (2010)'s fictional conversation with Postman: "[Jacques] Ellul reminds us that the values of a technological society present us with a certain imperative with which we seem only too happy to conform, namely: to do, to act, to respond, to achieve, to produce, without much regard for what it is, exactly, we are doing, acting on, responding to, achieving, or producing". This dissertation demonstrates that a necessary imperative of life in the 21st century, more-so than ever before, is a cognisance of one's behaviour and an altogether considered approach to correspondences between actions and intentions, behaviour and attention, and the interests that direct the choices we make. In attending to this imperative, as Turkle (2011, p. 296) asserts, "it is time to look again toward the virtues of solitude, deliberateness, and living fully in the moment" and, in this way, become more intentional with our attention.

"We must learn to reawaken and keep ourselves awake, not by mechanical aids, but by an infinite expectation of the dawn, which does not forsake us even in our soundest sleep. I know of no more encouraging fact than the unquestionable ability of man to elevate his life by a conscious endeavour. It is something to be able to paint a particular picture, or to carve a statue, and so to make a few objects beautiful; but it is far more glorious to carve and paint the very atmosphere and medium through which we look, which morally we can do. To affect the quality of the day, that is the highest of arts. Every man is tasked to make his life, even in its details, worthy of the contemplation of his most elevated and critical hour."

— Henry David Thoreau, *Walden*

Appendices

Appendix A

Electronic Database Search Strings

A.1 Web of Science

```
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*))
```

Results: $n = 889$ (15/02/2018)

A.2 Scopus

```
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)
```

Results: $n = 1420$ (15/02/2018)

A.3 Academic Search Premier

```
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*
```

Results: $n = 266$ (15/02/2018)

A.4 PsycINFO

```
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*
```

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

Appendix B

Data Extraction Form

Bibliographic Information

- Study ID:
- Report Number:
- Citation:

Eligibility Check

Confirm that the study meets each of the following eligibility criteria:

- **Population:** Individuals as unit of analysis.
- **Intervention:** Behavioural Change Intervention targeting media multitasking or related behaviours.
- **Comparison:** Condition, control or alternative treatment groups employed.
- **Outcome:** Cognitive control outcomes through self report measures, laboratory assessments, or non-standardised measures of performance relying on executive functioning.
- **Language:** English or Afrikaans
- **Publication Status:** Published or unpublished.

- **Time Period:** Between 2006 and February 2018.

Data Extraction

For each category the relevant data is to be extracted into the database along with its location in the text.

Population and Setting

- Population description (from which the sample is constituted)
- Source/setting of the population
- Recruitment method

Participants

- Total sample size
- Demographic characteristics
  - Age
  - Gender

Methods

- Study objective
- Study design
- Prescreening
- Sampling technique (e.g., convenience or random)
- Study duration
- Allocation method

- Baseline measurements taken
- If longitudinal:
  - Attrition rate
  - Attrition reasons

Intervention Implementation Details

- Intervention description for condition group
- Condition group sample size
- Intervention description for alternative treatment group (if necessary)
- Alternative treatment group sample size
- Control group procedures
- Control group sample size
- Did the authors provide details of factors that facilitated the implementation of the intervention? If yes, what were these factors. If not, can any factors be identified?
- Did the authors provide details of factors that hindered the implementation of the intervention? If yes, what were these factors. If not, can any factors be identified?

Measures

- Media multitasking measure
- Outcomes targeted
- When were data collected (baseline, post-treatment etc.)?
- For each outcome extract the measurement instrument
- For each measure, extract the scoring method (e.g., is a high score better than a low score?)
- If baseline measures were taken, were there differences between groups?
- If suitable, is there any information on intervention adherence?

Results and Findings

- For each outcome measure, extract the effect size and direction
- Statistical methods used
- Significance of effects
- Were there differences between the treatment groups and the control group?
- What were the differences between the treatment groups and the control group?
- Moderator variables
  - Describe the moderator variables identified by the authors
  - Describe potential moderator variables not explicitly identified by the authors
- Any other results reported
- Did the authors regard the intervention to be a success? If yes, why? If not, why?

Risk of Bias

- Is the sample representative of the target population?
- Was the sample randomly selected?
- Have the measurement instruments been shown to have reliability and validity?
- What is the degree of allocation concealment in the study?

Appendix C

Bibliographic Details of Reports Systematically Reviewed

This appendix presents the bibliographic details for the full-text reports considered in the systematic review. First, the details for those reports included in the final sample are presented. Next, following this, the bibliographic details for this excluded from the review are provided. Finally, Table C.1 provides a summary of the reasons for exclusion. In Chapter 6 when presenting search procedure results, the PRISMA flowchart represents the first criteria for which a study was excluded. As indicated in Table C.1 reports may have been deemed ineligible on multiple criteria.

C.1 Reports Included in the Review

1. Adler, R. F., Adepu, S., Bestha, A. and Gutstein, Y. 2015. Remind Me: Minimizing Negative Effects of Multitasking, In *Proceedings of the 6th International Conference on Applied Human Factors and Ergonomics*, Las Vegas, NV.

2. Gorman, T.E. and Green, C.S. (2016). Short-term mindfulness intervention reduces the negative attentional effects associated with heavy media multitasking. *Scientific Reports*, vol. 6, no. 1, p. 24542.

3. Hartanto, A. and Yang, H., 2016. Is the smartphone a smart choice? The effect of smartphone separation on executive functions. *Computers in Human Behavior*, 64, pp.329-336.

4. Irwin, M. (2017). *The Dynamics of Media Use, Attention, and Behavioral Control.* PhD Thesis, Ohio State University.

5. Jeuris, S. and Bardram, J.E., 2016. Dedicated workspaces: Faster resumption times and reduced cognitive load in sequential multitasking. *Computers in Human Behavior*, 62, pp.404-414.

6. Ie, A., Haller, C.S., Langer, E.J., Courvoisier, D.S., 2012. Mindful multitasking: The relationship between mindful flexibility and media multitasking. *Computers In Human Behavior* 28, 1526?1532.

7. Levy, D.M., Wobbrock, J.O., Kaszniak, A.W. and Ostergren, M., 2012, May. The effects of mindfulness meditation training on multitasking in a high-stress information environment. In *Proceedings of Graphics Interface 2012* (pp. 45-52). Canadian Information Processing Society.

8. Mark, G., Voida, S. and Cardello, A., 2012. A pace not dictated by electrons: an empirical study of work without email. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 555-564). ACM.

9. Mark, G., Iqbal, S. and Czerwinski, M., 2017. How blocking distractions affects workplace focus and productivity. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers* (pp. 928-934). ACM.

10. Pielot, M. and Rello, L., 2017, September. Productive, anxious, lonely: 24 hours without push notifications. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services* (p. 11). ACM.

11. Whittaker, S., Kalnikaite, V., Hollis, V. and Guydish, A., 2016. 'Don't Waste My Time': Use of Time Information Improves Focus. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 1729-1738). ACM.

12. Yildrim, C., 2017. *The self-distracting mind in the digital age: Investigating the influence of a brief mindfulness intervention on mind wandering.* (PhD Thesis). Iowa State University.

C.2 Reports Excluded from the Review after Full Text Considered

1. Angell, R., Gorton, M., Sauer, J., Bottomley, P., White, J., 2016. Don't distract me when I'm media multitasking: toward a theory for raising advertising recall and recognition. *Journal of Advertising* 45, 198 – 210.

2. Fatma Arslantas, 2017. *Exploring Metacognition, Multitasking and Test Performance in a Lecture Context.* (Masters Thesis). Wilfred Laurier University.

3. Baloian, N., Pino, J.A., Hoppe, H.U., 2008. Dealing with the Students' Attention Problem in Computer Supported Face-to-Face Lecturing. *Journal of Educational Technology & Society* 11, 192 – 205.

4. Cheong, P.H, Shuter, R & Suwinyattichaiporn, T 2016, Managing student digital distractions and hyperconnectivity: communication strategies and challenges for professorial authority *Communication Education*, 65(3), 272–289.

5. Cooper, P.S., Garrett, P.M., Rennie, J.L., Karayanidis, F., 2015. Task uncertainty can account for mixing and switch costs in task-switching. *PLoS ONE* 10(6).

6. Cuberos-Urbano, G., Caracuel, A., Valls-Serrano, C., Garcia-Mochon, L., Gracey, F., Verdejo-Garcia, A., 2016. A pilot investigation of the potential for incorporating lifelog technology into executive function rehabilitation for enhanced transfer of self-regulation skills to everyday life. *Neuropsychological Rehabilitation* 2, 1–13.

7. Kim, J., Cho, C. and Lee, U., 2017a. Technology Supported Behavior Restriction for Mitigating Self-Interruptions in Multi-device Environments. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 1(3).

8. Kim, I., Jung, G., Jung, H., Ko, M., & Lee, U., 2017b. Let's FOCUS: Mitigating Mobile Phone Use in College Classrooms, in: *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technology*, ACM.

9. Kononova, A., Joo, E., & Yuan, S., 2016. If I choose when to switch: Heavy multitaskers remember online content better than light multitaskers when they have the freedom to multitask. *Computers in Human Behavior* 65, 567 – 575.

10. Küper, K., Gajewski, P.D., Frieg, C., Falkenstein, M., 2017. A randomized controlled ERP study on the effects of multi-domain cognitive training and task difficulty on task switching performance in older adults. *Frontiers in Human Neuroscience* 11, 1 – 12.

11. Kushlev, K., Proulx, J. and Dunn, E.W., 2016. Silence your phones: Smartphone notifications increase inattention and hyperactivity symptoms. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 1011-1020). ACM.

12. Levy, D.M., Wobbrock, J.O., Kaszniak, A.W. and Ostergren, M., 2011, May. Initial results from a study of the effects of meditation on multitasking performance. In *CHI'11 Extended Abstracts on Human Factors in Computing Systems.* ACM.

13. Min, J., 2017. Effects of the Use of Social Network Sites on Task Performance: Toward a Sustainable Performance in a Distracting Work Environment. Sustainability 9.

14. Samson, P., 2011. Deliberate Engagement of Laptops in Large Lecture Classes to Improve Attentiveness and Engagement, in*: 2011 ASEE Annual Conference & Exposition.*

15. Rekart, J.L., 2011. Taking on multitasking. Phi Delta Kappan 93, 60–63.

16. Terry, C.A., Mishra, P., and Roseth, C.J., 2016. Preference for multitasking, technological dependency, student metacognition, & pervasive technology use: An experimental intervention. *Computers in Human Behavior* 65, 241–251.

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Table C.1: Studies excluded from the review along with reasons for exclusion.

Reference	Reason For Exclusion			
	Population	Intervention	Comparison	Outcome
Angell *et al.* (2016)		×	×	
Arslantas (2017)		×		×
Baloian *et al.* (2018)		×	×	×
Cheong *et al.* (2016)		×	×	×
Cooper *et al.* (2015)		×	×	
Cuberos-Urbano *et al.* (2016)	×	×		
Kim *et al.* (2017*a*)			×	
Kim *et al.* (2017*b*)			×	
Kononova *et al.* (2016)			×	
Küper *et al.* (2017)		×		
Kushlev *et al.* (2016)				×
Levy *et al.* (2011)[a]				
Min (2017)		×	×	
Samson (2010)		×	×	×
Rekart (2011)	×	×	×	×
Terry *et al.* (2016)		×		×
Winter *et al.* (2010)		×	×	×
Wu (2017)		×	×	
Yang *et al.* (2015)	×	×	×	×

[a] While this report was deemed eligible on all PICO criteria, it is a preliminary report of a study presented in full in a later report (e.g., Levy *et al.*, 2012).

Appendix D

Study Quality Assessment Tools

Two tools provided by the NHLBI were used to assess the quality of studies included in the systematic review. 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* (referred to as NHLBI-2) was used.

D.1 Quality Assessment of Controlled Intervention Studies

For each of the criteria represented below one of the following assessments were made: Yes; No; Cannot determine; not applicable; and not reported.

1. Was the study described as randomised, a randomised trial, a randomised clinical trial, or an RCT?
2. Was the method of randomisation adequate (i.e., use of randomly generated assignment)?
3. Was the treatment allocation concealed (so that assignments could not be predicted)?
4. Were study participants and providers blinded to treatment group assignment?
5. Were the people assessing the outcomes blinded to the participants' group assignments?

6. Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)?

7. Was the overall drop-out rate from the study at endpoint 20% or lower of the number allocated to treatment?

8. Was the differential drop-out rate (between treatment groups) at endpoint 15 percentage points or lower?

9. Was there high adherence to the intervention protocols for each treatment group?

10. Were other interventions avoided or similar in the groups (e.g., similar background treatments)?

11. Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants?

12. Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power?

13. Were outcomes reported or subgroups analysed prespecified (i.e., identified before analyses were conducted)?

14. Were all randomised participants analysed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?

D.2 Quality Assessment Tool for Before-After (Pre-Post) Studies With No Control Group

For each of the criteria represented below one of the following assessments were made: Yes; No; Cannot determine; not applicable; and not reported.

1. Was the study question or objective clearly stated?

2. Were eligibility/selection criteria for the study population prespecified and clearly described?

3. Were the participants in the study representative of those who would be eligible for the test/service/intervention in the general or clinical population of interest?

4. Were all eligible participants that met the prespecified entry criteria enrolled?
5. Was the sample size sufficiently large to provide confidence in the findings?
6. Was the test/service/intervention clearly described and delivered consistently across the study population?
7. Were the outcome measures prespecified, clearly defined, valid, reliable, and assessed consistently across all study participants?
8. Were the people assessing the outcomes blinded to the participants' exposures/interventions?
9. Was the loss to follow-up after baseline 20% or less? Were those lost to follow-up accounted for in the analysis?
10. Did the statistical methods examine changes in outcome measures from before to after the intervention? Were statistical tests done that provided p values for the pre-to-post changes?
11. Were outcome measures of interest taken multiple times before the intervention and multiple times after the intervention (i.e., did they use an interrupted time-series design)?
12. If the intervention was conducted at a group level (e.g., a whole hospital, a community, etc.) did the statistical analysis take into account the use of individual-level data to determine effects at the group level?

Appendix E

Self Report Scales and Questionnaires

E.1 Prescreening Questionnaire

The pre-screening questionnaire consisted of four parts. In the first, information about the study was provided and respondents were asked to provide informed consent. The second required respondents to provide a means of unique identification in the form of their university-linked student numbers. In addition to enabling the matching of respondents across sessions, these numbers enable respondents to be invited to subsequent aspects of the study.[1] The third part concerned respondents' demographics and eligibility and is described in Section E.1.1. The last part, described in Section E.1.2, presented the items necessary for calculating the MMI-S.

E.1.1 Demographic and Eligibility Questions

1. In what year were you born?
   a) 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002
2. Gender: Please select which gender you identify as
   a) Male

[1]At this institution student numbers are also email addresses.

   b) Female
   c) Other

3. Which population group do you consider yourself a member of?
   a) African/Black
   b) Coloured
   c) Indian/Asian
   d) White
   e) Other, please specify

4. First Language (language predominantly spoken at home)
   a) Afrikaans
   b) English
   c) Xhosa
   d) Zulu
   e) Other European language
   f) Other African language

5. I am currently a student at Stellenbosch University
   a) Yes
   b) No

6. For how many years have you been studying at a university level?
   a) 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, more than 10.

7. Select which mobile operating system you use on your phone (Note, the study requires the use of an Android smartphone).
   a) Android
   b) iOS
   c) Windows Phone
   d) Other

8. Do you use WhatsApp?

   a) Yes
   b) No

9. Do you use any focus management applications (e.g., Moment, Forest, OffTime etc.)?
   a) Yes
   b) No
10. Have you used any psychostimulants (e.g., Ritalin, Adderall, Concerta) in the past month?
    a) Yes
    b) No
11. Do you intend on using any psychostimulants in the coming months?
    a) Yes
    b) No
12. Do you suffer with an attention-related condition (e.g., ADHD or related learning disorder)?
    a) Yes
    b) No

E.1.2 Media Multitasking Index - Short (MMI-S)

The Media Multitasking Index-Short (MMI-S) developed by Baumgartner *et al.* (2017*a*) consists of two components. First, media use is measured. Second, relative tendencies to engage in media multitasking are assessed through the Media Multitasking Measure-Short (MMM-S). To determine media use, for each of the following media, participants indicated how long they used each category on an average day through a 6-point Likert scale with the options one (*not at all*), two (*less than 30 minutes*), three (*30 minutes to 1 hour*), four (*1 to 2 hours*), five (*2 to 3 hours*), and six (*3 hours or more*).

1. Watching video content.

2. Using Social media.
3. Sending messages via phone or computer.

Next, the following instruction was provided: "For each type of media displayed below, please indicate how often you simultaneously engage in each of the other types of media in a typical day". Responses were provided through a 4-point Likert scale with the following options: one (*never*), two (*sometimes*), three (*often*), and four (*very often*).

1. While watching video content, how often do you engage in the following activities?
   a) Listening to music.
   b) Sending messages via phone or computer.
   c) Using social networking sites.
2. While using social networking sites, how often do you engage in the following activities?
   a) Listening to music.
   b) Sending messages via phone or computer.
   c) Watching video content.
3. While sending messages via phone or computer, how often do you engage in the following activities?
   a) Listening to music.
   b) Using social networking sites.
   c) Watching video content.

E.2 Baseline and Post-intervention Measures

Over the course of the baseline and post-intervention phases five self-report scales were used to assess subjective aspects of everyday executive functioning.

E.2.1 Attention Related Cognitive Errors Scale (ARCES)

The ARCES (Carriere *et al.*, 2008) was adopted in both the baseline and post-intervention phases of the intervention assessment. This measure is in the public domain and does not require special permission to be used[2]. As Carriere *et al.* (2008) suggest, the following instruction preceded the 12 scale items: "The following statements are about minor mistakes and absent-mindedness everyone notices from time to time, but we have very little information about just how common they are. The great majority of time these little foibles are harmless, though they do have serious safety implications in industry and everyday life. We want to know how frequently these sorts of things have happened to you. There are 12 questions. Please select the most appropriate answer on the scale provided." These scales presented the following options: one (*never*), two (*rarely*), three (*sometimes*), four (*often*), and five (*very often*).

Table E.1: Attention Related Cognitive Errors Scale (ARCES)

No.	Item
1	I have gone to the fridge to get one thing (e.g., milk) and taken something else (e.g., juice)
2	I go into a room to do one thing (e.g., brush my teeth) and end up doing something else (e.g., brush my hair)
3	I have lost track of a conversation because I zoned out when someone else was talking
4	I have absent-mindedly placed things in unintended locations (e.g., putting milk in the pantry or sugar in the fridge)
5	I have gone into a room to get something, got distracted, and wondered what I went there for
6	I begin one task and get distracted into doing something else
7	When reading I find that I have read several paragraphs without being able to recall what I read
8	I make mistakes because I am doing one thing and thinking about another
9	I have absent-mindedly mixed up targets of my action (e.g., pouring or putting something into the wrong container)
10	I have to go back to check whether I have done something or not (e.g., turning out lights, locking doors)
11	I have absent-mindedly misplaced frequently used objects, such as keys, pens, glasses, etc.
12	I fail to see what I am looking for even though I am looking right at it

[2]See http://oops.theoptia.com/ARCES_Psychometrics.pdf.

E.2.2 Mindful Attention Awareness Scale - Lapses Only (MAAS-LO)

The MAAS-LO (Carriere *et al.*, 2008) was adopted in both the baseline and post-intervention phases of the intervention assessment. This measure is in the public domain and does not require special permission to be used[3]. The following instructions were provided to participants: "Below is a collection of statements about your everyday experience. Using the 1-6 scale, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be. Please treat each item separately from every other item". Responses were provided on a 6-point Likert scale with the following options: one (*almost never*), two (*very infrequently*), three (*somewhat infrequently*), four (*somewhat frequently*), five (*very frequently*), six (*almost always*)

Table E.2: Mindful Attention Awareness Scale - Lapses Only (MAAS-LO)

No.	Item
1	I could be experiencing some emotion and not be conscious of it until some time later.
2	I find it difficult to stay focused on what's happening in the present.
3	I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.
4	I tend not to notice feelings of physical tension or discomfort until they really grab my attention.
5	It seems I am "running on automatic," without much awareness of what I'm doing.
6	I rush through activities without being really attentive to them.
7	I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.
8	I do jobs or tasks automatically, without being aware of what I'm doing.
9	I find myself listening to someone with one ear, doing something else at the same time.
10	I find myself preoccupied with the future or the past.
11	I find myself doing things without paying attention.
12	I snack without being aware that I'm eating.

[3]See `https://goo.gl/B71Wfp`.

E.2.3 Attentional Control: Switching and Distractibility (AC-S and AC-D)

The AC-S and AC-D (Carriere *et al.*, 2013) was adopted in both the baseline and post-intervention phases of the intervention assessment. These scales are in the public domain and do not require special permission for their use. Each scale consists of four items, with responses provided through 5-point Likert scales with the following options: one (*almost never*), two (*sometimes*), three (*often*), four (*very often*), five (*always*). Before the provision of the scales the following written instruction was provided to participants: "For the following statements, please select the response that most accurately reflects your everyday attentional control ability".

Table E.3: Attentional Control: Switching and Distractibility (AC-S and AC-D)

No.	Item
Distraction	
1	I have difficulty concentrating when there is music in the room around me.
2	When I am working hard on something, I still get distracted by events around me.
3	It's very hard for me to concentrate on a difficult task when there are noises around.
4	When I am reading or studying, I am easily distracted if there are people talking in the same room.
Shifting	
1	I am slow to switch from one task to another.
2	It takes me a while to get really involved in a new task.
3	It is difficult for me to alternate between two different tasks.
4	After being interrupted, I have a hard time shifting my attention back to what I was doing before.

E.2.4 Spontaneous and Deliberate Mind-wandering (MW-S and MW-D)

The MW-S and MW-D (Carriere *et al.*, 2013) were adopted to assess spontaneous and deliberate mind wandering during both the baseline and post-intervention assessments. These scales are in the public domain and do not require special permission for their use. For both scales participants were required to respond by means of five point Likert scales ranging from one (*almost never*) to five (*very often*). Before the provision of the scales the following written instruction was provided to participants: "For the following statements please select the answer that most accurately reflects your everyday mind wandering".

Table E.4: Spontaneous and Deliberate Mind-wandering (MW-S and MW-D)

No.	Item
Deliberate	
1	I allow my thoughts to wander on purpose.
2	I enjoy mind-wandering.
3	I find mind-wandering is a good way to cope with boredom.
4	I allow myself to get absorbed in pleasant fantasy.
Spontaneous	
1	I find my thoughts wandering spontaneously.
2	When I mind-wander my thoughts tend to be pulled from topic to topic.
3	It feels like I don't have control over when my mind wanders.
4	I mind wander even when I'm supposed to be doing something else.

E.2.5 Brief Self-control Scale (BSCS)

The BSCS (Tangney *et al.*, 2004) was adopted in both the baseline and post-intervention phases of the intervention assessment. This measure is in the public domain and does not require special permission to be used. As the authors suggest, the following prompt preceded the scale-items: "Using the scale provided, please indicate how much each of the following statements reflects how you typically are". Responses are provided on a five point Likert scale ranging from one (*not at all like me*) to five (*completely like me*).

E.2.6 Irrational Procrastination Scale (IPS)

The IPS (Steel, 2002) was adopted in both the baseline and post-intervention phases of the intervention assessment. This measure is in the public domain and does not require special permission for its use.[4] As the authors suggest, the following prompt preceded the scale-items: "Below are a number of statements that relate to tendencies to put off doing tasks. Indicate to what extent you agree or disagree with each statement by selecting

[4]See `https://procrastinus.com/piers-steel/about-the-measure/` for more information.

Table E.5: Brief Self-control Scale (BSCS)

No.	Item
1	I am good at resisting temptation.
2[a]	I have a hard time breaking bad habits.
3[a]	I am lazy.
4[a]	I say inappropriate things.
5[a]	I do certain things that are bad for me, if they are fun.
6	I refuse things that are bad for me.
7[a]	I wish I had more self-discipline.
8	People would say that I have iron self-discipline.
9[a]	Pleasure and fun sometimes keep me from getting work done.
10[a]	I have trouble concentrating.
11	I am able to work effectively toward long-term goals.
12[a]	Sometimes I can't stop myself from doing something, even if I know it is wrong.
13[a]	I often act without thinking through all the alternatives.

[a] These items are reverse scored.

the answer that best describes your way of being and doing". Responses are provided on a five point Likert scale ranging from one (*not true of me*) to five (*true of me*).

Table E.6: Irrational Procrastination Scale (IPS)

No.	Item
1	I delay tasks beyond what is reasonable.
2[a]	I do everything when I believe it needs to be done.
3	I often regret not getting to tasks sooner.
4	There are aspects of my life that I put off, though I know I shouldn't.
5[a]	If there is something I should do, I get to it before attending to lesser tasks.
6	I put things off so long that my well-being or efficiency unnecessarily suffers.
7	At the end of the day, I know I could have spent the time better.
8[a]	I spend my time wisely.
9	When I should be doing one thing, I will do another.

[a] These items are reverse scored.

Appendix F

Follow-up Interview Question Guide

The following questions served to structure the follow-up interviews. The purpose of these questions was to guide the participants in recounting their experiences during the intervention phase. Note that, as semi-structured interviews, additional prompts and follow-up questions were provided in addition to the questions below.

> *This interview is for me to understand your experience over the past month. I am going to ask you questions about your experiences during the study, as well as your impressions and thoughts about aspects of the study.*

1. Before you participated in this study how would you describe your phone use?
2. Why did you choose to participate in the study?
3. What were your initial impressions and experiences of the study?
    a) What were your reactions when I explained what was going to be involved?
    b) What were some of your initial experiences with trying to manage your phone use in the first few days?
4. How did you change your behaviour to manage your phone use?
5. When you saw the daily screen-time amounts, were you surprised by how much you used your device?
6. Do you feel like you had to reduce your media use to meet the target?
7. Do you feel like you multitasked with your devices less?

8. Was the app helpful in managing your media multitasking? If so, how?

9. Were there days where you felt that it was easier to manage your phone use, to single-task and hit the goal?

   a) What was happening on those days?

   b) Why do you think that was?

10. Were there days where you felt that it was more difficult to manage your phone use, to single-task and hit the goal?

    a) What was happening on those days?

    b) Why do you think that was?

11. Did your media use or success at managing your phone use differ in different situations?

12. Where was it most difficult not to use your phone or not to multitask?

13. Did you use the restriction (tree) feature? If so why, if not why not? And, do you think it was useful to put aside your phone for those periods?

14. Can you describe any obstructions you experienced in managing your phone use and, if you noticed these, did you try and change your behaviour?

15. Do you think it was useful to not multitask as much with your phone? What benefits did you notice?

16. Were there any negatives of restricting your phone use? Did you feel cut off, or that you were missing out on things when you were trying to not use your phone?

17. Did you tell your friends and family about it, how did they react?

18. Would you continue trying to manage your phone use? Anything you would change? If no why?)

19. Is there anything else you would change about the process? What would you do differently?

20. What are your last thoughts, are there any other things you are thinking about?

Appendix G

Self-Report Scales: Correlations

Table G.1: Correlation matrix for self report measures at baseline and post-intervention assessment.

Scale	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. ARCES (1)	-															
2. ARCES (2)	.69***	-														
3. MAAS-LO (1)	.42***	.19	-													
4. MAAS-LO (2)	.39**	.53***	.57***	-												
5. AC-S (1)	.39**	.31*	.36**	.28*	-											
6. AC-S (2)	.36**	.35**	.33*	.36**	.71***	-										
7. AC-D (1)	.38**	.14	.40**	.31*	.54	.43***	-									
8. AC-D (2)	.33**	.26*	.32*	.41**	.55***	.54***	.63***	-								
9. MW-S (1)	.04	.12	.00	.06	.00	.07	.19	.16	-							
10. MW-S (2)	.13	.22	.21	.24	.22	.21	.27*	.37**	.79***	-						
11. MW-D (1)	.47***	.26*	.44***	.21	.29*	.24	.37**	.43***	.43***	.46***	-					
12. MW-D (2)	.46***	.43***	.43***	.43***	.42***	.29*	.36**	.47***	.39**	.57***	.77***	-				
13. BSCS (1)	-.47***	-0.38**	-.35**	-0.29*	-.44***	-0.36**	-.58***	-0.56***	-.29*	-0.47***	-.61***	-0.48***	-			
14. BSCS (2)	-0.41**	-.52***	-0.30*	-.39**	-0.30*	-.26	-0.40**	-.54***	-0.19	-.36**	-0.46***	-.47***	.80***	-		
15. IPS (1)	.41***	.28*	.45***	.27*	.26*	.36**	.49***	.42***	.29*	.40**	.53***	.50***	-.64***	-0.61***	-	
16. IPS (2)	.38**	.33*	.28*	.20	.24	.28*	.33*	.26*	.22	.31*	.45***	.51***	-0.45***	-.57***	.68***	-
Cronbach's α	.80	.86	.75	.81	.76	.83	.81	.84	.81	.84	.77	.83	.77	.74	.90	.84

Note. All correlation coefficients represent Pearson's r correlations.
For scale, 1 = baseline assessment session and 2 = post intervention assessment session.
$*p < .05$, $**p < .01$, $***p < .001$.

Appendix H

Institutional and Ethical Approval

UNIVERSITEIT • STELLENBOSCH • UNIVERSITY
jou kennisvennoot • your knowledge partner

INSTITUTIONAL PERMISSION:

AGREEMENT ON USE OF PERSONAL INFORMATION IN RESEARCH

Name of Researcher: Mr. Douglas Parry

Name of Research Project: Media Multitasking Induced Interference: Breaking the Cycle

Service Desk ID: IRPSD-962

Date of Issue: 27 July 2018

You have received institutional permission to proceed with this project as stipulated in the institutional permission application and within the conditions set out in this agreement.

Figure H.1: Institutional Approval Letter

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

APPROVED WITH STIPULATIONS
REC Humanities New Application Form

29 May 2018

Project number: INFO-2018-7207

Project title: Media Multitasking and Cognitive Control: Intervention Study

Dear Mr. Douglas Parry

Your REC Humanities New Application Form submitted on **10 May 2018** was reviewed by the REC: Humanities on and approved with stipulations.

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
29 May 2018	28 May 2021

REC STIPULATIONS:

The researcher may proceed with the envisaged research provided that the following stipulations, relevant to the approval of the project are adhered to or addressed:

1) The Researcher is requested to attach the Institutional Permission Letter to his application once he has received it from the the Division for Information Governance. **[ACTION REQUIRED]**

2) The Psychological Practitioner or the Centre for Student Counselling and Development Details should be provided in the Consent Form. Additionally, the Practitioner or Centre should be made aware that students might contact them in relation to your study. **[ACTION REQUIRED]**

Figure H.2: Initial Ethical Approval Letter

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

NOTICE OF APPROVAL

REC Humanities New Application Form

31 July 2018

Project number: 7207

Project Title: Media Multitasking and Cognitive Control: Intervention Study

Dear Mr. Douglas Parry

Your REC Humanities New Application Form submitted on **30 July 2018** was reviewed and approved by the REC: Humanities.

Please note the following for your approved submission:

Ethics approval period:

Protocol approval date (Humanities)	Protocol expiration date (Humanities)
29 May 2018	28 May 2021

Please take note of the General Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

If the researcher deviates in any way from the proposal approved by the REC: Humanities, the researcher must notify the REC of these changes.

Please use your SU project number **(7207)** on any documents or correspondence with the REC concerning your project.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

FOR CONTINUATION OF PROJECTS AFTER REC APPROVAL PERIOD

Please note that a progress report should be submitted to the Research Ethics Committee: Humanities before the approval period has expired if a continuation of ethics approval is required. The Committee will then consider the continuation of the project for a further year (if necessary)

Included Documents:

Document Type	File Name	Date	Version
Research Protocol/Proposal	ethics_proposal	09/05/2018	V1
Recruitment material	poster2	10/05/2018	1
Informed Consent Form	consent_form_written	10/05/2018	1
Informed Consent Form	consent_form_electronic	10/05/2018	1
Data collection tool	interview_guide	10/05/2018	1
Data collection tool	survey	10/05/2018	1
Request for permission	institutional_permission_letter	10/05/2018	1
Default	PARRY_PhD_Proposal_v2.6	10/05/2018	1
Default	Institutional Permission_Standard Agreement Douglas Parry IRPSD - 962	30/07/2018	1
Default	consent_form_electronic	30/07/2018	1
Default	Response to REC stipulations	30/07/2018	1

If you have any questions or need further help, please contact the REC office at cgraham@sun.ac.za.

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Figure H.3: Final Ethical Approval Letter

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