Media Multitasking and Executive Functioning in Young Adults

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Abstract

The purpose of this thesis was to determine the relationships between young adults executive functioning and media multitasking. This was addressed through the systematic exploration of executive functioning utilising behavioural performance tasks, informed by Diamond's (2013) executive function framework that details three functions; inhibition, working memory and cognitive flexibility, in relation to media multitasking.

In fulfilling this aim, an initial investigation was conducted which assessed self-reported frequency of media multitasking (utilising the Media Multitasking Index by Ophir, Nass & Wagner, 2009, including the full continuum of scores) in relation to performance on executive function tasks assessing inhibition, working memory and cognitive flexibility. No association between aspects of young adults executive functioning and self-reported frequency of media multitasking was found. Following this, the thesis continued with the systematic exploration of inhibition, working memory and cognitive flexibility in relation to media multitasking, progressing with the inclusion of a novel assessment of media multitasking ability. Within this second study, media multitasking was explored using objective measures, with participants completing a media multitasking situation. This type of media multitasking assessment has not previously been used in conjunction with performance on a full battery of executive function tasks. The study demonstrated an association between young adults' cognitive flexibility and their ability to media multitask, in terms of recall of information from a media multitasking situation. It also reflected real world implications of media multitasking in terms of including a novel manipulation of media multitasking within a single device or between multiple devices. Lastly, the final empirical study explored the proximal effects of media multitasking on executive functioning in young adults, for which none were found.

In addition to the main aim, a concern of the thesis was to explore the relationship between trait mood and media multitasking. In this regard, self-reported media multitasking was associated with trait anxiety, with higher levels of anxiety associated with more frequent media multitasking in young adults. Other aspects of mood were also assessed throughout the two latter empirical studies, which highlighted a possible fatiguing effect of media engagement (inclusive of media multitasking) on mood.

This thesis found no evidence that young adults' self-reported *frequency* of media multitasking is associated with their executive functioning. However, there is evidence of the involvement of cognitive flexibility in young adults' *ability* to media multitask, when assessing the recall of information from a session of media multitasking. Furthermore, media multitasking between multiple devices is no more detrimental than media multitasking within a single device in terms of the recall of information from a media multitasking situation. Additionally, media engagement (inclusive of media multitasking) does not proximally affect executive function performance although it may fatigue mood.

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Chapter 1. Thesis overview

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This initial chapter provides a summary of the eight chapters throughout the thesis. Beginning with Chapter 2, this literature review chapter sets the scene of the overarching research question, “what are the associations between young adults executive functioning and media multitasking?” It provides an exploration of the revolution of the technological landscape in which media multitasking has emerged. It explores what constitutes media multitasking behaviour, in terms of technological device/s, prevalence and diversification of this media engagement behaviour amongst varying age groups. In addition, it considers influential factors such as what motivates individuals to media multitask, and how psychological well-being can be either a result or a driver of media multitasking. Finally, it provides a working definition of media multitasking fundamental to answering the research question.

Following this initial exploration, Chapter 3 reviews the literature covering executive function theory, highlighting two key theories that have received substantial support, in terms of the theoretical debate surrounding executive functioning. Diamond’s (2013) executive function framework of inhibition, working memory and cognitive flexibility is brought to the forefront. Diamond’s framework is central to the executive function aspect of the research question. Not only highlighting executive function theory, the chapter also pin points methodological issues surrounding the measurement of executive function, and factors that need to be considered when assessing executive function.

The focus of Chapter 3 then changes to centre on the media multitasking and executive functioning literature that is vital to answering the research question. The chapter delves into what has currently been found in regards to self-reported frequency of media multitasking in relation to executive functioning. Findings are discussed by aspect of executive function informed by Diamonds (2013) executive function framework. There is then a summary of the literature, demonstrating gaps in the current evidence, highlighting the need to address the overarching research question, proposing distinct thesis objectives as solutions to achieving the research question.

One issue highlighted in Chapter 3 is the use of self-reported measures of media multitasking. Specifically, the majority of research exploring media multitasking and executive functioning has predominantly utilised the Media Multitasking Index (Ophir, Nass & Wagner, 2009) to assess media multitasking. Thus, in contrast to Chapter 3, Chapter 4 progresses to alternative methods used to explore media multitasking. It focuses on learning settings that have used performance based objective measures of media multitasking, in the sense of having participants engage with media multitasking in an experimental setting. The chapter details methods of using such an approach, how it can be implemented, and assesses what factors need to be considered.

Chapter 5 is the initial empirical investigation into self-reported frequency of media multitasking in relation to executive functioning. It is the starting point of answering the larger research question and determining what executive functions, of Diamond's framework, are associated with how often young adults media multitask. In addition to defining the association between young adults anxiety, depression and frequency of media multitasking.

Evolving from this, Chapter 6, (the second empirical chapter), advances from the initial empirical investigation in terms of different methodology and a slightly different aspect of the larger research question. This exploration focuses on individuals' ability to media multitask, essentially what makes an individual good at media multitasking in terms of their executive functioning. It uses a performance based objective measure of media multitasking, similar to studies reviewed in Chapter 4. The study also considers whether there are performance differences when individuals media multitask across two devices rather than within a single device.

Progressing further, Chapter 7 (the last of the empirical investigations) centres on the proximal effects of media multitasking, in terms of how a session of media multitasking directly affects individuals' executive function, utilising a method conducive of establishing cause and effect.

Lastly, Chapter 8 culminates with a general discussion, bringing together the key points of the reviewed literature and evidence from the empirical investigations. It details how the studies exploring ①self-reported frequency of media multitasking, ② ability to media multitask, and ③proximal effects of media multitasking, (all in association with executive function) elucidate and answer the overarching research question, and how this advances our understanding, providing real –world implications.

Chapter 2. Defining media multitasking and providing context of the thesis research

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2.2 Chapter overview

The following chapter will introduce the reader to the context in which the thesis sits, providing an overview of how the technological revolution has led to changes in media behaviour. It discusses how media multitasking is defined within the literature and progresses to explore the prevalence of media multitasking amongst varying age groups, the diversification of media multitasking behaviours and possible influential factors, (inclusive of mental health and well-being). Furthermore, it provides a working definition of media multitasking, which will be used throughout the thesis.

2.3 Context of thesis research

Media has a pivotal role in individuals' lives (Couldry, 2012). Since the advent of the internet and digital media, it has become even more influential. However, the role of digital media has since been revolutionised (Russo, Fallon, Zhang & Acevedo, 2014) by the arrival of tablet computers and smart phones (the first iPhone launched in 2007 and the first Android operated smartphone launched in 2008, Arthur, 2012). The portability, accessibility and usage of media devices has grown exponentially (Baumgartner, Weeda, Van der Heijden & Huizinga, 2014; Cain & Mitroff, 2011; Zhong, 2013). Not only has usage grown, it has also dramatically altered in terms of the types of media that individuals are engaging with. Various social media and other media platforms initially launched more than a decade ago, for example with the arrival of Myspace® in 2004 (Stenovec, 2011) and Facebook® in 2006 (Phillips, 2007). The availability of these platforms has continued to grow, with the release of Whatsapp® in 2009 (Rowan, 2014), Instagram in 2010® (Instagram, 2018), and Snapchat® in 2011 (Snap Inc., 2012), to name a few. More importantly, the continued evolution of these types of media, through the offering of various added on services and features tailored to users (e.g. the addition of Snapchat filters in 2015 (Heath, 2015), emoji reactions to Facebook®

status updates in 2016 and comments in 2017 (Facebook®, 2018)) is adding to the surge in use of such media platforms. To date the most popular social media platform is Facebook® with a reported estimate of 2.23 billion monthly active users in 2018 (Facebook, 2018). Thus, the technological revolution and changes in media availability have led to a transformation in the way in which media is consumed (Courage, Bakhtiar, Fitzpatrick, Kenny & Brandeau, 2015; Judd 2013; Ziegler, Mishra & Gazzaley, 2015). Individuals less frequently engage with only one form of media at a time (Kazakova & Cauberghe, 2013), rather they media multitask (Cain & Mitroff, 2011; Ophir, Nass & Wagner, 2009).

However, the precise definition of media multitasking is not clear-cut. Wang, Irwin, Cooper and Strivastava (2015) highlight the issue within the literature of how media multitasking is defined; they propose that research often defines it specifically to correspond with the context and purpose of the study. Research has indeed used various definitions of media multitasking, for example, Jeong and Fishbein (2007) defined media multitasking as media use with a non-media activity, such as listening to music whilst completing homework or eating whilst watching television. Other studies have also used similar definitions, for example Carrier, Cheever, Rosen, Benitez and Chang (2009) included non-media behaviours such as eating and talking face to face, alongside 10 media behaviours, when exploring multitasking. However, this use of the term “media multitasking”, i.e., media use with non-media activity, is less common within the literature. It is more commonplace for media multitasking to be defined as the simultaneous use of two or more information media (Baumgartner et al., 2014). Simultaneous, in the sense that individuals attempt to focus their attention on two or more tasks concurrently. This simultaneous focus of attention to two tasks is often referred to as dual-task performance (Pashler, 1994), a topic around which there is an abundance of research evidence and theoretical debate. For example, some argue that dual-task performance involves the switching of attention, altering attention from one information stream to another, which is often multiple and executed in rapid succession (Rubenstein, Meyer & Evans, 2001). For example, listening to music and responding to text messages are two media behaviours that are perceived to be easily executable at the exact same time, despite the various mechanisms which are required to carry out both behaviours. Whereas watching T.V. and reading is perceived to be a little more difficult, as both require complex processing to be carried out. These two behaviours also seem to require more back and forth switching of attention between the two media streams. However, the difference in difficulty is due to the tasks requiring some of the same processing resources (i.e. both T.V. and reading require visual processing). Dual-task performance research proceeds under the assumption that when two tasks require the same processes, bottlenecks transpire, which can be either peripheral or central. Peripheral in the sense that this type of processing initiates response to the demands of the task(s) whereas central processing is where the decision of selecting a response to the task(s) occurs. Therefore, even simple tasks can cause delayed execution of other tasks if some of the same processing resources are required and a bottleneck occurs, which can happen at either the peripheral or central stage. Dual-task performance postulates that attentional resources are limited, and that executive functions are needed to resolve the interference and progress from the bottleneck to complete both tasks concurrently (Szameitat, Vanloo & Mueller, 2016; Tombu, Asplund, Dux, Godwin, Martin & Marois, 2011), for reviews see Leone, Feys, Moumdjian, D'Amico, Zaapia et al., (2017) and Koch, Poljac, Muller and Kiesel, (2018).

2.3.1 Prevalence of Media Multitasking

Media multitasking is deemed by some as a way of life (Lui & Wong, 2012; Rideout, Foehr & Roberts, 2010) and is reported as a prevalent behaviour. However, it has also been observed that some individuals purposefully avoid this behaviour (Woodstock, 2014). In terms of the prevalence of media multitasking, it would appear that it is a very frequent way in which individuals engage with media, and that individuals who never media multitask are the exception. Indeed, Pilotta, Schultz, Drenik and Rist (2004) completed a survey on the American online population and found that more than 50% of the respondents reported engaging in media multitasking at least occasionally whereas only 15.9% reported that they did not media multitask. Although, the findings are not necessarily a true representation of the whole population.

Following on from this Foehr (2006) completed an expansive study into media multitasking as part of the Kaiser Family Foundation Study, exploring the prevalence and predictors of media multitasking and media use more widely. The study included diary and survey data of 3^{rd}-12^{th} graders' media multitasking habits (usually age 8-9 for 3^{rd} graders, and age 17-18 for 12^{th} graders). The study found that 25% to 33% reported multitasking most of the time, in terms of their time spent on media. However, the data also highlighted that some never multitask with specified media. In line with this evidence, Jeong and Fishbein (2007) completed a cross sectional survey looking at adolescents aged 14-16 and found that very few reported never multitasking. Since the first study by Foehr, the survey has since been repeated a further two times. In the latest survey for the Foundation, Rideout et al. (2010) found that of the adolescents, 29% of time spent on media is spent media multitasking, with 58% reporting that they media multitask most of the time, whereas 34% report never media multitasking. Comparable to this Moreno, Jelenchick, Koff, Eikoff and Diermyer et al., (2012) used an experience sampling method to look at older adolescents (mean age 18. 9 years), and they found that most of the adolescents' time spent on the internet was spent whilst media multitasking (56% of the time). Thus, the pattern of prevalence reveals that media multitasking is indeed a ubiquitous behaviour and seems to be the preferential way in which media is consumed, especially in young adults.

Despite the emerging pattern of the prevalence of media multitasking, there is a limitation with the previously reported literature in that the sample populations of the studies have tended to be adolescents or younger adults. Therefore, the notion that media multitasking is more prevalent in younger individuals' needs to be substantiated with evidence that also looks at media multitasking amongst older age groups. A few studies have looked at media multitasking across different generations. Carrier et al. (2009) compared baby boomers (those born between 1946 and 1964), members of generation X (those born between 1965 and 1979) and the Net generation (those born between 1980 to the present). The study found the younger generations to media multitask to a greater extent. More recently, Voorveld and Van der Groot (2013) examined diary data of individuals' media multitasking, comparing several age groups (age range of 13-65). Teens aged 13-16 were found to spend 31% of their media time media multitasking, whereas the older group (aged 50-65 years) trailed the youngest for absolute time spent media multitasking. In a recent UK Ofcom report, media multitasking was assessed across various age groups. Adolescents/ young adults aged 16-24 spent 35% of media and communication time media multitasking, whereas adults aged 25-34 spent 25%, the percentage of time spent media multitasking decreased as age increased with adults aged 55-64 spending 17% of media and communication time media multitasking and even less for those aged 65+ (Ofcom, 2015).

Thus, overall, media multitasking is prevalent amongst all age groups with research indicating that young adults tend to media multitask to a greater extent, especially 16 to 24 year olds. Although, it could be said that there is less research exploring older adults media multitasking. Adoption and familiarity of media is clearly a factor that influences individuals' media multitasking behaviour. Voorveld and Van der Groot (2013) suggest that the prevalence of media multitasking may be greater amongst adolescents due to the fact they have grown up with technologies such as computers and smartphones that are at the heart of media multitasking.

Fundamental to the reported prevalence of individuals' media multitasking is the diversification of media behaviours that media multitasking encompasses. Foehr (2006) found that individuals within their study reported never media multitasking with some of the media they specified. Furthermore, Voorveld and Van der Groot (2013) found generational differences in media multitasking due to the types of media that each generation is familiar with or has preference for. Thus, the type of media used is an important factor influencing media multitasking behaviour and survey research needs to ensure all possible media combinations are covered to capture accurate accounts of media multitasking behaviours.

2.3.2 *Diversification of media multitasking*

Media multitasking can consist of various types of media behaviours. The availability of multiple devices and various types of media to engage with ultimately facilitates a plenitude of combinations that constitute media multitasking. As previously mentioned, media multitasking can be through a single device or range of devices (Cardoso-Leite, Green & Bavelier, 2015; Voorveld & Van der Groot, 2013; Ziegler et al., 2015), such as a smartphone, tablet or laptop computer. In addition, as previously discussed, there are numerous types of media, inclusive of many forms of social media, video or music streaming and printed media. Therefore, in terms of media multitasking, an individuals' media multitasking behaviour could consist of watching T.V. whilst social networking on a smart phone, or watching Youtube® videos on a smartphone whilst also instant messaging on that same device (Baumgartner et al., 2014; Van Cauwenberge, Schaap & Van Roy, 2014).

In regards to the research exploring media multitasking, an array of studies have explored the considerable differences in individuals' media multitasking behaviours. In a sample of "online" Americans, Pilotta et al., (2004) found that the most popular combinations of behaviour were: going online and watching T.V (34.6%), and reading a newspaper and watching T.V. (23.8%). For example, in the latest Kaiser family survey, Rideout et al. (2010) found T.V. to be a form of media that was most commonly paired with other media.

However, other research has found social networking to be a prominent driver of media multitasking behaviour. Moreno et al. (2012) found that the most common media multitasking activity young adults engaged in was social networking (52.9% of the time-spent media multitasking). This was also apparent in Voorveld and Van der Groot, (2013) who found distinctive patterns of media multitasking across different age groups. Teens and Net generation individuals exceeded older age groups in their use of social networking, playing online games and listening to music. They suggested that the most common combinations of media included a minimum of one online activity, with online activity defined as internet enabled media, inclusive of listening to music, social networking sites, playing online games and e-mail. Online activity seems to be a crucial component of media multitasking, especially for young adults and adolescents. Rideout et al. (2010) found that computer activities are the most likely to be media multitasked with by young individuals, with teens and tweens engaging with several other media whilst using a computer, in their study computer activity was only topped by listening to music. Indeed, Foehr (2006) describes the computer as a gateway to media multitasking, which is supported by Voorveld and Van der Groot (2013) who suggest that online media facilitate quick and easy switching between media activities.

Although, a computer is not the only device that can be used to access online media, another device that has a significant role, especially for young adults, is the smartphone. Within the UK alone smartphones are present in 78% of households, rising from 66% of households reported in 2015 and are deemed the most important internet enabled device in people aged 16-24 and 25-34 (Ofcom, 2015/18). Therefore it would only be logical to suggest that akin to Rideout et al's., (2010) proposal of a computer as a gateway to media multitasking, so too are tablet computers and smartphones due to the ease of access to online media and the media multitasking that they facilitate.

2.3.3 Individual factors associated with media multitasking

Not only do various devices have implications for media multitasking behaviours, but there are also a number of other individual factors, such as: physical ownership of devices, adoption of devices and the resulting media multitasking environment. In terms of physical ownership of devices, if you own a device you have more opportunities to use that device, which equates to greater possible access to a media multitasking environment. In this regard, this is also where age is implicated in ownership, Lauricella, Cingel, Blackwell, Wartella and Conway (2014) and Lenhart (2012) both found that ownership of smartphones increases with age, throughout adolescence. Robinson and Stubberud (2012) found that half of all university students had internet capable devices, which has more than likely increased in the last 6 years. Indeed, in a recent report by Ofcom, 95% of respondents aged 16-24 stated that they owned a smartphone (Ofcom, 2018). In this regard, young adults have more control of their media multitasking and greater opportunities to media multitask as they are more likely to own devices that enable them to do so.

The importance of the role of opportunity and environment in media multitasking is emphasised by Rideout and Foehr (2008). The opportunity for adolescents to media multitask is also in part dictated by their parents, in terms of the adolescents' ownership of device and parents regulation of device usage. Adolescents have to rely on their parents to purchase devices such as smartphones or tablet computers. Furthermore, their parents can enforce rules in terms of the usage of devices. Rideout et al. (2010) found that of the 8-18 years olds 52% reported having their computer use regulated and 46% reported having their T.V. use regulated.

2.3.3.1 Motivation

Lastly, another major individual factor that influences media multitasking behaviour is the motivation to carry out such behaviours. Research has found individuals' personality, in terms of their impulsiveness to be a motivational factor (Sanbonmatsu, Stryer, Medeiros-Ward & Watson, 2013), along with sensation seeking (Duff, Yoon, Wang & Anghelcey, 2014; Jeong & Fishbein, 2007). However, research has also looked at the uses and gratifications theory (Zhang & Zhang, 2012) and social and psychological needs. In this regard, Zhang and Zhang (2012) found three distinctive motivational needs for media multitasking, with participants suggesting that they carried out such media behaviours out of habit, convenience or that they felt it was a more effective way of engaging with media. Hwang, Kim and Jeong (2014) explored content specific motivations for media multitasking. Similarly to Zhang and Zhang, Hwang et al., (2014) found that participants' general media multitasking was motivated out of force of habit and the need to engage with media efficiently. However, the need for information and the importance of enjoying media engagement were also motivators, in addition to social connections. In terms of specific media multitasking behaviours, internet-based multitasking was predicted by the need to obtain information and the need to gain enjoyment, whereas mobile-based multitasking was predicted by information motives. Chang (2016) suggests that there is a split within the literature, in regards to sensation seeking versus social and psychological needs as motivation to media multitask. Within his study, both needs and sensation seeking were explored in relation to media multitasking. The study found a mediated relationship, with individuals' media multitasking behaviour being influenced by the intensity of their need to use media, which was subsequently influenced by their level of sensation seeking. Sensation seeking was associated with the following motivational needs: entertainment, convenience, stylishness, social, cognitive and efficiency with convenience, social and efficiency being the needs that mediate media multitasking behaviours. Thus, Chang (2016) suggested that needs and sensation seeking are not distinctly separate influential factors. Therefore, individuals motivation to consume media simultaneously (media multitask) varies from being driven at a personality level such as impulsiveness, to a cognitive level such as purposes to gain information or for convenience, although these different motivations have been argued to be intertwined. Nonetheless, motivations to media multitask consequently influences the extent to which individuals media multitask and the manner in which they media multitask.

2.3.3.2 Mental health and well-being

A further factor influencing media multitasking, and a factor potentially influenced by media multitasking, is mental health and well-being. Frequent media multitasking has been associated with increased amounts of self-reported symptoms of depression and social anxiety. The multitasking consumption of media has been identified as a specific distinctive risk factor for mood and anxiety related mental health issues (Becker, Alzahabi, & Hopwood, 2013). It has also been associated with trauma symptoms (Nooner & Schaefer, 2012) which are defined as symptoms commonly experienced following a difficult event, e.g., issues sleeping or being jittery (Nooner & Schaefer, 2012). Another study investigated negative socioemotional outcomes in girls age 8-12, with media multitasking associated with outcomes such as not feeling normal or feeling socially unsuccessful (Pea, Nass, Meheula, Rance, Kumar, et al.,2012). Specifically, internet based media multitasking has been positively associated with increased perceived stress in individuals age 14-34, with perceived stress significantly associated with burnout, depression and anxiety (Reinecke, Aufenanger, Beutel, Dreier, Quiring et al., 2017). Thusly, this evidence suggests that media multitasking indirectly effects depression, anxiety and burnout. However, this study also highlights how mood can also influence media multitasking, as fear of missing out was found to be a driver of internet multitasking. Thus, it seems that media multitasking may have negative outcomes in terms of well-being. Indeed, smaller grey matter volumes have been found in individuals who more frequently media multitask and are purported as a possible explanation for negative socio-emotional outcomes related to media multitasking (Loh & Kanai, 2014).

However, there is also contrasting evidence finding no relationship between mental well-being and media multitasking (Shih, 2013). Shih (2013) created and implemented the Survey of the Previous Day (SPD) as a measure of media multitasking (inclusive of media-media multitasking and media non-media multitasking). They compared scores on the SPD with scores on the Ryff scale of psychological well-being, the Warwick-Edinburgh mental well-being scale, emotional positivity and psychological distancing, finding no significant correlations. Furthermore, research has also highlighted that media multitasking may also be positively associated to mental health. In a study examining media multitasking and different specific media activities, Xu, Wang and David (2016) found media multitasking during entertainment driven media activities to be positively associated with social success, normalcy and self-control. However, media multitasking during social interactions had differing results. Media multitasking during face-to-face, phone and video chat interactions had a negative, deleterious effect on well-being in terms of social success, compared to media multitasking during texting, email and instant messaging that had no effect.

The mixed results have also been found in regards to research exploring media multitasking in relation to social anxiety, negative and positive affect, and self-esteem. Hatchel, Negriff and Subrahmanyam (2018) found an association between more time-spent media multitasking (in terms of percentage), lower self-esteem and negative affect. However, individuals with high social anxiety, in combination with spending a great deal of time media multitasking, had higher self-esteem and greater positive affect. Thus, media multitasking can be beneficial in terms of positive affect for individuals with high social anxiety, although it has a negative effect on mood for individuals with low self-esteem. However, it should be noted that a causal relationship could not be determined in a number of these studies due to their cross-sectional nature.

Nonetheless, the research seems to indicate that media multitasking can negatively impact mental health and well-being, inclusive of anxiety, depression and aspects of psychological well-being (Van der Schuur, Baumgartner, Sumter and Valkenburg, 2015), at least for some individuals with vulnerabilities such as low self-esteem. However, the literature also demonstrates the complexities of the relationship between media multitasking, mental health and well-being, indicating the involvement of other factors and both direct and indirect relationships. In this regard, it is important to highlight that another factor could also play a part in the relationship of media multitasking with both cognition and mental health, that factor being sleep. Media multitasking has been associated with sleep problems (Calamaro, Mason, & Ratcliffe, 2009; Mark, Wang, Niiya, & Reich, 2016; Pea et al., 2012; Van der Schuur, Baumgartner, Sumter & Valkenburg, 2018), with more sleep problems reported by adolescents who engage in higher levels of media multitasking (Van der Schuur et al., 2018). This sleep association then implicates other factors that are associated with sleep (Van der Schuur et al., 2018), such as mental health (Colrain, 2011; Dewald, Meijer, Oort, Kerkhof, & Bogels, 2010; Orzech, Grandner, Roane, & Carskadon, 2016). Indeed, Van der Schuur et al., (2015) suggested that an array of factors need to be explored to fully understand the complex relationships media multitasking has with mental health and well-being. In a recent book chapter Cheever, Peviani and Rosen (2018) summarise the research surrounding media multitasking and numerous aspects of mental health, inclusive of anxiety, depression, body image and sleep disorders, providing guidance for clinicians.

2.4 Summary

In sum, exponential growth in technology inclusive of: advances in electronic devices, access to the internet, abundance of social media platforms and the ever evolving media environment have changed the way in which media is consumed. Media multitasking is a very common way in which individuals engage with media, applicable to individuals of all different ages. However, it seems more prevalent in young adults aged 16-24. The prevalence of media multitasking has mainly been determined by surveys from various populations, thus, there are inherent limitations with this self-report method. Media multitasking is not only ubiquitous but is extremely diverse, consisting of complex and varied media behaviours, for which there are many influential elements. Inclusive of environmental factors such as exposure and ownership of media devices and intra-personal factors, such as mental health and well-being, that could both be a driver and a product of media multitasking. It is important to take all of these aspects into account in order to understand the whole picture of what media multitasking entails. Fundamental to exploring media multitasking, and the place to start, is the way in which media multitasking is defined. As previously mentioned, media multitasking is most commonly defined as the simultaneous consumption of media from multiple media streams and will be the working definition used throughout this thesis.

Chapter 3. Executive functioning and media multitasking

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3.1 Chapter Overview

The following chapter discusses executive function theory from the early multi component model of working memory through to the fractionation of the central executive by Miyake, Friedman, Emerson, Witzki, Howerter and Wager (2000). It examines other fractionated models that have utilised factor analyses and then highlights the two key theoretical frameworks of executive functioning, Miyake et al., (2000) and Diamond (2013). The predominant focus is on Diamond's (2013) theory, as this is the chosen framework for the behavioural executive function tasks used within this thesis. Following on from this, it progresses to the debate about suitable measures of executive function and surrounding methodological issues. The latter emphasis of the chapter is on the crucial evidence fundamental to the thesis topic, media multitasking and the relationship it has with each of Diamonds proposed aspects of executive function: inhibition, working memory and cognitive flexibility. Finally this is summarised, demonstrating the aims and objectives of the thesis.

3.2 Theoretical Background

Media multitasking burdens cognitive processes in a novel way (Ophir, Nass & Wagner, 2009). It is a type of behaviour that puts high demand on executive functions; leading to reduced executive control and increased distractibility (Loh & Kanai, 2016). Executive function is an umbrella term for a number of complex top-down cognitive processes (Chan, Shum, Toulopoulou & Chen, 2008; Elliott, 2003). The understanding of these cognitive processes has emerged from the advancement of theoretical models. Baddeley (1986) and Baddeley and Hitch (1974) proposed a multi component model of working memory. The model initially consisted of the central executive as a key component with two supporting systems; the phonological loop and visuospatial sketchpad. However, a third component, the episodic buffer was later added by Baddeley (2000). The model emphasises that the central executive has a central role as a central attentional control system that co-ordinates and integrates information from the two subsystems as well as long term memory. It is responsible for focusing attention, specifying information that needs to be attended to in the service of current goals and priorities. In regards to the two other components, the phonological loop is a subsystem that has two aspects, the first being the phonological store. This stores acoustic information such as speech. The second is the articulatory control process that facilitates rehearsal of information from the phonological store. It is through rehearsal that we are able to recall words or numbers that are heard. It is also a vital aspect of speech production as it translates written material which is then conveyed to the phonological loop. The other subsystem, the visuospatial sketchpad, is responsible for storing and processing visual or spatial information. The last of the components, the episodic buffer, was later added as a result of a lack of explanation by the model for how the subsystems interact with each other and long-term memory. It is a temporary store that collates different forms of information, for example visual and spatial, in the form of a multi-modal representation (McLeod, 2012).

Despite the popularity and influence of this model, there was great dispute over the unified concept of the central executive, based on growing evidence finding different performance patterns (selective deficits) of patients, with performance on one task indicating a deficit whilst performance on another not demonstrating a deficit in the same patient (Godefroy, Cabaret, Petit-Chenal, Pruvo, & Rousseaux, 1999). Critical to this issue Miyake et al., (2000) investigated whether the central executive is indeed fractionated into separate executive functions. They focused on three key executive functions that are prominent within the literature: Shifting (which encompasses the ability to shift between mental sets or tasks), Updating (which is the ability to monitor and update representations held in working memory) and Inhibition (consisting of the ability to control prepotent responses), with the aim to determine the extent to which the three functions are both diverse and unified. They focused on using executive function specific tasks (three per function) in order to establish the commonalities between the executive functions and their respective tasks, otherwise known as latent variable analysis. Using this technique Miyake et al., (2000) found a significant correlation between the tasks aimed at tapping into the same executive function that did not correlate strongly with the other tasks measuring the other executive functions. They compared different confirmatory factor analysis (CFA) models, finding their three-factor model of executive function to best fit the data and thus concluded the three executive functions to be distinct concepts. However, it was also found that the three executive functions share an underlying unity as they were moderately correlated.

The latent variable approach has since been used to further explore the fractionation of the central executive (Adrover-Roig, Sesè, Barcelò, & Palmer, 2012; Fournier-Vicente, Larigauderie and Gaonac'h, 2008) with evidence supporting Miyake et al.'s, (2000) three component model (Henry & Bettenay, 2010). However, other research has found evidence to support a fourth component, access to long-term memory (Fisk & Sharp, 2004), evidence of a specific function that supports dual task performance (Logie, Cocchini, Della, Sala & Baddeley, 2004), or even indication of a five factor model of executive function, with the following factors: verbal storage and processing co-ordination, visuospatial storage and co-ordination, strategic retrieval, selective attention and shifting (Fournier-Vicente et al., 2008). This somewhat demonstrates the lack of clarity (Miyake et al., 2000) and consensus regarding the theoretical understanding of the concept of executive function (Packwood, Hodgetts & Tremblay, 2011). This poor construct validity of executive function (Rabbit, 1997) is a major issue within the literature (Snyder, Miyake & Hankin, 2012) emphasising the need for uniformed definitions of the different executive functions.

From a review of the literature Diamond (2013) puts forward a slightly different framework, proposing that inhibition, working memory and cognitive flexibility are the core facets of executive function. The framework is largely in agreement with the Miyake et al., (2000) model. However, it differs slightly in regards to the concept of working memory and in terms of structure, as compared to Miyake et al., (2000), Diamond (2013) suggests that cognitive flexibility is underpinned by inhibition and working memory.

Diamond (2013) defines inhibitory control as the process fundamental to the ability to control behaviour, emotions, attention and thoughts. It is the way in which one can supress impulsive or habitual behaviour. Inhibitory control consists of three interlinking concepts; inhibitory control of attention, cognitive inhibition and self-control (Friedman, 2004; Diamond, 2013). Inhibitory control of attention provides one with the ability to selectively attend to certain stimuli, whilst electing not to attend to other stimuli. Whereas cognitive inhibition enables suppression of unwanted thought, prepotent mental representations and resistance to both proactive and retroactive interference. Cognitive inhibition is the aspect of inhibition that supports working memory. Lastly, self-control is the ability to control behaviour through the control of emotions. It is the way in which impulsive urges are managed. However, it also has a role in staying on task and remaining disciplined.

Working memory is defined as the ability to manipulate or “work with” information currently held in mind (Baddeley, 2012; Diamond, 2013; Miyake et al., 2000), as previously discussed in Baddeley’s multi component model. It is markedly different from short-term memory in the sense that short-term memory is the simple recall of information held in mind that does not require any further processing (Diamond, 2013). In comparison to Miyake et al. (2000), Diamond’s (2013) description of working memory encompasses all processes involved in the manipulation of information held in mind. Whereas Miyake et al.’s concept is more specific to the updating of information, the integration of new information to that which is already held in mind and the discarding of information no longer relevant. However, Miyake et al. (2000) have also suggested that working memory encompasses monitoring of information in addition to updating and both accounts emphasise the active processing of information rather than passive storage.

The last facet proposed by Diamond is cognitive flexibility, which is suggested by others to be more difficult to define (Barbey, Colom & Grafman, 2013; Muller, Langner, Cieslik, Rottschy & Eikhoff, 2015). Nonetheless, Diamond (2013) defines cognitive flexibility as the ability to effortlessly adapt one's way of thinking, changing perspective (both spatially and interpersonally), adjusting to different or altered demands and switching between mental sets. Cognitive flexibility also encompasses the fluent generation of abstract thought (Diamond, 2013; Barbey et al., 2013). It is a function that draws on inhibition and working memory. For example, if you were to complete a phonetic fluency task, a cognitive flexibility task that requires the random generation of words beginning with F. First, you would hold the rule of only words beginning with F in short-term memory, in addition to any other restrictions such as the words cannot be place names. Then, as you proceed to generate words, working memory would be used to manipulate the task information (rules) and the word you have generated, i.e. contrasting the word you have generated to see if it fits with the rules, a process that is often rapid. Simultaneously, as you produce words, you often think of words that are related in some way e.g. phonetically or categorically. In this regard, you then have to inhibit the words that pop into your mind that are not task relevant e.g. pharmacy, as it is phonetically similar but does not begin with F. Furthermore, you also have to use working memory to remember previous responses (words generated) as well as inhibition to stop yourself from saying them again (repeating yourself). Thus, in this sense, cognitive flexibility as a function is facilitated by the inhibition of irrelevant information or no longer relevant information and the manipulation of task relevant information in working memory. This model, presented by Diamond (2013), was used as a guiding framework for the thesis in terms of executive function task selection. It was chosen as it is a framework that has consensus within the executive function literature, in addition to offering a slightly different perspective on working memory and in particular cognitive flexibility, in comparison to Miyake et al.'s, (2000) framework that has similar support.

3.2.1 *Measuring executive function*

Theoretical understanding and assessments of executive function originate to a large extent from neuropsychological research into brain lesions (Miyake et al., 2000). Executive function is assessed through performance on a task or number of tasks (Van de Schuur, Baumgartner, Sumter & Valkenberg, 2015). Tasks are created based on specific models and theories of executive function and are designed to tap into the concept of the desired executive function (Chan et al., 2008), which is known as task specificity (Deak & Wiseheart, 2015). There is an issue of tasks being under specified (Chan et al., 2008), in the sense that a task is not completely specific to the cognitive processes it is engaging and intended to assess. Due to the prevalence of proposed executive functions various tasks have been designed (Diamond, 2013) and utilised in a variety of populations. Demonstrating executive function deficits in individuals with; ADHD (Brown, 2013), brain injuries (Godefroy, Azouvi, Robert, Roussell, LeGall et al., 2010), Substance misuse (Fisk & Montgomery, 2009), Autism (Van Eylen, Boets, Steyaert, Evers, Wagemans et al, 2011) and biases in young media multitaskers (Ophir et al., 2009).

There are some key traditional executive function assessments that have been extensively used in the literature such as; the Stroop task (Stroop, 1935) to assess inhibition, Wisconsin card sorting task (Grant & Berg, 1948) to assess cognitive flexibility, flanker task (Eriksen & Eriksen, 1974) to assess attention and backwards digit span (Groeger, Field & Hammond, 1999) to assess verbal working memory. These are just a few examples. It is important to highlight that the traditional measures of executive function are sometimes criticised for having low ecological validity (Lalonde, Henry, Drouin-Germain, Nolin & Beauchamp, 2013). They have often failed to capture executive function deficits in test situations of individuals who display dysexecutive problems in the real world (Burgess, 1998). This may in part be due to the way they measure executive functions separately, whereas in everyday life executive functions are simultaneously employed (Jansari, Agnew, Akesson & Murphy, 2004). Due to the lack of ecological validity of traditional measures other tasks have been developed. Modern technology has facilitated executive function research in terms of virtual paradigms. Virtual paradigms involve tasks that use virtual reality to specifically measure an array of executive function. They are high in ecological validity as they assess how executive functions operate together in a more realistic setting (Robertson, 2008). These include tasks such as the Edinburgh virtual errands task (Logie, Law, Trawley & Nissan, 2010), Jansari, Agnew, Akesson and Murphy (JAAM task) (Jansari et al., 2004), Executive Secretarial Task (Lamberts, Evans & Spikman, 2010) and The Breakfast Task (Craik & Bialystock, 2006). Despite technological advancements, the accuracy of the distinguishability provided by traditional measures of executive function is still needed in order to determine the presence of a cognitive impairment in clinical groups (Lamberts et al., 2010).

Traditional and virtual reality tasks are not the only way in which executive function can and has been measured. Self- report measures have been implemented with those such as the; Behaviour Rating Index of Executive function (BRIEF) (Gioia, Isquith, Guy & Kenworthy, 2000) or the Executive Function Index (Miley & Spinella, 2006) (for a more comprehensive list, see Toplak, West & Stanovich, 2013). Self-report measures are suggested by some to be more multi-dimensional, providing a more accurate account of an individuals' everyday executive functioning and consequently deemed higher in ecological validity (Roth, Isquith & Gioia, 2005). However, they are open to subjectivity and others argue that they cannot specifically identify discrete executive function deficits (Gioia, Isquith, Retzlaff & Espy, 2002).

Thus, there is a vast array of tasks that can be used to assess different executive functions which has both negative and positive implications. The negative aspect is that the plethora of tasks exacerbates the issue of the proliferation of concepts of executive function (Packwood et al., 2011). Whereas the positive impact is that the wide variety of tasks available means that the more reliable and valid of these tasks can be selected and utilised, as there is an issue over the reliability of some executive function tasks. For example the Stroop task (Stroop, 1935) is a traditional measure of inhibition. It is a task that involves the presentation of words (colours) e.g., red, blue, green. The words are displayed in different coloured fonts to the actual words and the participant has to read the words and say the colour of the font out loud. Thus, measuring inhibition in terms of requiring the individual to withhold the urge to shout out the word that is read and not the font of the word. However, some have argued that this task is not valid as it is not sufficient at evoking inhibition (Shao & Roelofs, 2015) and does not necessarily measure inhibitory control (Diamond, 2013), instead placing a greater demand on working memory than inhibition as well as strategic retrieval (Fournier-Vicente, 2008).

This also highlights a fundamental issue within the measurement of executive function. Not only is there disagreement amongst researchers over the definition but also in the tasks used to measure executive functions. One of the key concerns within executive function research is impurity of the assessment tasks used (Miyake et al., 2000; Snyder, Miyake & Hankin, 2012). Impurity in the sense that a task does not measure one executive function, rather the tasks used often place demand on more than one function (Rabbit, 1997); overlapping in their assessment of the theoretical constructs of each executive function, with most executive function tasks also involving contributions from other domain specific functions (Phillips, 1997; Miyake et al., 2000). However, this is ingratiated with the nature of executive functions being both separable and unified (Burgess, 1997). As a means of tackling the nature of executive function, tasks aimed at assessing the executive function in question can be and are designed to place higher demand on the desired executive function whilst placing less demand on other executive functions that are also implicated. A solution to the issue of task impurity is to use more than one task to measure the executive function of interest (Snyder et al., 2012).

Another issue is the test/re-test reliability of executive function measures. Executive functions support the ability to be able to cope with novel situations (Rabbit, 1997; Phillips, 1997; Snyder et al., 2012) thusly; executive function assessments fundamentally need to be novel. Deficits in executive function are assessed via the interaction between the demands of the task, the processes that are impaired and the novelty of the situation (Burgess, 1997); as soon as some executive function tasks are repeatedly performed they lose their efficacy (Rabbit, 1997). In this regard many of the more complex assessment of executive function cannot be repeated within the same sample and reliably re-produce previous results as the task is no longer novel. However, the reliability of various more simplistic executive function measures has been established. Comparisons have been made across studies with tasks successfully identifying deficits in targeted executive functions for which performance based norms have been generated (Suchy, 2009). Furthermore, various solutions to repeating executive function tasks have been suggested. Falleti, Maruff, Collie and Darby (2006) propose that parallel version of executive function tasks can be used, parallel in the sense that the task essentially remains the same but features different stimuli. An approach that has been used in a range of studies, using a variety of tasks, such as the backwards digit span and trail making tasks (Barcelos, Shah, Cohen, Hogan, Mulkerrin et al., 2015), flanker tasks (White, Flannery, McClintock & Machado, 2018), and backwards Corsi block task (Hackney, Byers, Butler, Sweeney, Rossbach and Bozzorg, 2015). It is important to note that no executive function task is without imperfections, and in the section that follows the literature that has used these tasks in relation to measures of media multitasking is reviewed.

3.3 Media multitasking and executive function

Media multitasking is a relatively new concept with only a small evidence base investigating the relationship between media multitasking and executive function (Van de Schuur et al., 2015). However, this area of research is gaining in popularity due to the ubiquitous nature and prevalence of media multitasking. Present research has utilised a variety of measures to assess the relationship between frequency of media multitasking and executive function (as indicated by the performance on a task). Self-report measures of executive function have also been used in relation to exploring media multitasking. For example, Baumgartner, Weeda, Van der Heijden and Huizinga (2014) used the Dutch version of the BRIEF and found media multitasking to be associated with everyday problems in inhibition, working memory and task switching. With more frequent media multitasking associated with difficulties in inhibiting inappropriate behaviour, focusing attention and shifting between tasks. However, self-report measures of executive function will not be discussed in detail within this literature review. For studies utilising these measures of executive function please see the following; Magen, (2017) and Ralph, Thompson, Cheyne and Smilek (2014).

In a pioneering study, Ophir et al., (2009) investigated the systematic differences in media multitaskers styles of information processing. In order to measure media multitasking and establish groups of light (infrequent) or heavy (frequent) media multitaskers, a trait Media Multitasking Index (MMI) was developed. The MMI is a questionnaire based index that addresses 12 forms of media; music, non-music audio, video or computer games, television, computer-based video (streaming

T.V episodes, Youtube), text messaging, telephone/mobile phone calls, instant messaging, email, web surfing and other computer applications e.g., (word processor). For each type of media participants are required to indicate how many hours a week they use a form of media. Participants also have to complete a media multitasking matrix. Pertinent to this, participants have to indicate how often they use a primary type of media whilst simultaneously using another e.g., (whilst watching TV, if they browse the web). Answers are recorded using “Most of the time, some of the time, a little of the time or never” which are then given numerical values. Media multitasking user frequency status was determined via one standard deviation below the mean for light users and one standard deviation above the mean for heavy. It is noteworthy that the Media Multitasking Index (MMI) is a reliable and valid self-report measure that is used throughout the literature (Van de Schuur et al., 2015; Uncapher et al., 2016) although alterations or adaptations have been made (Pea, Nass, Meheula, Rance, Kumar et al., 2012) to the type of media included in the list. In addition, research using the MMI has used either an individual differences approach using the full continuum of MMI scores, or an extreme-groups design based on different MMI score cut offs. An adapted version of the MMI and the full continuum of scores is used in study 1 presented in this thesis (Chapter 5), published as Seddon, Law, Adams and Simmons (2018). The following detailed review of the media multitasking literature will be structured with clearly defined sections, split by Diamonds sub-divisions within executive function. Each function and surrounding literature will be dissected in turn.

3.3.1 *Inhibitory control*

As previously discussed, Diamond’s (2013) theory posits attentional control as an aspect of a more general construct of inhibitory control. This section of the literature review will first discuss the research examining media multitasking and attentional control and then move on to discuss the research exploring media multitasking and response inhibition. In this regard, Ophir et al., (2009) looked at varying aspects of executive function and media multitasking. The study used an AX-continuous performance task (AX-CPT) to assess attentional control, which involved the participants being shown cue-probe pairs. The cue-probe pairs consist of the letters A and X; if these two letters are together then the participant had to press the button for yes. If any other letter combination was presented then participants had to press the button for no. No significant differences in response times or accuracy were found for heavy media multitaskers (HMMs) versus light media multitaskers (LMMs). Similarly, Ralph, Thomson, Seli, Carriere and Smilek (2015) explored sustained attention, utilising a metronome task (experiment 1). However, in contrast to Ophir et al., (2009) they suggest that HMMs sustained attention is poor in comparison to LMMs, with greater response variability positively correlated with more frequent media multitasking. This result was replicated in a further experiment with a larger sample (experiment 3a). However, in this latter experiment, when age was controlled for, the significant correlation became marginal.

Additionally, however, Ophir et al., (2009) also used an altered version of the AX-CPT task that included distractor letters in different colours. Using this version of the task HMMs and LMMs were found to significantly differ in their response times with HMMs being slower. Therefore, the data highlighted that HMMs struggle to disregard irrelevant stimuli and are more affected by distractors. In this regard, the authors suggest that HMMs display a breadth-based bias in attentional processing. Normally attention to stimuli is regulated by cognitive control and thusly utilises a top-down approach to process information (Diamond, 2013; Gazzaley & Nobre, 2012). If HMMs were utilising this technique of processing they would be able to focus on the target and filter out the distractors. However, they display a bias of a bottom-up attentional processing technique. This is associated with the way in which HMMs habitually attend to information from more than one stream at a time and is analogous to the situation of media multitasking.

As stated previously, this was a ground-breaking study highlighting the negative biases in attentional control associated with media multitasking. However, since this initial exploration, further research has attempted to replicate and expand upon these initial findings. Cain and Mitroff (2011) suggest that Ophir et al., (2009) fail to provide a specific locus of the attentional bias. In their study, Cain and Mitroff (2011) utilised an additional singleton distractor task in order to precisely determine the media multitasking related attentional deficit. The task requires the participant to search for a shape singleton within two conditions; one where there are irrelevant colour singletons present, known as the "sometimes" condition and the other where they are not, known as the "never" condition. The stimuli stay visible and do not change for each trial thus the task places less demand on working memory. Significant differences in response times between the two conditions were greater for LMMs. LMMs modified their performance between conditions, ignoring colour singletons in the never condition and not ignoring them in the sometimes condition. Therefore, utilising top-down processing to control their attention and perform the task as instructed. Whereas HMMs did not differ in their processing across conditions, they did not ignore colour singletons in the never condition (as instructed) which enabled them to perform better when a colour singleton was the target. Therefore highlighting that HMMs implement a bottom-up attentional processing technique, further supporting the attentional bias associated with frequent media multitasking.

This bias of attention has also been supported by Cardoso-Leite, Kludt, Vignola, Ma, Green, et al., (2016) who utilised the same AX-CPT task as Ophir et al., (2009), comparing media multitasking and video game experience, as action video gaming has been associated with greater attentional control. The study found HMMs to perform worse overall, supporting the media multitasking associated attentional bias. However, the distractor specific bias (as found by Ophir et al., 2009) was not replicated. In terms of the AX-CPT task, Wiradhany and Niewenstein (2017) conducted 2 studies attempting to replicate the findings of Ophir et al., (2009). In study 1, they found HMMs were slower to respond on BX trials than LMMs, but there was no difference in response times on AX trials. Indicating that HMMs were more affected by distractors (resulting in slower response times) but no different in terms of responding correctly to targets. However, Wiradhany and Nieuwenstein (2017) conducted various power and Bayesian analyses with Bayes factor analyses indicating the findings (significant and non-significant) to be based on anecdotal evidence, (when the Bayes Factor is 1-.33, evidence for the alternative hypothesis, (Jeffreys, 1961), is also weak (Raftery, 1995)). Thusly, they conducted study 2, which found the opposite, with HMMs being slower than LMMs on AX trials but not BX trials, with Bayesian analyses indicating findings based on moderately strong evidence. Thus, Wiradhany and Niewenstein (2017) only partially support the findings of Ophir et al., (2009), with Heavy media multitaskers demonstrating slowing in performance only on AX trials, where they have correctly responded to a target.

Lastly, there has also been research that has utilised more ecologically valid tasks to explore attentional control and media multitasking. Moisala, Salmela, Hietajarvi, Salo, Carlson et al., (2016) utilised speech-listening and reading tasks and the MMI as well as a media multitasking score (MMT) that represented absolute time spent media multitasking, reported by participants, in addition to using functional magnetic resonance imaging (fMRI) technology. The tasks were either written or spoken sentences that were either congruent or incongruent. Participants had to specify the sentence congruency in three different conditions; an undistracted attention condition, where they were instructed to either read or listen to sentences with only one modality presented; a distracted attention condition where sentences were presented either visually or spoken with distractors simultaneously presented in the opposite modality; and a divided attention condition where both spoken and written sentences were presented and had to be attended to. For the distractor condition higher MMT score was associated with worse performance and increased activity in the right prefrontal cortex (PFC), indicating that adolescents and young adults who frequently media multitask are more affected by distractors. Thus generally supporting Ophir et al.'s, (2009) finding of HMMs sensitivity to distraction. Whereas performance in the divided attention condition was not associated with MMT, indicating that frequency of media multitasking does not affect individuals' ability to divide attention. Thus, media multitasking is associated with distractibility and increased recruitment of areas of the brain involved in attentional and inhibitory control. By using speech-listening and reading tasks, deemed more relevant to real world situations, this study provides more ecologically valid evidence of an attentional bias associated with frequency of media multitasking. It is the first study to demonstrate increased brain activity associated with distractibility related to media multitasking.

The evidence so far would seem to indicate a negative bias of attentional control associated with more frequent media multitasking. However, the breadth bias in attention may actually be advantageous in some situations. Lui and Wong (2012) explored media multitasking and individuals' attentional control with the intention of determining the difference between LMM's and HMM's tendency to capture irrelevant information. They used a visual search task that also featured an auditory signal "Pip & Pop paradigm" as devised by Van der Burg, Olivers, Bronkhorst and Theeuwes (2008). HMMs performed worse on the task without the auditory signal in comparison to LMMs, although they improved when the auditory signal was present. Therefore, heavy media multitaskers did exhibit a breadth bias, attending to irrelevant stimuli, which in this case facilitated a better performance highlighting their better ability of multi-sensory integration. In regards to this beneficial aspect of the biased attentional control displayed by heavy media multitaskers Yap and Lim (2013) had individuals complete the MMI and an attentional location task. The task consisted of two conditions, a single cue and a double cue. A significant difference was found in regards to response times for targets in cued locations compared to targets in irrelevant locations, with HMMs responding faster than LMMs. This was interpreted as suggesting that individuals who more frequently media multitask have a split mode of attention rather than the traditional unitary mode which is displayed by light media multitaskers.

In contrast to the evidence reviewed above, there is evidence opposing the idea that heavy media-multitaskers have a breadth-based bias in attention. The bias in attention pertains to frequent media multitaskers' tendency to avoid focusing on a singular source of information (Ralph, Thomson, Seli, Carriere & Smilek, 2015). However, other authors suggest that frequent media multitaskers do not display a deficit. Minear, Brasher, McCurdy, Lewis and Younggren, (2013) explored heavy and light media multitaskers performance on the attention network task (ANT), a task that encompasses a variety of attentional assessments. The study found no difference between HMMs and LMMs orientation of attention, alerting attention and executive attention.

In addition to this, some studies have failed to find evidence that HMMs and LMMs differ significantly in their ability to focus attention to stimuli and process information. When implementing a flanker task, Murphy, Mc Lauchlan and Lee (2017) found no significant difference in HMMs and LMMs performance in terms of congruency conflict, a response time measure of attentional control. However, other research using flanker tasks has found HMMs to perform better than LMMs, with faster response times on incongruent trials (Baumgartner et al., 2014), as well as the opposite, with HMMs performing significantly worse than LMMs (Gorman & Green, 2016). However, the finding by Baumgartner et al., (2014) was only marginally significant. Furthermore, despite the findings showing no relationship with media multitasking or differences between light and heavy media multitaskers, in two recent reviews of the literature by Uncapher et al., (2017) and Uncapher and Wagner (2018) suggest that the overall evidentiary picture is that of a negative relationship between attentional control and more frequent media multitasking. See appendix 1.a for summary table of attentional control studies. Indeed, research has begun to explore the longitudinal effects of media multitasking and attention, with Baumgartner, Van der Schuur, Lemmens and te Poel (2017) finding media multitasking to possibly have a long-term harmful effect for early adolescents, in terms of self-reported attentional problems, inclusive of adolescents being easily distracted by media and issues focusing attention when media distractors are present. Furthermore, they showed that adolescents with attentional problems engage more frequently with media multitasking.

However, attention is not the only aspect of inhibition, even though this is where the focus of the majority of the research lies. Another aspect that has only been explored briefly (Van der Schuur et al., 2015) is response inhibition as measured using tasks such as the Stop-Signal (Verbruggen, Logan, & Stevens, 2008) or Go No-go tasks. As previously mentioned, inhibition is the way in which we control behavioural responses to environmental cues. Thus, one's ability to inhibit responses may be associated with the very nature of media multitasking and dictate the extent to which one media multitasks, especially in the current media multitasking environment. Ophir et al., (2009) used a stop-signal task, featuring categorisation of words as animal or non-animal. The study found no difference in LMMs and HMMs ability to withhold a response to a stimulus. Similarly, they also found no difference in response times on a version of the standard AX-CPT task that is indicative of ability to inhibit prepotent responses. This is further supported by Ralph et al., (2015) who used the Sustained Attention to Response Task (SART) (Robertson, Manly, Andrade, Bddeley & Yield, 1997), a type of Go No-go task and found no significant difference in performance associated with frequency of media multitasking in terms of both no-go errors and response times (experiment 2, 83 participants). Although, when they replicated the experiment, a borderline significant correlation between MMI and no-go errors was found, but the non-significant MMI and response time correlation was replicated (experiment 3b, larger sample of 152 participants). Similarly, Gorman and Green (2016) who used a Go No-go task, found HMMs to perform significantly worse than LMMs. However, Ralph et al., (2015) conducted a further experiment, utilising a type of Go No-go task called a vigilance task. The vigilance task differs from a stereotypical Go No-go as the task includes a larger amount of non-responsive trials and small amount of infrequent response trials. In this experiment, there was no association between response time and MMI. However, there was a weak, negative correlation between overall sensitivity and MMI. Ralph et al., (2015) suggest that media multitasking is not associated with an individuals' ability to remain attentive. More recently, Murphy et al., (2017), utilised a Go No-go task to explore media multitasking and response inhibition. The study compared light, average and heavy media multitaskers. Average media multitaskers (AMMs) were unexpectedly found to make significantly more errors than LMMs and HMMs. There was no significant difference in errors for LMMs and HMMs. Therefore in terms of findings, collectively the research seems to demonstrate that more frequent media multitasking is not associated with response inhibition and that the minority of research showing a relationship, the relationships have tended to be weak. However, further research is needed to clarify the evidentiary discrepancies and determine the association between media multitasking and response inhibition. An interesting point to note is that in their explorations of attentional control and response inhibition Ralph et al., (2015), and Ralph and Smilek (2017) reported compliance issues, with participants multitasking whilst taking part in their research. Thus, it is a point of contemplation for conducting experimental research into media multitasking. A summary table of the studies reviewed in this section can be seen in appendix 1.b).

3.3.2 *Working memory*

In this section, studies examining the relationship between working memory and media multitasking will be reviewed. Overall, the evidentiary picture of the media multitasking and working memory association is very unclear with a great deal of inconsistency. Some research has found no differences in heavy media multitaskers and light media multitaskers performance on working memory tasks (e.g. Baumgartner et al., 2014; Cardoso-Leite et al., 2016). Whereas other evidence suggests that HMMs display a reduction in working memory performance in terms of the ability to manipulate information (Sanbonmatsu, Strayer, Medeiros-Ward & Watson, 2013). More importantly however, a variety of working memory tasks have been used across the literature with some studies using the same or similar tasks as others but no consistent pattern of results has emerged for any one task.

When utilising a filter task, a task that indexes working memory through the demand it places on the constant processing and ability to discriminate information, (i.e. participants are shown an image and then shown a following image and have to distinguish whether the stimuli within the image has changed, a task that has also been used as an attention task), Ophir et al., (2009) found that LMMs were effectively able to filter out irrelevant information whereas HMMs were negatively affected by distractors. This is further supported by Uncapher et al., (2016), who utilised the same rectangles task as Ophir et al., (2009), and found that LMMs tended to hold more task relevant information in mind whereas HMMs hold less accurate representations. HMMs were less able to differentiate between the absence and presence of a change. That is, HMMs tended to incorrectly validate a change when none occurred. Furthermore, Uncapher et al., (2016) compared across all MMI scores as well as using extreme groups. They found that the higher the MMI score, the poorer working memory discriminability. In this regard, Gorman and Green (2016) and Cardoso-Leite et al., (2016) add to this, as they both found heavy media multitaskers to perform worse than light media multitaskers, and intermediate multitaskers (Cardoso-Leite et al., 2016), on the same filter task used by Ophir et al. (2009). Although, both Gorman and Green (2016) and Cardoso-Leite et al., (2016) did not quite fully replicate the results as no reliable difference in distractor effects were found when contrasting heavy and light media multitaskers. Which can similarly be said about

Wiradhany and Nieuwenstein, (2017) experiment 1, as they found HMMs to perform worse overall than LMMs. However, they found no significant interaction for distractor effects and the opposite trend to Ophir et al., (2009), with LMMs demonstrating more susceptibility to increasing distractors. Thus, the majority of findings based on filter tasks demonstrate poorer overall working memory performance associated with more frequent media multitasking. However, not all of these findings have demonstrated an increased susceptibility to distractors associated with media multitasking. There is also opposing evidence showing no significant association between media multitasking and performance on a filter task (Cain, Leonard, Gabrielli & Finn, 2016) and no difference in HMMs and LMMs performance on a filter task (Wiradhany & Nieuwenstein, 2017, experiment 2). Furthermore, as previously highlighted, filter tasks have also been classed as attention tasks, which raises the question as to whether this type of task really indexes working memory. The processes that the task assesses could be viewed to place more demand on visual short term memory, as the filter task does not involve a great deal of manipulation of information. Indeed, Diamonds (2013) executive function framework posits working memory with a focus on the processes involved in the manipulation of information, and how working memory works with information, not just the updating of information.

In contrast, complex span tasks, tasks that require the concurrent storage and processing of information, have also been used to explore working memory and have demonstrated null findings. The majority of the research indicates no association between working memory performance and media multitasking. However, the same specific tasks have not necessarily been used. Minear et al., (2013) utilised the automated reading span task and found no difference in HMMs and LMMs performance. Whereas Baumgartner et al., (2014) utilised both a forwards and backwards digit span task, totalling the scores, and found that media multitasking did not predict performance. Gorman and Green (2016), further support this with their use of a backwards digit span task that also found no main effects or interactions between media multitasking and working memory performance. At this point, it is important to highlight that there is a difference between forward and backwards digit span tasks, in terms of memory. The forwards version has been suggested to assess short-term memory, whilst the backwards version captures working memory, as it requires more manipulation (Richardson, 2007). Furthermore, summing the total scores from both versions of the digit span task is a less common outcome measure of task performance, total scores or mean span from either the forwards or backwards version of the task are more commonly reported separately. Nonetheless, returning to the media multitasking and working memory literature, contrary to the aforementioned null findings, Sanbonmatsu et al., (2013) and Cain et al., (2016) found an association between media multitasking and working memory performance on an operation span task (OSPAN) (Sanbonmatsu et al., 2013), and a count span task (Cain et al., 2016) with lower capacity associated with more frequent media multitasking. Thus, it would seem that these two latter studies are the only ones showing a reduced performance on a complex span task associated with media multitasking, whilst the majority of the literature demonstrates no association and no reduction in working memory capacity.

Lastly, however, n-back tasks have also been used to assess working memory throughout the media multitasking literature, which has also resulted in varied findings. The n-back task involves the presentation of a stream of stimuli, to which a participant has to confirm whether the current stimulus matches the nth back (i.e. shown a stream of x letters and recall the letter presented 2 positions back from the current position). This type of task indexes working memory as it requires the constant updating and manipulation of information held in working memory (i.e. the constant remembering of stimuli presented, in a specific order, and the remembering of the current stimulus to then be compared to the nth stimulus required, in order to complete the task) . Ophir et al., (2009) used both a 2-back and 3-back version of the n-back task. They found that HMMs displayed a greater decrease in performance on the 3-back task, with worse performance indicated by the number of false alarms. The number of false alarms increased over time, which happened more quickly and to a greater extent for HMMs compared to LMMs. Whereas no significant differences were found for hit rates, with both groups showing similar decreases. Ophir et al., (2009) suggested that the larger false alarm rate was indicative of interference in working memory associated with familiarity of items. The difference in heavy and light media multitaskers n-back performance is further supported by Cain et al., (2016) who utilised a 1, 2, and 3 back task, and found that worse performance on the task, (measured in terms of hits minus false alarms) was associated with more frequent media multitasking (as indicated by higher MMI scores). Whereas, Ralph and Smilek (2017) used two versions of the media multitasking index (the original MMI by Ophir et al., 2009 and an adapted version of MMI taken from Clifford Nass' research website, labelled MMI 2) and a 2-back and 3-back version of the n-back task. The study found heavy media multitasking to be associated with poor performance on both the 2-back and 3-back versions of the task, with higher MMI scores predicting less hits, and specifically, higher scores on the MMI-2 predicting more false alarms, when age was not controlled for. However, when controlling for age, the association of media multitasking with hits, only remained for performance on the 2-back task whilst the false alarm association with media multitasking scores from the MMI-2 remained. The study also examined omissions, also known as no responses to trials. In this regard, there was a significant positive correlation between media multitasking (inclusive of both MMI measures) and the proportion of omitted trials. Furthermore, when age and omissions were controlled for, there was no media multitasking association with change in hits but heavier media multitasking remained associated with higher false alarm rates. The authors also assessed compliance, and found that individuals scoring higher on the MMI are poor at following instructions and more likely to disengage from the task. Thus, the research seems to highlight that age is an influential factor for performance on the n-back in terms of hit rates, whereas individuals who media multitask more frequently are more likely to make more false alarms on an n-back task regardless of age.

However, some research has also found no difference in HMMs and LMMs performance. Cardoso-Leite et al., (2016) attempted to replicate the findings of Ophir et al., (2009), but found no significant difference in HMMs and LMMs performance on both 2-back and 3-back tasks, specifically finding no significant difference in overall false alarm rates. Similarly, Wiradhany and Nieuwenstein (2017) tried to replicate previous findings; however the results from both experiment 1 and 2 also found no significant difference in HMMs and LMMs performance on both a 2-back and 3-back, as indicated by false alarm rates. Therefore, this evidence would suggest that media multitasking is not associated with interference in working memory. In this regard, Minear et al., (2013) specifically assessed the aspect of interference within working memory, with the use of a recent probes task and found no significant difference between HMMs and LMMs performance on non-recent and recent negative probes in terms of accuracy and response time. Therefore adding to the research that demonstrates no association between media multitasking and interference, in terms of misrepresentation of information in working memory. Furthermore, Minear et al., (2013) also argue that n-back tasks are not as pure a measure of interference as the probe task.

Thus, in sum, there is no distinct evidentiary relationship of performance on a single working memory task and media multitasking, not one task stands out as having a clear relationship with MMI score. Which is demonstrated in appendix 1.c, summarising the literature surrounding working memory and media multitasking. From the use of filter, complex span and n-back tasks there has been evidence showing an association between media multitasking and task performance, and evidence showing no association. It is an area within the media multitasking literature that is in desperate need of clarification, a consistent pattern of evidence, especially considering the potential significant role working memory may play in media multitasking (Uncapher et al., 2016). However, as discussed previously filter tasks may not best reflect working memory performance, in terms of the “manipulation of information held in mind” aspect of working memory, whereas complex span tasks may place a greater demand in terms of manipulation. Therefore, research should progress with the use of complex span tasks to assess working memory in relation to media multitasking, which has been undertaken in the present thesis.

3.3.3 *Cognitive Flexibility*

The following section will examine the evidence regarding media multitasking and cognitive flexibility. First, the way in which cognitive flexibility is defined determines the way in which it is assessed (Barbey et al., 2013). Within the media multitasking literature the focus tends to be on defining cognitive flexibility as the ability to switch between two tasks presented simultaneously, resulting in task switching assessments (Diamond, 2013). Frequent media multitaskers are perceived to be good at task switching as they habitually switch between media simultaneously (Minear et al., 2013). However, there is disparity within the small collective of research (Uncapher, et al., 2017; Van der Schuur et al., 2015). Forming part of their pioneering study, Ophir et al., (2009) explored the relationship between media multitasking and cognitive flexibility. They used a number and letter switching classification task to assess cognitive flexibility in terms of switching between task sets. Participants had to classify either letters as vowels or consonants, or numbers as odd or even. HMMs were significantly slower than LMMs in both switch and non-switch trials in terms of switch cost. The authors suggest that this slowing is indicative of interference from the task set that is currently irrelevant. Therefore, frequency of media multitasking is associated with poor switching ability related to interference from no longer relevant task –set representations (Ophir et al., 2009). Wiradhany and Nieuwenstein (2017) further support this slower performance in task switching. In an attempt to replicate the key findings of Ophir et al., (2009), Wiradhany and Niewenstein (2017) conducted two studies utilising the same task switching task. Experiment 1 found that HMMs were slower in switch trials and had a larger switch cost than LMMs, however HMMs were not slower than LMMs in repeat trials. Whereas experiment 2, also found HMMs to be significantly slower in switch trials than LMMs, but there was no significant difference in switch costs and repeat trial response times. Thus, HMMs mainly demonstrated differences in performance on switch trials.

In contrast, other replication research has found heavy media multitaskers to perform better on switching tasks. Alzahabi and Becker (2013) utilised the same number/letter categorisation task as Ophir et al., (2009). However, they failed to replicate their findings, instead finding the opposite with heavy media multitaskers being more efficient at switching between tasks than light media multitaskers, with faster responses during task switching trials rather than slower responses in repeat trials. In a later study, Alzahabi, Becker and Hambrick, (2017) were interested in examining and factor analysing aspects of task switching, and exploring the relationship between underlying latent constructs of task-switching performance and media multitasking. They utilised three different task-switching classification tasks, Animal/Furniture, Number/Letter and Plant/Transport. The resulting model consisted of two independent factors; advanced preparation and passive decay. In regards to the media multitasking relationship, a shorter time to implement a switch was associated with a higher media multitasking score, and a reduction in switch cost was found with no increase in errors, indicating an association between more frequent media multitasking and a more efficient ability to reconfigure task set. The opposite findings of better or worse cognitive flexibility associated with media multitasking are reflective of the nature of media multitasking, as it is a behaviour that requires change between mental sets and various information streams and task executions. The negative findings have been interpreted in terms of a possible fatiguing effect of media multitasking on cognitive flexibility. Whereas, the positive findings would be indicative of a possible beneficial effect of media multitasking more frequently, what some may see as practice or training.

However, there have also been null findings. Minear et al., (2013) also used the same task switching assessment as described by Ophir et al., (2009) albeit with contradictory results. HMMs and LMMs were found to not significantly differ in their task switching performance. This is further supported by Cardoso-Leite et al., (2016) who found no significant difference in HMMs and LMMs performance on the same task switching task, and Gorman and Green (2016) who used a number categorisation task and found no difference in HMMs and LMMs performance. The null effect is further supported by Baumgartner et al., (2014) who explored a sample of early adolescents, and found that frequency of media multitasking did not predict performance on a dot and triangle switching-task, with no difference between HMMs and LMMs performance. Despite the lack of a deficit in performance, a self-report measure of executive function was also included in this study, which found HMMs reported more negative behavioural problems, in relation to executive functioning in everyday life when shifting between tasks. However, Ralph et al., (2014) also utilised self-report measures of switching attention and media multitasking, finding no significant relationship between frequency of media multitasking and reported difficulties of switching attention. For a summary of the cognitive flexibility studies reviewed here, please see appendix 1.d.

A prominent factor possibly responsible for the inconsistency of the literature is the method of assessment of cognitive flexibility. The majority of the research focuses on the use of switching tasks, with the majority utilising classification tasks. Whereas Diamond (2013) purports cognitive flexibility encompasses more than just the ability to rapidly switch between tasks and mental sets and that it pertains the generation of abstract thought. Therefore, research needs to explore cognitive flexibility with the utilisation of a variety of tasks that have not previously been used in the literature, inclusive of assessments aimed at tapping into the generation of abstract thought in addition to task switching, which is an approach that was adopted within this thesis.

3.4 *Methodological considerations underpinning the thesis objectives*

In regards to the overall literature surrounding executive function and media multitasking there are several issues. The Media Multitasking Index (MMI) developed by Ophir et al., (2009) is a reliable self-report measure, with a good standard of test-retest reliability (Baumgartner et al., 2016; Wiradhany & Nieuwenstein, 2017), designed to determine individuals' frequency of media multitasking. It has been widely used within the literature with researchers using the MMI to distinguish media multitaskers by frequency, grouping them into light media multitaskers and heavy media multitaskers. This is known as extreme grouping of which there are two key issues. First of all the use of extreme groups introduces the risk of bias through the implication of possibly missing vital data that is simply ignored (Preacher, Rucker, MacCallum & Nicewander, 2005). Secondly, there is no standardised way of determining light and heavy media multitaskers. Research has used both standard deviation (Ophir et al., 2009) and quartiles (Cain & Mitroff, 2011) to define the two groups making it difficult to compare results across studies, standardised cut-offs are needed (Minear et al., 2013). However, instead of using standardised cut-offs it has also been proposed that a full continuum of MMI scores should be included and correlated with executive function performance (Van der Schuur et al., 2015). Tackling these issues will improve comparability between studies (Minear et al., 2013) and consequently the generalisability of results (Uncapher et al., 2016). In this regard, it is important to highlight that the full continuum approach is gaining momentum (recently implemented by Ralph & Smilek, 2017) and has been used in approximately half of the research, with a number of studies using both the full continuum and extreme groups (e.g. Baumgartner et al., 2014). Thus, research has progressed, making results more easily comparable and should continue with the full continuum approach (Ralph & Smilek, 2017).

More significant than this is the fundamental issue of the lack of evidence for a causal relationship between media multitasking and executive function. Causality has not been established nor can it be, based on the reliance on cross-sectional studies (Van der Schuur et al., 2015). It is not known whether media multitasking causes biases in executive functions such as attentional inhibition and working memory, or whether media multitasking could be the consequent behaviour of individuals who have pre-existing cognitive biases that could be further enhanced (Baumgartner et al., 2014; Cain & Mitroff, 2011; Ophir et al., 2009; Van der Schuur et al., 2015). Indeed, the biases could be enhanced in a cyclical fashion, for example, in the manner of individuals' having biases in attentional control that leads them to media multitask more frequently that then consequently further exacerbates the bias in their attentional control and so on, as suggested by Baumgartner et al., (2017). Establishing causality is crucial in understanding the mechanisms underlying the associations between aspects of executive functioning and media multitasking (Uncapher & Wagner, 2018). Research is evolving to explore media multitasking associations, utilising methods conducive of establishing causality, such as longitudinal studies (e.g. Baumgartner et al., 2018) and experimental methods such as objective measures of media multitasking (e.g. Kazzakova, Cauberghe, Pandelaere & De Pelsmacker, 2015, that is discussed in further detail in Chapter 4). Nonetheless, the lack of causality has not stopped sensationalist reporting by the media of the harmful effects of media multitasking. Some of the recent headlines have been; "Why the modern world is bad for your brain" as featured in The Guardian (Levitin, 2015) and "Why multitasking is BAD for your brain; Neuroscientist warns it wrecks productivity and causes mistakes" as featured in the Mailonline (O'Hare, 2017). Nor has the lack of causality prevented media multitasking being an acknowledged concern of policy makers, as the possible harmful effects of media multitasking have also been discussed in Parliament as a debate in the House of Lords initiated by Baroness Greenfield (United Kingdom, House of Lords, Parliamentary Debates, 2011).

3.5 Summary

In sum, the literature surrounding media multitasking and executive functioning is advancing, with some aspects of executive function, such as attentional control, having been investigated to a greater extent than others, such as response inhibition or cognitive flexibility. In terms of the findings, some of the media multitasking associations are more distinct than others, such as the media multitasking associated bias in attentional control. The research surrounding working memory and media multitasking is clear in demonstrating no increase in working memory performance associated with media multitasking. However, clarification of the negative and null findings is needed. Similarly, the clarification of the evidence showing greater, worse and no difference in cognitive flexibility associated with media multitasking is needed. Furthermore, research that explores cognitive flexibility should utilise a variety of tasks to assess cognitive flexibility other than classification task— switching tasks. Additionally, future research that is conducted with the MMI should continue to utilise the full continuum approach in order to make it more comparable to previous research. The present thesis will address the aforementioned issues through the systematic exploration of executive functioning. It will explore all aspects of executive functioning as detailed in Diamond's (2013) framework (inhibition, working memory and cognitive flexibility) in relation to media multitasking. Specifically, Diamond's (2013) framework offers a different perspective on cognitive flexibility, postulating it to reflect more than task switching and thusly the function of cognitive flexibility will be assessed using different behavioural tasks than those used previously. Furthermore, when assessing self-reported frequency of media multitasking an individual differences approach will be implemented. The thesis will also advance on the previous media multitasking literature, through the progression of empirical research that utilises objective measures of media multitasking whilst systematically exploring executive function in relation to media multitasking. Lastly, the cross-sectional nature of the associations that have been found between inhibition, working memory and cognitive flexibility and media multitasking, highlight the imperative to establish causality of these relationships. Therefore, the final empirical exploration of this thesis will utilise an experimental design that is conducive to establishing causality, whilst examining the relationship between media multitasking and executive functioning.

Chapter 4. Research utilising performance based, objective measures of media multitasking

Chapter 4. Research utilising performance based, objective measures of media multitasking

4.1 Chapter overview

This chapter will examine studies that have used performance based objective measures of media multitasking ability rather than self-report measures of media multitasking frequency. The research that has used this methodology predominantly comes from studies exploring learning or academic performance and thusly, the chapter will initially discuss what associations have been found for academic performance, media use and media multitasking. It will then progress to discuss experimental explorations that utilise objective measures of media multitasking. Lastly, the discussion will focus on the methodological considerations for measuring performance-based media multitasking and the methodological gap between this research and the research exploring executive function in relation to media multitasking frequency.

4.2 Associations between academic performance, media use and media multitasking

The prevalence of media multitasking caused by the advancement in technology has created a multitasking generation of students (Ellis, Daniels & Jauregui, 2010). It is common place to see students media multitasking by sending/ receiving instant messages or text messages, checking emails or social media (Clayson & Hayley, 2012; Judd, 2013; Walsh, Fielder, Carey & Carey, 2013) during class (Burak, 2012; Lee, Lin & Robertson, 2010; Pettijohn, Frazier, Vaughn & Hupp-Wilds, 2015; Tindell & Bohlander, 2012;) or periods of private study (Calderwood, Ackerman & Conklin, 2014). These observations stimulated research into academic performance and media multitasking (Ellis et al., 2010). Excessive media use, and media multitasking, have been suggested to negatively affect academic performance (Aagaard, 2014; Burak, 2012; Chen & Yan, 2016; Walsh et al., 2013). Research looking specifically at media use in classroom, study or learning environments has found text messaging during class to result in lower exam scores (Ellis et al., 2010), disrupt comprehension and retention of learning material (Conard & Marsh, 2014; Dietz & Henrich, 2014; Gingerich & Lineweaver, 2014) interfere with study (David, Kim, Brickman, Ran & Curtis, 2014) and hinder grade performance (Demirbilek & Talan, 2017). Similarly the use of Facebook® during study activities impacts on hours spent studying, lower grade point averages (GPA) (Judd, 2014; Junco & Cotton; 2012; Kirschner & Karpinski, 2010; Rosen, Carrier & Cheever, 2013) and grade performance (Demirbilek & Talan, 2017). Furthermore, media multitasking during study has been associated with worse exam performance (Patterson, 2016). Further research has also found multitasking with social media to significantly, negatively predict academic performance in terms of cumulative GPA (Lau, 2017). Although, there may be other factors that influence the way in which media multitasking negatively effects academic performance. Le Roux and Parry (2017) highlighted that the negative effects of media multitasking, during lectures, on academic performance are not applicable for all subjects studied at university. They found that the influence of media multitasking (during lectures) had negative effects on those studying social science. However, they also found that general media use, specifically social media use, negatively predicted academic performance for those studying engineering, medical and health sciences. Thus, in sum, the research has found various ways in which media usage inclusive of media multitasking impacts academic performance. Although, it is important to highlight the methodologies used in the research, although some of the findings come from correlational studies of self-reported media multitasking, other research has used experimental methods with media multitasking manipulations, and measured people’s ability to take in the information presented.

4.2.1 *Experimental explorations of the impact of media multitasking on learning*

In this regard, exploring a classroom environment with the inclusion of a manipulation of media multitasking, Rosen, Lim, Carrier and Cheever (2011) had students watch a 30-minute video lecture, during which participants were sent text messages that they were instructed to promptly respond to. Participants were allocated into three different text interruption conditions; a no/low interruption group where they received/responded to no texts; a moderate text interruption group where they received/responded to 4 text messages and a high text interruption group where they received/responded to 8 text messages. The text messages were sent at time points to coincide with information delivered in the lecture, which would be tested later on. The study found that the participants in the high text interruption group performed significantly worse in terms of recall, than those in the no/low text interruption group. Similar to this, Kuzznekoff and Titsworth (2013) simulated a classroom environment where students were shown a video lecture and instructed to take notes (as they would normally). Students were assigned to either a; control condition, a low distraction or a high distraction condition. In the control condition participants had to put their mobile phones away whilst watching the lecture, whereas as those in the low distraction and high distraction had to respond to text messages and posts sent to them by the researchers, with a greater frequency of messages being sent to those in the high distraction group. They found that the students who used their mobile phones (regardless of low or high distraction) during the lecture wrote down less information in their notes, recalled less and performed worse on multiple choice tests of the lecture. More recently, Waite, Lindberg, Ernst, Bowman and Levine (2018) explored the impact of texting during an academic presentation. There were two texting conditions, concurrent texting and no texting, as well as a no presentation control group. The study found that non-texters scored higher on multiple choice tests of low-order information and made more quality notes, whereas concurrent texters performed poorly on the multiple-choice tests. Therefore, media multitasking in the form of texting or posting on social media during class negatively impacts studious behaviour inclusive of the ability to effectively process information in short-term memory. This adds to previous research by Wood, Zivcakova, Gentile, Archer and De Pasquale et al., (2012) who conducted a similar classroom study. They included four types of digital multitasking; texting, emailing, Microsoft Service Network (MSN) messenger and Facebook® and a learning task (multiple-choice test). They found Facebook ® and MSN to negatively impact learning. Therefore, the research would seem to suggest that media multitasking with digital technology, inclusive of instant messaging services and social networking sites within academic contexts has a negative impact on learning.

However, this is not the only way in which academic performance and media multitasking has been investigated. A number of academic performance studies have investigated media multitasking in conjunction with the completion of a reading task, which is more analogous to a real-world situation where students are media multitasking whilst studying. Lee et al., (2010) utilised a timed reading comprehension test with three different conditions; silence (reading only), background multitasking (reading with a non-tested video shown simultaneously) and test multitasking (reading with a tested video shown). No significant differences in reading scores were found between all of the conditions. However, of the participants in the multitasking conditions those in the multitasking tested condition performed better on comprehension of the video, indicating that they were able to effectively split their attention. Individuals may simply have not attended to the video in the non-tested condition. This indicates the importance of instructing participants that they will be tested on all information streams, if experimenters wish to ensure that they actually media multitask.

Furthermore, research has also explored reading comprehension and instant messaging. Fox, Rosen & Crawford (2009) had participants read in an uninterrupted condition or whilst holding an IM conversation. They found students reading comprehension was not affected by instant messaging. However, further analyses revealed individuals who spent more time instant messaging also had lower self-reported GPA. Similarly Bowman, Levine, Waite, and Gendron, (2010) investigated media multitasking and reading comprehension with the inclusion of three instant messaging conditions; instant messaging before the reading task, during and none at all. Those who were instant messaging whilst completing the reading task took longer to finish the task whilst no condition-specific difference in comprehension performance was found. Despite the lack of a significant result, it was suggested that Individuals multitasking in this way would have to spend more time to achieve the same level of performance in comparison to those who do not. Therefore multitasking in this sense would have a detrimental effect on the performance of an academic task.

Pertinent to the relationship between media multitasking and executive functioning are the methods by which academic performance and media multitasking are being explored. There is a noteworthy distinct difference in the methodology used within the applied literature investigating academic performance, and the cognitive psychology literature reviewed in the previous Chapter (Van der Schuur et al., 2015). A key concern within the executive function research is that media multitasking is often measured using self-reports which encompass issues such as, reliability and ecological validity (Moreno, Jelenchick, Koff, Eikoff, Diermyer, et al., 2012). Self-report measures are also used alongside performance tasks based in a lab. These lab-based experiments tend to use meaningless or abstract stimuli (Srivastava, 2013) and do not capture the full picture of what happens in real life (Lin, 2009). In contrast, academic performance research has progressed to use experiments that are more naturalistic and include objective performance based assessments of media multitasking that are higher in ecological validity (Lin, 2009). Thus, research exploring media multitasking and executive functioning needs to progress by utilising this type of objective performance based measure of media multitasking, which in turn will provide more ecologically valid findings and advance research towards establishing causality. However, in terms of the use of such methods, there are various issues to be contended with.

4.2.2 ***Methodological considerations for performance based measures of media multitasking***

Comprehension tasks are the most commonly implemented method for measuring media multitasking performance, with the use of multiple choice tests (as in; Bowman et al., 2010; Kuznekoff & Titsworth, 2013; Lee et al., 2013; Van Cauwenberghe et al., 2014) assessing the viewing of videos and reading material. They have even been used in research exploring the effect of media multitasking on the enjoyment of watching T.V (Oviedo, Tornquist, Cameron & Chiappe, 2012) or message relevance (Strivastava, 2013).Videos are not the only tasks to be used for media multitasking. A number of studies have used instant messaging and or text messaging as a media multitasking condition in conjunction with the completion of a task (as in Kuznekoff & Titsworth, 2013; Wood et al., 2012). Performance on these types of media multitasking is assessed in a slightly different way than video viewing. Most studies specify that participants have to respond to messages they receive, although it is possible that messages will not be responded to. Therefore, assessing media multitasking performance of instant messaging requires checking for total responses and percentage as well as the mean time taken to respond (Conard & Marsh, 2014). Some research has also additionally included self-report measures of texting action (Dietz & Henrich, 2014) and it might also be valuable to assess content recall of text/ instant messages sent and received.

Furthermore, there are several varying factors to be manipulated when using instant messages (IM) or texts. The rate at which messages are sent is important and should be considered as research necessitates the reflection of real-world media multitasking situations (Kononova & Chiang, 2015). Bowman et al., (2010) had participants receive one instant message per page of reading material. On the first page, all participants received an IM after 17 s. On the second, third, fourth, and fifth pages all students received an IM after 15, 29, 20, and 26 s, respectively. In Kuznekoff & Titsworth's

(2013) study, participants in the low distraction group were given new text/ posts every 60 seconds, viewing in total 12 texts/ posts and participants in the high distraction group received texts/ posts every 30 seconds, totalling 24 texts/ posts. In this regard the times the messages are sent in relation to task phase performance, IMs should initially be sent before the participant is deeply engaged in the task (Czerwinski, Cutrell & Horvitz, 2000). Another factor associated with the use of instant messages is the content of the message sent. Bowman et al., (2010) framed instant messages as realistic questions whereas Wood et al., (2012) used scripted questions such as; book a follow up appointment. It is possible to tailor messages to the content of the included video or article or have them completely different in content. If IMs are not highly relevant to the content of the other material they take longer to process and make it more difficult to re-engage task context, thus they are more distracting and disruptive (Czerwinski et al., 2000) and may be more representative of the real-world (Dietz & Hendrich, 2014).

Other research has included the use of interacting with social media such as Facebook® as the form of media multitasking with multiple ways of assessing performance. Wood et al., (2012) had participants complete a scavenger hunt on Facebook that consisted of participants visiting Facebook profiles of people to obtain specific information. Whereas Oviedo et al., (2012) had participants update their status, comment on a picture, comment on a friends' wall, like a post, message a friend and more, at different specified time intervals. Again, the time intervals at which tasks are to be completed are important.

The studies reviewed in this section show that it is possible to measure the extent to which people have learned information during media multitasking, by testing their knowledge afterwards. In contrast, studies investigating the relationships between media multitasking and basic cognitive functioning have tended to use self-report measures of the frequency of media multitasking in daily life. One exception is the study by Kazakova, Cauberghe, Pandelaere and De Pelsmacker (2015) who had participants complete a local/ global perceptual processing task and media exposure session (a website and two films; animated Disney). Participants were instructed to pay full attention to the media presented (sequential group) or instructed to attend equally to both media presented (media multitasking group). After completion of the media sessions participants completed a comprehension measure (similar to Oviedo et al., 2012). Within the media multitasking condition individuals tended to have a local perceptual processing style indicating that media multitasking leads to the focusing of attention to confined features rather than more global formations. Therefore, this research is embarking on bridging the methodological gap by utilising an experimental approach to explore the impact of media multitasking on cognitive functioning.

Therefore, there is progression within the executive function research to conduct studies that objectively measure aspects of media multitasking performance directly rather than using self-report such as the MMI. However, other factors need to be addressed and included. There are a number of studies that utilise a media multitasking situation, of just two forms of media such as a reading task and instant messaging. Thus future executive function research needs to include more than two forms of media when assessing media multitasking performance which will be more representative of real-world media multitasking situations that are gaining ever more in their complexity. Additionally, it has been argued that simulated media multitasking conditions should be situation specific pertaining to either a leisurely or a studious media multitasking situation (Kononova & Chiang, 2015). In this regard, study 2 and study 3 of this thesis have utilised a media multitasking situation designed to reflect a studious media multitasking situation.

Furthermore, media multitasking can be within a single device or across multiple devices (Wallis, 2010; Kononova & Chiang, 2015). At present there is little research measuring media multitasking within a single device and across multiple devices and making comparisons between these two situations. A single study, Van Cauwenberge, Schaap & Roy (2014) investigated the effect of second screen viewing on information processing. Individuals had to watch a news broadcast whilst looking up information online. They compared viewing on two separate screens with split screens and found cognitive load to mediate the effect of second screen viewing on comprehension of news and factual recall. Thus, future research also needs to compare media multitasking performance on a single device and across multiple devices.

4.3 Conclusion

In conclusion, media use and specifically media multitasking has been negatively associated with various aspects of academic performance, predominantly in terms of learning and retaining information. More importantly, applied setting research into academic performance has used naturalistic settings and objective measures of media multitasking, with the use of reading tasks, videos and instant messages. However, not all three of these types of media have been used in one single study. Furthermore, there is only one study to date, that we know of, that has explored information processing style and objective measures of media multitasking, specifically Kazakova et al., (2015). Research is needed that explores executive function and media multitasking, utilising similar objective measures of media multitasking that have been used in the applied setting research and by Kazakova et al., (2015). Lastly, the research that explores this also needs to compare multiple device and single device media multitasking. This approach of using an objective measure of media multitasking performance, rather than self-reports of frequency, was adopted in the second and third studies presented in this thesis. The comparisons of media multitasking by device will also be adopted in the second study as a means to progress the systematic exploration of executive functioning in relation to media multitasking and provide more ecologically valid results.

Chapter 5. Frequency of media multitasking (self-reported) and executive function in young adults

Chapter 5. Frequency of media multitasking (self-reported) and executive function in young adults

5.1 Chapter overview

The following chapter reports an empirical investigation of the relationship between self-reported media multitasking (as measured by the MMI) and executive functioning. It is set out in the standardised format, starting with a concise re-cap of the literature reviewed in Chapter 3, proceeding to state the methodology used, results found and overall discussion. This empirical chapter has been published in the Journal of Cognitive Psychology as “Exploring the relationship between executive functions and self-reported media-multitasking in young adults”, Seddon, Law, Adams and Simmons, (2018), of which the full text can be found by following the link below http://dx.doi.org/10.1080/20445911.2018.1525387

5.2 Introduction

Information media have always had an important part in individuals’ lives. However, in recent years media behaviours have dramatically evolved; especially in regards to media consumption behaviours (Ziegler, Mishra & Gazzaley, 2015). Individuals no longer engage with media one at a time, they simultaneously engage with media through multiple devices, otherwise known as media multitasking (Cain & Mitroff, 2011). This type of media behaviour is a ubiquitous behaviour especially amongst young adults and has been associated with biases in cognitive functioning (e.g. Ophir, Nass & Wagner, 2009). It is also a behaviour that has garnered negative press coverage that has postulated harmful effects of media multitasking.

In regards to cognition, there is evidence of media multitasking being associated with biases in all three facets of Diamond’s executive function framework: inhibition, working memory and cognitive flexibility. In terms of inhibition, both attentional control and response inhibition have been explored, although not to the same extent. The literature surrounding attentional control is more abundant and was a focus of the pioneering study by Ophir et al., (2009), who found a bias in attentional control associated with more frequent self-reported media multitasking. Further studies have attempted to replicate their findings and have been successful in further demonstrating a media multitasking associated bias in attentional control (e.g. Cain & Mitroff, 2011; Cardoso-Leite, Kludt, Vignola, Ma,Green, et al., 2016; Gorman & Green, 2016; Wiradhany & Nieuwenstein, 2017). However, evidence has also revealed the benefits of such an attentional bias (Lui & Wong, 2012; Yap & Lim, 2013) as well as in some cases reporting null findings (Minear, Brasher, McCurdy, Lewis & Younggren, 2013; Murphy, McLauchlan & Lee, 2017). Despite the varying results, the majority of the research highlights a negative bias (Uncapher, Lin, Rosen, Kirkorian & Baron et al., 2017; Uncapher & Wagner, 2018) with high MMI being associated with poorer attentional control. In comparison, there is only a small number of studies exploring response inhibition, that has found either an association with media multitasking and differences between heavy and light media multitaskers (Gorman and Green, 2016; Ralph, Thomson, Seli, Carriere & Smilek, 2015, experiment 3b and experiment 4) or no association (Murphy et al., 2017; Ophir et al., 2009; Ralph et al., 2015, experiment 2).

When it comes to working memory, there is not necessarily a lack of evidence more so a lack of clarity. A variety of tasks have been used, inclusive of, filter tasks (sometimes characterised as an attention task), n-back tasks, and complex span tasks. However, no single study has found a reduction in performance across all of the working memory tasks it has implemented. For example, Cain, Leonard, Gabrieli, and Finn (2016) found a reduction in performance on a count span task and n-back task associated with more frequent media multitasking, but no significant difference in performance on a filter task. Furthermore, no single task has a consistent pattern of results. For example when using an n-back task Ophir et al., (2009), Cain et al., (2016), and Ralph, and Smilek

(2017) found worse performance to be associated with more frequent media multitasking. Whereas, Cardoso-Leite et al., (2016) and Wiradhany and Nieuwenstein (2017) found no significant difference in heavy and light media multitaskers' performance. This pattern of evidence is also similar to that of the complex span task and filter task performance. Thus, clarification is needed.

In addition to working memory, the research exploring cognitive flexibility and media multitasking has resulted in an array of findings. More frequent media multitasking has been associated with better task-switching performance (Alzahabi & Becker, 2013; Alzahabi, Becker & Hambrick, 2017), worse performance (Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017) and no difference in performance (Baumgartner, Weeda, Van der Heijden, & Huizinga, 2014; Cardoso-Leite et al., 2016; Minear et al., 2013). Thus, the association between media multitasking and cognitive flexibility is also in need of clarification. Pertinent to this is the fact that the majority of studies have explored cognitive flexibility in terms of task switching, with studies mainly utilising classification tasks. Baumgartner et al., (2014) are the only ones to not use a classification task to explore task switching, instead opting for a dots-triangles task that required the distinguishing of amount of stimuli displayed on a screen (that changed location) , switching between dots or triangles. Therefore, research needs to explore cognitive flexibility under a slightly different paradigm and using different task selection.

In this regard, it is important to highlight that there are multiple frameworks of executive function, with tasks developed in association with each framework, as previously discussed in Chapter 3. Therefore, the chosen framework underpins task selection. Diamond (2013) postulates an executive function framework that takes a slightly different stance to cognitive flexibility, proposing that cognitive flexibility encompasses more than task switching, such as the generation of abstract thought, and thusly suggesting the use of slightly different tasks to explore cognitive flexibility (e.g.

fluency tasks). In terms of task selection, there is also the issue of task impurity, (where tasks tap multiple low-level functions as well as the executive function of interest) which Snyder, Miyake and Hankin, (2015) suggest can be reduced with the use of multiple tasks. This process also enables the utilisation of a latent variable approach, which has been implemented by Alzahabi et al., (2017). The use of multiple tasks to assess each executive function of interest, and a latent variable approach, was adopted in the present study.

As discussed in Chapter 3, the Media multitasking index (MMI) (Ophir et al., 2009) has been a crucial tool in assessing media multitasking, widely used across the literature. However, research using the MMI has often grouped individuals in terms of extreme scores, highest versus lowest, referred to as extreme groups. This creates further issues, as a standardised method of distinguishing groups has not been established, studies have used both quartiles and standard deviation as cut-off points. This consequently affects the comparability of results (Minear et al., 2013). Furthermore, Preacher, Rucker, MacCullum, and Nicewander, (2005) argued that the utilisation of extreme groups misses signals in data and can introduce bias. However, as previously mentioned in Chapter 3, around half of the literature has used a continuous approach (full continuum of MMI scores) or both continuous and extreme groups. Ralph and Smilek (2017) state that research needs to continue to use the full continuum approach, which will in turn improve comparability of findings (Uncapher et al., 2016), and this was the approach adopted in the present study.

5.3 Rationale

In summary, inconsistent evidence has been found in regards to previous research exploring media multitasking and executive function performance. The inconsistencies predominantly concern the associations between media multitasking, working memory and cognitive flexibility. More research is needed to elucidate the relationships between media multitasking and executive functioning.

In this regard, the aim of the present study was to explore the relationship between self-reported media multitasking frequency and executive function components (inhibition, working memory and cognitive flexibility), utilising the Media Multitasking Index (Ophir et al., 2009) to assess self-reported frequency of media multitasking and include the full continuum of scores. Similar to Alzahabi et al., (2017) the present study adopted a data reduction approach to examine the functional components reflecting the three theoretical constructs of executive function proposed by Diamond (2013). It was hypothesised that the latent constructs reflecting inhibition, working memory and cognitive flexibility would be associated with MMI score, with a higher MMI score associated with worse inhibition and working memory performance. As reviewed in Chapter 1, anxiety has been associated with how often individuals' media multitask. Thus, an additional endeavour of the present study was to replicate the previous findings by Becker et al., (2013), therefore measures of anxiety and depression and mood were also included in the study.

5.4 Method

5.4.1 *Participants*

Participants (N= 112), were recruited from the university student population and members of the public, inclusive of 76 females (67.9%), aged 18- 25 years old (mean=20.83, SD=2.12). The study protocol was approved by the university research ethics committee, and the experiment was conducted in accordance to this and to the ethical guidelines set out by the British Psychological Society. Complete data were collected for all participants and data were not analysed until the final sample was obtained.

5.4.2 *Procedure*

Following the attainment of informed consent, participants began by completing questionnaires. There were three in total, the first of which was a mood inventory (Matthews, Jones & Chamberlain, 1990), the second an anxiety and depression inventory (Zigmond & Snaith, 1983) and lastly an adapted version of the Media Multitasking Index (MMI) (Ophir et al., 2009). These were then followed by the completion of a battery of ten executive function tasks (see measures section below for description). All stimuli for the executive function tasks were presented on an Ilyama prolite B1980SD monitor, powered by a Viglen desktop computer with a 3.20 GHz Intel® Core™ I5-6500 processor.

5.4.3 Measures

5.4.3.1 Media multitasking

A modified version of the Media Multitasking Index (MMI) designed by Ophir et al. (2009) was used to assess media multitasking. Modifications were made to update the featured types of media, so that the current media-multitasking milieu was better reflected. The following 12 categories of media were used in the present study; non-music audio, video/computer games, phone calls, browsing and posting on social media, instant messaging, e-mail, web surfing and other computer applications (e.g., Microsoft Word), video (TV or computer based), music and print/ text media (magazines, text books, e-readers).The first part of the MMI requires participants to indicate how many hours a week they use each form of media. The second part of the MMI includes a matrix that assesses how often each type of media is used simultaneously with another. Comparable to Ophir et al. (2009), texting as a form of media was only included in the matrix and not in the first part which asks participants to estimate the number of hours. Furthermore, MMI score was calculated using the same method and formula as Ophir et al. (2009). The formula is as follows:

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

The ratings of all possible combinations of the 11 primary media with other media were summed. The result of this is the (mi) score which was then multiplied by (hi), which is the number of hours spent using that primary medium. This is then divided by the total number of hours spent using all media (htotal). The score produced from this signifies a typical hour spent media multitasking; with a higher MMI score representing more frequent media multitasking (Ophir et al., 2009).

5.4.3.2 Mood

The UWIST (University of Wales Institute of Science and Technology) mood adjective checklist (UMACL; Matthews et al., 1990) was used to assess state mood. The checklist is split into three different constructs; arousal, anxiety and depression with 6 different adjectives pertaining to each construct, resulting in a total of 18 adjectives in the check list. Participants have to use a five-point Likert scale to rate each adjective that relates to how they are feeling at that particular time. The following ratings are used "not at all, slightly, moderately, very or extremely". The reliability of the mood inventory in the present study had the following Cronbach's alpha scores for each subscale; arousal (α= .74), anxiety (α= .70) and depression (α= .60).

An assessment of trait anxiety and depression was also included in the present study. These aspects of mood were assessed using the Hospital Anxiety and Depression scale (HADS) (Zigmond & Snaith, 1983). The scale consists of seven questions relating to anxiety and seven relating to depression resulting in a total of 14 questions. Responses to questions are scored on a 0-3, 4 point Likert scale. The Cronbach's alpha scores were .75 and .67 for the 7 anxiety items and the 7 depression items.

5.4.3.3 Inhibition tasks

Attentional Inhibition: Two flanker tasks were used to assess attentional inhibition. The first flanker task consisted of numerical stimuli and a total of 160 trials. It was an implementation of the flanker task used by Moore, Keogh and Eccleston (2011). The second flanker task used was taken from the the Psychological Experiment Building Language (PEBL) test battery designed by Mueller and Piper (2014). This flanker task included arrow stimuli and was adapted to include 80 trials. In terms of the premise of a flanker task, they are designed to capture an individuals' ability to "zoom in" attention. That is they require the individual to focus on specific stimuli presented, whilst ignoring other stimuli, which is outside the realm of the attentional focus, outside of the "zoom" per se, to then facilitate a specific response, such as a button press (Stins, Polderman, Boomsma & de Geus, 2007). In each of the flanker tasks there were four conditions; congruent (flanked with the same stimuli), incongruent (flanked with the opposite stimuli, e.g. an arrow pointing right flanked by arrows pointing left (←←→←←) and vice versa, or a 2 flanked by a 4 (44244), or, neutral (flanked by "—" in the arrow task and "h" in number task) and null (not flanked by any stimuli). In the numerical task there were 40 trials per condition, whereas in the arrow flanker task there were 20 trials per condition. The difference between mean response time for congruent and incongruent trials was calculated, resulting in the congruency conflict. This was then used to indicate attentional inhibition performance.

Response Inhibition: Two tasks were used to assess response inhibition, a Go No-go task and the Stop-signal task. The present study implemented Moore et al's (2011) Go No-go task. In this task, participants are presented with two horizontal lines and a central fixation circle. The horizontal lines are displayed, with one on either side of the screen and are in the participants' periphery field of vision: participants' angle of vision was 14.2°. Participants were instructed to respond when either of the lines turned vertical (pressing "5" for the line on the right and "1" for the line on the left), but only when the central fixation circle was black, if the fixation circle was red they had to not press either key, withholding their response. There were a total of 150 trials, 30 no-go trials and 120 go trials. Number of correct inhibitions was used to index performance, with a higher number indicating greater inhibitory control.

The stop-signal task was the implementation of the Verbruggen, Logan and Stevens (2008) Stop-it programme. In this task, participants are presented with different shapes on a computer screen, either a circle or a square, with shapes appearing one at a time on the screen. Participants were instructed to respond to each shape with a button press, pressing"/ " for circle and "z" for square. Whilst the shapes were appearing on the screen participants also had to listen out for a beep. If a beep occurred at the same time a shape was presented then the participant had to withhold their response (not press the button). Performance on the stop signal task is indicated by the stop signal response time (SSRT). The SSRT is calculated using a horse race model, which is essentially the race between finishing times of a go process (pressing a button) and stop process (withholding a response) (Verbruggen et al., 2008). The SSRT is the covert latency of the internal stop process reflecting inhibition.

5.4.3.4 Working Memory tasks

Two computerised tasks taken from the Millisecond library for Inquisit were implemented as measures of working memory. A backwards digit span task, based on Woods, Kishiyama, Yund, Herron, Edwards et al. (2011) was used as an assessment of verbal working memory. The span task begins with participants presented auditorily with a span of 2 digits; the span increases in length as the task progresses and can go up to a maximum of 9 digits. The length of span changes on trials based on a 1:2 staircase ratio, with a single correct response increasing the length of the span, whilst two incorrect responses are needed to reduce span length; there are a total of 14 trials to be completed by participants. Mean span was used to indicate performance, with a longer span demonstrating a greater working memory capacity.

A backwards Corsi block task was used to assess visuo-spatial working memory. For the task, participants are shown a display of 9 blue boxes on a screen. The task begins with a pattern of 2 of the 9 boxes lighting up and can go up to a maximum of 9. The pattern that the boxes light up in must be repeated in reverse order to what the participant is shown. If the participant correctly repeats the pattern, then the next pattern increases by one box. However, if they incorrectly repeat the pattern then the same number of boxes appears again, in a new pattern. Mean span was used to assess performance, with a longer span signifying a greater working memory capacity. Participants also completed forward versions of the digit span and Corsi block tasks. However, they do not require the manipulation of information, therefore do not meet the definition of working memory proposed by Diamond and were not included in the analysis.

5.4.3.5 Cognitive Flexibility tasks

Four separate tasks were used to assess cognitive flexibility. The first task was the short version of the Wisconsin Card sorting task, a computerised 64 card version taken from the PEBL psychological test battery (see Piper, Li, Eiwaz, Kobel, Benice, et al., 2011). In this task participants are shown four cards on a screen that feature; different shapes in different colours with different numbers of shapes. Below these four cards there are corresponding outlines of cards (▯). During the task a new card appears on the right side of the screen and the participant has to sort this card into one of the piles, by clicking on the outline of a card below the card of the pile they believe it belongs to. When the participant sorts a card they are given feedback on the screen, stating whether their sort was "correct" or "incorrect". The premise of the task is that the rule of sorting (colour, shape or number of shapes) changes during the task; participants have to use the feedback they receive to recognise when and what the sorting rule has changed to. Performance in terms of percentage of perseverative errors (trials where participants continue to sort based on the previous rule and fail to change to a new sorting rule) was used as an indicator of cognitive flexibility, with higher percentages indicative of poorer cognitive flexibility.

The second task used was a computerised version of the Trail Making Task (TMT) Reitan (1958). The task was the implementation devised by Mueller and Piper (2014) taken from the PEBL battery. For the task, participants are required to click on circles shown on a computer screen, using a mouse. The circles contain either a sequence of numbers (trail A) or a sequence of both number and letters (trail B). The circles have to be clicked on in order, as quickly as possible. During trail B trials the participant has to switch between clicking on numbers with clicking on letters. Before each trial, participants had to complete a practice; there were a total of four practice trials and four test trials for each trail condition. The computer randomly generated different arrangements of circles for each trial. The mean difference in response times on trail A trials and trail B trials was summed and the ratio score (trail B-trail A mean response time) was calculated and used as an indicator of cognitive flexibility, with faster response times representing greater cognitive flexibility.

The third and fourth tasks consisted of two different fluency tasks. The third task was a phonetic fluency task, which involved the participant being given a letter for which they have to generate as many words as possible, in 60 seconds. The task consisted of the use of the letters F, A,S as these are widely used in the literature (Hermann, Ehlis & Fallgater, 2003; Laws, Ducan & Gale, 2010). The fourth cognitive flexibility task was a semantic fluency task, where participants were given categories, instead of letters. The categories used were; Animals, clothing and food as these are the most frequently used within the literature (Luo, Luk & Bialystock, 2010; Nusbaum & Silvia, 2011). For each category participants had to state as many words as possible in 60 seconds. Fluency task scoring was carried out in line with Luo et al., (2010) where proper names, numbers, places and words in different forms were excluded. Cognitive flexibility was represented by summing the mean total scores for the phonetic (3 letters) and semantic (3 categories) tasks, with higher scores indicating greater cognitive flexibility.

5.5 Results

Following initial data exploration, performance scores with outliers greater than 3 standard deviations from the mean were removed from the data set, which consequentially led to the removal of 7 participants. The resulting data set for analysis of executive function data had a final sample of 105. Mean scores and descriptive statistics for all variables are shown in Table 5.1.

Table 5.1. Mean scores and descriptive statistics for MMI, mood measures and executive function task

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

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

5.5.1 *Factor analysis of executive function tasks*

Data reduction of the battery of ten executive function tasks was undertaken, to determine if the individual tasks would produce a three-factor model of executive function, as specified by Diamond's (2013) theoretical framework. Confirmatory Factor Analysis was implemented, and two models were tested using this approach. The initial model, Model 1, consisted of the three executive function factors proposed by Diamond (inhibition, working memory and cognitive flexibility) with each of the factors featuring different indicators. Inhibition had the following four; Arrow Flanker task, Number Flanker task, Go No-go and the Stop-Signal Task. Working memory had the Backwards digit span and Backwards Corsi block. Lastly, cognitive flexibility had the Wisconsin Card Sorting Task (WCST), Trail Making Task (TMT), Phonetic fluency and Semantic fluency. The fit of this model was poor (see table 5.2), the iteration limit was reached and there was negative error variance for the Backwards digit span task, thus the model was also inadmissible. Following procedures of Byrne (2001) modification indices were inspected, that reflected a change in regression weights for Backwards Corsi, Backwards digit span and TMT, as well as correlations between the error variances of the Go No-go and Backwards Corsi, Arrow Flanker and Number Flanker both with the TMT.

Based on these modification indices, exploratory factor analysis was employed to produce a post hoc model. In this model, Model 2, the error variances were correlated with TMT, and TMT was moved to the latent construct of working memory. This fits with Diamonds (2013) theory of executive functioning, which suggests cognitive flexibility as a function draws on working memory. Thus, the Trail Making Task may have placed a higher demand on working memory. Nonetheless, Model 2 was a better fitting model than Model 1. However, the issue of negative error variance for the Backwards digit span re-occurred making Model 2 inadmissible (see table 5.2, for model fit indices). Moreover, the model revealed that some of the indicators of the latent variables had poor reliability, thus the removal of these was implicated. In this regard, the Stop-signal and Go No-go indicators would be the only remaining tasks of the latent factor of inhibition. Phonetic fluency and Semantic fluency would be the only remaining tasks of the cognitive flexibility factor. Backwards Corsi would be removed from the working memory factor, which would result in only the Backwards digit span indicator for working memory. Thus, in this regard, the models may have been driven by shared method variance.

In sum, performance on individual executive function tasks could not be reduced into theoretically substantiated latent constructs, a reliable model could not be produced. In this regard the relationship between media multitasking and executive function was explored through performance on individual executive function tasks. For the graphical representations of the tested factor models, please see appendix 2.

Table 5.2. Model factors examining best fit for executive function factors.

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

5.5.2 ***Correlational analysis of executive function tasks***

Correlational analysis of MMI and the 10 individual executive function tasks revealed no association between frequency of self-reported media multitasking and executive function performance. No significant correlations between performance on each individual task and MMI were found, all ps > .05, based on an α-value Bonferroni correction (see Table 5.3). Thus, the hypothesis of worse inhibition and working memory performance relating to higher MMI scores was not supported, nor was a relationship between cognitive flexibility and MMI found.

Table 5.3. Correlation co-efficients for media multitasking and the battery of executive function tasks

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

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

5.5.3 *Mood*

No significant correlations were found for state measures of; anxiety, depression and arousal, or trait depression and MMI score, all *p*s >. 05. However, there was a significant positive correlation for trait anxiety and MMI score (r=.267, p<.01) indicating that individuals who have higher levels of trait anxiety more frequently media-multitask.

Table 5.4. Correlation co-efficients for media-multitasking, anxiety, depression and state mood measures

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

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

5.6 Discussion

The present study found no association between measures of executive function and self-reported frequency of media multitasking. Data reduction analyses were unable to produce a substantive model, thus the relationships between MMI scores and individual task performance scores were explored. The present study included a battery of executive function tasks that consisted of 10 tasks intended to measure inhibition, working memory and cognitive flexibility. No significant relationships between self-reported frequency of media multitasking and performance on the individual tasks were found. However, a significant relationship between trait anxiety and MMI was found, with a positive correlation between higher levels of anxiety and more frequent media multitasking, that withstood a Bonferroni correction for multiple comparisons.

Unfortunately, the present study was unable to produce a reliable model of latent constructs of the three executive functions, unlike Miyake et al., (2000) and Fisk and Sharp (2004). This was possibly due to tasks not being distinct enough from one another, resulting in a high level of shared method variance, a limitation that is discussed further below.

5.6.1 Prior media multitasking research

5.6.1.1 Inhibition

The present study found no association between MMI score and performance on two flanker tasks in terms of congruency conflict. Thus, the present study was consistent with Murphy et al., (2017) who found no difference between HMMs and LMMs on performance of a flanker task, in addition to extending other null findings within the literature (e.g. Minear et al., 2013). However, the findings are not consistent with Gorman and Green (2016) who found HMMs to perform worse than LMMs on a flanker task or Baumgartner et al., (2014) who found a trend of better performance for HMMs on a flanker task. Nor are they in line with the majority of the literature that demonstrates a bias in attentional control associated with media multitasking (e,g. Cain & Mitroff, 2011; Ophir et al., 2009; Cardoso-Leite et al., 2016; Lui & Wong, 2012;Moisala et al., 2016; Ralph et al., 2015 experiment 1 and 3a; Wiradhany & Nieuwenstein, 2017; Yap & Lim, 2013). Therefore, the present study provides no evidence for the involvement of attentional control in media multitasking, specifically how often individuals media multitask does not relate to their ability to focus attention.

In terms of response inhibition, performance on the Go No-go task (amount of correct inhibitions) and the Stop-signal task (SSRT response time) was not associated with MMI score. Therefore, the current findings replicated those of Ophir et al., (2009) and Ralph et al., (2015) experiment 2, as neither of the studies found any association between response inhibition and media multitasking. In addition to partially supporting Murphy et al., (2017) who found no difference when comparing heavy and light media multitaskers performance. Although, Murphy et al., (2017) interestingly found that average media multitaskers, those falling within the middle of the extremes performed worse. Therefore, with the inclusion of the current findings, the majority of this small composite of research indicates no association between media multitasking and response inhibition. Specifically, an individuals' ability to control behavioural/prepotent responses does not relate to how often they media multitask. Which may seem illogical, considering how media multitasking is often carried out through habit (Hwang, Kim & Jeong, 2014; Zhang & Zhang, 2012) and response inhibition is a key part of habitual behaviour (Jahanshahi, Obeso, Rothwell & Obeso, 2015). However, it is important to highlight that response inhibition has also been explored in terms of trait impulsivity. Greater levels of self-reported frequency of media multitasking have been associated with higher levels of impulsivity (Sanbonmatsu, Strayer, Medeiros-Ward & Watson, 2013; Wilmer & Chein, 2016).

5.6.1.2 Working memory

The literature surrounding media multitasking and working memory has been greatly fraught with inconsistent evidence**,** with clarification needed. The present study used both a backwards digit span task and the backwards Corsi block task and found no association with performance on either task (in terms of mean span) and MMI score. Therefore, the results of the current study specifically support the previous research by Gorman and Green (2016) and Baumgartner et al., (2014), although Baumgartner used a combination of scores from the forwards and backwards version of the digit span task. Nonetheless, in this regard the present study can thusly be said to provide clarification to this aspect of the literature, indicating no association between media multitasking and performance on a span task. Only two other studies had utilised span tasks to explore working memory in relation to media multitasking, Cain et al., (2016) and Minear et al., (2013), with the latter study also demonstrating no association. Furthermore, the present study adds novelty to the literature with the inclusion of the backwards Corsi block task, that has never been used in relation to media multitasking. However, it is important to note that the present findings only clarify the evidence surrounding span task performance. Indicating that individuals' ability to manipulate information held in mind does not relate to how often individuals media multitask, considering span tasks place a greater demand on the manipulation of information held in mind. Other task performance (filter task and n-back) and media multitasking associations remain unclear. Indeed, as previously discussed, filter tasks may be placing a greater demand on attentional control rather than working memory and therefore may be obfuscating the media multitasking and working memory associations. Further research is need to determine the relationship between working memory and media multitasking.

5.6.1.3 Cognitive flexibility

The present study included four tasks assessing cognitive flexibility. The Trail Making Task and the Wisconsin Card Sorting Task (WCST) were two of them. These two tasks are seen as more traditional task switching tasks, akin with tasks previously used in the literature. In regards to these two tasks, there was no association between overall MMI score and Trail Making Task performance, in terms of the calculated difference in Trail A and Trail B response times. Nor was there an association between performance on the WCST and MMI in terms of percentage of perseverative errors (failure to change). Thus, the present study expands previous literature showing no association between media multitasking and cognitive flexibility (Baumgartner et al., 2014; Cardoso-Leite et al., 2016; Minear et al., 2013), adding further novelty with the use of tasks that have not previously been used in the media multitasking literature. Highlighting that individuals' ability to generate abstract thought, switch between mental sets and adapt their way of thinking does not relate to how often they engage in media multitasking. However, the findings are not consistent with research that has found HMMs to be worse at task switching (Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017) or the opposite evidence demonstrating more frequent media multitasking ability to be associated with better task switching (Alzahabi & Becker, 2013; Alzahabi et al., 2017). Thus, research using simple task-switching paradigms has shown associations. Although, the effects may be too small to be detected in more complex tasks involving switching, consequently restricting the real-world implications.

However, the present study also utilised two verbal fluency tasks (phonetic and semantic) as a novel assessment of cognitive flexibility, supported by Diamond (2013) and Reske, Delis and Paulus (2011). The study found no association between MMI and the average amount of correct responses on both fluency tasks. Fluency tasks have not previously been implemented in relation to exploring media multitasking associations with cognition. Thus, in this regard the present study brings novelty to the literature, which is more apparent as verbal fluency has also been categorised as access to semantic memory (Fisk & Sharp, 2004). Therefore, the present study could also be said to demonstrate no involvement of access to long-term memory in how often individuals' media multitask.

5.6.1.4 Mood and media multitasking

In the present study both state and trait mood were explored in relation to media multitasking. State mood (inclusive of depression, anxiety and arousal) was not found to be associated with media multitasking, nor was trait depression. Only trait anxiety as measured using the Hospital Anxiety and Depression scale (HADS) was found to be significantly related to media multitasking, with more frequent media multitasking associated with higher levels of anxiety. Therefore, the present study was successful in replicating Becker et al., (2013), who found that for mood and anxiety-related mental health issues, media multitasking is an implicated distinctive risk factor. Consequently, the findings expand the scarce research that has explored the MMI in relation to mood, as there is only one other study, Shih (2013). Furthermore, the result of the present study in combination with the findings of Becker et al., (2013) demonstrate a relationship between media multitasking and anxiety, whereas Shih (2013) found no significant correlation between well-being and MMI. However, it is important to highlight that it is not known whether more frequent media multitasking leads to higher levels of anxiety or if more anxious individuals gravitate towards media multitasking more often, the direction of causality needs to be established (Van de Schuur et al., 2015). Despite finding a significant correlation for trait anxiety, there was no association between state anxiety and media multitasking. In this regard, an interesting point to note is the difference in timescales of these two anxiety measures. The state anxiety measure asks participants to rate how they are currently feeling, at that specific moment in time, whereas the HADs questionnaires asks participants to consider how they have felt for the previous week, thus a longer timescale.

5.6.2 Implications

The position of the present study and other null findings within the literature highlight that media multitasking may not be as cumulatively harmful to cognitive functioning as it is portrayed by the media. It could then be said that the media tends to augment and somewhat amplify the negativity of media multitasking and cognitive ability, which to a certain extent may be inappropriate until further research evidence is ascertained.

Despite the lack of an association of attentional control and media multitasking, a relationship was found for trait anxiety, with more frequent media multitasking associated with higher levels of reported trait anxiety. However, as previously discussed, due to the cross-sectional nature of the study, the direction of causality cannot be established. In this regard, individuals' with anxiety may be more inclined to have issues in their controlling of attention. Indeed, Eysenck, Derakshan, Santos and Calvo, (2007), proposed that anxiety impedes the efficiency of the goal-directed attention system, in their attention control theory. The theory has been supported with evidence demonstrating highly anxious individuals (as measured in terms of trait anxiety) to perform worse on a range of attentional control tasks. Tasks including the ANT-I (Pacheco-Ungetti, Acosta, Callejas & Lupiáñez, 2010), a visual search task (Bishop, 2009), a colour singleton task (Moser, Becker, & Moran,2011) and an antisaccade task (Derakshan, Ansari, Hansard, Shoker & Eysenck, 2009), for example. Furthermore, research has found an association between media multitasking and reduced attentional control (e.g. Cardoso-Leite et al., 2016; Ophir et al., 2009). Research that also included a mindfulness intervention that was found to improve attentional control performance and have more of a beneficial effect for those who media multitasked more frequently (Gorman & Green, 2016). Additionally, mindfulness is known to be an effective way of reducing anxiety (Hofmann, Sawyer, Witt & Oh, 2010; Hofmann & Gomez 2017). Thus, anxiety may be playing a part in the attentional control bias associated with media multitasking.

5.6.3 Methodological limitations

The main limitation of the present study is the reliance on a self-report measure of media multitasking. For the MMI, people have to approximate how often their time is spent on different combinations of primary and secondary media, and the number of hours they spend on different types of media, which is then calculated to a score that represents an average hour of media multitasking for that person. Thus, it is possible that individuals will inaccurately reflect on how often they media multitask and not quite report their true media multitasking behaviour. It is important to note that this issue is applicable to all previous research that has utilised the MMI as a self-report measure of media multitasking.

Another important matter is the impact individuals' media multitasking has on their ability to accurately report their media multitasking behaviour. Since the MMI was initially developed and used to assess media multitasking, there has been a great deal of technological advancement, in particular the invention of the smartphone and its ever-evolving technological capability. A smartphone is a crucial piece of technology in terms of media multitasking as it provides the individual with greater media multitasking opportunities due to its ability to access a large and varying amount of media platforms. It is the most widely owned device by individuals aged 16-64 (Ofcom, 2017) and has been found to be one of the devices that individuals most frequently use to media multitask (Van Cauwenberge, Schaap & Van Roy, 2014), with individuals compulsively using these devices to media multitask (Lee, Chang, Lin & Cheng, 2014). In this regard, individuals check there phones so frequently that they are not necessarily aware of the full extent to which they media multitask on these devices, and therefore they struggle to accurately remember and report mobile phone use (Boase & Ling, 2013). Thus, it brings into question the efficacy of using self-report measures to assess individual's media multitasking. Research needs to progress to the use of a performance-based method of media multitasking (see chapter 3), in order to more reliably and accurately assess individuals' media multitasking. However, this is not the only issue with using the MMI to assess media multitasking. Wilmer, Sherman and Chein (2017) suggest that the MMI is insensitive to various media activities and combined media activities, and their respective attentional demands. This suggests that it does not distinguish between an individual's purpose of multitasking, in particular whether they are combining complex media activities or simply distracting themselves with a second media. They suggest this based on how the MMI score is constructed, and the mathematical weightings given to each form of multitasking. Proposing it to have a contributory role in the mixed results within the media multitasking and attentional control literature that has used individual difference samples (see Wilmer et al., 2017 for a full review).

A further limitation of the study was the inability to produce a reliable model of latent constructs of executive function. Future research could utilise more distinctly different tasks to form a larger battery of tasks (which would reduce the issue of shared method variance) to create a model of all three executive functions. However, the use of a large battery of tasks does bring with it the practical issue of participants' time commitments. A better, more practical approach would be to focus on a single executive function and use multiple different tasks to assess that function, an approach used by Alzahabi et al., (2017) to explore task switching. This would be an especially interesting approach to use to explore the media multitasking and working memory relationship, considering the lack of clarity within that literature and the use of varying tasks.

5.6.4 Conclusion

To summarise, the present study found no evidence of a relationship between frequency of self-reported media multitasking and executive function. Thus, the findings undermine the sensationalist reporting by the media of the cumulatively harmful effects of media multitasking on cognitive functioning. However, data revealed a significant relationship between media multitasking and anxiety, which in combination with previous research revealed the potential importance of including this variable in future research. Furthermore, the findings of the present study could be used to inform policies surrounding young adults media multitasking, policies should focus on the potential implications of frequent media multitasking on psychological well-being.

Chapter 6. Media multitasking ability and executive functioning in young adults

Chapter 6. Media multitasking ability and executive function in young adults

6.1 Chapter Overview

The following chapter reports an empirical investigation of the relationship between executive function and the ability to media multitask, in terms of recall from a media multitasking situation. It states the key points of the literature reviewed in Chapter 4 and is set out in line with the standardised reporting of empirical investigations.

6.2 Introduction

Media multitasking has been associated with biases in varying aspects of executive function; attentional control (Ophir, Nass & Wagner, 2009), working memory (Uncapher, Thieu & Wagner, 2016) and cognitive flexibility (Alzahabi, Becker & Hambrick, 2017). Although, the evidence from Study 1 of this thesis would suggest no association. Importantly, the previous research has predominantly looked for relationships with self-reported *frequency* of media multitasking (see Chapter 3 for a review). This raises issues of inadequate representations of media multitasking, which could be a component in the inconsistency of the literature. Whereas, studies that have focussed on what people *remember* from a media multitasking situation, as previously discussed in Chapter 4, have focused on individuals' media multitasking ability. In this context, media multitasking ability refers to an assessment of the extent to which an individual can successfully monitor and process information from multiple simultaneously presented streams of media.

This emphasis on media multitasking ability is the path on which media multitasking research needs to progress, changing tack to understand what executive functions are involved in media multitasking, in order to gain insight and understanding of the reported biases in executive functioning associated with how often individuals media multitask. Indeed, considering there is research that has found biases in executive function associated with how often individuals media multitask, it demonstrates the possible involvement of executive functioning in media multitasking, in terms of the monitoring and processing of information from multiple simultaneously presented streams of media. Furthermore, if executive functioning is facilitative of media multitasking, it is logical that effective media multitasking will be associated with greater executive functioning ability. Specifically, Individuals who are better at controlling their attention, have a greater working memory capacity and better ability to switch between mental sets (cognitive flexibility), will be better able to engage with multiple streams of media and recalling information from said engagement.

Research has begun on the path of exploring media multitasking ability. Much of the literature reviewed in Chapter 4 has used distinctly different methodology as a means of exploring media multitasking, conducting studies that take place in real world settings of classrooms or study environments and utilising objective measures of media multitasking. For example, Wood, Zivcakova, Gentile, Archer and De Pasquale et al., (2012) explored a classroom setting and the impact of media multitasking on learning; their study included multiple tasks of texting, emailing, MSN and Facebook®. Lee, Lin and Robertson (2010) had participants complete a reading task whilst watching a video, whereas others have observed instant messaging and reading, for example Fox, Rosen and Crawford (2009), and Bowman, Levine, Waite and Gendron (2010) (see Chapter 4 for an extensive review). Thus, the research has utilised objective measures of media multitasking, in the form of having participants engage in media multitasking, whilst completing academic tasks. This has then been explored to determine the relationships between media multitasking and the amount of information remembered. In terms of research focussing on the relationships between media multitasking and executive function, to the best of our knowledge no research has explored these relationships using objective measures of media multitasking (objective in the sense of having participants media multitask as part of the study). Only one study to date has explored cognitive control in relation to media multitasking, using an objective measure of media multitasking, specifically Kazakova, Cauberghe, Pandelaere and De Pelsmacker, (2015). Within the study Kazakova et al., (2015) required participants to complete a session of media multitasking or a session of sequential media engagement, which included watching an animated video and viewing a website, with the media multitasking session lasting 8 minutes and the sequential session lasting 16 minutes with 8 minutes spent on each medium. Following the completion of the media sessions, participants completed a figure comparison task assessing perceptual processing style. The study found that individuals in the media multitasking condition demonstrated a more local perceptual processing style and the study was thusly innovative in using objective measures (having participant engage in media multitasking or sequential media consumption) to demonstrate an association between media multitasking and perceptual processing. However, the focus of the study was centred on the impact of media multitasking on task performance, rather than an individuals' ability to media multitask. Thus, it can be said that this present study is novel as it is the first of its kind to explore media multitasking ability, in terms of an objective performance based measure of media multitasking, in relation to executive functioning.

In this regard, it is important to discuss how best media multitasking ability might be measured. Previous research (e.g. Lee et al., 2010; Kuznekoff & Titsworth, 2013; Van cauwenberghe, Schaap & van Roy, 2014) (see Chapter 4) has implemented comprehension tasks that consist of multiple choice tests that pertain to the recall of either content of the media included video or reading text. Thus, retention of information from the media engaged with and the use of multiple-choice tests to assess the extent to which the information has been retained, seem to be the most common approach used for assessing media engagement. Whereas, the assessment of instant messaging is somewhat different, and most commonly focuses on the average time taken to respond to a message/messages, as well as percentage of messages responded to. However, it is important to consider other methodological intricacies, in terms of the time intervals for sending instant messages, the content of instant messages, whether it should be related to the information from the other media streams or not, which have previously been discussed in Chapter 4.

However, the assessment and evaluation of task performance is not the only important methodological factor. When assessing individuals' ability to media multitask through the inclusion of a session of media multitasking, that session should to the best of its ability reflect real-world, every day, media multitasking behaviours. As previously stated in Chapter 1, Voorveld and Van der Groot, (2013), and Ziegler, (2015) suggest that media multitasking is carried out through many means, either within a single device such as a laptop or smartphone, but also through the use of multiple devices, e.g. smartphone, T.V. and laptop simultaneously. Thus, both media multitasking within a single device and between devices should be explored in terms of media multitasking sessions, to reflect the diverse reality of media multitasking and improve the ecological validity and real-world implications of an experiment. Intriguingly, the difference in single device or multiple device media multitasking has not to our knowledge previously been explored in terms of individuals' ability to media multitask. It is not yet known if media multitasking on a single device is directly comparable to media multitasking through multiple devices, in terms of the amount of information recalled.

6.3 Rationale

To summarise, previous research has most commonly implemented self-report measures of media multitasking frequency, specifically using the Media Multitasking Index (MMI) (Ophir et al., 2009). Thus, the aim of the present study was to determine what executive functions are most strongly associated with individuals' ability to media multitask, utilising an objective measure of media multitasking. The present study included the same battery of executive function tasks as study 1 (see Chapter 5), and a correlational analysis of the individual executive function task scores with media multitasking ability. An individual task battery was used so that direct comparisons could be made between the relationships of self-reported media multitasking *frequency* and executive function performance found in study 1, and the present exploration of the relationships between media multitasking *ability* and executive function performance. A factor analyses approach was not undertaken due to issues with negative error variance during model testing discussed in the previous chapter. In addition to this, the relationship between media multitasking, mood (state arousal, anxiety and depression) and trait anxiety and depression was also explored, in order to examine whether the association between trait anxiety and frequency of media multitasking found in study 1 (Chapter 5) translates to individuals' ability to media multitask.

It was hypothesised that media multitasking ability would be associated with enhanced performance on inhibition, working memory and cognitive flexibility tasks, based on Diamonds (2013) theory of executive functioning and the perceived processes of those executive functions in media multitasking specific to this study. It is perceived that the media multitasking situation (watching a video, whilst reading a piece of text and responding to instant messages) places demand on inhibition in terms of controlling attention and behavioural responses, requiring the splitting of attentional focus between multiple streams of media, as well as controlling behavioural responses to environmental cues and ignoring no longer relevant information. For example, switching from watching the video and reading the piece of text and responding to instant messages, inclusive of responding to audio/visual cues of instant messages. The perception of the role of working memory is that the media multitasking situation will require the manipulation and retention of information from multiple media streams, the remembering to focus between multiple media streams and respond to anticipated instant messages. Lastly, in terms of cognitive flexibility, the media multitasking situation will require the switching between mental sets/ways of thinking to facilitate changing between watching a video and reading a piece of text, as well as disengaging from ongoing task performance (retaining information from the video and text) to respond to instant messages. Indeed, a greater ability to focus and split attention, retain and work with information held in mind and adapt one's way of thinking and change between mental sets would equate to more efficient media multitasking, in terms of the simultaneous engagement with multiple streams of media. The combination of inhibition, working memory and cognitive flexibility would be crucial to facilitating media multitasking in this context, and enabling information from a media multitasking situation to be retained to a greater extent, with the present study assessing media multitasking ability directly in terms of information retained from the media multitasking situation. Thus, positive associations between executive functioning performance and media multitasking are expected, based on the facilitative role of executive functioning in the simultaneous engagement with and processing of information from multiple streams of media, that enables the retention of information from said streams.

In regards to the different device conditions (within device and between devices), these were included to represent real-world media multitasking behaviours, where individuals use single devices to media multitask or media multitask across multiple devices; providing a more ecologically valid experimental set up. It was hypothesized that media multitasking across devices would be more difficult resulting in slower response times to instant messages and worse media multitasking scores. This hypothesis is based on the perceived greater amount of disengagement from one task to another, and the switching of focus between devices that media multitasking across devices would entail.

For the between device condition, participants had to engage with a video and instant messages on a single screen, whilst reading a piece of text on a tablet computer, which could be held by the participant and moved about. Therefore, in comparison to the single device condition, where all media streams are together in a small viewing area (visual field); the between device condition features more distance from one media information stream to another. This difference in distance between information streams and physical devices to be interacted with possibly places a greater demand on attentional control and the other executive functions involved in media multitasking, as mentioned previously. Indeed, those in the across device condition would have to use attentional control to a greater extent, in order to be able to disengage from reading the text on the device and watching the video on the other device, and vice versa. Compared to those in the within condition who have a smaller attentional switch from media streams within a small visual field, and no movement of device. Furthermore, individuals in the between device condition may be more reliant on working memory for the responses to instant messages, compared to the within device group, as the prompt for the messages is a visual pop up and auditory signal. If the participant did not happen to be looking at the screen at the time of the message popping up, it might be missed. Whereas those in the within device group would be more likely to catch the pop up in their peripheral vision, if they had not remembered to anticipate messages or missed the auditory signal. Thusly, considering media multitasking ability was indexed by the ability to recall information from engagement with multiple streams of media, differences related to devices were expected. The device manipulation meant that the multiple streams of media were being engaged with in different ways, with one deemed more executive function intensive than the other, although the same media were being engaged with by both groups.

In terms of mood, it was hypothesised that there would be a decrease in arousal levels after completion of executive function tasks, and a further decrease in arousal levels after media multitasking. There was no directional hypothesis for self-reported levels of anxiety and depression across the three different time points. Nor was there a directional hypothesis for trait depression. However, trait anxiety was hypothesised to be associated with media multitasking ability, with trait anxiety increasing as media multitasking ability decreased. This was based on research showing anxiety to have a negative impact on executive functioning (Shields, Moons, Tewell, & Yonelinas, 2016), and the involvement of executive functioning in media multitasking.

6.4 Method

6.4.1 Participants

One hundred and sixteen participants, 84 females (72.4 %), 18- 25 years old (mean= 20.47, SD=2.04) were recruited from the university student population and members of the public. The university research ethics committee granted approval for the study protocol and the experiment ran in accordance with this guidance. Ethical guidelines set out by the British Psychological Society were also adhered to. Complete data were collected for all participants and data were not analysed until the full sample was achieved. A correlational design was implemented for executive function performance and media multitasking ability. Additionally, a between groups design was implemented to explore the relationship between media multitasking by device, with the inclusion of two groups (within device and between devices) and media multitasking ability.

6.4.2 Procedure

After informed consent was obtained, participants completed the questionnaires, ten cognitive tasks and a media multitasking situation. The questionnaires included the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) and a mood inventory (Matthews, Jones & Chamberlain, 1990), the latter of which was completed at three different time points; at the beginning of the experiment, after the executive function tasks and after the media multitasking situation.

Participants were randomly allocated to either device group of the media multitasking situation. Those in the between device group were instructed to read the piece of text on the tablet computer, which they could hold up with their hand/s or place on the desk, whilst watching the video on one half of the desktop computer screen and monitoring/responding to instant messages on the other half of the desktop screen. Participants in the within device group were instructed to read the selected text on the right hand side of the desktop screen, whilst watching the video in the top half of the left hand side of the screen and monitor/respond to instant messages appearing in the bottom half of the left hand side of the screen (see Figure 6.1 for screenshot of experimental set up, for both device conditions). All participants, regardless of device condition, were instructed to pay equal attention to the text, video and instant messages, and to respond to any instant messages as soon as they were received and were informed that they would be tested, in terms of recall, on the content of the video and text. Finally, participants were given two multiple choice tests, one pertaining to the media multitasking video and the other to the text content, which were counter balanced. The content of these tests were devised specifically for the experiment and had been piloted beforehand on a sample of 21 participants from the same population (see appendix 3 for summary of the pilot study). Participants were given a total of 13 minutes to complete the multiple-choice tests, with 6.5 minutes for each part (questions relating to the video and questions relating to the text). All stimuli for the executive function tasks and the within device media multitasking condition were presented on an Ilyama prolite B1980SD monitor, powered by a Viglen desktop computer with a 3.20 GHz Intel® Core™ I5-6500 processor. In the between device media multitasking condition stimuli were also presented on a 9.7" LCD 16 GB Samsung Galaxy Tab A.

6.5 Measures

6.5.1 Mood

The University of Wales Institute of Science and Technology (UWIST) mood adjective checklist (UMACL) (Matthews et al., 1990) was again used to assess state mood (see Chapter 5, page 79 for further details).The reliability of the mood inventory for the present study is as follows; Arousal (time 1 α = .713 , time 2 α = .762, time 3 α =.818), Anxiety (time 1 α = .714, time 2 α = .739, time 3 α = .811) and Depression (time 1 α = .813, time 2 α = .733, time 3 α = .787). The Hospital Anxiety and Depression scale (HADS) was again used to assess trait mood (see Chapter 5, page 79 for further details). The reliability for HADS Anxiety and Depression was α = .698 and α =.732.

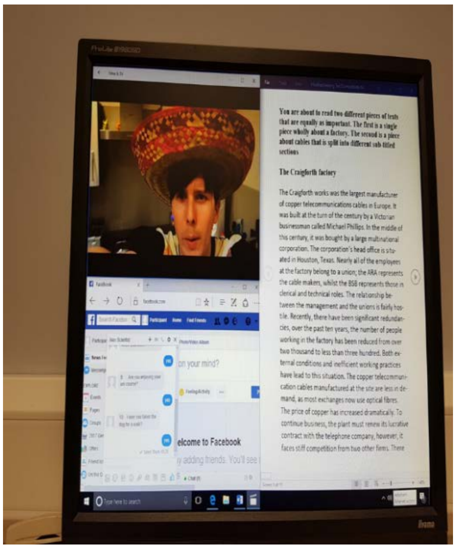
6.5.2 Tasks used to measure Inhibition, Working Memory and Cognitive Flexibility

Attentional inhibition, response inhibition, working memory and cognitive flexibility were assessed using a battery of 10 executive function tasks. The tasks used were the same as those in study 1. Please see Chapter 5, pages 80-84 for specific task details.

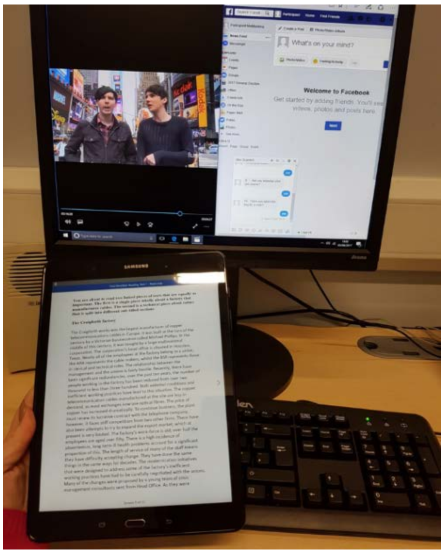
6.5.3 Media multitasking

6.5.3.1 *Media multitasking situation*

Media multitasking ability was assessed using the following media multitasking situation. The situation which required participants to read a piece of text, whilst watching a video whilst also responding to instant messages on Facebook® lasted 20 minutes. Participants were split into two different device conditions, which differed in terms of experimental set up (as described previously in the procedure.section), for which the different media condition experimental setups can be seen below in Figure 6.1.



Within Device condition



Between Devices condition

Figure 6.1. Media multitasking situation screenshots demonstrating experimental configuration of media for each device group.

6.5.3.2 *Reading text*

The text to be read comprised two pieces of text both focussing on the topic of electronic information cables. The first text selection was taken from Simmons and Singleton (2000) and the second piece from Wikipedia (see appendix 4 for both pieces of text).

6.5.3.3 *Video*

The video used in the present study was a combination of two Youtube® videos from the series produced by professional vloggers a “Day in the life of Dan and Phil“. The length of the video was 20 minutes. See appendix 5 for a link to the video.

6.5.3.4 Instant messages

Facebook messenger was used to send instant messages during the media multitasking situation. There were a total of 10 instant messages sent to each participant by the experimenter. Messages were sent at fixed, pseudo-random time intervals throughout the 20-minute media multitasking situation, with one message being received within every 2-minute window. The pseudo-random time intervals of the messages were carefully constructed so that none of the messages interrupted auditory information from the video that was to be assessed in the multiple-choice test. Before beginning the media multitasking situation, the participant was instructed to respond straight away to the messages they received giving simple "yes" or "no" answers. The messages included questions such as; "Are you sat in front of a computer?", "Did you buy a pint of milk?", for four of the ten messages truthful answers were required, as a way of monitoring participant engagement. Only five of the participants were found to have provided a false response to one or more instant message. Response times to instant messages were recorded using a stopwatch, with the stopwatch started and laps paused when each instant message was sent and as soon as the response was received. For a list of all the instant messages used and the times at which they were sent please see appendix 6.

6.5.3.5 Media multitasking multiple-choice recall tests

Two multiple-choice recall tests were included to assess media multitasking ability in terms of memory for the content presented in each medium. There was thus a recall test for the text and a recall test for the video. The reading text recall test included questions such as "Where is the Craigforth factory's head office situated?", "What does tensile strength measure?". The video recall test included questions such as "Which celeb attacks them?", "What are Dan and Phil on the search for?". All material required for the completion of both multiple-choice tests could be directly retrieved from the presentation and did not require the generation of inference. There were a total of 42 questions in each test, with four answer options given for each question. As previously mentioned, both tests were carefully piloted beforehand (please see appendix 7 for initial piloted recall tests). For the versions used in the study, please see appendix 8 for the reading text recall test and appendix 9 for the video recall test. In terms of the dependent variable, media multitasking ability was indexed as the total number of questions answered correctly, combined from both the multiple-choice tests (maximum = 84).

6.6 Results

Following the same procedure as study 1 (see Chapter 5), initial data exploration, inclusive of histogram, skew and kurtosis inspection, led to the removal of 5 participants. A further 3 participants were removed due to low scores (less than 25%) on either of the reading text or video multiple-choice questionnaires (an indicator of non-compliance), leaving a total of 108 for executive function analysis. The mean scores and descriptive statistics for media multitasking ability, instant messages and all executive function tasks are shown in Table 6.1, the mood variables are shown in Table 6.2.

Table 6.1. Mean scores for media multitasking ability, instant message response time and executive function task

	Mean	S.D	Skew	Kurtosis
Media multitasking Ability (Combined multiple choice score)				
Within Device	42.71	7.77	-.108	-.477
Between Device	41.45	7.78	.133	-.735
Instant Message Response time				
Within Device	8.45	3.247	1.212	1.169
Between Device	10.33	3.470	1.239	2.535
Executive Function Task				
Stop-Signal (SSRT)	248.540	41.263	.379	.758
Go-No go (Correct inhibitions)	21.731	6.122	-1.250	1.510
Number Flanker (Congruency conflict)	40.668	27.192	-.110	-.270
Arrow Flanker (Congruency conflict)	53.568	26.700	.322	.522
Phonetic fluency (Total words correct)	11.802	3.085	.072	-.677
Semantic fluency (Total words correct)	19.262	4.769	.209	.310
WCST (% Perseverative Error)	13.108	6.945	1.397	1.480
Trail making (B-A Difference)	7207.069	4225.597	.823	.240
Backwards digit span (Mean span)	5.695	1.01	.411	-.167
Backwards Corsi block (Block span)	6.250	1.095	-.297	1.671

6.6.1 Device group

It was hypothesized that individuals in the between device group would perform worse than individuals in the within device group, in terms of lower media multitasking ability scores, which were the combination of the reading text and video multiple choice questionnaire scores. However, this was not supported as the difference in mean scores 1.261, CI [-1.639, 4.161], was not significant t (111) = .861, p= .391, with a small effect size ($\eta^2 < .01$). There were also no order effects for the completion of the reading text and video multiple-choice questionnaires (p=.334).

However, as predicted there was a significant difference in average time taken to respond to instant messages based on device group (*MD*= -1.874, CI [-3.110, -.637], *t* (114) = -3.003, *p* < .01). Individuals in the between device group took longer to respond to instant messages (M= 10.33 seconds, SE= .456) than those in the within device group (M= 8.45 seconds, SE= .426), with a medium effect size ($\eta^2 = .07$).

6.6.2 Relationships with Individual executive function tasks

Table 6.2. Correlation coefficients for media multitasking ability and all executive function tasks (collapsed over device condition)

	Media multitasking ability
Inhibition Tasks	
Stop-Signal	.095
Go-No go	-.072
Numbers Flanker	-.101
Arrow Flanker	-.012
Working Memory Tasks	
Backwards digit span	.226*
Backwards Corsi block	.198*
Cognitive Flexibility Tasks	
Phonetic Fluency	.282*B
Semantic Fluency	.335**B
Wisconsin Card Sorting Task	-.323**B
Trail Making task	-.237*

N= 108, * significant at p < .05, ** significant at *p* < .001, B= remained significant after the application of a Bonferroni correction

In terms of executive function and media multitasking, a correlational analysis of the 10 individual executive function tasks and media multitasking ability was carried out. There were no significant correlations between the four inhibition tasks and media multitasking ability: Arrow Flanker *r*= -.012, *p* > .05, Number Flanker *r*= -.101, *p* > .05, Go No-go *r*= -.072, *p* > .05 and the Stop-Signal task *r*= .095, *p* > .05. Thus, the hypothesis of a relationship between inhibition and media multitasking ability was not supported, which is demonstrated in Table 6.2.

However, significant correlations with media multitasking ability were found for the two working memory tasks: backwards digit span (*r*= .226, *p*= .019) and backwards Corsi block (*r*= .198, *p*= .040). Additionally, the four cognitive flexibility tasks were also significantly correlated with media multitasking ability: Phonetic fluency *r*= .282, *p*= .003, Semantic fluency *r*= .335, *p*= .001, Wisconsin Card Sorting task *r*= -.323, *p*= .001 and the Trail Making task *r*= -.237, *p* = .013, which can be observed in Table 6.2. However, due to multiple comparisons a Bonferroni correction to the α level was applied, which consequently reduced six significant correlations down to three, only the Wisconsin Card Sorting Task, Phonetic and Semantic fluency tasks remained significantly associated with media multitasking ability *p* < .004.

6.6.3 Relationships between media multitasking and mood

Table 6.3. Mean scores and descriptive statistics for trait mood measures

Mood Measure	Mean	S.D	Skew	Kurtosis
Trait				
HADs Anxiety	6.634	3.052	.465	.422
HADs Depression	2.921	2.413	1.201	1.216

6.6.4 Mood

Correlational analysis revealed that neither trait anxiety nor depression were found to be associated with media multitasking ability (trait anxiety *r*= .122, *p* > .05; trait depression *r*= -.014, *p* > .05). However, the results for state mood were somewhat different, with statistically significant changes occurring over the time period of the experiment as detailed below.

6.6.4.1 State Arousal

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean scores for arousal differed significantly between time points (F (1.835, 211.002) =17.193, $p < .01$, with a large effect size, partial $\eta^2 = .130$. Post hoc tests using Bonferroni correction revealed that self-reported levels of arousal did not significantly change from baseline after completion of the executive function tasks. However, self-reported levels of arousal did significantly decrease after completion of the media multitasking situation ($p < .01$), and were significantly lower than baseline ($p < .01$), see figure 6.2 below for a graphical representation. Thus, only partly supporting the hypothesis, as we initially predicted arousal to significantly decrease linearly after completion of the executive function battery and decrease further after the media multitasking situation. Therefore, the results seem to indicate a fatiguing effect of media multitasking on mood as arousal only significantly decreased following the completion of media multitasking.

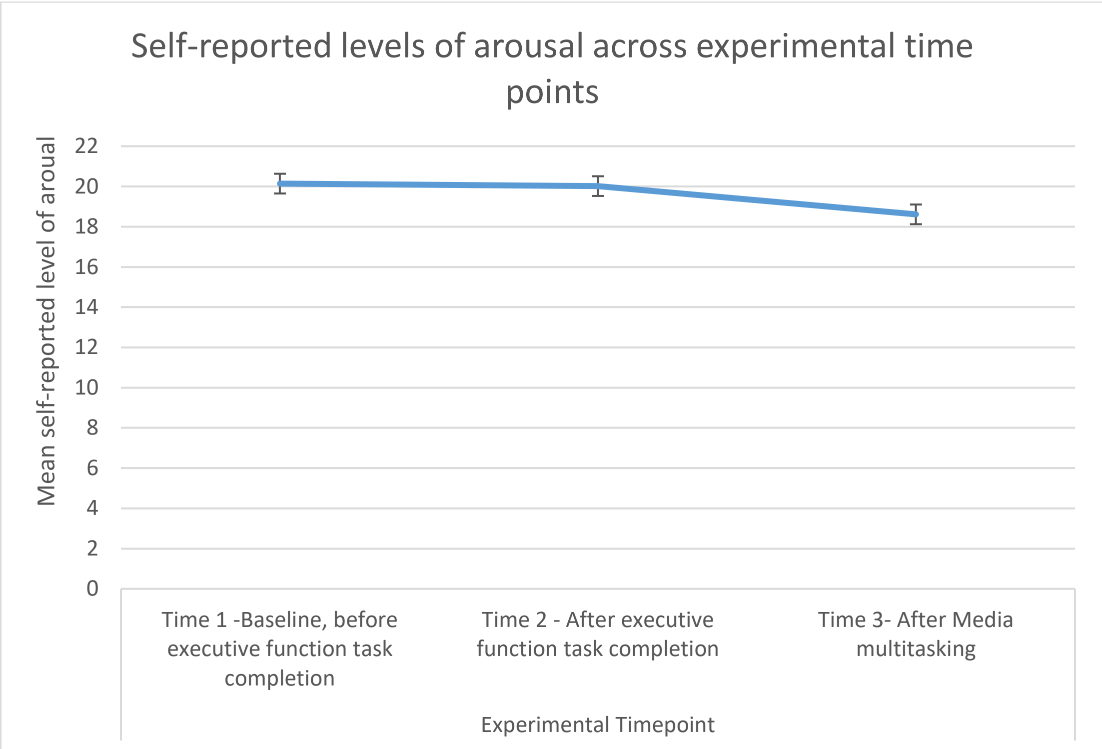


Figure 6.2. Mean level of self-reported arousal at each experimental time point

6.6.4.2 State Anxiety

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean self-reported levels of anxiety significantly differed between time points (F (1.819, 207.346) = 16.226, p < .01, partial η^2 = .125 . Post hoc tests using Bonferroni correction revealed that self-reported levels of anxiety significantly increased after completing the executive function tasks (p < .01). However, self-reported levels of anxiety did not significantly change further after completion of the media multitasking situation but remained significantly higher than baseline (p < .01). Thus, the results highlight an anxiety inducing effect of the completion of executive function tasks. Please see figure 6.3 below.

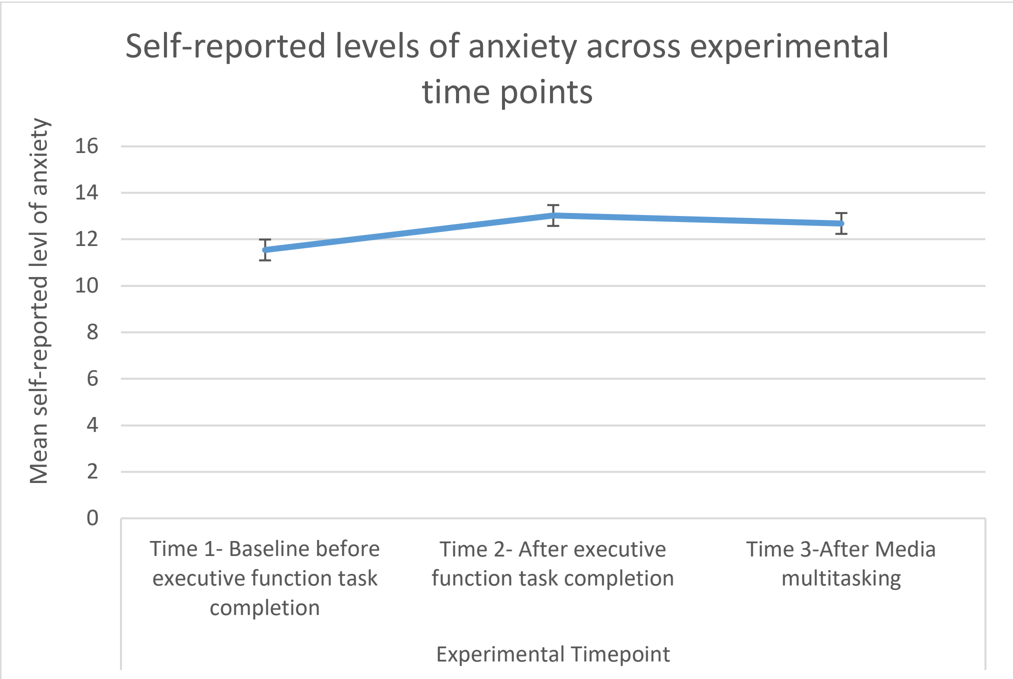


Figure 6.3. Mean level of self-reported anxiety at each experimental time point

6.6.4.3 State Depression

A repeated measures ANOVA determined that mean scores for depression differed significantly between time points (F (2,226) = 17.554, p < .01, partial η^2 = .134. Post hoc tests using Bonferroni correction indicated that self-reported levels of depression significantly increased after completion of the executive function tasks (p< .05) and again after completion of the media multitasking situation ($p < .01$). Thus, indicating that completion of executive function tasks has a depressive effect on mood, which is further exacerbated by media multitasking, which can be seen in figure 6.4 below.

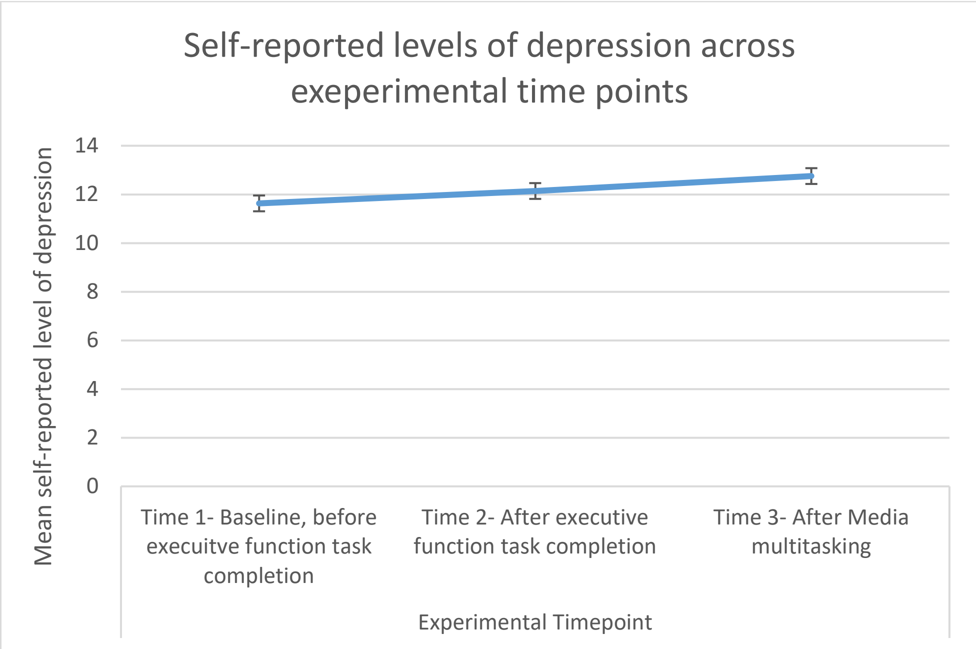


Figure 6.4. Mean level of self-reported depression at each experimental time point

6.7 Discussion

In the present study it was hypothesised that executive function performance would be associated with media multitasking ability, with enhanced performance on inhibition, working memory and cognitive flexibility tasks associated with greater media multitasking ability.

In terms of the hypotheses, inhibition was not associated with media multitasking ability, nor, surprisingly, was working memory performance. Although, positive correlations were observed for performance on the backwards digit span and backwards Corsi block but they did not survive correction for multiple comparisons. Lastly, however the present study did find measures of cognitive flexibility to be associated with media multitasking ability, as measured in terms of the recall of information from a media multitasking situation. Specifically, performance on the phonetic and semantic fluency tasks and the Wisconsin Card Sorting task was associated with better media multitasking ability. Thus, the ability to adapt the way one thinks, generate abstract thought and change between mental sets is associated with a greater ability to recall more information from a media multitasking situation. Therefore, the present study provides evidence of the involvement of executive function in individuals' ability to media multitask in terms of cognitive flexibility.

Media multitasking ability was assessed in the present study, which included a novel manipulation of media multitasking by device. There were two different media multitasking groups. One group media multitasked within a single device (desktop pc) and the other group media multitasked between two devices (desktop pc and tablet computer). This manipulation is representative of some of the everyday media multitasking behaviours that have been observed in the current media multitasking climate, as previously discussed in chapter 1. Unexpectedly the hypothesis that media multitasking between devices would be more difficult and result in worse media multitasking ability scores was not supported, as media multitasking ability was not found to be significantly different between the two groups. However, those in the between devices group did take significantly longer to respond to instant messages, as predicted.

6.7.1 Position of the present study in line with the media multitasking literature

In regards to previous literature, the present study may be able to elucidate the association between media multitasking and task switching. Previous research exploring self-reported frequency of media multitasking has been pervasively inconsistent with evidence showing no association (Baumgartner et al., 2014), evidence finding heavy media multitaskers to be worse at task switching (Ophir et al., 2009), and the opposite with heavy media multitaskers being found to be better at task switching (Alzahabi, Becker & Hambrick, 2017). The present study explored media multitasking ability and found an association with cognitive flexibility. Specifically, performance on the Wisconsin Card Sorting task was associated with individuals' media multitasking ability, and performance on the Trail Making task would have been significantly associated, but it did not withstand a correction for multiple comparisons that has been considered conservative by some (Steiner & Norman, 2011). Nevertheless, the present study could be said to not provide support for previous research that has demonstrated no association between media multitasking and cognitive flexibility (Baumgartner et al., 2014; Cardoso-Leite et al., 2016; Gorman & Green, 2016; Minear et al., 2013), inclusive of the findings from study 1, chapter 5 of this thesis. If individuals' cognitive flexibility is associated with their ability to media multitask, then it is logical to expect a cumulative relationship between how often individuals media multitask and their cognitive flexibility, although the type of relationship is not known. Indeed, engaging more frequently in media multitasking may possibly enhance individuals' task switching ability. In this regard the present study could be said to support previous research by Alzahabi and Becker, (2013) who found heavy media multitaskers to be better at task switching, demonstrating a lower switch-cost and Alzahabi et al., (2017) who found faster task switching to be associated with media multitasking. However, the opposite could also be argued, that if you are media multitasking more often and media multitasking ability is associated with cognitive flexibility, then there may be a fatiguing effect, thus supporting the research finding heavy media multitaskers to be worse at task switching (e.g. Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017). Indeed, a caveat of the present study was that it revealed a possible fatiguing effect of media multitasking on mood in terms of arousal. Furthermore, a novel measure of media multitasking ability was included in the current study, with a single 20 minute period of media multitasking. It would be interesting to explore whether there is a fatiguing effect of media multitasking on cognitive flexibility and the possibility of it being cumulative (multiple sessions of media multitasking).

Based on Diamond's (2013) executive function framework, fluency tasks were utilised to assess cognitive flexibility. Similar to study 1, Chapter 5, the fluency tasks were a novel measure of cognitive flexibility that have not previously been used in relation to media multitasking, other than the research conducted in this thesis. The present study found a significant association between performance on both the phonetic and semantic fluency tasks and media multitasking ability. Therefore, the present study not only proposes a role of cognitive flexibility in media multitasking ability, but also access to semantic memory, as previously discussed in chapter 5, Fisk and Sharp (2004) interpreted performance of these two fluency tasks as reflecting access to long-term memory. Thus, interpreted in this light it is unsurprising that performance of these tasks should be related to individuals' ability to recall information from a media multitasking situation.

In this regard, it is important to highlight that the two working memory tasks, backwards digit span and backwards Corsi, would have been significantly associated with media multitasking ability if not for the Bonferroni correction. Thus, there is an indication of a possible role of working memory in media multitasking ability, as measured in terms of the recall of information from a media multitasking situation. Again, it is logical that memory measures would relate to media multitasking ability, due to the nature of the assessment in the study reported here. As previously discussed in Chapter 3, there is the concept of task impurity in executive function tasks. That being, executive function tasks do not purely tax one executive function, rather the tasks used tend to place demand on a number of executive functions, placing higher demand on one function more than another. Thus, with performance on the Wisconsin Card sorting task (a cognitive flexibility task that also places demand on working memory) associated with media multitasking ability, its association (in addition to performance on both backwards digit span and Corsi block tasks approaching significance) indicates an association of working memory with media multitasking ability. Indeed, Diamond's (2013) theory of executive function suggests that both inhibition and working memory are functions that facilitate and support cognitive flexibility. Therefore, by demonstrating a possible role of working memory in media multitasking ability there is the prospect of a cumulative relationship between how often individuals media multitask and their working memory capacity. Thus, considering there is no evidence of working memory capacity increasing in line with more frequent media multitasking, the present study could be said to support evidence demonstrating heavy media multitaskers having worse working memory capacity (Cain et al., 2016; Ralph & Smilek, 2017; Sanbonmatsu, Strayer, Medeiros-Ward & Watson, 2013; Uncapher et al., 2016), in comparison to those who media multitask less frequently. Although, it does not clarify the inconsistent performance across working memory tasks. Essentially, the study highlights the possible need for good working memory capacity to be able to media multitask but that frequently media multitasking may also fatigue working memory in a cumulative manner.

Despite the purported supporting role of inhibition in cognitive flexibility, inhibition was found not to be significantly associated with media multitasking ability. Thus, the present study could be said to support previous evidence finding no association between frequency of media multitasking and attentional control, such as Minear et al., (2013) and study 1 of this thesis (see Chapter 5). In the sense that if inhibition had a role in individuals' ability to media multitask, then it would be logical that the extent to which individuals media multitask would have some sort of relationship with their ability to control their attention. Thus, as the present studies exploration of ability indicates no role of inhibition in media multitasking, it would suggest that individuals' ability to control their attention would not be related to how often they engage in media multitasking. Considering this, the present study can be said to neither support the majority of the media multitasking frequency literature that has demonstrated a negative bias in attentional control (e.g. Cain & Mitroff, 2011; Cardoso-Leite et al., 2016; Ophir et al., 2009; Ralph et al., 2015, experiments 1 and 3a) nor the one study finding heavy media multitaskers to perform better than light in terms of their attentional control (Baumgartner et al., 2014).

Contrastingly, in the same line of argument, the present study supports frequency of media multitasking research that has found no association between response inhibition and media multitasking. Such as, Ralph et al., (2015) experiment 2, that found no association between no-go errors and self-reported media multitasking, and experiment 4, that found no association between response times on a vigilance tasks and the Media Multitasking Index (MMI). The present study demonstrates no relationship between an individuals' ability to media multitask and their ability to control behavioural/prepotent responses, and consequently could be argued to indicate that there would be no relationship between how often individuals media multitask and their response inhibition. Therefore, the present study could be said to not support research that has found heavy media multitaskers to be worse than light media multitaskers in terms of response inhibition performance (Gorman & Green, 2016). Thus, the present study highlights no role of inhibition in media multitasking ability and provides no support for studies demonstrating negative biases in attentional control. However, it may be possible that the negative biases in attentional control are not cumulative based on the MMI frequency assessment, but cumulative in the sense of carrying out multiple sessions of media multitasking. In the present study participants only media multitasked for a single 20-minute period, thus it would be interesting to explore multiple sessions of media multitasking, utilising the novel objective measure of media multitasking ability. Although, the lack of a relationship may be due to the way in which media multitasking ability was measured. In the present study memory for content was used to reflect media multitasking ability, whereas if the equality of time spent looking at the two media was observed then more of a relationship with attentional measures may have been observed.

6.7.2 Mood

Objectively assessed media multitasking ability was not found to be associated with trait anxiety or depression. Trait anxiety and depression were explored as previous research by Becker et al., (2013) found anxiety to be associated with self-reported media multitasking, a result replicated in this thesis (see study 1, Chapter 5). However, the present study found no association between trait anxiety and media multitasking ability, nor with trait depression. Therefore indicating that individuals' ability to media multitask is not associated with their tendency to feel depressed or anxious. However, the findings do not necessarily rule out anxiety and depression as factors driving media multitasking, for example Reinecke, Aufenanger, Beutel, Dreier, Quiring et al., (2017) found fear of missing out, a specific type of anxiety, to be a driving force for media multitasking with internet based content.

State mood, (in terms of how participants currently felt at that precise moment of time), was also measured, with state arousal, anxiety and depression assessed at three varying time points across the experiment. The present study found self-reported levels of depression increased linearly across all three experimental time points. Anxiety only significantly increased following the completion of the executive function battery. More interestingly, self-reported levels of arousal only significantly decreased after completion of the media multitasking situation. Thus indicating that media multitasking may fatigue mood through depleting an individuals' level of arousal, although this mood assessment was taken at the end of the experiment, so it could be due to the time course of the experiment. Indeed, considering the known relationship between fatigue and executive function performance, media multitasking may have a fatiguing effect on executive function performance, directly or indirectly.

6.7.3 Limitations

Media multitasking ability was assessed through questionnaires measuring individuals' ability to recall information from the media situation. Before beginning the media situation participants were clearly instructed to pay equal attention to each of the media and respond to instant messages as soon as they were received: they were also informed that they would be tested on the content of the text and video. In this regard, it is possible that participants may not have done as instructed and could have payed more attention to one media stream than the other. However, response times to individual instant messages were observed, none of the messages were un-answered before receiving the next message (i.e. receiving message 3, not answering, receiving message 4 and then answering 3 and 4 at the same time) which was a determinant of non-compliance. Furthermore, none of the times to respond to instant messages exceeded a minute, which was implemented as a non-compliance cut off, considering the intervals at which messages were sent. Additionally, media multitasking ability scores were also explored to determine if participants had complied, by checking if the score on either the text or video questionnaire was no less than 25% based on the level of chance in relation to the amount of multiple choice options to each question on the questionnaire. If the minimum of 25% was not reached the participant was classed as non-compliant and their data was removed. Thus, there were measures in place to check whether participants had followed instructions and paid equal attention to the media streams presented. However, future research could also include eye tracking during the media situation as a means to observe individuals' split of attention during media multitasking, an aspect that was examined in Kazakova et al., (2015). In their study, Kazakova et al., (2015) video recorded head and eye movements of participants in the media multitasking condition, using the information to calculate frequency of switches between the two simultaneously presented media (website and short film). Frequency calculations were used as a means for checking non-compliance, two participants who failed to follow instructions and switch between media, only focusing on one medium were removed.

Although the present study is novel in its approach and further advances the media multitasking literature, it still succumbs to the issue within the rest of the literature in regards to establishing cause and effect. The present study provides evidence of an association between media multitasking ability and cognitive flexibility that is higher in ecological validity, but due to the methodology we are unable to fully determine the association in terms of cognitive flexibility facilitating media multitasking ability or vice versa. Thus, future research needs to implement a methodology that enables cause and effect to be established, for example through experimental or longitudinal designs.

Furthermore, regardless of the lack of cause and effect, there is a further issue considering the degree to which the findings can be interpreted as evidence of an association between cognitive flexibility and individuals' ability to media multitasking, as the present study did not include a control group. A control group was not included as the aim of the study was specifically looking for the extent to which executive functions are involved in media multitasking with a video, whilst reading a piece of text and responding to instant messages. Thus, it is possible that an association between cognitive flexibility and non-media multitasking of a video, reading a piece of text and responding to instant messages could be found. Further research exploring a similar experimental set up should consider the inclusion of a sequential engagement with media control group, which would help to determine and strengthen found associations.

6.7.4 Implications

The present study is the first of its kind to explore individuals' ability to media multitask in relation to standardised measures of executive functioning. It specifically looked at media multitasking ability in terms of individuals' ability to recall information from a media multitasking situation. This measure in itself highlights the question as to why individuals media multitask. What is the purpose of media multitasking? Is it a product of the ever-evolving media environment that is self-perpetuating? Do we want to retain information from all of the media that we are simultaneously engaging with or does one media stream have more precedence over another, or are there different motivations for the specific combination of media behaviours. Indeed, Hwang, Kim & Jeong, (2014) explored the varying needs involved with specific media multitasking behaviours. They found that multitasking using the internet was driven by information and enjoyment. It may be, for example, a person may media multitask by listening to music whilst internet shopping and instant messaging. In this scenario it is possible that the music is included to make the experience more enjoyable, whilst the internet shopping Is the main task, e.g. to find a present for someone, and the instant messaging is time efficient as it can be done at the same time. In this scenario, the information from the music might not necessarily be important to be recalled afterwards, it would still be enjoyable. Thus, the validity of trying to further explore objective measures of media multitasking should also consider the motivation for multitasking, despite the complexities involved.

Interesting results were observed for the novel manipulation of the media multitasking situation, media multitasking either within a single device or between devices. Interesting, in that there was no difference in media multitasking ability associated with device. Therefore, the study Indicates that media multitasking across devices is not necessarily more difficult than a single device when it comes to recalling information. However, it did take individuals' in the between device condition longer on average to respond to instant message. Thus, media multitasking across devices may simply be less efficient, time wise, than media multitasking within a single device, although this may differ depending on the specific media multitasking tasks.

6.7.5 Conclusion

In sum, the ability to remember information from a media multitasking situation is associated with cognitive flexibility but not attentional control. Being better able to generate abstract thought, change between mental sets and adapt the way you think enables more information to be recalled from a media multitasking situation. In terms of recalling information, media multitasking across devices is not inherently more difficult than within the same advice, although this is dependent on the specific combination of media multitasking behaviours. More importantly, the findings highlight the need to explore the direct effects media multitasking has on executive function in addition to mood, in order to determine if media multitasking fatigues the executive functions that are vital in being able to media multitask.

Chapter 7. Proximal effects of media multitasking on executive functioning

Chapter 7. Proximal effects of media multitasking on executive functioning

7.1 Chapter Overview

The following chapter details an empirical investigation of the direct effects media engagement has on young adults executive functioning, with a comparison between the effects of media multitasking and sequential media engagement. The layout follows the standard format that has been used to present previous empirical investigations of this thesis.

7.2 Introduction

Media multitasking has been associated with biases in attentional control (Ophir, Nass & Wagner, 2009) and working memory (Uncapher, Thieu & Wagner, 2016) (see Chapter 3 for an extensive review). Albeit with some evidence showing no biases, such as study 1, Chapter 5, presented in this thesis. Nevertheless, the majority of the research that has explored and found associations between executive function and media multitasking has employed self-report measures to assess media multitasking, predominantly through the use of Ophir et al's., (2009) Media Multitasking Index (MMI), or adapted versions. However, as previously discussed in Chapter 4 some research has explored media multitasking using experimental designs, although that area of research has predominantly examined media multitasking in relation to academic performance. In this regard, media multitasking in classroom and study environments has been shown to have a proximal effect on the learning and retention of information, slowing the learning process and making it somewhat less efficient (Conard & Marsh, 2014; Dietz & Henrich, 2014; Gingerich & Lineweaver, 2014; May & Elder, 2018). It has also been related to grade performance (Demirbilek & Talan, 2017) and grade point averages (Judd, 2014; Junco & Cotton, 2012; Kirschner & Karpinski, 2010; Lau, 2017).

Other research has begun to utilise objective measures of media multitasking performance (rather than self-reports of frequency) to explore associations with aspects of cognition. For example, Oviedo, Tornquist, Cameron & Chiappe, (2012) investigated the effect of media multitasking on the enjoyment of T.V. They carried out an experiment where participants watched a T.V. sitcom and interacted with Facebook, manipulating how much individuals had to interact with Facebook. They found that individuals who had more interactions with Facebook enjoyed the T.V. sitcom less and had worse memory of the episode than those who interacted less with Facebook. Whereas Strivastava (2013) explored media multitasking performance in relation to the processing of messages within media. The study highlighted a negative impact of multitasking on message processing, in terms of memory performance. Individuals made more errors on recognition and free recall tasks during multitasking.

Most relevant to the present study, there is only one study to date, Kazakova, Cauberghe, Pandelaere and De Pelsmacker, (2015) that has explored the impact of media multitasking on subsequent information processing style, utilising a media multitasking performance task. The study had participants take part in a media situation for which there were two, one group of participants completed a media multitasking situation, where they simultaneously engaged with media, whilst the other group of participants sequentially engaged with media. The study utilised a media situation consisting of two animated Disney films and a website. The sequential media group spent 16 minutes engaging with the media, 8 minutes on each medium, whereas the media multitasking group spent 8 minutes in total with both media. Following the media situation participants completed a figure comparison task consisting of geometric shapes (either squares or triangles), for which participants had to determine which of two presented shapes was most comparable to a figure presented at the top of the screen. The study found that individuals who had media multitasked demonstrated a local perceptual processing style whereas individuals who had sequentially engaged with media demonstrated a global processing style. Thus, the study provides evidence of a proximal association of media multitasking with information processing style. In this regard, study 2 presented in this thesis found an association between media multitasking ability and cognitive flexibility, utilising a performance based measure of media multitasking similar to Kazakova et al., (2015). Thus, there may well be a proximal effect of media multitasking on cognitive flexibility, in addition to other executive functions.

However, it is important to note that in Kazakova et al., (2015) processing style was only measured post sequential engagement or media multitasking, thus there is the issue of establishing causality. This is also a prevalent issue within the media multitasking and executive function literature, cause and effect has not previously been established nor could it be, based on the correlational designs that have been implemented, and reliance on self-report measures. Thusly, it is not known what direct effects media multitasking has on executive function. Furthermore, although study 2 of this thesis used an objective measure of media multitasking performance to look at relationships with executive function, causality could not be established. However, the study did indicate a possible fatiguing effect, in terms of decreased levels of arousal and increased levels of depression associated with media multitasking. Therefore, it is possible that media multitasking may have a proximal effect on both mood and executive function in terms of fatigue. This may occur to a greater extent than sequential media engagement, akin with Kazakova et al., (2015) who found differences in information processing style associated with different forms of media engagement (sequential and media multitasking).

7.3 Rationale

Accordingly, the present study aimed to explore the direct effects of media multitasking on different aspects of executive functioning, inclusive of inhibition, working memory and cognitive flexibility. Assessments of executive function were made pre and post the completion of a media situation, an experimental method conducive of establishing cause and effect. In regards to the media situation, there was a further manipulation, with the inclusion of two different groups. One group completed a media multitasking version of the media situation, where they had to simultaneously engage with media (watch a video and read a piece of text). Whereas the other group completed a sequential media situation, where they engaged with each media one after the other, with the order counter-balanced across participants. The two groups were included so that contrasts between sequential media engagement and media multitasking could be made.

7.4 Methodological considerations

In line with the rationale, Kazakova et al., (2015) highlighted the various intricacies that need to be considered when designing a sequential media control condition. Indeed, it is important to decide what the best way to design a sequential media control condition is. Should the total time spent engaging with media sequentially be the same as the total time spent media multitasking, or should the sequential condition be twice as long as the media multitasking condition so that participants would view the same amount of content as the media multitasking condition (the approach used by Kazakova et al., 2015). In the present study, the sequential media condition was designed to last the same amount of time as the media multitasking condition, so that general fatigue would be reduced and time would not be a confounding factor when looking for a media engagement effect. Considering the aim of the study in determining the proximal effects of media multitasking, it was important that participants engaged with the media presented. Therefore, a manipulation check was included to ensure that participants had engaged with the presented media.

In the present study, a smaller battery of executive function tasks was used, in comparison to the batteries used in study 1 and study 2. The battery was reduced from ten tasks to seven, focusing on tasks that had previously been associated with media multitasking in study 2, and enabling the shortening of the overall running time of the experiment, so that general fatigue was kept to a minimum. In terms of the seven-task battery, the number flanker task and the Stop-signal task were removed, so that the arrow flanker task and Go No-go task remained as measures of inhibition. Although no previous association between inhibition tasks and media multitasking had been found in study 1 or 2, we still wanted to explore inhibition as the majority of the literature has indicated a media multitasking association. Furthermore, it was important for continuity to explore the three strands of Diamond's (2013) executive function theory; inhibition, working memory and cognitive flexibility. The arrow flanker and the Go No-go tasks were chosen so that there was a single task assessing each aspect of inhibition (attentional control and response inhibition) and compared to the other inhibition tasks they both had a shorter running time. Both working memory tasks remained (Backwards digit span and Backwards Corsi block), as in study 2 a significant relationship between media multitasking had been found before applying a Bonferroni correction. With the experimental design of pre and post assessment of executive function, we were aware of possible practice effects and that some tasks are more susceptible to this issue. In this regard, despite the association found in study 2, the Wisconsin Card sorting task was removed, as it was perceived to be more prone and vulnerable to practice effects. Whereas the Trail Making task remained as it was perceived to be less susceptible to practice effects and performance on this task had been associated with media multitasking in study 2, before a Bonferroni correction was applied. Lastly, both the semantic fluency and phonetic fluency tasks were included as an association between performance on both of these tasks and media multitasking was found in study 2 (after a Bonferroni correction).

It was hypothesized that participants would perform worse on the post media situation set of executive function tasks. More specifically, the difference in performance would be more pronounced for the participants in the media multitasking condition. Furthermore, as with previous studies, state mood was also measured across different time points. Based on the results of Study 2, it was hypothesised that self-reported levels of arousal would decrease as the study progressed and be significantly more pronounced in the media multitasking group, whereas self-reported rates of depression would increase and also be more pronounced for media multitaskers compared to individuals in the sequential media group. There was no directional hypothesis for anxiety.

7.5 Method

7.5.1 Participants

A total of 76 participants, 51 females (67.10%), aged 18-25, (Mean=21.38, SD= 2.1) were recruited from the university population and general public. None of them had taken part in Study 1 or Study 2. The experiment was performed in agreement with protocols approved by the university research ethics committee and ethical principles set by the British Psychological Society. Complete data were collected for all participants and data were not analysed until data collection was completed.

7.5.2 Design

A 2x2 mixed design was implemented, with time point (pre and post media situation) by media situation group (media multitasking or sequential media engagement). Dependent measures were performance on the flanker task (congruency conflict), Go No-go task (amount of correct inhibitions), Backwards Corsi block and Backwards digit span (mean span), phonetic fluency and semantic fluency (total amount of correct words), and Trail making task (B-A difference response times).

7.5.3 Procedure

Once consent had been obtained, participants completed a mood inventory (Matthews, Jones, & Chamberlain, 1990) followed by a battery of seven executive function tasks. After the task battery, they completed another mood scale and then a media situation (media multitasking or sequential media). For the media situation, participants were instructed to pay equal attention to both media and were informed that they would have to answer questions at the end. Following the media situation participants completed a further mood scale and a second battery of executive function tasks. After completion of the second battery of tasks, a further mood scale and media manipulation-check questionnaire were completed.

7.5.4 Measures

The present study included two batteries of seven executive function tasks, in each battery there were the following tasks; Arrow Flanker, Go No-go, phonetic fluency and semantic fluency, Trail Making, Backwards digit span and Backwards Corsi block (see Chapter 5 for details of the tasks). As the battery of tasks was presented pre and post media engagement, parallel forms of the tasks were needed. Within the arrow flanker task, Go No-go task, backwards digit span and trail making task, trials are randomly generated each time the task is completed, thus the same tasks were used in the first battery of executive function tasks and the second. For the phonetic fluency and semantic fluency tasks, specific letters and categories are given to participants for them to generate answers. Thus, parallel versions of the phonetic and semantic fluency tasks were created, with the use of the letters; M, C, and L for the phonetic fluency and the categories of; supermarket (things you will find in a supermarket), furniture and girls names for the semantic fluency (see Chapter 5 for phonetic and semantic fluency procedure). These letters and categories were chosen based on their common use in the literature (e.g., Henry & Crawford, 2004; Troyer, 2000; Nusbaum & Silva, 2011; Unsworth, 2011). The order in which the different versions of both the phonetic and semantic fluency tasks were presented were counterbalanced within each group. Furthermore, a second version of the backwards Corsi block was created; the task was still implemented via Inquisit. However, the script was altered in order to change the presentation of the boxes lighting up, as the previous task used does not randomly generate the pattern of boxes lighting up (see Chapter 5, page 82 for details on the task).

7.5.4.1 Mood

The UWIST mood adjective checklist was used to assess mood, which has previously been used in the two other studies discussed within this thesis (see Chapter 5 and Chapter 6). Within the present study, the mood scale was administered at four different time points during the experiment; at baseline, after the first executive function battery, after the media situation, and after the second executive function battery. The particular Cronbach's alphas for arousal, anxiety and depression were; arousal- time 1 α= .63, time 2 α= .74, time 3 α= .82 and time 4 α= .81. Anxiety -time 1 α= .77, time 2 α= .69, time 3 α= .77 and time 4 α= .76, and depression- time 1 α= .74, time 2 α= .75, time 3 α= .79 and time 4 α=.78.

7.5.4.2 Media situation

There were two media situations that participants were randomly allocated to, either a media multitasking situation or a sequential media situation. Both situations consisted of watching a video and reading a piece of text. The same video and text as used in study 2 (see chapter 6) were implemented. In the media multitasking situation, participants had 20 minutes to watch the video and read the piece of text simultaneously, whereas participants in the sequential situation had to view each medium one after the other, spending 10 minutes on each. The presentation order of the media in the sequential group was randomised across participants. It was decided that the length of time spent in each media condition would be equated, so that the extraneous variable of the fatiguing effect of time would be reduced. This resulted in a reduction in the specific content of each medium that the sequential media situation group would be exposed to. Therefore, this was a factor that was also considered in the manipulation check media questionnaire.

7.5.4.3 Manipulation check media questionnaire

Participants were instructed to pay equal attention to both media in the media situation, as a means to ensure participants had followed the instructions; a questionnaire was included to ascertain whether the participant had been attending to both sources of media. The questionnaire included 14 multiple-choice questions with seven referring to the text and seven to the video, inclusive of questions such as “What do Dan and Phil go on a mission to purchase?” and “Where is the head office of the factory?”, see appendix 10 for questionnaire. The questions were all based on the first parts of the video and text, so that they could be answered by individuals in the sequential condition who only viewed 10 minutes of the video and spent 10 minutes reading.

7. 6 Results

Following the procedure of the two previous studies (Chapter 5 and Chapter 6), data were explored and outliers greater than 3 standard deviations were removed, which resulted in the removal of three cases from the executive function tasks and three cases from the mood inventory . A mixed ANOVA analysis was implemented for each of the executive function tasks with Bonferroni corrections, with two levels of the between-subjects factor media group (multitasking, sequential) and two levels of the within-subjects factor of time (pre-media, post-media).

Table 7.1. Means and descriptive statistics for executive function tasks pre and post media situation

	Time 1				**Time 2**			
	Mean	**S.D**	**Skew**	**Kurtosis**	**Mean**	**S.D**	**Skew**	**Kurtosis**
Media Multitasking								
Flanker	45.180	25.219	-.598	.780	50.670	27.194	.039	-1.027
Go No-go	23.135	4.984	-1.242	1.048	21.289	5.877	-1.091	.994
Backwards Digit span	5.362	1.125	.272	.123	5.889	1.244	.148	-.219
Backwards Corsi Block	6.395	1.104	.027	2.264	6.289	1.431	.100	-.407
Trail Making	6882.007	4105.853	1.061	1.424	4111.426	2670.456	.910	.614
Phonetic Fluency	11.824	2.921	.554	-.264	12.754	3.255	.280	-.612
Semantic Fluency	18.833	4.464	.146	-.374	18.439	4.817	.893	1.130
Sequential Media								
Flanker	56.839	36.909	.396	3.251	58.774	26.376	.370	-.731
Go No-go	22.459	4.180	-1.071	1.471	22.447	5.535	-1.211	1.550
Backwards Digit span	5.580	1.220	.053	-.369	6.052	.955	-.005	-.487
Backwards Corsi Block	6.211	1.189	-.838	3.762	6.526	1.370	-.524	.104
Trail Making	7618.194	5273.409	1.002	.715	4112.896	3277.095	1.604	3.042
Phonetic Fluency	11.105	2.971	.688	.027	12.026	3.005	.723	.549
Semantic Fluency	18.860	3.540	.016	-.904	18.877	5.188	.442	-.619

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

7.6.1 Inhibition

A flanker task and a Go No-go task were included in the present study to assess attentional control and response inhibition. A mixed ANOVA with a Greenhouse-Geisser correction found no significant effect of time for the flanker task $F(1, 74)=.833$, $p >.05$, $\eta^2 = .011$, no significant effect for media group $F(1, 74)= 3.409$, $p> .05$, $\eta^2 = .044$, and no significant interaction for flanker task and media group $F(1, 74)= .191$, $p >.05$, $\eta^2 = .002$. Thus indicating that across the two experimental time points flanker task performance did not significantly change for both media groups. Despite no significant effect or interaction for the flanker task, there was a trend of a decrease in performance on the second flanker task for both groups indicated by an increase in response times (as shown in Table 7.1).

For the Go No-go task, a Greenhouse-Geisser corrected mixed ANOVA revealed there was no significant effect of time point for Go No-go performance $F(1, 72) = .942$, $p > .05$, $\eta^2 = .012$, no significant effect of media group $F(1, 72)= .015$, $p >.05$, $\eta^2 < .001$, nor were there any significant interactions between time point and media group $F(1, 72)= 1.620$, $p> .05$, $\eta^2 = .021$. The trend in performance for the Go No-go task (as observed from the means in Table 7.1) indicated a decrease in performance for those in the media multitasking group whilst those in the sequential group essentially remained the same. Thus, in terms of the hypothesis, the results demonstrate that engaging with media does not significantly fatigue attentional control or response inhibition. Furthermore, media multitasking as a specific media engagement behaviour is not significantly more fatiguing than sequential media consumption.

7.6.2 Working Memory

Both a backwards Corsi block and digit span task were included as assessments of working memory. The trend observed (see Table 7.1) was that of those in the media multitasking group decreasing in performance and those in the sequential group improving their performance. A mixed ANOVA with a Greenhouse-Geisser correction revealed no significant difference between time points on Corsi block performance $F(1, 74) = .411$, $p > .05$, $\eta^2 = .005$, no significant effect of media group $F(1, 74) = .012$, $p > .05$, $\eta^2 = .000$, and no significant interaction between media group and time point on backwards Corsi block performance, $F(1, 74) = 1.642$, $p > .05$, $\eta^2 = .021$. Therefore, the hypothesis of a significant reduction in visual-spatial working memory performance following a media situation is not supported. Media engagement did not significantly fatigue this aspect of working memory.

Interestingly, a significant main effect of time, based on a mixed ANOVA with a Greenhouse-Geisser correction, was found for the backwards digit span task $F(1, 74) = 24.604$, $p < .01$, $\eta^2 = .24$. However, there was no main effect for media group performance on this type of verbal working memory task $F(1, 74) = .623$, $p > .05$, $\eta^2 = .008$. Contrary to the hypothesis there was no significant interaction between the two media groups and across the two experimental time points for the digit span task $F(1, 74) = .073$, $p > .05$, $\eta^2 < .001$. The opposite performance pattern was found, with both the sequential media and media multitasking group significantly improving their performance, as shown in Figure 7.1 below.

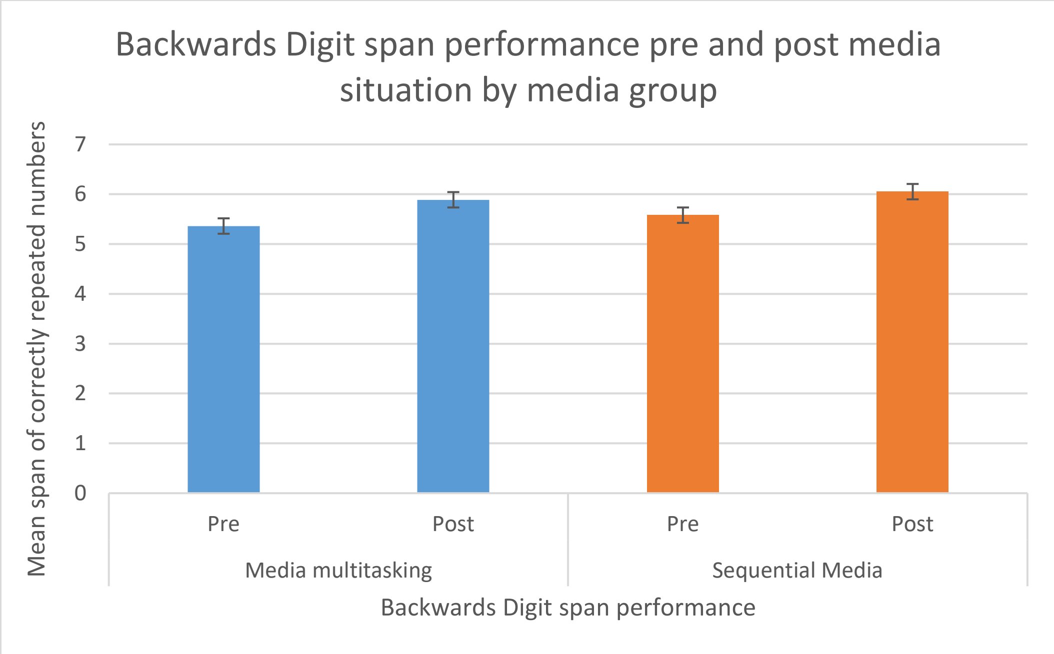


Figure 7.1. Backwards Digit span performance pre and post media situation by media group

7.6.3 Cognitive Flexibility

A Trail Making Task and both a phonetic and semantic fluency task were included as measures of cognitive flexibility. Mixed ANOVAs were conducted with Greenhouse-Geisser corrections. Performance on the Trail Making Task was found to significantly differ for the two experimental time points $F(1, 71)= 47.115$, $p< .01$, $\eta^2 = .396$. However, there was no significant effect of media group $F(1, 71)= .237$, $p > .05$, $\eta^2= .003$ and no significant interaction between the two media groups and Trail Making Task performance across the two experimental time points $F(1, 71) = 646$, $p > .05$, $\eta^2 = .005$. Contradictory to the hypothesis, both media multitaskers and sequential media engagers performed better on the trail making task, post media situation, with faster response times, demonstrating that performance improved with practice regardless of the type of media engagement as demonstrated in Figure 7.2.

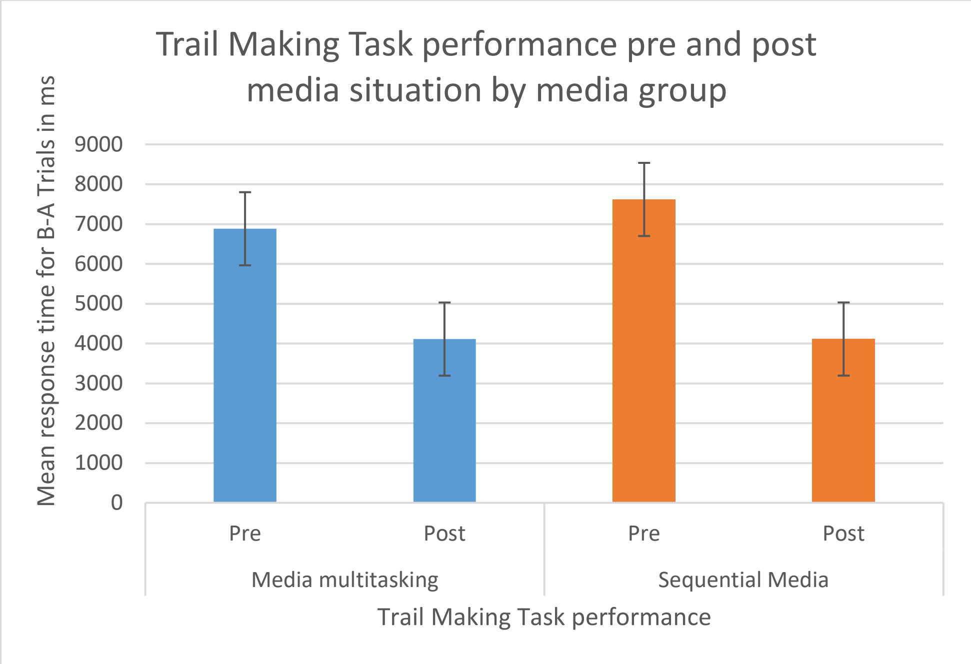


Figure 7.2. Trail Making task performance pre and post media situation by media group

Similarly, a mixed ANOVA revealed a significant effect for phonetic fluency performance across the two time points $F(1, 72)= 15.365$, $p< .01$, $\eta^2 = .174$. However, there were no significant group differences in overall phonetic fluency performance $F(1, 72)= 1.215$, $p> .05$, $\eta^2 = .016$, nor were there any interactions between the two experimental time points and media group $F(1, 72)= .001$, $p> .05$, $\eta^2= .001$. As previously mentioned, a parallel version of the phonetic fluency task was included in the present study, with the order of task randomised within each group. Thus, a 2x2x2 mixed ANOVA was conducted. There were no order effects for phonetic fluency across the two experimental time points $F(1,72)= .017$, $p> .05$, $\eta^2 < .001$, nor were order effects found for the two media groups across the two time points and the order in which the version of the fluency task was presented $F(1,72)= .694$, $p> .05$, $\eta^2 = .007$. Performance on the phonetic fluency task increased from pre to post media situation regardless of media group and version of the task completed (see Figure 7.3). Thus finding no evidence to support the hypothesis of a fatiguing effect of media engagement on cognitive flexibility.

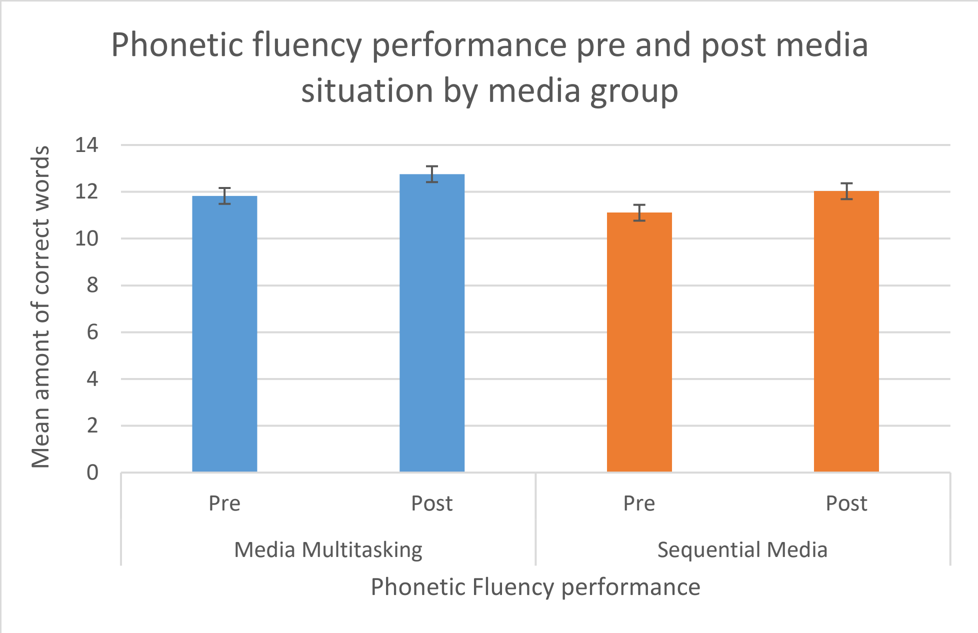


Figure 7.3. Phonetic fluency performance pre and post media situation for both media groups (N.B. order of presentation of version of phonetic task is not presented in the graph, as no order effects were found)

Furthermore, there was no significant main effect for semantic fluency across the two experimental time points $F(1, 72)= .462$, $p > .05$, $\eta^2 = .002$, and no significant group differences in overall semantic fluency performance $F(1, 72)= .067$, $P > .05$, $\eta^2 < .001$. There was also no interaction between pre and post semantic fluency by media group $F(1, 72)= .553$, $p > .05$, $\eta^2 = .002$. Similar to the phonetic fluency task a parallel version of the semantic task was included in the present study and thus a 2x2x2 mixed ANOVA was conducted. In this regard, a significant interaction for semantic fluency performance and order of fluency task administered was found $F(1, 72)= 135.909$, $p < .01$, $\eta^2 = .647$, although there was no significant interaction between the two media groups for semantic fluency and order of fluency task administered $F(1, 72)= .995$, $p > .05$, $\eta^2 = .004$. Thus, the results indicate an issue of order effects of the task presented. The two versions of the task included the following categories, animals, food and clothing, and furniture, supermarket and girls names. Through inspection of the plots (see Figure 7.4), it was identified that regardless of media group, when participants completed the furniture, supermarket and girls names version of the semantic fluency task first, their performance improved the second time they completed the semantic fluency task (animals, food and clothing version). Whereas, when they completed the animals, food and clothing version first, their performance decreased. However, no interactions with media group were apparent (see Figure 7.5).

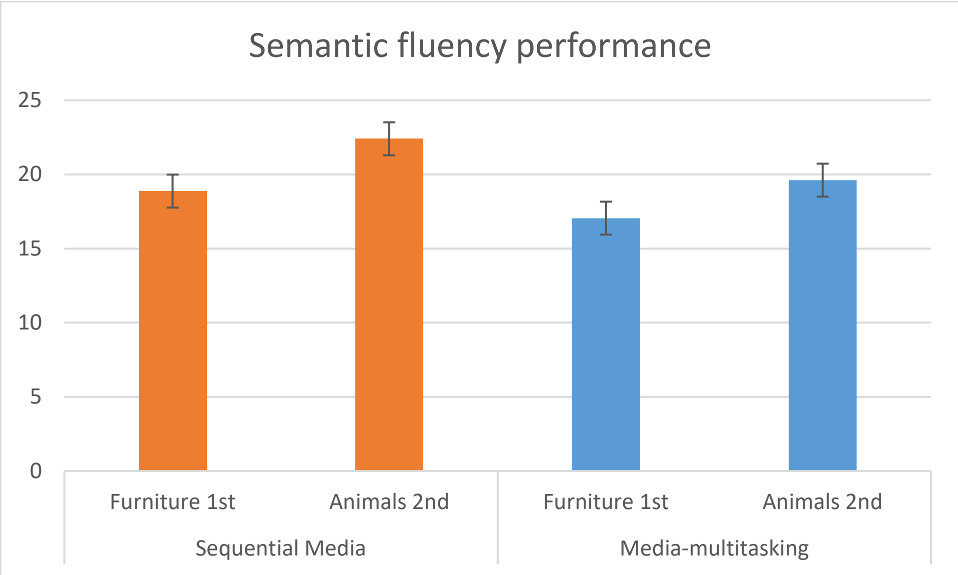


Figure 7.4. Semantic fluency performance when the Furniture version of the semantic fluency task is used pre media situation

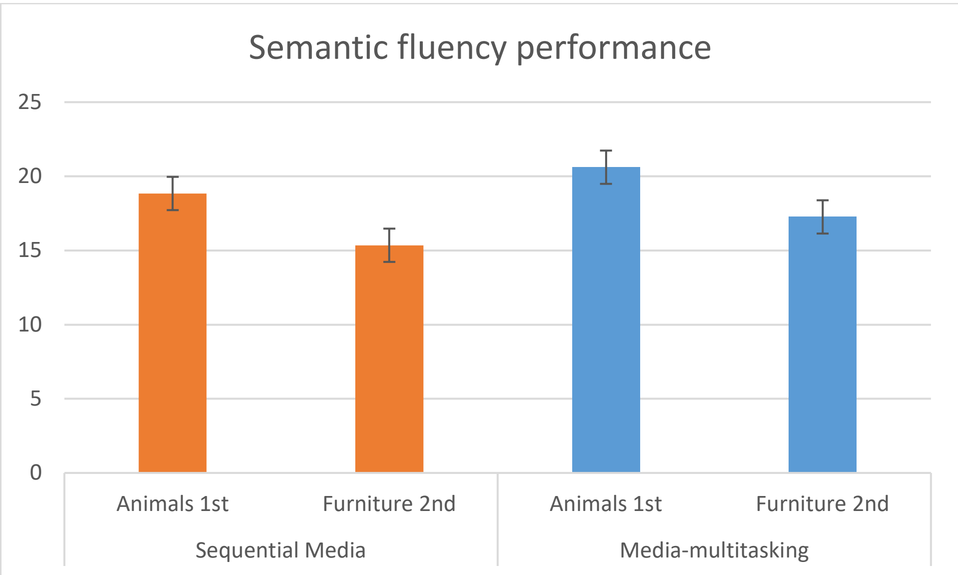


Figure 7.5. Semantic fluency performance when the Animals version of the semantic fluency task is used pre media situation

7.6.4 Mood

Mixed measures ANOVA were conducted for the three aspects of state mood; arousal, anxiety and depression, with Greenhouse-Geisser corrections.

7.6.4.1 Arousal

A significant difference in self-reported levels of arousal across experimental time points was found, $F(1.966, 145.451) = 36.718$, $p < .01$, $\eta^2 = .329$. However, there was no significant interaction based on group $F(1.966, 145.451) = .675$, $p > .05$, $\eta^2 = .006$. Both media groups demonstrated a similar pattern of self-reported arousal, with levels of arousal decreasing progressively across the experimental time points, apart from individuals' in the sequential media group who on average reported an increase in arousal at time point 4, see figure 7.6 below. However, the significant difference in experimental time points occurred from time point 2, $p < .01$ (after completion of the first set of executive function tasks) to time point 3 (after completion of the media situation) $p < .01$, with self-reported arousal levels significantly decreasing. The difference in self-reported levels of arousal between baseline (time point 1) and time point 2; and the difference between time point 3 and time point 4 were not significantly different. Thus the hypothesis of arousal levels decreasing as the experiment progressed was only partially supported. There was no difference between media groups for self-reported levels of arousal across time points, thus media multitaskers decrease in self-reported levels of arousal was not more pronounced than individuals in the sequential media group (see Figure 7.6). However, the significant difference in self-reported levels of arousal from time point 2 and time point 3 is indicative of a general fatiguing effect of media engagement.

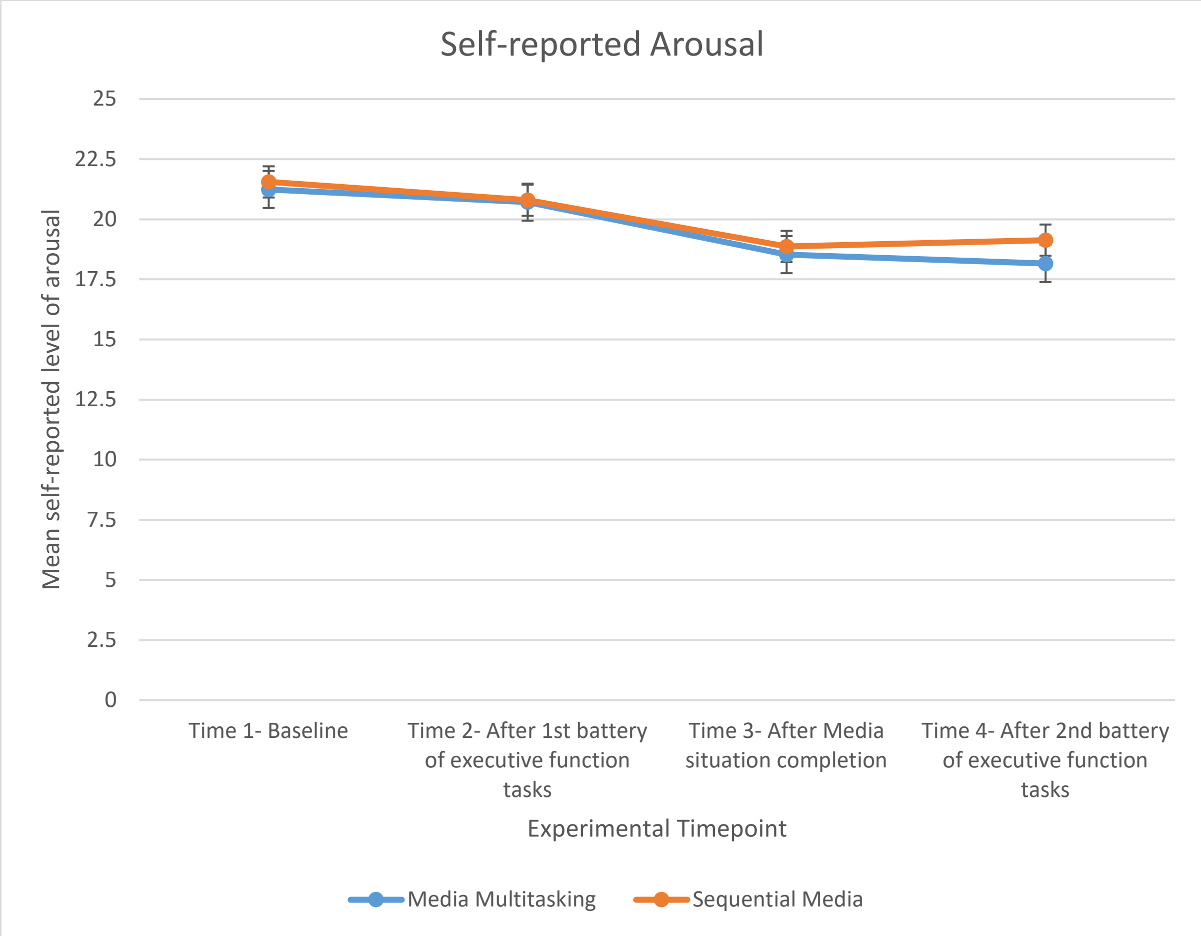


Figure 7.6. Mean level of self-reported arousal across experimental time points by media group

7.6.4.2 Anxiety

There was no significant difference in self-reported levels of state anxiety between the experimental time points $F(2.623, 188.858)= 2.628$, $p > .01$, $\eta^2 = .035$, based on a Bonferonni correction to the alpha level. Overall, anxiety increased across the experimental time points, although there was a slight decrease in sequential media multitaskers' self-reported anxiety at time point 4. Nonetheless, there was no significant difference between the two media groups and overall anxiety $F(1, 72)= 4.719$, $p > .01$, η^2 .= .061, and no significant interaction between anxiety and media group $F(2.623, 188.858)= .094$, $p > .05$, $\eta^2 = .001$. A Bonferonni correction to alpha levels was applied, thus it could be argued that a difference in self-reported anxiety levels approached significance. There was no directional hypothesis for anxiety, thus it is interesting to observe an increase in anxiety over time, shown in Figure 7.7 below.

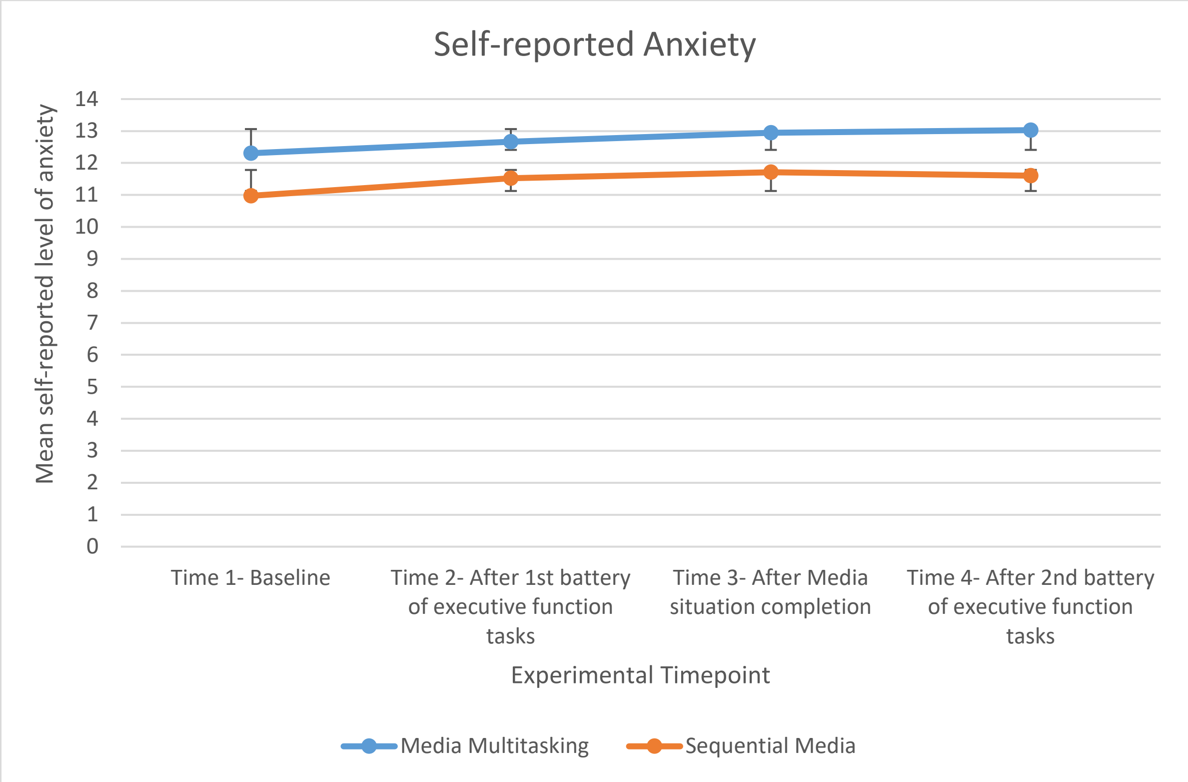


Figure 7.7. Mean level of self-reported anxiety across experimental time points by media group

7.6.4.3 Depression

There was no significant effect of group on self-reported levels of state depression $F(1, 73)= 3.573$, $p> .05$, $\eta^2 = .046$. However, a significant difference in self-reported depression across the four experimental time points was found $F(1.864, 136.067)= 19.041$, $p< .01$, $\eta^2 = .206$. There was a linear pattern of increased levels of self-reported depression, with post hoc analysis indicating participants had reported significantly higher levels of depression from time point 2 (after completion of the first executive function battery) to time point 3 (after the media situation), with depression remaining significantly higher than baseline at these two time points, regardless of group (see figure 7.8). Although, depression levelled off from time point 3 to time point 4. Thus, the hypothesis of increased levels of depression for both groups was supported. It is interesting to see a significant increase in self-reported levels of depression from after the completion of the first battery of executive function tasks (time point 2) and the media situation (time point 3), which further demonstrates a fatiguing effect of media engagement on mood in this context (see Figure 7.8 for graphical representation).

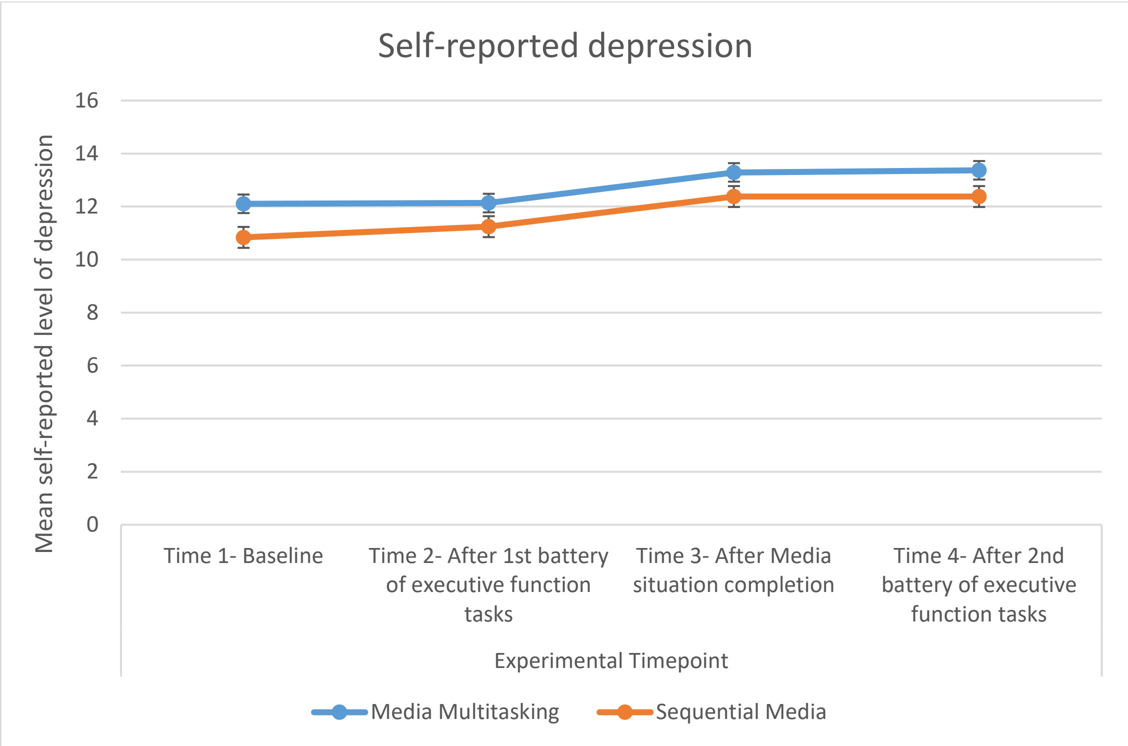


Figure 7.8. Mean self-reported depression at each experimental time point by media group

7.7 Discussion

The present study found no significant decline in executive function performance associated with media consumption. Media multitasking was not found to have a proximal effect on executive functioning, specifically, it did not fatigue executive functioning. There were no significant differences in performance between individuals who had media multitasked and those who had sequentially engaged with media. Furthermore, not only did engaging with media (sequentially or media multitasking) not fatigue executive function, significant results for the opposite effect were found for the backwards digit span task, phonetic fluency task and trail making task, indicative of general practice effects.

Different aspects of inhibition were assessed, with the inclusion of a flanker task to measure attentional control and a Go No-go task to measure response inhibition. For both tasks no significant effect of time point was found nor were group differences. This was the same for performance on the backwards Corsi block task, assessing visuo-spatial working memory. Thus, indicating that engagement with media, inclusive of media multitasking, does not have a proximal fatiguing effect on attentional control, response inhibition or visuo-spatial working memory. Furthermore, contradicting our hypothesis, performance on the cognitive flexibility measures (Trail Making Task and phonetic fluency task) and the backwards digit span task (verbal working memory task) significantly improved after engagement with media, with both media groups improving their performance. Thus, demonstrating that media multitasking as well as sequential media engagement does not have a fatiguing effect on cognitive flexibility or verbal working memory. However, it does not insinuate the opposite, as improved performance is more than likely due to practice effects. Although, practice effects are normally defined when task completion follows task completion without an intervention in between (Bartels, Wegrzyn, Wiedl, Ackermann & Ehrenreich, 2010). The issue of practice effects are discussed further on in the limitations section.

Within the present study, parallel versions of both the phonetic and semantic fluency tasks were implemented, with the order of different versions randomised across both groups. As previously mentioned there was a significant effect for phonetic fluency but no group differences, regardless of the version of the task used (letters F, A, S or M, C, L) performance improved. Whereas for the semantic fluency task, there was a significant interaction between semantic fluency performance and the order in which task they completed first. For both groups when they completed the furniture, supermarket and girls names version of the semantic fluency task first, performance on the second semantic fluency task increased. However, when the animals, food and clothing version of the task was completed first, performance on the second semantic fluency task decreased. Thus indicating that the categories of furniture, supermarket and girls names may be more difficult than animals, food and clothing. This highlights an important factor for further research interested in using a semantic fluency task.

7.7.1 Relationship to previous research

In terms of previous research, Kazakova et al., (2015) found a proximal effect of media multitasking on information processing style, with individuals who had media multitasked demonstrating a global processing style. Other research has found proximal effects of media multitasking on learning and retention of information (Conard & Marsh, 2014; Dietz & Henrich, 2014; Gingerich & Lineweaver, 2014; May & Elder, 2018) and memory for messages (Strivastava, 2013). Whereas, the present study found no evidence of a proximal effect of media multitasking on subsequent measures of inhibition, working memory or cognitive flexibility. However, the present study assessed executive function performance pre and post media situation engagement, whereas Kazakova et al (2015) only assessed processing style after completion of media engagement, and Strivastava (2013) only assessed memory of messages after media multitasking. Therefore, it may be the case that attempting to measure the proximal effects of media multitasking on executive function may be more difficult, due to the nature of executive functioning assessments needing to be novel for the participant. Furthermore, some aspects of executive functioning may be more susceptible to practice effects than others, such as working memory and cognitive flexibility, which were demonstrated in the present study. Indeed, it would be interesting to see if a pre and post assessment of information processing style would replicate the findings of Kazakova et al., (2015).

As previously discussed, the present study is novel in terms of the exploration of proximal effects of media multitasking on executive functioning. This new study is thusly difficult to place in terms of previous research investigating executive function and media multitasking. Previous research has focused on associations between self-reported frequency of media multitasking and executive function, utilising both individual differences and extreme group approaches. Therefore, at first glance it would seem that the present study is inconsistent with the research that has found media multitasking to be associated with executive function and differences between heavy and light media multitaskers (e.g. Ophir et al., 2009; Uncapher et al., 2016; Alzahabi et al., 2017) as the present study found no proximal effects of media multitasking on executive functioning. Indeed, if a proximal fatiguing effect of media multitasking on executive functioning had been found, it would be logical to conclude that those who more frequently engage in a behaviour that has a fatiguing effect would then demonstrate worse performance. Thus, reported differences between heavy and light media multitaskers may highlight a possible cumulative fatiguing effect of media multitasking, as in the present study participants only media multitasked for a single acute period. However, it could be that the direction of causality runs the opposite way, and that studies in the literature that have found a relationship between media multitasking and executive function have arisen due to individuals having pre-existing biases in executive function (weaker executive functioning) which leads them to media multitask more often. These biases could then be exacerbated by media multitasking (Baumgartner, Van der Schuur, Lemmens & te Poel, 2017).

7.7.2 Mood

Mood has previously been associated with media multitasking in terms of anxiety and self-reported media multitasking (Becker, 2013), as replicated in Chapter 5. However, media multitasking ability has also been associated with arousal and depression. In Chapter 6, participants displayed increased levels of self-reported depression and decreased levels of arousal following a period of media multitasking. Within the present study, anxiety, arousal and depression were assessed at four different time points. Time point 1-at baseline, time point 2- after completion of the first battery of executive function tasks, time point 3-after completion of the media situation and time point 4-after completion of the second battery of executive function tasks. Across the experimental time points self-reported levels of anxiety did not significantly differ, nor were there any group differences, just a general trend of increased self-reported anxiety as the experiment progressed. However, in regards to arousal and depression there were significant differences in self-reported levels of both, across the experimental time points but with no group effects. The overall trend of arousal was that of decreasing over time, with significant decreases in self-reported arousal occurring from time point 2 to time point 3. Whereas self-reported depression increased as the experiment progressed, with significant increases occurring at time point 2 and time point 3. This indicates that the completion of a media situation, either sequential engagement with media or media multitasking, has a fatiguing effect on depression and arousal, as from time point 3 to time point 4 there were no significant differences in self-reported levels of these aspects of mood. In this regard, the present study replicates the findings of the previous study in Chapter 6, demonstrating the effects of media engagement on self-reported levels of arousal and depression. However, the present study provides further insight, as the pre and post design enables the difference in self-reported levels of arousal and depression across experimental time points to be clearly pin pointed and thusly distinct associations of media engagement and decreases in arousal and increases in depression can be made.

7.7.3 Limitations

One of the possible limitations to the present study is the novel experimental set-up for media multitasking. During the experiment, participants had only two forms of media to engage with in either media condition. Thus, it is possible that the media multitasking scenario was not complex enough. In real life, individuals can engage in a number of varying media activities during a single period of media-multitasking (Van Cauwenberge, Schaap & Van Roy, 2014). This could include watching T V, whilst responding to instant messages, whilst internet shopping and scrolling through Facebook. Furthermore, the time period for media multitasking varies, whether it is for 5 minutes, 20 minutes or up to an hour with multiple sessions of media multitasking throughout a single day. Thus, the time spent media multitasking is a factor to be considered. Indeed, it is possible that the media engagement period in the present study may have been too short and having a single period of media multitasking might be insufficient and not necessarily be fatiguing. A cumulatively fatiguing effect of media multitasking is not inconceivable with a stronger manipulation.

In this regard, future research could definitely benefit from further exploring the use of objective measures of media multitasking. It should perhaps focus on including a more complex media multitasking scenario. For example in Chapter 6, participants also had to respond to instant messages whilst watching a video and reading a piece of text. Additionally, future research could compare different complex media multitasking scenarios, such as exploring a single period of media multitasking or multiple episodes of media multitasking. Furthermore, research should also attempt to conduct longitudinal studies exploring the previously found associations between media multitasking and executive functioning. So far, only Baumgartenr, Van der Schuur, Lemmens and te Poel (2018) have conducted longitudinal studies, exploring attentional problems in relation to media multitasking.

Another limitation, previously mentioned, is an innate issue with trying to measure executive functioning at different time points. As previously discussed in Chapter 2, executive function tasks need to be novel (Burgess, 1997), indeed something is only novel once (Chan, Shum, Toulopoulou & Chen, 2008). Thus, attempting to test pre and post executive performance on tasks is vulnerable to the issue of practice effects. Individuals can improve performance just by having done the tasks once before. However, it is difficult to establish cause and effect without using a pre and post approach, with some researchers suggesting the use of different tasks, which raises further issues, as it is difficult to find tasks that similarly tap into the same aspect of executive function. Whereas others have suggested that using the same tasks with altered stimuli, that are essentially parallel versions of the original tasks, is acceptable (Falleti, Maruff, Collie & Darby, 2006). Nonetheless, research has also purported that some executive functions and their respective assessments may be more susceptible to practice effects than other tasks (Bartels et al., 2010; Falleti et al., 2006) and that fatigue can cancel out practice effects, which in this present study may be applicable as significant increases in self-reported depression and decreases in self-reported arousal were found. Although, the general fatigue effect was the same for both media situation groups.

7.8 Conclusion

In sum, the present study indicates that time spent engaging with media either sequentially or media multitasking does not fatigue executive functioning in subsequent tasks. However, mood indices did demonstrate that media engagement, regardless of type, has a fatiguing effect on self-reported levels of arousal and depression, in terms of increasing individuals' feeling of depression and reducing their level of arousal. Any effects of media multitasking on executive functioning may indeed be cumulative, and too small to be observable within a single session. Future research needs to continue to explore the direction of causality in the media multitasking and executive functioning associations, through the utilisation of single or multiple complex media scenarios or longitudinal designs.

Chapter 8. General Discussion

Chapter 8. General Discussion

8.1 Chapter Overview

This final chapter summarises the main aims of the presented thesis and the three studies that were conducted in addressing the key research question. It then presents an overview of the findings from the three studies, firstly examining study 1 in relation to current literature and is structured by each of Diamonds executive functions; inhibition, working memory and cognitive flexibility. It progresses to discuss the findings of study 2 and 3, regarding media multitasking ability and the proximal effects of media multitasking, before examining the implications, limitations and direction of future research.

8.2 Introduction

The overall aim of the thesis was to examine the associations between executive functioning and media multitasking in young adults. In addressing the aim, three empirical studies were conducted. The initial exploration investigated self-reported media multitasking frequency in relation to executive functioning, inclusive of inhibition, working memory and cognitive flexibility. The research progressed to explore these same aspects of executive function in relation to an objective measure of media multitasking, asking a slightly different question as to what executive functions are involved in individual's ability to media multitask. Following on from this, the research evolved to explore the proximal effects media multitasking might have on executive function performance, to determine whether media multitasking fatigues executive functioning. Throughout the empirical projects of the thesis, aspects of trait and state mood were also explored in relation to media multitasking.

8.3 Executive functioning and self-reported measures of media multitasking; a review of findings

Study 1 found no association between frequency of self-reported media multitasking and executive functioning. All aspects of Diamonds (2013) executive functioning framework were explored, inclusive of attentional control, response inhibition, working memory and cognitive flexibility. Thus, the study was clear in demonstrating no association between attentional control and frequency of media multitasking, bolstering previous null findings of Minear, Brasher and McCurdy (2013) and Murphy, McLauchlan and Lee (2017) and going against the commonly reported biases found.

Furthermore, in combination with previous findings by Murphy et al., (2017), Ophir et al., (2009) and Ralph et al., (2015) experiment 2 and experiment 3b, the study reveals an unambiguous depiction of no association between response inhibition and frequency of self-reported media multitasking. Which may seem odd, considering the view of media multitasking as a habitual behaviour (Aagaard, 2014), motivated through habit (Hwang, Kim and Jeong, 2014), and the role response inhibition plays in habitual behaviours (Jahanshahi, Obescos, Rothwell & Obesco, 2015). Specifically, the role of both a process that enables the control of prepotent responses, whilst also being a response selection, underlying tendencies to respond (e.g. the tendency to pick up a phone and media multitask) (Jasinska, 2013). Nonetheless, the findings show no support of a relationship between how often individuals' media multitask and their ability to control responses to environmental cues.

Working memory has been explored in similar scrutiny to that of attentional control. However, the evidence is pervasively inconsistent. The findings of this initial study are definitive in showing no association between performance on complex span tasks and self-reported frequency of media multitasking, inclusive of novel evidence of performance on a Corsi block task, assessing visual-spatial working memory, that has not previously been explored in this context, expanding previous research by Minear et al. (2013), Baumgartner et al., (2014), and Gorman and Green (2016). However, the discrepancies within research surrounding the association between media multitasking and performance on other working memory tasks (i.e. filter tasks and n-back tasks) still remain. Although, it is clear that there is no improved performance in terms of working memory associated with media multitasking, this particular executive function needs to be further explored in relation to media multitasking (Uncapher, Lin, Rosen, Kikorian and Baron et al., 2017).

The study was distinct in showing no association between media multitasking and cognitive flexibility in terms of performance on the Wisconsin Card Sorting task, Trail Making task and two fluency tasks (phonetic and semantic). Previous research has found both better task switching ability (Alzahabi & Becker, 2013; Alzahabi, Becker & Hambrick, 2017) and worse task switching ability (Ophir et al., 2009) to be associated with more frequent media multitasking. Thus, the present findings in combination with previous research by Baumgartner et al., (2014) and Cardoso-Leite, Kludt, Vignola, Ma and Green et al., 2016), provide clarity and reveal an emerging evidentiary picture of no association between media multitasking and cognitive flexibility. Another facet of the study is the novel inclusion of the phonetic and semantic fluency tasks as measures of cognitive flexibility (Diamond, 2013). These tasks have also been characterised as assessing flexibility in terms of access to long-term memory (Fisk & Sharp, 2004). Thus, their inclusion could also highlight no association between media multitasking and access to long-term memory.

More interestingly, the study successfully replicated the findings of Becker, Alzahabi and Hopwood (2013), who specifically used the Media multitasking Index (MMI) of Ophir et al. (2009) and found media multitasking to be a specific distinctive risk factor for mental health issues related to anxiety.

With the present study finding higher levels of anxiety associated with a greater MMI score, reflecting more frequent media multitasking.

To conclude, Study 1 was a crucial starting point, as it provided the footings of exploring the associations between media multitasking and executive functioning. Demonstrating no association between individuals frequency of media multitasking and their executive functioning, based on findings that are more relevant to current real-world media multitasking as the study used an adapted version of the Media Multitasking Index (Ophir, Nass & Wagner,2009), modified to represent the current media multitasking environment.

8.4 Novel explorations- Media multitasking ability and proximal effects of media multitasking: a review of findings

The latter two empirical investigations of the thesis were the most novel and utilised similar media multitasking set ups, in the context of participants engaging with multiple media streams. In addition to the use of some of the same executive function tasks.

To begin with, study 2 found no association between media multitasking and trait anxiety and depression. This is interpreted as highlighting the cumulative nature of the relationship between media multitasking and anxiety. That being, the frequency with which individuals engage with media multitasking is more imperative to their mental health in terms of anxiety, which was found in study 1.

In regards to executive functioning, the first of these two studies, study 2 found no association between attentional control, response inhibition and ability to media multitask, in the terms of recalling information from a media multitasking situation. Interestingly, study 3 found no effect of media engagement, (both media multitasking and sequential media engagement) on attentional control or response inhibition. Thus, the findings give emphasis to the non-involvement of attentional control in being able to media multitask, which is further evidence by the lack of a proximal effect of media engagement, inclusive of media multitasking on these two aspects of executive functioning. Given the combined findings of study 1, 2 and 3, the thesis provides a clear demonstration of no association with, nor effect of media multitasking on inhibition

In terms of the other aspects of executive functioning, Study 2 found cognitive flexibility to be associated with media multitasking ability, and no association between working memory and media multitasking ability. The findings indicate no connection of working memory, which can be considered somewhat un-expected considering the perceived processes of engaging with multiple streams of media and recall of information from said engagement. Nonetheless, the finding of the key role of cognitive flexibility in media multitasking ability, may account for the lack of association with working memory in the context that cognitive flexibility is a function underpinned by inhibition and working memory (Diamond, 2013). That being, the media multitasking situation may have placed a greater demand on cognitive flexibility, compared to other executive functions. Furthermore, the phonetic and semantic fluency tasks were used to index cognitive flexibility and found to be significantly associated with media multitasking ability. Considering they are tasks also known to index access to long-term memory, these findings may highlight an association between media multitasking ability and access to long-term memory rather than working memory.

Moving forward, study 3 found the opposite proximal effects of those expected, with performance on the backwards digit span, trail making task and phonetic fluency task significantly increasing following media engagement, for both the sequential media engagement and the media multitasking groups. This indicates that any form of media engagement does not fatigue working memory or cognitive flexibility, but instead has a beneficial effect. This beneficial effect of media engagement on executive function may underpin the discrepancies in the research exploring frequency of media multitasking. In the sense that the studies purport biases based on cumulative media multitasking having a negative effect on cognitive flexibility and working memory. Indeed, the combination of study 2 demonstrating an association between cognitive flexibility and media multitasking ability and study 3 finding media engagement to increase cognitive flexibility performance can be interpreted to indicate that media multitasking may indeed utilise cognitive flexibility but not necessarily place a heavy demand on this aspect of executive functioning. Similarly, the combination of the working memory findings of study 2 and 3 may be fundamental to the pervasively inconsistent cumulative associations of media multitasking and working memory. Considering they demonstrate media multitasking as not necessarily taxing working memory, it is unlikely that a cumulative negative (taxing) association will be found. Thus, the findings further evidence no association between media multitasking and working memory, supporting the findings of study 1 of this thesis and previous evidence showing no association (e.g. Cain et al., 2016, Minear et al., 2013, Cardoso-Leite et al., 2016). In addition, the findings provide support for research showing a cumulative positive association of media multitasking and cognitive flexibility, such as Alzahabi and Becker (2013) and Alzahabi, Becker and Hambrick, (2017). Furthermore, the increase in performance on the phonetic fluency task also indicates a possible beneficial effect of media engagement on access to long-term memory.

To conclude, these two empirical investigations provided a truly original contribution to the literature, revealing a possible explanation of the inconsistent research of associations between frequency of media multitasking, working memory and cognitive flexibility. The latter of these studies utilised a pre and post media engagement assessment of executive function, thus increases in performance could be susceptible to the issue of practice effects. Nonetheless, it was crucial in determining causality, of which establishing causality is imperative considering the correlational evidence of associations between media multitasking and executive function. Certainly, research is attempting to establish causality through the use of varying methodology, for example Baumgartner, Van der Schuur, Lemmens and te Poel (2017) recently used cross-lagged correlations to explore self-reported attentional problems in relation to media multitasking at various time lag intervals (3 month and 6 month), finding a potential harmful long-term effect of media multitasking for early adolescents.

8.5 Associations and impact of media multitasking on state mood

Throughout study 2 and 3, state mood, inclusive of; arousal, anxiety and depression were explored to determine fluctuations in mood associated with experimental events, as previous research has found associations between media multitasking and negative and positive affect (Hatchel, Negriff and Subrahmanyam, 2018). In terms of state anxiety, only study 3 revealed a significant increase in anxiety associated with media engagement, with both sequential and media multitasking increasing feelings of anxiety. More interestingly, media multitasking and media engagement (inclusive of media multitasking) were found to specifically significantly decrease self-reported levels of arousal, and exacerbate (increase significantly) self-reported levels of depression. Which can be purported to be indicative of a general fatiguing effect on mood.

8.6 Implications

Study 1, published as Seddon et al. (2018), was clear in showing no association between self-reported media multitasking and executive function, advancing the literature, bolstering previous null findings. Similarly, study 2 found no association between media multitasking ability, inhibition and working memory, and study 3 demonstrated no negative effects of media engagement on executive functioning no. Thus, the findings of the thesis found no evidence that media multitasking is as cumulatively harmful as suggested by sensationalist headlines in the media, inclusive of; "multitasking makes your brain smaller and could be damaging your career" as featured in the Mailonline, (Zolfagharifard, 2014); "Why the modern world is bad for your brain" as featured in The Guardian (Levitin, 2015) and "Why multitasking is BAD for your brain: Neuroscientist warns it wrecks productivity and causes mistakes" as featured in the Mailonline (O'Hare, 2017). Media multitasking was also an issue of concern, that was brought up for debate in the House of Lords by Baroness Greenfield who postulated the harmful effects of technological engagement with multiple media and through multiple devices on individuals' cognition, labelling it as productive of "mind change" (United Kingdom, House of Lords, Parliamentary Debates, 2011). In this regard, there is no evidence here that young adults should be concerned with the extent to which they media multitask, as the evidence would indicate no cumulative detrimental effect of this behaviour on their executive functioning. Additionally, policy makers should not worry about young adults media multitasking as a general activity being harmful to their cognition, although clearly there can be harmful consequences in specific settings such as lectures. However, the study 1 did find an association between self-reported media multitasking and trait anxiety.

Regarding anxiety, there is an interesting implication, considering the use of a correlational design and the lack of being able to establish cause and effect. It is not known whether more anxious individuals' media multitask more frequently or whether more frequent media multitasking increases anxiety. Indeed, anxious individuals have been shown to demonstrate issues with attentional control, with Eysenck, Derakshan, Santos and Calvo (2007) proposing the attention control theory, which details the mechanism by which anxiety impairs the goal-directed attentional system. Furthermore, there is evidentiary support of this theory with research finding trait anxiety to interfere with performance on a variety of attentional control tasks. Tasks such as; an antisaccade task (Derakshan, Ansari, Hansard, Shoker & Eysenck, 2009), the ANT-I task (which is a task that follows a flanker procedure with a spatial cuing paradigm) (Pacheco-Unguetti, Acosta, Callejas & Lupiáñez, 2010), and visual search tasks, inclusive of a letter search task (Bishop, 2009) and a colour singleton task (Moser, Becker, & Moran, 2011). Furthermore, it is important to highlight that the anxiety associated cognitive deficits have been found when using emotionally neutral tasks, such as those mentioned previously, thus the anxiety related cognitive deficits are not just a product of the anxiety associated threat bias (Berggren & Derakshan, 2013). Additionally, despite the null findings of study 1, many studies do indicate a negative bias between attention and media multitasking. Thus, it is possible that anxiety could be driving the attentional control association in media multitasking – i.e., people with higher anxiety have problems with attentional control and are also driven to media multitask more often. Indeed, Przybylski, Murayama, DeHaan, and Gladwell, (2013) found that a person's need to be constantly connected to social media is driven by anxiety, a specific anxiety characterised by the worry of not being included and missing out on what other individuals are doing (e.g. not being on Facebook or Instagram when others are). This is known specifically as "Fear of missing out" (FoMo), which has been specifically associated as a motivator for media multitasking (Reinecke, Aufenanger, Beutel, Dreier, Quiring et al., 2017). Thus, media usage, inclusive of media multitasking, could be driven by anxiety, which may have been reflected in the findings of study 1, as performance on the attentional inhibition and response inhibition tasks did not correlate with trait anxiety or media multitasking, media multitasking only correlated with trait anxiety. Furthermore, Gorman and Green (2016) included a short-term mindfulness intervention and found that performance on attention tasks improved following the intervention, with heavy media multitaskers benefitting to a greater extent than light media multitaskers. Thus, it might be possible that the heavy media multitasking individuals in Gorman and Green's (2016) study had higher levels of anxiety compared to light media multitaskers, as mindfulness has been found to reduce anxiety (Hofmann, Sawyer, Witt & Oh, 2010; Hofmann & Gomez 2017), and that their performance increased as a result of a reduction in their anxiety. However, the study did not include an assessment of anxiety. Therefore, young adults should be concerned with the possible impact media multitasking has in relation to their well-being, particularly, whether their engagement with media multitasking is driven by anxiety or if their media multitasking is increasing their anxiety. Furthermore, policy makers should also be concerned with the implications on young adults mental well-being associated with their media multitasking.

Study 2 provides novel real-world implications in relation to individuals' media multitasking behaviours. Specifically, it highlights a role of cognitive flexibility in individual's ability to media multitask and demonstrates that media multitasking across multiple devices is not inherently more difficult than media multitasking within a single device. Although, those who media multitasked across devices did take longer to respond to instant messages. Thus for individuals who prefer to media multitask across devices rather than within a single device, it makes no detriment to their remembering of information from their multitasking experience (e.g. if they wanted to retain information from watching T.V whilst instant messaging). However, it also highlights that if an individual wishes to media multitask more efficiently, it could be better for them to media multitask within a single device.

Additionally, the study expands the current literature, as executive functioning in relation to media multitasking ability has not previously been explored, nor has the implementation of a media multitasking situation, inclusive of three media streams, been utilised in the assessment of media multitasking ability. The study also brings to the forefront a further research question as to what motivates individuals to media multitask. Is the recall of information from a media multitasking situation important to individuals' decision to media multitask? Certainly, individuals' motivations for media multitasking differ depending on the context or need, whether it is for leisure, work or if it is habitual. For example, Wang and Tchernev (2012) found the need to media multitask as a force of habit further perpetuates the gratification from carrying out the behaviour and reinforces individuals to continue to media multitask. Furthermore, the study also found that media multitasking is often incorporated to make an experience more enjoyable, such as watching T.V. whilst studying. Convenience can also be a motivator (Zhang & Zhang, 2012), with an example being someone watching T.V. whilst instant messaging a friend about a birthday present for another friend, whilst looking for the birthday present online. Thus, the various motivations to media multitask are also an important factor in how often individuals' media multitask. Motivation could also be a factor in the extent to which each executive function: inhibition, working memory and cognitive flexibility are involved in media multitasking. It is possible that motivation dictates the specific components of media multitasking, e.g. instant messaging whilst watching music videos on T.V., and that specific media streams and combinations of media behaviours may place different demands on executive function than other combinations. Thus, motivation to media multitask and task specificity may be key in understanding the associations between executive function and the ability to media multitask. Furthermore, this may have further implications on how often individuals' carry out specific media multitasking behaviours and consequential cumulative effects. For example, attentional and response inhibition may be more strongly involved when individuals have a clear primary task.

Lastly, study 3 adds to the literature in terms of originality and novelty through the exploration of the proximal effects of media multitasking on executive function, which to our knowledge has never been done before. The study was clear in demonstrating no evidence of a negative impact of media multitasking on subsequent executive functioning, instead finding positive effects. Thus, the study highlights potential difficulties of assessing executive function at multiple time points, considering an increase in performance could be a result of practice effects. Which provides insight into design considerations for future research interested in exploring the proximal effects of media multitasking

Overall, the research presented in this thesis has implications for the academic literature and the real world. The exploration of frequency of media multitasking highlighted no cumulative effects, indicating media multitasking may not be as detrimental to one’s cognition as reported in the media, which is further supported by the evidence showing no proximal effects of media multitasking on executive functioning. Thusly, indicating that young adults may not need to be concerned with their media multitasking behaviours in terms of their executive functioning. However, trait anxiety was associated with how often individuals media multitask, and therefore young adults should consider whether anxiety is driving them to media multitask or whether they feel anxious after media multitasking. Furthermore, general engagement with media, inclusive of media multitasking can result in a fatiguing effect on mood, which young adults should consider in relation to carrying out other tasks and their level of arousal (e.g. should I media multitask if I need to be more alert to go driving?). Lastly, in terms of media multitasking within or between devices, it is more efficient to media multitask within a single device, but using multiple devices is no more detrimental when trying to recall information from the media that has been engaged with.

8.7 Limitations

Through conducting three empirical studies, a number of limitations arose. Starting with the initial exploration of self-reported media multitasking, the main limitations surround the use of the Media multitasking index (MMI) (Ophir et al., 2009). An adapted version of the MMI was used, to update the questionnaire to better represent the current climate of media multitasking behaviours. The adaptations may have made the MMI more ecologically valid, however it did not eliminate the issues surrounding the answers given by participants. Indeed, people might struggle to accurately estimate the true nature of their media multitasking behaviours, which could be further exacerbated by the way in which the media landscape has evolved. The advent of smartphones, tablets and other devices has enabled a reality in which individuals have instant access to various media, which has resulted in individuals constantly checking internet enabled devices, inclusive of phones (Boase & Ling, 2013), whether it is to go on Facebook, check messages or go on the internet. However, this need to be constantly connected, or habitual media engagement behaviour (Aagaard, 2014), means individuals do not realise the extent to which they are checking their phones (Boase & Ling, 2013). As with any self-report measure, there is also the issue that participants may respond with answers they perceive to be more desirable. Furthermore, the way in which the MMI score is constructed is insensitive to the complexities of media multitasking behaviours, failing to provide a distinction between individuals carrying out complex media multitasking behaviours and those who are simply engaging in a second media as a means of distraction. Based on the way the MMI gives each media behaviour combination the same mathematical weighting and treats all combined media behaviours equally to one another (Wilmer et al., 2017).

A further limitation was the failure to produce a reliable model of latent constructs reflecting Diamond's (2013) executive function framework, which was possibly a result of shared method variance of executive function tasks implemented. Therefore, the solution to this would be to utilise a larger battery of tasks that are more distinctly different from each other, however, this brings about further practical issues of time commitment, considering the focus on all three aspects of executive functioning and not just a single function.

Following on from this, the limitations with study 2 were in regards to the way in which media multitasking ability was assessed. In this study, recall of information from a media multitasking situation was utilised to represent individuals' ability to media multitask. Thus, participants might have focused more on one media than the other. However, they were instructed to pay equal attention to each of the media, which was examined through exploring the scores to the individual media components, checking to see if participants had achieved a minimum of 25% on each set of media questions (there were four multiple choice options to each question). Those who failed to do so were deemed as non-compliant and removed, (only three participants). Furthermore, the method of assessment may have been restrictive in capturing a connection between inhibition and media multitasking, as it is more of a memory based assessment. A solution to this would be the additional use of eye tracking, as used by Kazakova et al., (2015). Lastly, a non-media multitasking condition was not included, thus the interpretations of the findings are somewhat limited,, nor can cause and effect be established, which is also applicable to study 1.

Study 3 developed and applied a novel methodology for investigating the proximal effects of media multitasking on subsequent performance of executive function tasks, which raised the issue of practice effects on the executive function tasks. This is an inherent issue with measuring executive function at multiple time points, as the nature of measuring executive function is that assessments need to be novel (Burgess, 1997; Rabbit, 1997; Phillips, 1997; Snyder, Miyake & Hankin, 2012). However, some tasks are more susceptible to practice effects than others, which may be the case with the backwards digit span, Trail Making and phonetic fluency tasks in study 3, as the study found performance on these tasks to improve the second time they were completed. Both the use of different tasks that are meant to measure the same executive function of interest, and parallel versions of tasks, (parallel in terms of altering the specific stimuli used), have been suggested as a way of assessing executive function performance at multiple time points (Bartels, Wegrzyn, Wiedl, Ackermann & Ehrenreich, 2010; Falleti, Maruff, Collie & Darby, 2006). A further issue concerns the media multitasking situation used. In study 3, media multitasking included watching a video and reading a piece of text. Whereas study 2 included reading a piece of text, watching a video and responding to instant messages. Instant messages were removed from study 3, as including instant messages would have created a media multitasking demand even in the sequential group. Thus the media multitasking scenario may not have been complex enough to illicit any proximal negative effects of media multitasking on executive functioning. The inclusion of only a single session of media multitasking may also not have provided a strong enough manipulation, which could be resolved with the inclusion of multiple sessions of media multitasking.

8.8 Future research

Through the progression of the thesis, various directions for future research were brought to light. Study 1 explored self-reported media multitasking and executive function. The study utilised a battery of ten executive function tasks and attempted to model the tasks into representative factors, similar to that of Alzahabi et al., (2017). Unfortunately, this resulted in a non-substantive model with an issue of shared method variance. Furthermore, the study added to the mixed evidence in the literature of the working memory and media multitasking association. In this regard, future research could conduct a single study, utilising a large number of working memory tasks (e.g. N-back, backwards digit span, backwards Corsi block) and then attempt to model the tasks into factors. This type of investigation would be beneficial as the reduction of working memory tasks into latent constructs, that reflect various aspects of the executive function of working memory, may highlight the specific aspects of working memory that are associated with media multitasking Indeed, this would be especially valuable in terms of addressing the evidence, that may have been obscured by studies that have used different definitions of working memory and resulting tasks. Consequently, this approach would advance our theoretical understanding of the media multitasking associations with self-reported media multitasking, going beyond the performance on individual tasks and help to disentangle the inconsistent evidence.

Furthermore, study 1 highlighted an association between trait anxiety and media multitasking, which as stated above could be an underlying mechanism for the association between media multitasking and attentional control. Specifically, more frequent media multitasking has been associated with biases in attentional control (e.g. Ophir et al., 2009) but not in this thesis, and anxiety has been associated with biases in attentional control (e.g. Pacheco-Ungetti, Acosta, Callejas & Lupiáñez, 2010). It would be worthwhile for research to explore anxiety, attention and self-reported frequency of media multitasking utilising a moderation/mediation analysis approach. This would enable the mechanism underlying attentional control issues associated with media multitasking to be distinctly determined, and to elucidate whether anxiety or media multitasking is driving the biases in attentional control, in addition to determining whether anxiety is driving people to media multitask more frequently.

In terms of study 2, the findings highlight the need for future research to continue to explore objective measures of media multitasking in relation to executive function. Considering the novelty of this approach, future research could explore other executive function tasks previously used in the literature (e.g AX-CPT with distractors, filter/change detection task, N-back or dots and triangles), to see if findings can be replicated with measures of media multitasking ability. A further methodological innovation would be to utilise eye tracking alongside the recall of information from the media multitasking situation, which may more accurately capture the involvement of attention in media multitasking ability. Eye tracking technology can provide information on where the participant has spent the majority of their time looking through measures of dwell time. Specific screen locations can be set, so that switching between multiple locations can be examined in terms of both frequency and total time, inclusive of heat map representations. For example, if eye tracking had been implemented in study 2, it would have been possible to examine how much time was spent viewing either the video, text or instant messages. This direct observation of how individuals split their vison across multiple streams of media would also advance our theoretical understanding of how individuals media multitask.

As previously mentioned, a limitation with Study 3 may have been the relatively low complexity of the media multitasking situation used, in addition to the fact that only a single session of media multitasking was included. Future research should continue to explore the proximal effects of media multitasking and possibly include a condition of multiple sessions of media multitasking. It would also be worthwhile for research to undertake longitudinal investigations into media multitasking and executive function, focusing on previous associations that have been found. An approach previously discussed that was recently used by Baumgartner et al. (2017), to explore the media multitasking associations with attentional control. Indeed, a longitudinal approach would help in the progression of disentangling cause and effect.

8.9 Conclusion

In sum, the research presented within this thesis found no evidence that self-reported frequency of media multitasking is associated with three aspects of executive functioning: inhibition, working memory and cognitive flexibility. Contrastingly, the research highlights that there is a role of cognitive flexibility in individuals' ability to media multitask, when assessing recall of information from a media multitasking situation. It also demonstrates the possibility of a role for working memory in supporting this process. Thusly, in combination with previous research the working memory association with media multitasking is in desperate need of clarification. Furthermore, media multitasking across multiple devices is not necessarily more difficult than media multitasking within a single device, again when the motivation is to recall information from a media multitasking situation. It is simply less time efficient, although this depends on the specifics of the various media multitasking activities constituting a period of media multitasking. Additionally, no evidence was found that media multitasking fatigues executive functioning, although media engagement inclusive of media multitasking had a generally negative effect on self-reported feelings of fatigue. Future research should make headway by focusing on objective measures of media multitasking and exploring a range of executive functions, with the inclusion of multiple sessions of media multitasking. It may also be useful for researchers to include measures of trait anxiety in future work. Thus, the research presented in this thesis and the potential future directions for research continue to highlight the vital importance of elucidating the relationship between media multitasking and executive functioning.

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Appendices

Appendix 1- Summary tables of studies reviewed in chapter 3

Appendix 1a: Summary of research exploring media multitasking and attentional control

Task	Author	Approach	Task/Measures	Main Findings
AX-CPT				
	Ophir et al., (2009)	Extreme groups	AX-CPT with distractors	HMMs slower than LMMs on both AX and BX trials
	Cardoso-Leite et al., (2016)	Extreme groups, including intermediate media multitaskers	AX-CPT with and without distractors	HMMs overall worse performance, no specific distractor interaction
	Wiradhany and Nieuwenstein (2017)	Extreme groups	Experiment 1- AX-CPT with distractors	HMMs slower than LMMs on BX trials only. However, issue with evidence indicated by Bayesian analyses
			Experiment 2- AX-CPT with distractors	HMMs slower than LMMs on AX trials, not BX. Bayesian analyses indicating moderate to strong evidence.
Flanker				
	Baumgartner et al., (2014)	Full continuum/extreme groups	Flanker task- arrow	HMMs faster response times on incongruent trials. More media multitasking associated with less distraction by irrelevant information.
	Gorman and Green (2016)	Extreme groups	Flanker task- arrow	HMMs performed worse than LMMS (Z-scores of response time and accuracy)
	Murphy et al., (2017)	Extreme groups, including average media multitaskers	Flanker task- letters, low and	No difference in media groups performance

			high perceptual load conditions	
other				
	Cain and Mitroff (2011)	Extreme groups	Singleton distractor task	HMMs responded more quickly than LMMs. Significant interaction between condition and group, LMMs modulated performance between conditions to a greater extent than HMMs.
	Lui and Wong (2012)	Full continuum/ extreme groups	Visual search, with auditory signal	Positive correlation between MMI and accuracy of multi-sensory integration index. HMMs larger multisensory integration effect in terms of accuracy compared to LMMs.
	Minear et al., (2013)	Extreme groups	Attention Network Task (ANT)	No significant difference in HMMs and LMMs executive attention, orienting of attention and alerting attention.
	Yap and Lim (2013)	Extreme groups	Attention location task- Empty white square and white dot that changed locations (McCormick, Klein and Johnston, 1998)	HMMs response times to targets in cued locations compared to targets in irrelevant locations faster than LMMs. HMMs demonstrate a split mode of attention.

	Moisala et al., (2016)	Full continuum	Sentence congruency, in 3 conditions (undistracted, distracted and divided attention)	No main effect of MMI in undistracted condition and divided attention. Distracted attention significant main effect of MMT. Correlation between MMT score and activity in the right prefrontal cortex during distracted attention
	Ralph et al., (2015)	Full continuum	Experiment 1- Metronome Response Task (MRT)	Significant positive correlation between MMI and MRT response variability
			Experiment 3a	Significant positive correlation between MMI and MRT response variability. However, became marginal after controlling for age.

Appendix 1b. Summary of research exploring media multitasking and response inhibition

Author	Approach	Task/Measures	Main Findings
Ophir et al., (2009)	Extreme groups	Stop-signal (animal/non-animal categorisation)	No difference between HMMs and LMMs performance.
		Standard AX-CPT (that Ophir et al. suggest is a response inhibition task	No difference between HMMs and LMMs in accuracy and response times.
Ralph et al., (2015)	Full continuum	Experiment 2- SART	No significant association between MMI and No-Go errors and response times.
		Experiment 3b-SART	No significant correlation between MMI and response times.
			Borderline significant correlation between MMI and no-go errors.
		Experiment 4-vigilance task	Weak significant correlation with overall sensitivity.
Gorman and Green (2016)	Extreme groups	TOVA-Go-No go with square stimuli	HMMs performed worse than LMMs, with higher z-scores of reaction time and amount of incorrect errors.
Murphy et al., (2017)	Extreme groups, including average media multitaskers	Go-No go task- Letter and shape colour (low and high perceptual load versions)	Average media multitaskers made more errors than LMMs and HMMs in high load condition.
			No difference between LMM and HMM in terms of errors in high load condition.

Appendix 1c. Summary of research exploring media multitasking and working memory, by year of publication and type of task used

Task	Author	Approach	Specific task used	Main Findings
Filter task				
	Ophir, et al., (2009)	Extreme groups	Rectangles filter task	HMMs linearly negatively affected by distractors. LMMs unaffected by distractors.
	Gorman and Green (2016)	Extreme groups	Rectangles filter task	HMMS performed worse than LMMs, based on sensitivity, No significant interaction between group and amount of distractors
	Uncapher et al., (2016)		Rectangles filter task	LMMs hold task relevant representations in mind compared to HMMs. HMMs struggle to discriminate between change (greater false alarm rate). No difference in HMMs and LMMs hit rate.
	Cardoso-Leite et al., (2016)	Extreme groups	Rectangles filter task	HMMs performed worse than LMMs and IMMs. No significant difference in distractor effects.
	Cain et al., (2016)	Full continuum	Circles featuring red or yellow stars (3 trial types; high and low mneumonic load, and distractor)	No association between media multitasking and performance (difference in accuracy between low-mneumonic trials and distraction trials).
	Wiradhany and Nieuwenstein (2017)	Extreme groups	Experiment 1- Rectangles filter task	HMMs performed worse overall compared to LMMs. LMMs increased susceptibility to distractors.
			Experiment 2- Rectangles filter task	No significant difference between HMMs and LMMs. No significant interactions between group and distractor sets
Span Tasks				

	Minear et al., (2013) experiment 1	Extreme groups	Automated reading span	No significant difference between HMMs and LMMs performance.
	Sanbonmatsu et al., (2013)		OSPAN	Significant negative correlation with MMI and OSPAN task performance
	Baumgartner, (2014)	Full continuum	Forwards and Backwards digit span	Media multitasking did not significantly predict performance in terms of total score.
	Gorman and Green (2016)	Extreme groups	Backwards digit span	No significant difference in HMMs and LMMs performance, in terms of accuracy.
	Cain et al., (2016)	Full continuum	Count span	More frequent media multitasking associated with lower working memory capacity
N-back				
	Ophir et al., (2009)	Extreme groups	2-back and 3-back	HMMS more false alarms on 3 back.
	Cain et al., (2016)	Full continuum	1,2,3-back	More frequent media multitasking associated with overall performance (hits minus false alarms)
	Cardoso-Leite et al., (2016)	Extreme groups	2-back and 3-back	No significant difference in HMMs and LMMs performance, in terms of overall false alarm rates
	Ralph and Smilek (2017)	Full continuum	2-back and 3-back	Heavy media multitasking associated with poor performance on 2-back and 3-back. Higher MMI score predicted less hits on 2-back. Media multitasking measured using MMI-2 predicted false alarms, higher score more false alarms. Significant positive correlation between media multitasking and omitted trials
Probe task				
	Miner et al., (2013)	Extreme groups	Recent probes item recognition	No difference between HMMs and LMMs accuracy or response times on recent vs non-recent probes

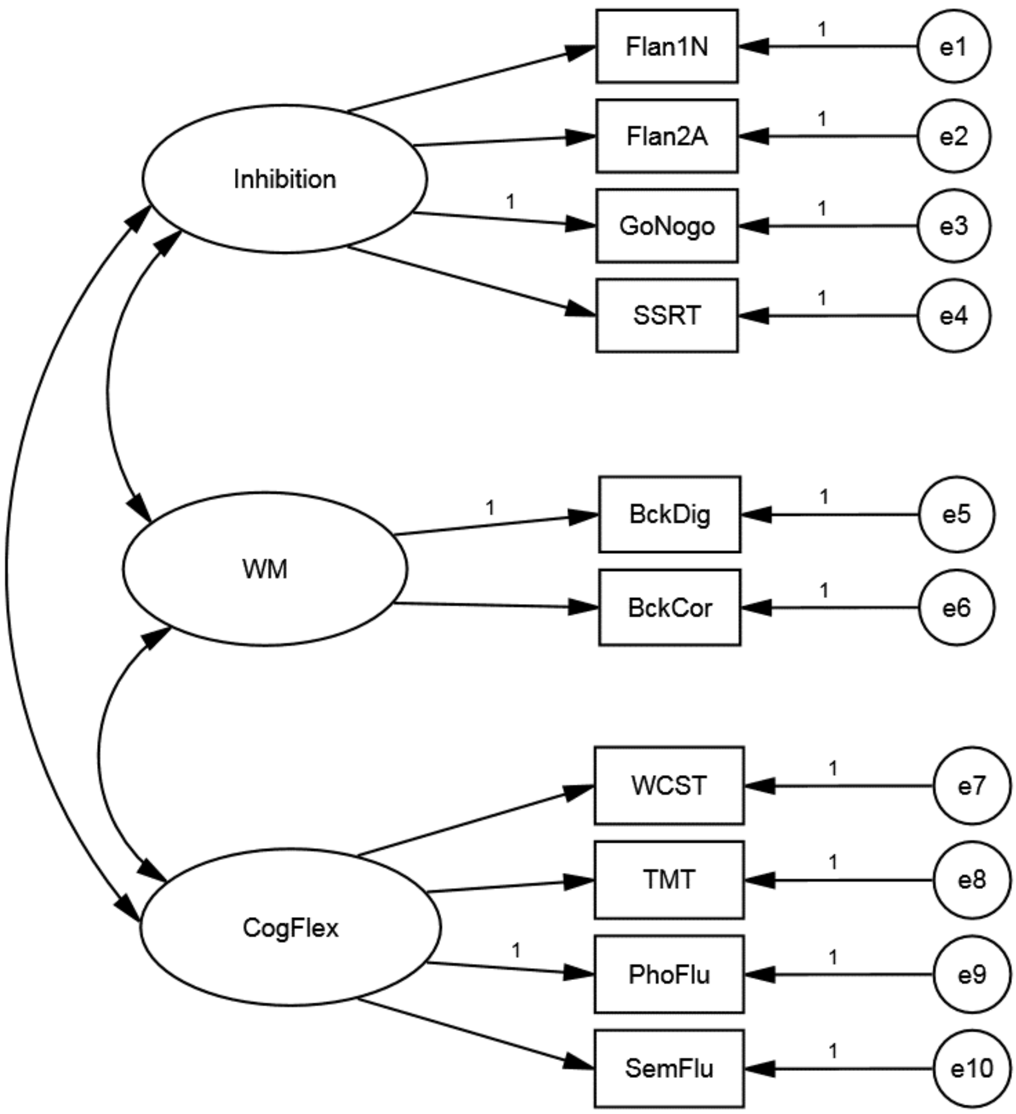
Appendix 1d . Summary of research exploring media multitasking and cognitive flexibility (task switching), by year of publication

Author	Approach	Task/Measures	Main Findings
Ophir et al., (2009)	Extreme groups	Number/Letter categorisation switching task	HMMs significantly slower than LMMs in both switch and non-switch trials based on switch cost.
Alzahabi and Becker (2013)	Full continuum/ extreme groups	Dual task and task switching- Number letter categorisation	Media multitasking negatively correlated with task switching. Group and trial type interaction; HMMs less slowing in switch trials. No association between all dual task measures and MMI.
Minear et al., (2013)	Extreme groups	Experiment 1- Number/Letter categorisation switching task	No group difference in task-switching performance as indicated by switch cost and mixing
		Experiment 2- Number/Letter categorisation switching task	No group difference in task-switching performance as indicated by switch cost and mixing
Baumgartner et al., (2014)	Full continuum/ extreme groups	Dots and Triangles	No association with media multitasking and task-switching in terms of switch cost.
Cardoso-Leite et al., (2016)	Extreme groups, including intermediate media multitaskers (IMMs)	Number/Letter categorisation	No significant difference between HMMs and LMMs in terms of inverse efficiency scores.
Gorman and Green (2016)	Extreme groups	Number categorisation- odd/even and high/low	No significant difference in heavy media multitaskers and light media multitaskers performance (z-scores of response time and accuracy).
Alzahabi, Becker and Hopwood (2017)	Full continuum	3x Classification tasks Animal/Furniture Number/Letter Plant/Transport	Media multitasking associated with ability to prepare in advance during task switching and faster ability to reconfigure tasks. Media multitasking associated with shorter time to switch.
Wiradhany and Nieuwenstein (2017)	Extreme groups	Experiment 1- Number/Letter categorisation	HMMs slower in switch trials than LMMs, HMMs have a larger switch cost than LMMs.

	Experiment 2- Number/Letter categorisation	HMMs were not slower than LMMs in repeat trials. HMMs significantly slower in switch trials than LMMs No significant difference in switch costs and repeat trial response times

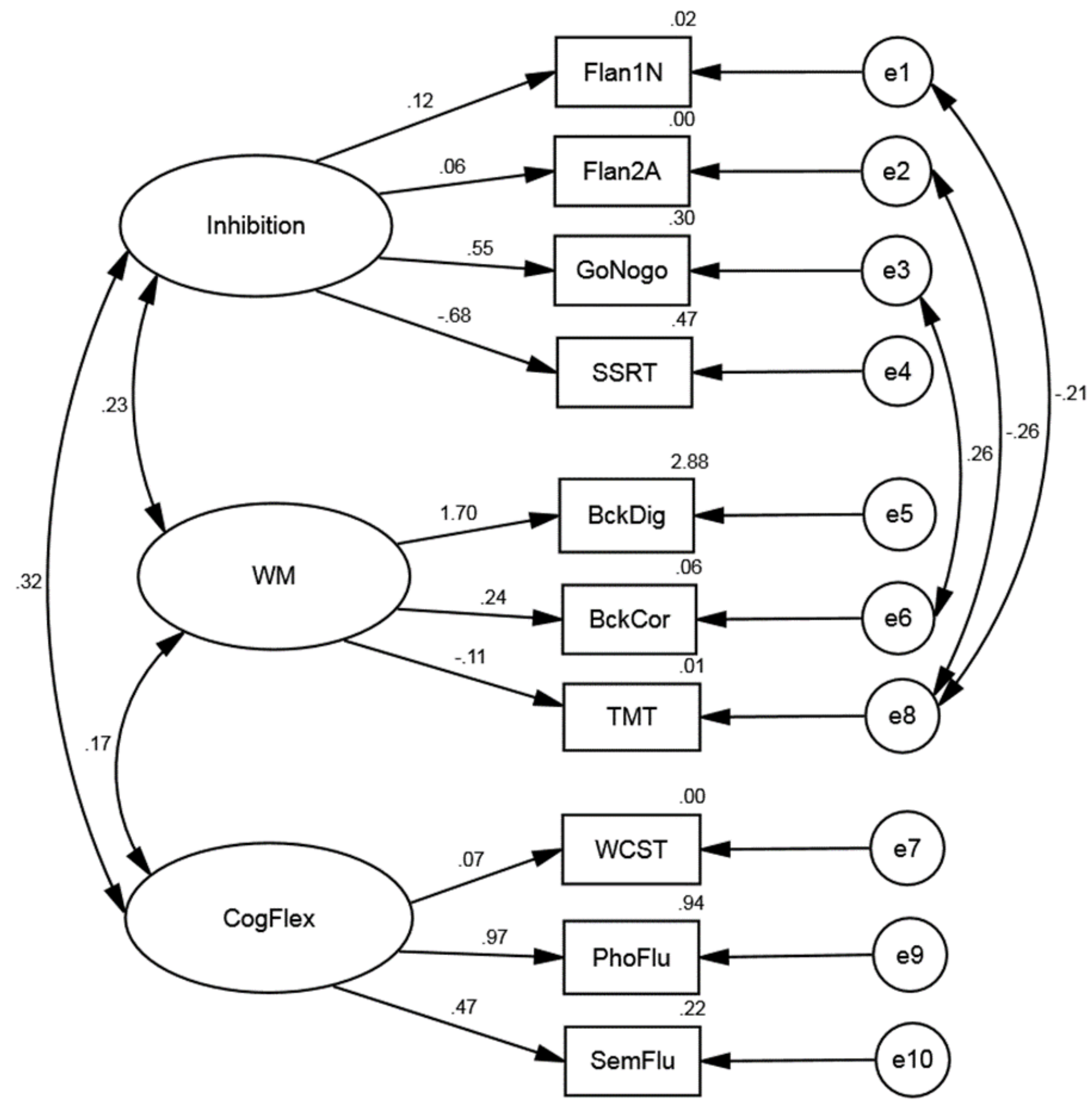
Appendix 2- Graphical representations of three factor models

Model 1



χ^2 = 54.204, P= .008, DF = 32, CFI= .755, NFI= .601, RMSEA= .082

Model 2



χ^2 = 30.677, DF= 29, CFI= .982, NFI= .774, RMSEA= .024

Appendix 3. Pilot study summary for study 2 media multitasking situation and multiple-choice tests

In study 2 participants had to complete an objective measure of media multitasking which consisted of a media multitasking situation. The situation involved participants watching a video, whilst reading a piece of text, whilst responding to instant messages. These media were chosen based on previous literature utilising; reading task, video and instant messaging. The specific video/s were chosen as they were non offensive, freely available and deemed not widely viewed by our target audience, the latter of which was confirmed when asking participants if they had seen the videos before. The specific texts were chosen as they were deemed neutral rather than emotional in nature and differed in context from the videos.

Furthermore, as discussed in chapter 6, media multitasking ability would be assessed through a composite score reflecting recall of content from the video and from the piece of text. Thus, tests pertaining to the content of each media needed to be created. Multiple-choice recall tests were developed for both the video and Text. The video multiple-choice test included a total of 57 questions with four multiple-choice options per question (see appendix 7a). The reading questionnaire included 26 questions with 10 referring to the 1st piece of text (see appendix 7b) and 16 referring to the second piece of text on cables (see appendix 7b). The first piece of text was taken from Simmons and Singleton (2000) and therefore the reading recall test for this piece of text was adapted from the questionnaire used by Simmons and Singleton (2000) (See appendix 7b for initial reading recall test). For the initial recall test for the 2nd piece of text see appendix 7c.

The video and reading recall tests were initially piloted on a sample of 16 students who were recruited via opportunity sampling. The piloting had been ethically approved by the University Research Ethics committee and was ran in accordance with BPS ethical guidelines. The pilot, had participants complete the whole media multitasking situation. That being, participants watched the video, read the pieces of text and responded to instant messages. In this sense, we were able to assess the running of the experiment in addition to refining the two questionnaires. Participants in this pilot completed the 57 question version of the video multiple-choice test and the 26 question version of the reading multiple-choice test.

Following the piloting, scores on the tests were investigated in order to see which questions were most commonly correct and incorrect. Please see Table 1, Table 2 and Table 3 below. From observing this, decisions were made to improve the questionnaires. This led to the removal of 15 questions from the video multiple-choice test (leaving 42 questions), and the editing of the reading text and reading recall test, with the change and addition of questions, increasing the number to 42. Thus, the reading recall test would have the same amount of questions as the video test, with 20 on the Craigworth text and 22 on the cable text.

Furthermore, after this pilot of the entire media multitasking situation, we decided that we would like to record response times to the instant messages, so that we could compare average time to respond to messages across the two media multitasking groups in study 2, see chapter 6. In this regard, a further pilot of the media multitasking situation, inclusive of the new recall tests for both the text and video was conducted. This last pilot was on a sample of 5 students. The scores from the reading and video multiple-choice tests were both explored to assess whether participants had payed equal attention to all aspects of the media multitasking situation, as instructed. Please see Table 5 and Table 6 for percentage response to questions, and Table 7 for overall scores. It was important to have a composite score that reflected media multitasking ability and thus if individuals' scored lower than 25% on either of the multiple-choice tests, they would have been classed as not paying equal attention to both media (non –compliance). The 25% cut off was chosen based on the likelihood of getting a correct answer when there are four multiple-choice options to each question, in both tests.

Table 1. Amount of participants and percentage of correct answers to each video question from initial pilot

Q1	9 (56.2%)	**Q11**	9 (56.2%)	**Q21**	7 (43.75%)	**Q31**	15 (93.75%)	**Q41**	9 (56.2%)	**Q51**	16 (100%)
Q2	4 (25%)	**Q12**	11 (68.75%)	**Q22**	8 (50%)	**Q32**	9 (56.2%)	**Q42**	13 (81.25%)	**Q52**	11 (68.75%)
Q3	10 (62.5%)	**Q13**	11 (68.75%)	**Q23**	10 (62.5%)	**Q33**	13 (81.25%)	**Q43**	6 (37.5%)	**Q53**	15 (93.75%)
Q4	9 (56.2%)	**Q14**	11 (68.75%)	**Q24**	10 (62.5%)	**Q34**	15 (93.75%)	**Q44**	7 (43.75%)	**Q54**	15 (93.75%)
Q5	4 (25%)	**Q15**	12 (75%)	**Q25**	12 (75%)	**Q35**	13 (81.25%)	**Q45**	11 (68.75%)	**Q55**	9 (56.2%)
Q6	9 (56.2%)	**Q16**	7 (43.75%)	**Q26**	12 (75%)	**Q36**	8 (50%)	**Q46**	6 (37.5%)	**Q56**	11 (68.75%)
Q7	9 (56.2%)	**Q17**	12 (75%)	**Q27**	13 (81.25%)	**Q37**	13 (81.25%)	**Q47**	6 (37.5%)	**Q57**	14 (87.5%)
Q8	10 (62.5%)	**Q18**	5 (31.25%)	**Q28**	14 (87.5%)	**Q38**	12 (75%)	**Q48**	11 (68.75%)		
Q9	8 (50%)	**Q19**	12 (75%)	**Q29**	7 (43.75%)	**Q39**	8 (50%)	**Q49**	8 (50%)		
Q10	10 (62.5%)	**Q20**	9 (56.2%)	**Q30**	9 (56.2%)	**Q40**	14 (87.5%)	**Q50**	13		

Table 2. Amount of participants and percentage of correct answers to each reading text 1 question from initial pilot

Q1	8 (50%)	**Q3**	1 (6.25%)	**Q5**	9 (56.2%)	**Q7**	1 (6.25%)	**Q9**	0
Q2	14 (87.5%)	**Q4**	4 (25%)	**Q6**	4 (25%)	**Q8**	1 (6.25%)	**Q10**	0

Issue with reading article 1, participants scored very low on questions

Table 3. Amount of participants and percentage of correct answers to each reading text 2 question from initial pilot

Q1	9 (56.2%)	**Q5**	3 (18.75%)	**Q9**	7 (43.75%)	**Q13**	9 (56.2%)
Q2	5 (31.25%)	**Q6**	12 ()	**Q10**	5 (31.25%)	**Q14**	7 (43.75%)
Q3	6 (37.5%)	**Q7**	8 (50%)	**Q11**	3 (18.75%)	**Q15**	4 (25%)
Q4	10 (62.5%)	**Q8**	4 (25%)	**Q12**	5 (31.25%)	**Q16**	4 (25%)

Table 4. Overall scores for initial pilot of multiple-choice tests

Participant	**Reading score 1**	**Reading score 2**	**Total Reading Score**	**Video Score**	**Total MMT**	**% IM Response**
1	3	8	11	27	38	100%
2	3	10	13	44	57	100%
3	4	6	10	39	49	100%
4	3	7	10	40	50	90%
5	3	8	11	40	51	100%
6	4	7	11	33	44	100%
7	2	6	8	26	34	100%
8	1	6	7	41	48	100%
9	4	8	12	31	43	100%
10	4	7	11	46	57	100%
11	2	7	9	42	51	100%
12	2	4	6	40	46	100%
13	3	3	16	37	53	100%
14	2	3	5	35	40	100%
15	1	7	8	36	44	100%
16	1	4	5	27	32	100%

Table 5. Percentage correct responses to each video question from 2nd pilot

Q1	40	**Q8**	40	**Q15**	80	**Q22**	60	**Q29**	60	**Q36**	60
Q2	60	**Q9**	100	**Q16**	40	**Q23**	80	**Q30**	0	**Q37**	40
Q3	60	**Q10**	60	**Q17**	40	**Q24**	40	**Q31**	80	**Q38**	80
Q4	40	**Q11**	80	**Q18**	40	**Q25**	20	**Q32**	0	**Q39**	40
Q5	80	**Q12**	20	**Q19**	20	**Q26**	40	**Q33**	40	**Q40**	100
Q6	60	**Q13**	60	**Q20**	40	**Q27**	40	**Q34**	80	**Q41**	80
Q7	20	**Q14**	60	**Q21**	40	**Q28**	60	**Q35**	60	**Q42**	0

N=5

Table 6. Percentage correct response to each reading question from 2nd pilot

Q1	60	**Q8**	40	**Q15**	0	**Q22**	0	**Q29**	60	**Q36**	40
Q2	20	**Q9**	80	**Q16**	0	**Q23**	0	**Q30**	20	**Q37**	40
Q3	60	**Q10**	20	**Q17**	60	**Q24**	40	**Q31**	60	**Q38**	20
Q4	40	**Q11**	60	**Q18**	80	**Q25**	80	**Q32**	40	**Q39**	60
Q5	60	**Q12**	100	**Q19**	60	**Q26**	60	**Q33**	0	**Q40**	60
Q6	60	**Q13**	60	**Q20**	20	**Q27**	20	**Q34**	60	**Q41**	20
Q7	20	**Q14**	60	**Q21**	20	**Q28**	40	**Q35**	20	**Q42**	20

Table 7. Overall scores for reading and video multiple-choice test and resulting media multitasking ability score

Participant	Video Score	Reading Score	MMT Score
1	30	29	59
2	14	16	30
3	22	15	37
4	17	13	30
5	24	14	38

Appendix 4. Reading text

You are about to read two linked pieces of text that are equally as important. The first is a single piece wholly about a factory that manufactures cables. The second is a technical piece about cables that is split into different sub-titled sections

The Craigforth factory

The Craigforth works was the largest manufacturer of copper telecommunications cables in Europe. It was built at the turn of the century by a Victorian businessman called Michael Phillips. In the middle of this century, it was bought by a large multinational corporation. The corporation's head office is situated in Houston, Texas. Nearly all of the employees at the factory belong to a union; the ARA represents the cable makers, whilst the BSB represents those in clerical and technical roles. The relationship between the management and the unions is fairly hostile. Recently, there have been significant redundancies, over the past ten years, the number of people working in the factory has been reduced from over two thousand to less than three hundred. Both external conditions and inefficient working practices have lead to this situation. The copper telecommunication cables manufactured at the site are less in demand, as most exchanges now use optical fibres. The price of copper has increased dramatically. To continue business, the plant must renew its lucrative contract with the telephone company, however, it faces stiff competition from two other firms. There have also been attempts to try to expand the export market, which at present is very limited. The factory's work-force is old; over half the employees are aged over fifty. There is a high incidence of absenteeism, long term ill health problems account for a significant proportion of this. The length of service of many of the staff means they have difficulty accepting change. They have done the same things in the same ways for decades. The modernization initiatives that were designed to address some of the factory's inefficient working practices have had to be carefully negotiated with the unions. Many of the changes were proposed by a young team of crisis management consultants sent from Head Office. As they were outsiders, their ideas were viewed with suspicion. There was also a drive to create a more flexible labour force. The cable making process consists of three stages; core (where the copper is stretched and coated in plastic), twin (where the wires are twisted together) and sheath (where the wires are coated in rubber). Before the modernization initiatives were implemented, the operatives were only trained in the skills necessary for one stage, a programme is now in place to equip the employees with the skills necessary for all three stages. The staffing structure has been changed. The redundancies included a substantial number of staff in white collar roles. Many middle management jobs were viewed as unnecessary, consequently, a flatter management structure was introduced. The whole of the payroll department was scrapped. The old system of a weekly cash payment has been replaced by monthly salary, which is transferred straight into the employee's bank accounts. This new arrangement is administered by head office. A significant number of other clerical tasks can now be done by computers.

On the shop floor, a team-based approach to work has been implemented, supervisors and charge hands have been replaced by team leaders. Much of the work previously done by middle managers has been transferred to the team leaders. Some of the old supervisors who were recruited into these new roles have had difficulty coping with the additional work. They are receiving additional training in computing and people management skills. To encourage the new teams to work well together, they have been sent away with the senior management team on various outdoor activity weekends. They completed a number of tasks designed to improve group working and problem solving skills. Some managers thought that the weekends were a waste of time, they felt that in such desperate times, the company should not be paying for 'holidays'. Union representatives also had reservations about the whole team working approach, they were concerned that it would simply mean fewer people having to do more work. However, there was little risk of industrial action, the employees were frightened by the recent redundancies.

Cable

A **cable** is two or more wires running side by side and bonded, twisted, or braided together to form a single assembly. The term originally referred to a nautical line of specific length where multiple ropes, each laid clockwise, are then laid together anti-clockwise and shackled to produce a strong thick line, resistant to water absorption, that was used to anchor large ships.

In mechanics, cables, otherwise known as wire ropes, are used for lifting, hauling, and towing or conveying force through tension.
In electrical engineering cables are used to carry electric currents. An optical cable contains one or more optical fibres in a protective jacket that supports the fibres.

Etymology

Ropes made of multiple of strands of natural fibers such as, hemp, sisal, manila, and also cotton have been used for 1000 years for hoisting and hauling. By the 19th century, deeper mines as well as construction of larger and larger sailing ships increased demand for stronger ropes. In 1830 the Royal Navy defined a cable as three hawser laid (clockwise) ropes, each approximately 120 fathoms in length, laid anti-clockwise, tightly twisted and shackled to a resulting length of approximately 100 fathoms. The tight twists, shortened the overall length of the ropes but both strengthened the ropes and reduced the ability of the rope to absorb water making them ideal for mooring.

Improvements to steelmaking techniques made high-quality steel available at lower cost, and so wire ropes became common in mining and other industrial applications while continuing the practice of anti-cyclical twists to strengthen them even further. By the middle of the 19th century, manufacture of large submarine telegraph cables was done using machines similar to those used for manufacture of mechanical cables. As the move from rope to wire happened, the specific length associated with a cable fell into disuse. As electricity became even more ubiquitous the practice of using more than bare copper led to groupings of wires and various sheathing and shackling methods that resembled the mechanical cabling so the term was adopted for electrical wiring. In the 19th century and early 20th century, electrical cable was often insulated using cloth, rubber or paper. Plastic materials are generally used today, except for high-reliability power cables. The term has also come to be associated with communications because of its use in electrical communications.

Electrical cables

Electrical cables are used to connect two or more devices, enabling the transfer of electrical signals or power from one device to the other. Cables are used for a wide range of purposes, and each must be tailored for that purpose. Cables are used extensively in electronic devices for power and signal circuits. Long-distance communication takes place over undersea cables. Power cables are used for bulk transmission of alternating and direct current power, especially using high-voltage cable. Electrical cables are extensively used in building wiring for lighting, power and control circuits permanently installed in buildings. Since all the circuit conductors required can be installed in a cable at one time, installation labour is saved compared to certain other wiring methods.

Physically, an electrical cable is an assembly consisting of one or more conductors with their own insulations and optional screens, individual covering(s), assembly protection and protective covering(s). Electrical cables may be made more flexible by stranding the wires. In this process, smaller individual wires are twisted or braided together to produce larger wires that are more flexible than solid wires of similar size. Bunching small wires before concentric stranding adds the most flexibility. Copper wires in a cable may be bare, or they may be plated with a thin layer of another metal, most often tin but sometimes gold, silver or some other material. Tin, gold, and silver are much less prone to oxidation than copper, which may lengthen wire life, and makes soldering easier. Tinning is also used to provide lubrication between strands. Tinning was used to help removal of rubber insulation. Tight lays during stranding makes the cable extensible (CBA – as in telephone handset cords).

Cables can be securely fastened and organized, such as by using trunking, cable trays, cable ties or cable lacing. Continuous-flex or flexible cables used in moving applications within cable carriers can be secured using strain relief devices or cable ties.

At high frequencies, current tends to run along the surface of the conductor. This is known as the skin effect.

Cables and electromagnetic fields

Any current-carrying conductor, including a cable, radiates an electromagnetic field. Likewise, any conductor or cable will pick up energy from any existing electromagnetic field around it. These effects are often undesirable, in the first case amounting to unwanted transmission of energy which may adversely affect nearby equipment or other parts of the same piece of equipment; and in the second case, unwanted pickup of noise which may mask the desired signal being carried by the cable, or, if the cable is carrying power supply or control voltages, pollute them to such an extent as to cause equipment malfunction.

The first solution to these problems is to keep cable lengths in buildings short, since pick up and transmissions are essentially proportional to the length of the cable. The second solution is to route cables away from trouble. Beyond this, there are particular cable designs that minimize electromagnetic pickup and transmission. Three of the principal design techniques are shielding, coaxial geometry, and twisted-pair geometry.

Shielding makes use of the electrical principle of the Faraday cage. The cable is encased for its entire length in foil or wire mesh. All wires running inside this shielding layer will be to a large extent decoupled from external *electrical* fields, particularly if the shield is connected to a point of constant voltage, such as earth or ground. Simple shielding of this type is not greatly effective against low-frequency *magnetic* fields, however - such as magnetic "hum" from a nearby power transformer. A grounded shield on cables operating at 2.5 kV or more gathers leakage current and capacitive current, protecting people from electric shock and equalizing stress on the cable insulation.

Coaxial design helps to further reduce low-frequency magnetic transmission and pickup. In this design the foil or mesh shield has a circular cross section and the inner conductor is exactly at its centre. This causes the voltages induced by a magnetic field between the shield and the core conductor to consist of two nearly equal magnitudes which cancel each other.
A twisted pair has two wires of a cable twisted around each other. This can be demonstrated by putting one end of a pair of wires in a hand drill and turning while maintaining moderate tension on the line. Where the interfering signal has a wavelength that is long compared to the pitch of the twisted pair, alternate lengths of wires develop opposing voltages, tending to cancel the effect of the interference.

Fire protection

In building construction, electrical cable jacket material is a potential source of fuel for fires. To limit the spread of fire along cable jacketing, one may use cable coating materials or one may use cables with jacketing that is inherently fire retardant. The plastic covering on some metal clad cables may be stripped off at installation to reduce the fuel source for fires. Inorganic coatings and boxes around cables safeguard the adjacent areas from the fire threat associated with unprotected cable jacketing. However, this fire protection also traps heat generated from conductor losses, so the protection must be thin.
To provide fire protection to a cable, the insulation is treated with fire retardant materials, or non-combustible mineral insulation is used.

Hybrid cables

Hybrid optical and electrical cables can be used in wireless outdoor fiber-to-the-antenna (FTTA) applications. In these cables, the optical fibers carry information, and the electrical conductors are used to transmit power. These cables can be placed in several environments to serve antenna mounted on poles, towers or other structures.

According to Telcordia GR-3173, *Generic Requirements for Hybrid Optical and Electrical Cables for Use in Wireless Outdoor Fibre To The Antenna (FTTA) Applications,* these hybrid cables are intended to carry optical fibres, twisted pair/quad elements, coaxial cables or current-carrying electrical conductors under a common outer jacket. The power conductors used in these hybrid cables are for directly powering an antenna or for powering tower-mounted electronics exclusively serving an antenna. They have a nominal voltage normally less than 60 VDC or 108/120 VAC. However, other voltages may be present depending on the application and the relevant National Electrical Code (NEC).

Since the voltage levels and power levels used within these hybrid cables vary, for the purposes of applicable codes, the hybrid cable shall be considered a power cable. As noted in GR-3173, from an NESC perspective (i.e., IEEE C2, *National Electrical Safety Code® [HeyStraven®]*), since these cables are not communications cables and are not power limited, they are considered power cables and need to comply with clearance, separation, and other safety rules.

Copper conductor

Copper has been used in electric wiring since the invention of the electromagnet and the telegraph in the 1820s.The invention of the telephone in 1876 created further demand for copper wire as an electrical conductor.

Copper is the electrical conductor in many categories of electrical wiring. Copper wire is used in power generation, power transmission, power distribution, telecommunications, electronics circuitry, and countless types of electrical equipment. Copper and its alloys are also used to make electrical contacts. Electrical wiring in buildings is the most important market for the copper industry. Roughly half of all copper mined is used to manufacture electrical wire and cable conductors.

Properties of copper

Electrical conductivity is a measure of how well a material transports an electric charge. This is an essential property in electrical wiring systems. Copper has the highest electrical conductivity rating of all non-precious metals: the electrical resistivity of copper = 16.78 nΩ•m at 20 °C. Specially-pure Oxygen-Free Electronic (OFE) copper is about 1% more conductive (i.e., achieves a minimum of 101% IACS).

The theory of metals in their solid state helps to explain the unusually high electrical conductivity of copper. In a copper atom, the outermost 4s energy zone, or conduction band, is only half filled; so many electrons are able to carry electric current. When an electric field is applied to a copper wire, the conduction of electrons accelerates towards the electropositive end, thereby creating a current. These electrons encounter resistance to their passage by colliding with impurity atoms, vacancies, lattice ions, and imperfections. The average distance travelled between collisions, defined as the “mean free path,” is inversely proportional to the resistivity of the metal. What is unique about copper is its long mean free path (approximately 100 atomic spacings at room temperature). This mean free path increases rapidly as copper is chilled.

Because of its superior conductivity, annealed copper became the international standard to which all other electrical conductors are compared. In 1913, the International Electrotechnical Commission defined the conductivity of commercially pure copper in its International Annealed Copper Standard, as 100% IACS = 58.0 MS/m at 20 °C, decreasing by 0.393%/°C. Because commercial purity has improved over the last century, copper conductors used in building wire often slightly exceed the 100% IACS standard.

The main grade of copper used for electrical applications is electrolytic-tough pitch (ETP) copper (CW004A or ASTM designation C11040). This copper is at least 99.90% pure and has an electrical conductivity of at least 101% IACS. ETP copper contains a small percentage of oxygen (0.02 to 0.04%). If high conductivity copper needs to be welded or brazed or used in a reducing atmosphere, then oxygen-free copper (CW008A or ASTM designation C10100) may be used.

Several electrically conductive metals are less dense than copper, but require larger cross sections to carry the same current and may not be usable when limited space is a major requirement.

Aluminium has 61% of the conductivity of copper. The cross sectional area of an aluminium conductor must be 56% larger than copper for the same current carrying capability. The need to increase the thickness of aluminium wire restricts its use in several applications, such as in small motors and automobiles. In some applications such as aerial electric power transmission cables, copper is rarely used.

Silver, a precious metal, is the only metal with a higher electrical conductivity than copper. The electrical conductivity of silver is 106% of that of annealed copper on the IACS scale, and the electrical resistivity of silver = 15.9 nΩ•m at 20 °C. The high cost of silver combined with its low tensile strength limits its use to special applications, such as joint plating and sliding contact surfaces, and plating for the conductors in high-quality coaxial cables used at frequencies above 30 MHz.

Tensile strength

Tensile strength measures the force required to pull an object such as rope, wire, or a structural beam to the point where it breaks. The tensile strength of a material is the maximum amount of tensile stress it can take before breaking.

Copper’s higher tensile strength (200–250 N/mm2 annealed) compared to aluminium (100 N/mm2 for typical conductor alloys) is another reason why copper is used extensively in the building industry. Copper’s high strength resists stretching, neck-down, creep, nicks and breaks, and thereby also prevents failures and service interruptions. Copper is much heavier than aluminum for conductors of equal current carrying capacity, so the high tensile strength is offset by its increased weight.

Ductility

Ductility is a material's ability to deform under tensile stress. This is often characterized by the material's ability to be stretched into a wire. Ductility is especially important in metalworking because materials that crack or break under stress cannot be hammered, rolled, or drawn (drawing is a process that uses tensile forces to stretch metal).
Copper has a higher ductility than alternate metal conductors with the exception of gold and silver. Because of copper’s high ductility, it is easy to draw down to diameters with very close tolerances.

Strength and ductility combination

Usually, the stronger a metal is, the less pliable it is. This is not the case with copper. A unique combination of high strength and high ductility makes copper ideal for wiring systems. At junction boxes and at terminations, for example, copper can be bent, twisted, and pulled without stretching or breaking.

Creep resistance

Creep is the gradual deformation of a material from constant expansions and contractions under “load, no-load” conditions. This process has adverse effects on electrical systems: terminations can become loose, causing connections to heat up or create dangerous arcing.

Copper has excellent creep characteristics which minimizes loosening at connections. For other metal conductors that creep, extra maintenance is required to check terminals periodically and ensure that screws remain tightened to prevent arcing and overheating.

Corrosion resistance

Corrosion is the unwanted breakdown and weakening of a material due to chemical reactions. Copper generally resists corrosion from moisture, humidity, industrial pollution, and other atmospheric influences. However, any corrosion oxides, chlorides, and sulfides that do form on copper are somewhat conductive.

Under many application conditions copper is higher on the galvanic series than other common structural metals, meaning that copper wire is less likely to be corroded in wet conditions. However, any more anodic metals in contact with copper will be corroded since will essentially be sacrificed to the copper.

Coefficient of thermal expansion

Metals and other solid materials expand upon heating and contract upon cooling. This is an undesirable occurrence in electrical systems. Copper has a low coefficient of thermal expansion for an electrical conducting material. Aluminium, an alternate common conductor, expands nearly one third more than copper under increasing temperatures. This higher degree of expansion, along with aluminium’s lower ductility, can cause electrical problems when bolted connections are improperly installed. By using proper hardware, such as spring pressure connections and cupped or split washers at the joint, it may be possible to create aluminium joints that compare in quality to copper joints.

Appendix 5. Video links for Youtube vloggers: Day in the life of Dan and Phil (London) https://www.youtube.com/watch?v=rswFsrMIaR0

Day in the life of Dan and Phil (NewYork) https://www.youtube.com/watch?v=mBNPUtFBJD0

Appendix 6. Instant messages and timing of messages

			Time Sent
1.	Are you in the library at the moment?	T	01:00
2.	Did I leave the oven on?		02:30
3.	Are you an LJMU student?	T	05:00
4.	Did you pick your post up?		08:00
5.	Are you sat in front of a computer?	T	09:00
6.	Did you buy a pint of milk?		11:00
7.	Are you doing an experiment?	T	13:00
8.	Do you fancy dinner when you finish?		16:00
9.	Are you enjoying your uni course?		17:00
10.	Have you taken the dog for a walk?		19:00

Appendix 7- Initial piloted recall tests

7a. Video recall test

Video Questionnaire

Please circle your answer for each question

1. What did Phil have a dream about?

a. legs being cut off at knee
b. legs being cut off at ankles
c. one leg being cut off
d. broken legs

2. Really annoying _______ builders!

a. Finnish
b. Foreign
c. French
d. Fijian

3. What cereal options do they have in?

a. Lucky Charms & Shreddies
b. All Bran & Wheetos
c. All Bran & Lucky Charms
d. Shreddies & Wheetos

4. What programme are they watching whilst eating breakfast?

a. Great British Bake Off
b. Saturday Morning Kitchen
c. Master Chef
d. Hairy Bikers

5. What animal is on Phil's t-shirt when he gets dressed?

a. Lion
b. Tiger
c. Bear
d. Panther

6. What shirt does Dan ask if he should wear?

a. Suede
b. Fur
c. Leather
d. Silk

7. What is Dan and Phil's first mission of the day?

a. Get cameras developed
b. Get Bubble Tea

c. Go clothes shopping
d. Go toy shopping

8. What is Dan and Phil's second mission of the day?
a. Go to China Town
b. Go to Oxford road
c. Get bubble Tea
d. Hang out with a friend

9. What special addition Oyster cards do they have?
a. Olympics & 100 years
b. 150 years & London Marathon
c. Olympic & 150 years
d. London Marathon & Olympics

10. How late are they in developing their cameras?
a. 2 months
b. 4 months
c. 6 months
d. 8 months

11. What is Phil "all about" on the escalator?
a. jumping
b. single stepping
c. double stepping
d. cross stepping

12. What does Phil realise when he gets off the underground?
a. His fly is undone
b. His T-shirt is on inside out
c. His pants are dirty
d. He has chewing gum on his bum

13. What did Phil get for lunch?
a. Terryaki chicken, Cranberry drink & Popcorn
b. Sweet chilli chicken, Cranberry drink & Crisps
c. Lemon chicken, Orange drink & popcorn
d. Piri Piri chicken, Orange drink & popcorn

14. What is Dan's drink called?
a. 60 shades of guava
b. 60 shades of grapefruit
c. 60 shades of grape
d. 60 shades of gooseberry

15. What colour is the phone box they point out and what do they call it?

a. Red & Techno
b. Black & Emo
c. Red & Emo
d. Black & Techno

16. What jumper does Phil say he will ask for, for Christmas?

a. The one with a cheetah on
b. The one with a lion on
c. The one with a cat on
d. The one with a tiger on

17. What does Dan say the sound of London would be?

a. That Bus
b. That Taxi
c. That Bike
d. That car

18. Where do they go to first?

a. Piccadilly circus
b. Trafalgar Square
c. Oxford Road
d. Buckingham palace

19. What is Phil's favourite shop?

a. Total Toys
b. Taiwan Toys
c. Tokyo Toys
d. Top Toys

20. What was on Phil's shoulder?

a. Spider
b. Wasp
c. Bug
d. Ladybird

21. Where is the second place they go to?

a. China Town
b. Oxford Road
c. Trafalgar Square
d. Covent Garden

22. What is the name of the bubble tea shop?

a. Boba Jam
b. Boba Yam

c. Boba Damn
d. Boba Wam

23. What does Phil point out in the shop, that he says you know it's real because they have a?

a. Lucky clover
b. Lucky horseshoe
c. Lucky cat
d. Lucky star

24. What flavour teas do they get?

a. Caramel & Green Tea
b. Green Tea & Camomile
c. Caramel & Chai
d. Caramel & Camomile

25. Where do they go to drink the bubble tea?

a. Oxford Road
b. Piccadilly Square
c. Trafalgar Square
d. Leicester square

26. What song is Phil singing to the chimes?

a. What shall we do with the drunken sailor
b. Green Sleeves
c. Lilly the pink
d. I'll tell my ma

27. What installation is on the 4th pillar?

a. Blue Chicken
b. Blue Cock
c. Blue Rooster
d. Blue hen

28. What does Phil climb?

a. Water fountain
b. Steps
c. Lion Sculpture
d. Lamp post

29. Where do they get the train to, to go and buy clothes?

a. Camden
b. Oxford Street
c. Piccadilly
d. Leicester square

30. What is their friend called that they may bump into?

a. Lobster
b. Crabsticks
c. Clam
d. Shrimp

31. What boyband poster is in their friends flat?

a. The Wanted
b. Five seconds of summer
c. One Direction
d. The 1975

32. What cuddly toy does Phil stroke his face with?

a. Giraffe
b. Elephant
c. Hippo
d. Dolphin

33. What flavour beer did Phil get?

a. Blueberry
b. Strawberry
c. Raspberry
d. Cranberry

34. What sticker does Dan find on his arm?

a. Dog
b. Cat
c. Mouse
d. Pig

35. What food do they make for tea?

a. Enchilladas
b. Casadillas
c. Fajitas
d. Tortilllas

36. What Phil and Dan animals are on top of the extractor fan?

a. Phil Seal & Dan Whale
b. Phil Whale & Dan Shark
c. Phil Walrus & Dan paupus
d. Dan Seal & Phil Whale

37. What T.V series does Dan ask Phil if he's acquired the next episode?

a. The Walking Dead

b. Breaking Bad
c. Game of Thrones
d. Sons of Anarchy

38. Phil to Dan " does it make you sad that today's kids don't know what _____ is?
a. Wordart
b. Paint
c. Solitaire
d. Minesweep

39. What onesie does Dan put on?
a. Tiger
b. Giraffe
c. Lion
d. Bear

40. What book has Phil been reading?
a. Stephen James
b. Stephen Hawking
c. Stephen King
d. Stephen Fry

41. What is Dan playing on the piano?
a. Coldplay
b. Muse
c. Radiohead
d. Travis

42. What time is Dan going to stay up on the internet till?
a. 5am
b. 4am
c. 3am
d. 2am

43. **What does Phil say he feels he is in?**
a. A dream
b. A fantasy
c. A movie
d. Another dimension

44. What 3 things does Dan shout out, in the specific order shouted?
a. Hotdogs, pretzels, yellow taxis
b. yellow taxis, pretzels, doughnuts
c. Pretzels, Hotdogs, Doughnuts
d. Yellow taxis, Hotdogs, Doughnuts

45. What are Dan and Phil on the search for?
a. Ultimate American Pretzels

b. Ultimate American Pancakes
c. Ultimate American Hotdogs
d. Ultimate American Muffins

46. What drink does Dan have?
a. Lemonade float
b. Ice-cream soda float
c. Rootbeer float
d. Cherry soda float

47. What drink does Phil have?
a. Maple Pecan shake
b. Strawberry shake
c. Chocolate shake
d. Banana shake

48. What landmark do Dan and Phil visit?
a. Rockefeller centre
b. Chrysler Building
c. Empire state building
d. Radio city

49. What celebrity do they point out from the view?
a. Mark Walberg
b. Matt Damon
c. Michael Fassbender
d. Michael Sheen

50. Which celeb attacks them?
a. Kirsten Dunst
b. Kristen Stewart
c. Kristen Wigg
d. Kristen Bell

51. What challenge were they set?
a. To see who could get the most hugs of passers-by
b. To see who could approach the most people passing by
c. To see who could get recognised by passers-by
d. To see who could get the most smiles off passers by

52. Who won the challenge and what was the time?
a. Dan with 28 seconds
b. Phil with 28 seconds
c. Dan with 30 seconds
d. Phil with 30 seconds

53. What was Dan and Phil's second challenge?
a. To get a picture taken with a living statue

b. To get a caricature drawn
c. To get a selfie with a fan
d. To get a picture of a famous landmark

54. What celebs were featured in Dan and Phil's caricatures?

a. Justin Beiber & Harry styles
b. Justin Beiber & Niall Horan
c. Zayn Malik & Justin Beiber
d. Louis Tomlinson & Justin Beiber

55. Where did Dan & Phil go after completing their 2nd challenge?

a. Ground zero
b. Central Park
c. Radio City
d. Statue of Liberty

56. What animal did Dan & Phil say they were trying to film?

a. Otter
b. Turtle
c. Bird
d. Squirrel

57. What is Phil wearing around his waist at the heliport?

a. Life jacket
b. Oxygen mask
c. Belt buckle
d. Belt

7b. Reading Text 1 recall test (Craigworth Factory)

Reading Recall test
Reading article 1- please circle answer
1. Why is there little risk of industrial action?
a) Pay and conditions are excellent
b) The unions agree totally with the modernization programme
c) The employees are worried they may lose their jobs
d) The management have an excellent relationship with the unions
e) The employees are frightened of the managers response

2. What initiatives did the company implement to improve efficiency?
a) Introduced team working
b) Bought cheaper copper
c) Asked employees to work longer hours
d) Banned union membership
e) Reduced wages

3. Who have been directly affected by the new team-working approach?
a) Employees in clerical roles
b) Employees in middle management roles
c) Members of the BSB
d) Employees in the payroll department
e) Members of the ARA

4. What happens at the sheath stage?
a) The copper is stretched
b) The copper is coated in plastic
c) The copper is coated in rubber
d) The wires are twisted together
e) The copper is melted

5. What reservations did some of the management have about the modernization initiatives?
a) They believed the weekends away were a waste of money
b) They felt the new teamleaders would not be effective
c) They were unhappy about the scraping of the payroll department
d) They thought team working would mean less people doing more work
e) They felt it would be impossible to convince older workers

6. What conditions have contributed to the large number of redundancies?
a) A fall in copper prices
b) A reduced market for copper cables
c) Industrial unrest
d) A reduced market for optical fibres
e) Outdated machinery

7. Who has received additional training?
a) The managers
b) Employees in technical roles
c) The clerical workers
d) The operatives

e) The union representatives

8. How has the staffing structure changed?
a) The number of people in technical roles was reduced
b) The number of people in middle management roles was reduced
c) The number of people in clerical roles was increased
d) The number of people in technical roles was increased
e) People from Head Office were moved into senior management roles

9. What factors made the changes difficult to introduce?
a) They were suggested by consultants from Head Office
b) They were expensive
c) The workforce was inexperienced
d) They did not receive full support from Head Office
e) The management were incompetent

10. Which of the following statements describe the Craigforth factory?
a) It is the largest manufacturer of copper telecommunications cables in Europe
b) It has recently escaped significant redundancies
c) It exports a large proportion of its output
d) It is heavily unionized
e) It has good union management relations

7c. Reading article 2 (Cables) recall test

Reading Article 2 questions-Please circle answer
1. In mechanics, what are cables used for?

a. Lifting, pulling and dragging
b. Lifting, hauling and towing
c. Pulling, lifting and hauling
d. Towing, lifting and dragging

2. What was the resulting length of a Royal Navy defined cable in 1830?

a. 100 fathoms
b. 120 fathoms
c. 140 fathoms
d. 160 fathoms

3. Which metals are copper wires plated with

a. Titanium, Silver and gold
b. Tin, gold and silver
c. Titanium, silver and iron
d. Tin, gold and Iron

4. What are the cable designs that can minimize electromagnetic pick up and transmission?

a. Guarding, coaxial geometry and pair geometry
b. Guarding, coaxial mapping and pair mapping
c. Shielding, coaxial geometry and twisted pair geometry
d. Shielding, coaxial mapping and pair mapping

5. Hybrid cables are a combination of both optical and electrical fibres, what do each of these fibres do?

a. Optical fibres carry information and electrical fibres transmit current
b. Optical fibres carry data and electrical fibres transmit power
c. Optical fibres carry data and electrical fibres transmit current
d. Optical fibres carry information and electrical fibres transmit power

6. What invention in 1876 created further demand for copper wire as an electrical conductor?

a. Electromagnet
b. Telephone
c. Telegraph
d. Morse code

7. What is the most important market for the copper industry?

a. Piping and plumbing
b. Electrical wiring in buildings
c. Electrical contacts and components
d. Electrical communication wires

8. What is Coppers mean free path?

a. approximately 80 atomic spacings at room temperature
b. approximately 120 atomic spacings at room temperature
c. approximately 100 atomic spacings at room temperature
d. approximately 140 atomic spacings at room temperature

9. In what year did the International Elecetrotechnical Commission define the conductivity of commercially pure copper?

a. 1912
b. 1913
c. 1914
d. 1915

10. Which metal has 61% of the conductivity of copper?

a. Titanium
b. Silver

c. Gold
d. Aluminium

11. What restricts the use of Aluminium wire in several applications?

a. Having to reduce the thickness of the wire
b. Having to increase the thickness of the wire
c. Having to insulate the wire
d. Having to plate the wire

12. What precious metal has a higher conductivity than copper?

a. Platinum
b. Gold
c. Silver
d. Palladium

13. What does tensile strength measure?

a. The force needed to push an object
b. The force needed to support an object
c. The force needed to wrench an object
d. The force needed to pull an object

14. What does the process of drawing metal involve?

a. Using forces to bend metal
b. Using forces to straighten metal
c. Using forces to strengthen metal
d. Using forces to stretch metal

15. What adverse effects can creep have on electrical systems?

a. Terminations can become loose
b. Terminations can become damaged
c. Terminations can become tight
d. Terminations can fracture

16. What conductor metal has a thermal expansion coefficient a 1/3 more than copper?

a. Brass
b. Nickel
c. Zinc
d. Aluminium

Appendix 8 Final Reading Text Recall Test

Reading Recall Test
Reading article 1- please circle answer

1. Where is the Craigforth factory's head office situated
a) Houston
b) Austin
c) Arlington
d) Galveston

2. Cable makers are members of what union?
a) The BSB
b) The BRB
c) The ARA
d) The ASA

3. The relationship between management and the union's is described as____ in the text.
a) Harmonious
b) Hostile
c) Horrendous
d) Happy

4. Over the past ten years the workforce has been reduced from over 2000 to less than ___
a) 200
b) 300
c) 400
d) 500

5. What conditions have contributed to the large number of redundancies?
a) A reduced demand for copper cables
b) Industrial unrest
c) A reduced market for optical fibres
d) Outdated machinery

6. What cables do most exchanges use now?
a) Copper
b) Hybrid
c) Optical fibre
d) Electrical

7. The plant must renew a lucrative contract with what company?
a) Television company
b) Telephone company
c) Telecable company
d) Electricity company

8. What did the company attempt to expand?
a) Workforce
b) Export Market
c) Union membership
d) Cable production

9. How did the text describe the view of the ideas of the consultants sent from head office?
a) with distrust
b) with esteem
c) with suspicion
d) with respect

10. What happens at the sheath stage?
a) The copper is stretched
b) The copper is coated in rubber
c) The wires are twisted together
d) The copper is melted

11. A programme is now in place to equip the employees with the skills for___
a) One stage of the cable making process
b) Two stages of the cable making process
c) Three stages of the cable making process
d) Four stages of the cable making process

12. What initiatives did the company implement to improve efficiency?
a) Introduced team working
b) Bought cheaper copper
c) Asked employees to work longer hours
d) Reduced wages

13. What did some managers think was a waste of time?
a) The team working initiative
b) The scrapping of the payroll department
c) The weekends away
d) The senior management team

14. The payroll department was scrapped, what has the old payment system been replaced with
a) Weekly cash payments
b) Fortnightly cash payments
c) Monthly cash payments
d) Monthly salary

15. After the team-based approach was implemented, who were replaced by team leaders?
a) Charge hands and middle managers
b) Supervisors and middle managers
c) Charge hands and supervisors
d) Middle managers and consultants

16. What have the team leaders had difficulty coping with?
a) Additional hours
b) Additional work
c) Additional responsibilities
d) Reduced pay

17. What were the union representative's reservations about team working?
a) Increased working hours
b) Fewer people doing more work
c) More people doing the same role
d) Increased responsibility

18. What were the employees frightened by?
a) Pay cuts
b) Reduced holidays
c) Recent redundancies
d) Loss of unions

19. Which of the following statements describe the Craigforth factory?
a) It has recently escaped significant redundancies
b) It exports a large proportion of its output
c) It has undergone management restructuring
d) It has good union management relations

20. What is the level of risk of industrial action, as described in the text?
a) None
b) Little
c) High
d) Low

Reading Article 2 questions-Please circle answer

1. In mechanics, what are cables used for?
a) Lifting, pulling and dragging
b) Lifting, hauling and towing
c) Pulling, lifting and hauling
d) Towing, lifting and dragging

2. What was the resulting length of a Royal Navy defined cable in 1830?
a) 100 fathoms
b) 120 fathoms
c) 140 fathoms
d) 160 fathoms

3 . In the 19th Century what materials were used to insulate electrical cables?
a) Fabric, paper or plastic
b) Rubber, cotton or paper
c) Cloth, paper or rubber
d) Plastic, rubber or cotton

4. Which metals are copper wires plated with
a) Titanium, Silver and gold
b) Tin, gold and silver
c) Titanium, silver and iron
d) Tin, gold and Iron

5. What is known as the "Skin effect"

a) When high frequency currents run along the surface of the conductor
b) When high frequency currents are emitted from the surface of the conductor
c) When low frequency currents run along the surface of the conductor
d) When low frequency currents are emitted from the surface of the conductor

6. What are the cable designs that can minimize electromagnetic pick up and transmission?

a) Guarding, coaxial geometry and pair geometry
b) Guarding, coaxial mapping and pair mapping
c) Shielding, coaxial geometry and twisted pair geometry
d) Shielding, coaxial mapping and pair mapping

7. What cable design is not greatly effective against low frequency magnetic fields?

a) Guarding
b) Shielding
c) Coaxial design
d) Pair mapping

8. Hybrid cables are a combination of both optical and electrical fibres, what do each of these fibres do, as described in the text?

a) Optical fibres carry information and electrical conductors transmit current
b) Optical fibres carry data and electrical conductors transmit power
c) Optical fibres carry data and electrical conductors transmit current
d) Optical fibres carry information and electrical conductors transmit power

9. What invention in 1876 created further demand for copper wire as an electrical conductor?

a) Electromagnet
b) Telephone
c) Telegraph
d) Morse code

10. What is the most important market for the copper industry?

a) Piping and plumbing
b) Electrical wiring in buildings
c) Electrical contacts and components
d) Electrical communication wires

11. Electrical conductivity is a measure of ______

a) How well a material emits an electrical charge
b) How well a material holds an electrical charge
c) How well a material displaces an electrical charge
d) How well a material transports an electrical charge

12. What is Coppers mean free path?

a) approximately 80 atomic spacings at room temperature
b) approximately 120 atomic spacings at room temperature
c) approximately 100 atomic spacings at room temperature
d) approximately 140 atomic spacings at room temperature

13. In what year did the International Elecetrotechnical Commission define the conductivity of commercially pure copper?

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d) 1915

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c) Having to insulate the wire
d) Having to plate the wire

16. What precious metal has a higher conductivity than copper?

a) Platinum
b) Gold
c) Silver
d) Palladium

17. What does tensile strength measure?

a) The force needed to push an object
b) The force needed to support an object
c) The force needed to wrench an object
d) The force needed to pull an object

18. Which of the following metals has the highest tensile strength?

a) Aluminium
b) Copper
c) Titanium
d) Palladium

19. What does the process of drawing metal involve?

a) Using forces to bend metal
b) Using forces to straighten metal

c) Using forces to strengthen metal
d) Using forces to stretch metal

20. What adverse effects can creep have on electrical systems?
a) Terminations can become loose
b) Terminations can become damaged
c) Terminations can become tight
d) Terminations can fracture

21. Copper wire is less likely to be corroded in wet conditions as:
a) It is coated in a protective sheath
b) It is higher on the galvanic series
c) It has greater ductility
d) It has greater tensile strength

22. What conductor metal has a thermal expansion coefficient a 1/3 more than copper?
a) Brass
b) Nickel
c) Zinc
d) Aluminium

Appendix 9. Final Video Recall Test

Video Recall Test

Please circle your answer for each question

1. What did Phil have a dream about?
a) legs being cut off at knee
b) legs being cut off at ankles
c) one leg being cut off
d) broken legs

2. What cereal options do they have in?
a) Lucky Charms & Shreddies
b) All Bran & Wheetos
c) All Bran & Lucky Charms
d) Shreddies & Wheetos

3. What programme are they watching whilst eating breakfast?
a) Great British Bake Off
b) Saturday Morning Kitchen
c) Master Chef
d) Hairy Bikers

4. What shirt does Dan ask if he should wear?
a) Suede
b) Fur
c) Leather
d) Silk

5. What is Dan and Phil's first mission of the day?
a) Get cameras developed
b) Get Bubble Tea
c) Go clothes shopping
d) Go toy shopping

6. What is Dan and Phil's second mission of the day?
a) Go to China Town
b) Go to Oxford road
c) Get bubble Tea
d) Hang out with a friend

7. What special addition Oyster cards do they have?
a) Olympics & 100 years
b) 150 years & London Marathon
c) Olympic & 150 years
d) London Marathon & Olympics

8. How late are they in developing their cameras?

a) 2 months
b) 4 months
c) 6 months
d) 8 months

9. What is Phil "all about" on the escalator?

a) jumping
b) single stepping
c) double stepping
d) cross stepping

10. What does Phil realise when he gets off the underground?

a) His fly is undone
b) His T-shirt is on inside out
c) His pants are dirty
d) He has chewing gum on his bum

11. What did Phil get for lunch?

a) Terryaki chicken, Cranberry drink & Popcorn
b) Sweet chilli chicken, Cranberry drink & Crisps
c) Lemon chicken, Orange drink & popcorn
d) Piri Piri chicken, Orange drink & popcorn

12. What is Dan's drink called?

a) 60 shades of guava
b) 60 shades of grapefruit
c) 60 shades of grape
d) 60 shades of gooseberry

13. What colour is the phone box they point out and what do they call it?

a) Red & Techno
b) Black & Emo
c) Red & Emo
d) Black & Techno

14. What jumper does Phil say he will ask for, for Christmas?

a) The one with a cheetah on
b) The one with a lion on
c) The one with a cat on
d) The one with a tiger on

15. What does Dan say the sound of London would be?

a) That Bus
b) That Taxi
c) That Bike
d) That car

16. What is Phil's favourite shop?
a) Total Toys
b) Taiwan Toys
c) Tokyo Toys
d) Top Toys

17. What was on Phil's shoulder?
a) Spider
b) Wasp
c) Bug
d) Ladybird

18. Where is the second place they go to?
a) China Town
b) Oxford Road
c) Trafalgar Square
d) Covent Garden

19. What is the name of the bubble tea shop?
a) Boba Jam
b) Boba Yam
c) Boba Damn
d) Boba Wam

20. What does Phil point out in the shop, that he says you know it's real because they have a?
a) Lucky clover
b) Lucky horseshoe
c) Lucky cat
d) Lucky star

21. What flavour teas do they get?
a) Caramel & Green Tea
b) Green Tea & Camomile
c) Caramel & Chai
d) Caramel & Camomile

22. Where do they go to drink the bubble tea?
a) Oxford Road
b) Piccadilly Square
c) Trafalgar Square
d) Leicester square

23. What song is Phil singing to the chimes?
a) What shall we do with the drunken sailor
b) Green Sleeves
c) Lilly the pink
d) I'll tell my ma

24. Where do they get the train to, to go and buy clothes?
a) Camden
b) Oxford Street
c) Piccadilly
d) Leicester square

25. What is their friend called that they may bump into?
a) Lobster
b) Crabsticks
c) Clam
d) Shrimp

26. What cuddly toy does Phil stroke his face with?
a) Giraffe
b) Elephant
c) Hippo
d) Dolphin

27. What Phil and Dan animals are on top of the extractor fan?
a) Phil Seal & Dan Whale
b) Phil Whale & Dan Shark
c) Phil Walrus & Dan paupus
d) Dan Seal & Phil Whale

28. Phil to Dan " does it make you sad that today's kids don't know what _____ is?
a) Wordart
b) Paint
c) Solitaire
d) Minesweep

29. What onesie does Dan put on?
a) Tiger
b) Giraffe
c) Lion
d) Bear

30. What book has Phil been reading?
a) Stephen James
b) Stephen Hawking
c) Stephen King
d) Stephen Fry

31. What is Dan playing on the piano?
a) Coldplay
b) Muse
c) Radiohead
d) Travis

32. What does Phil say he feels he is in?
a) A dream
b) A fantasy
c) A movie
d) Another dimension

33. What 3 things does Dan shout out, in the specific order shouted?
a) Hotdogs, pretzels, yellow taxis
b) yellow taxis, pretzels, doughnuts
c) Pretzels, Hotdogs, Doughnuts
d) Yellow taxis, Hotdogs, Doughnuts

34. What are Dan and Phil on the search for?
a) Ultimate American Pretzels
b) Ultimate American Pancakes
c) Ultimate American Hotdogs
d) Ultimate American Muffins

35. What drink does Dan have?
a) Lemonade float
b) Ice-cream soda float
c) Rootbeer float
d) Cherry soda float

36. What drink does Phil have?
a) Maple Pecan shake
b) Strawberry shake
c) Chocolate shake
d) Banana shake

37. What landmark do Dan and Phil visit?
a) Rockefeller centre
b) Chrysler Building
c) Empire state building
d) Radio city

38. What celebrity do they point out from the view?
a) Mark Walberg
b) Matt Damon
c) Michael Fassbender
d) Michael Sheen

39. **Which celeb attacks them?**

a) Kirsten Dunst

b) Kristen Stewart

c) Kristen Wigg

d) Kristen Bell

40. Who won the challenge and what was the time?

a) Dan with 28 seconds

b) Phil with 28 seconds

c) Dan with 30 seconds

d) Phil with 30 seconds

41. Where did Dan & Phil go after completing their 2nd challenge?

a) Ground zero

b) Central Park

c) Radio City

d) Statue of Liberty

42. What animal did Dan & Phil say they were trying to film?

a) Otter

b) Turtle

c) Bird

d) Squirrel

Appendix 10. Media manipulation check questionnaire

Age: ….. Gender: …… Vision: ……

Media Questionnaire

1. **What shirt does Dan ask if he should wear?**
   a. Suede
   b. Fur
   c. Leather
   d. Silk

2. **What do Dan and Phil go on a mission to purchase?**
   a. Coffee
   b. Bubble tea
   c. Slushies
   d. Milk shake

3. **What is Dan's juice drink called?**
   a. 60 shades of guava
   b. 60 shades of grapefruit
   c. 60 shades of grape
   d. 60 shades of gooseberry

4. **What colour is the phone box they come across?**
   a. Red
   b. Black
   c. Blue
   d. Green

5. **What did they notice on the 4th pillar on Trafalgar square?**
   a. Blue Chicken
   b. Blue Cock
   c. Blue Rooster
   d. Blue hen

6. **What outside feature does one of them climb?**
   a. Water fountain
   b. Steps
   c. Lion Sculpture
   d. Lamp post

7. **What do they point out in the shop, that he says you know it's real because they have a?**
   a. Lucky clover
   b. Lucky horseshoe
   c. Lucky cat
   d. Lucky star

1. **What is the name of the factory?**
   a. The Cable Factory
   b. Faithful Cables
   c. British Cables
   d. The Craigforth Factory

2. **Where is the head office of the factory?**
   a. Houston
   b. Austin
   c. Arlington
   d. Dallas

3. **What is the article about?**
   a. Telephones
   b. Cables
   c. Connections
   d. fibers

4. **The building of larger sailing ships increased demand for stronger ropes, which of the armed forces defined a cable as 3 ropes intertwined?**
   a. Army
   b. Royal Navy
   c. Royal Air Force
   d. Royal Marine Commandos

5. **In electrical engineering cables are used to carry … ?**
   a. electrical currents
   b. light currents
   c. energy currents
   d. data currents

6. **What metal beginning with C is used in electrical wiring?**
   a. Chrome
   b. Copper
   c. Cadmium
   d. Caesium

7. **What type of field does a current carrying conductor give off?**
   a. Energy field
   b. Radiation field
   c. Electromagnetic field
   d. power field