Examining the short-term effects of video exposure on children's attention and other cognitive processes

Katarzyna Kostyrka-Allchorne

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Department of Psychology
University of Essex

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Abstract

The literature suggests that fast editing pace (usually operationalised with a number of cuts and scene changes; McCollum & Bryant, 2003), which is typical of much of children's programming, may have detrimental developmental consequences. Previous studies that examined the effects of fast pace on children's attention and cognition produced inconclusive findings. The major weakness of this research was using programmes that varied in both pace and content. Thus, this thesis focused on examining the effects of the differential editing (fast vs. slow) using specially produced videos, which allowed manipulating the pace while maintaining strict content control.

Experiments 1-4 investigated the short-term effects of differentially paced videos on children's attention. In these experiments, attention was either measured indirectly, through an observation of play (Experiment 1) or directly with a continuous performance task (Experiments 2-4). To address the recent proposals about the potential detrimental role of pace and content on children's executive function (Lillard, Drell, Richey, Boguszewski, & Smith, 2015; Lillard & Peterson, 2011), Experiments 3 and 4 included the assessment of the inhibitory control component of executive function. Additionally, Experiments 2 and 5 employed psychophysiological methods (i.e., electroencephalography and cardiovascular measures) to investigate the effects of pace and content on internal attentional and inhibitory processing. Finally, a questionnaire study measured children's current media preferences and use and investigated parental supervision methods and media beliefs.

Results indicated that watching fast-paced videos resulted in more unsettled behaviour during play and less thoughtful responding on the formal laboratory tests of attention. Moreover, the pace of video editing affected neural processes that underpin inhibition. Finally, watching the videos containing elements of fantasy improved children's inhibitory control. By identifying harmful features, as well as the potential benefits of watching videos, this new evidence contributes to a better understanding of how to optimise children's media use.

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Overview of chapters

The research described in this thesis investigates whether video exposure affects young children's attention and cognition. Specifically, it focuses on examining the effects of differential editing pace (fast vs. slow) on children's attention and inhibitory control using a broad range of methodological approaches. The role of video content is also explored. Finally, to address the potential confound of content and pace, which characterises studies that utilise commercial television programmes, four experiments described in this thesis used a novel experimental paradigm developed by Cooper, Uller, Pettifer, and Stolc (2009). In this paradigm, the same raw camera footage is edited to produce fast- and slow-paced experimental videos.

This thesis is organised into seven chapters. Chapter One provides a broad context for the key topic of interest by presenting the results of a systematic review of the literature studying the association between television viewing and children's executive function, academic performance, attention, language and play. Chapter Two examines whether watching a fast- or a slow-paced video affects how preschoolers interact with their toys. In Chapter Three event-related potentials are employed to examine the neural processes underlying children's inhibition after video exposure. Chapter Four aims to disentangle the effects of the video pace and content on children's attention and inhibitory control whereas Chapter Five draws on physiological measures to measure the level of engagement and cognitive effort during watching a video and taking part in the formal laboratory assessment tasks. Chapter Six explores children's media preferences and use, parental supervision practices and media attitudes. Chapter Seven summarises the key points from each empirical study, discusses the limitations and proposes ideas for future research. The remainder of this section provides a brief description of each of these chapters.

Chapter One: The relationship between television exposure and children's cognition and behaviour: A systematic review.

The aim of this chapter is to systematically review the literature exploring the associations between childhood television viewing and executive function, academic performance, attention, language and play. The articles reviewed in this chapter are organised according to study design into three groups: cross-sectional correlation, longitudinal correlation and experimental. This allowed evaluating the literature in consideration of the strengths and weaknesses of the different research methodologies. This chapter aims to offer a comprehensive synthesis of the current state of the literature and to provide a broad context for the empirical work, which is presented in Chapters Two-Six. The content of this chapter has been published in *Developmental Review.*

Chapter Two: Differential effects of video on preschool children's behaviour dependent on editing pace.

Considering the lack of conclusive findings regarding the effects of television and video editing pace, the experiment reported in this chapter examined whether exposure to a differentially paced video affected 2.5-4-year-old children's behaviour. In this study, observation method was used to analyse the children's behaviour during two free-play sessions; one before and one after they watched the specially edited experimental videos. Of particular interest was the frequency with which the children shifted their attention between the toys available in the test room. The outcomes of this study have been published in *Acta Paediatrica*.

Chapter Three: The effects of video editing pace on neural markers of children's inhibition during sustained attention.

Building on the findings from Chapter Two, this chapter reports the data of an experiment, which investigated the effects of watching differentially paced experimental videos on 7-year-old children's performance on a go/no-go task. Moreover, to address the lack of research into the effects of editing pace on neural processes this is the first study in this field of research to use electroencephalography. Specifically, event-related potentials were used to examine whether the video editing pace would modulate the cortical mechanisms underpinning inhibition during the no-go trials of the task.

Chapter Four: Disentangling the effects of video pace and content on children's attention and inhibitory control.

The two-experiment study reported in this chapter was motivated by (1) a proposition that fast pace affects not only attention but also executive function, and (2) a suggestion that processing of unrealistic events in video impairs children's executive function. Thus, to examine these proposals, this study examined the influence of video pace and content on 4- and 5-year old children's attention (assessed with a continuous performance tests) and inhibitory control (assessed with a Stroop paradigm). Specifically, Experiment 3 investigated the effects of pace with commercial children's television programmes. Experiment 4 examined both pace and content using specially produced experimental videos matched for other audio-visual features. The findings reported in this chapter have been submitted to a peer-reviewed journal.

Chapter Five: Attention and cardiovascular adaptation in children: Heart rate and heart rate variability during video watching and psychological performance assessment.

This chapter explores the idea that attentional and cognitive processes might be reflected in the parallel changes in cardiovascular activity. Specifically, Experiment 5 examined the task-related changes in heart rate and heart variability of the 4- to 5-year-old children during three activities that are thought to have different attentional and cognitive demands. Cardiovascular measurements were continuously recorded while children took part in a continuous performance task, inhibitory control tests and watched the experimental video. This experiment also examined a relationship between heart rate variability and task performance.

Chapter Six: Touchscreen Generation: Children's current media use, parental supervision methods and attitudes towards contemporary media.

A study reported in this chapter was motivated by the growing popularity of touchscreen devices among young children. Within the overarching goal of gaining more insight into the key factors that shape the family media environment, this study sought to document young children's (<6 years) current media preferences and use and to investigate parents' monitoring methods and beliefs about contemporary media. It also aimed to examine whether young children engaged in simultaneous multi-screen activities and whether such early 'multitasking' with media was related to the use of touchscreen devices. The outcomes of this study have been published in *Acta Paediatrica*.

Chapter Seven: General Discussion

This concluding chapter summarises the key points from each empirical study, discusses the implication of the research presented in this thesis, addresses the limitations and proposes ideas for future research.

Author’s note:

Except for Chapter Seven, each chapter in this thesis has been written with an aim to be submitted to a peer-reviewed journal. Thus, individual chapters constitute standalone pieces of research. However, they are joined by a common theme; that is, the effects of video and television exposure on children’s attention and cognition. Consequently, some repetition, for example, in the literature synthesis and explanation of concepts, has been inevitable. Finally, in Chapters One, Two and Six some terminology that was present in the published originals has been changed to retain the consistency of language throughout the text of this thesis.

Chapter One: The relationship between television exposure and children's cognition and behaviour: A systematic review.

Abstract

The aim of this chapter is to systematically review the literature studying the association between television viewing and children's executive function, academic performance, attention, language and play. Using keywords: *television, children, infants, attention, language, education* and *cognition*, five online databases were searched. Seventy-six studies that met all the inclusion criteria were reviewed. The findings suggest the relationship between television viewing and children's development is complex. First, the likely effects of television may depend on children's individual characteristics, family and social context. Second, the features of television, such as content and editing pace, and the type of exposure (foreground or background) may affect outcomes. Specifically, watching high-quality educational content during preschool years improves children's basic academic skills and predicts subsequent positive academic performance. Conversely, television viewing in infancy is disruptive to play; it reduces the quality and quantity of child-parent interactions and is associated with inattentive/hyperactive behaviours, lower executive functions, and language delay, at least in the short-term. It remains unclear whether these interactions between television and cognition are long lasting. Future research should focus on the systematic investigation of the pathways that link particular components of television and the type of exposure with individual and contextual factors, to investigate their potential unique and combined effects on development. Researchers must also address the challenge of investigating the diverse and rapidly changing technologies to which the current generation of children are exposed.

Introduction

The relationship between screen-based media, television in particular, and children's cognitive development has been researched for over four decades, producing conflicting results. On the one hand, literature provides support for the long-term benefits of educational television for cognitive development and behaviour (e.g., Mares & Pan, 2013). On the other hand, the negative associations reported in correlational studies between television and children's development, especially attention and language outcomes, are a cause for concern among parents and early-years professionals.

There is little doubt that children and adolescents are prolific users of visual media. Adolescents simultaneously use a variety of different media, multitasking between a computer to do their homework, chatting with their friends on social networking sites, and listening to music or playing a computer game (Roberts & Foehr, 2008). Younger children still prefer "traditional" television over newer forms of media (Rideout, 2013). However, in light of recent figures showing that three-quarters of under-fives in the UK use a tablet or a smartphone (Childwise, 2016) traditional media may soon lose its dominance, even among the youngest of users. Although watching television remains young children's favourite pastime, the rise in popularity of touchscreen devices and the new means of accessing TV content have created further challenges for researchers that go above and beyond studying the potential effects of single-screen viewing. As Oakes (2009, p.1139) puts it "media exposure is now like air or water: ubiquitous, ever evolving and not easily coded as data for a given analysis". Therefore, it appears timely to examine and summarise the results of research into traditional media, to identify robust associations and effects, to help develop a theoretical framework that could guide future research on children's development in this "new media age".

The extent to which cognitive processes are affected by television viewing is contentious. Some studies indicate that time spent viewing (e.g., Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004), exposure to particular content (Conners-Burrow, McKelvey, & Fussell, 2011), early onset (e.g., Chonchaiya & Pruksananonda, 2008) and editing pace (e.g., Lillard & Peterson, 2011) are associated with poor attention, lack of behavioural control, delayed language and deficits in executive functions. However, other studies have suggested that television viewing is not a strong predictor of these cognitive skills (Bittman, Rutherford, Brown, & Unsworth, 2011; Schmidt, Rich, Rifas-Shiman, Oken, & Taveras, 2009; Stevens & Mulsow, 2006). Finally, there is some support for the potential benefits of watching age-appropriate educational content. For example, watching programmes designed to reinforce preschool learning (e.g., *Sesame Street* or *Blues Clues*) improves children's early numeracy and literacy skills (Baydar, Kağitçibaşi, Küntay, & Gökşen, 2008) and is associated with positive educational outcomes in adolescence (Anderson, Huston, Schmitt, Linebarger, & Wright, 2001).

Despite these inconsistencies, abundant correlational evidence, supported by a number of methodologically sound experimental studies, should allow one to identify the key associations between television viewing and developmental outcomes, as well as the mechanisms underlying these relations. Given the complexity of today's digital media, and the challenges that this rapidly evolving technology poses for scientific inquiry, it is important to identify any methodological gaps in past research to guide the creation of effective ways of investigating the potential impact of new media on children's development.

Previous reviews tended to summarise findings pertinent to a particular age group (e.g., Thakkar, Garrison, & Christakis, 2006), synthesised literature concerning a single TV programme (e.g., Fisch, Truglio, & Cole, 1999; Mares & Pan, 2013) or focused on a single outcome measure (e.g., Moses, 2008; Nikkelen, Valkenburg, Huizinga, & Bushman, 2014). No review to date has integrated the findings covering a wide age range and a broad spectrum of outcomes. Thus, the aim of this chapter is to review the current state of literature to explore the associations between childhood television viewing and this broad spectrum of outcomes. Specifically, we intend to evaluate this literature in the light of the strengths and weaknesses of the different research methodologies used. Most research has used one of two methods: either cross-sectional or longitudinal correlation between television viewing and psychological measures. However, in the last decade, there has been an increase in the number of experiments, which predominantly examine vocabulary learning from televised material, the effects of editing features on children's cognition and behaviour and child-caregiver interactions in the presence of television. Finally, this review aims to offer a comprehensive synthesis of the current literature and to provide a resource for researchers studying the potential effects of media on children's cognitive development.

Method

Search procedure and inclusion criteria

MedLINE (PubMed), Cochrane Library, ERIC, PsycARTICLES, and the Web of Science were last searched in December 2015 using the following strategy: child* OR infant* OR preschool* AND television OR film AND attention, play, academic, education, behaviour, cognition, vocabulary, language. Further hand searching of the reference lists in the relevant published literature was conducted to identify any studies that were not returned in the electronic search. There was no date restriction concerning the manuscript publication. Only articles published in the English language were considered for inclusion.

To be included in the review, the studies had to involve participants younger than 14 years or, for longitudinal research, participants had to be younger than 14 during the first wave of data collection. Furthermore, included studies had to investigate either the associations between (correlational studies) or the effects of (experiments) foreground or background television exposure on cognition, attention or play. Finally, for the experimental studies, the outcome variable had to measure the effects of television on specified outcomes, and not attention to or comprehension of the material presented on the screen. Materials used in the studies considered for the review included “real-life” television/films (including those that were specially edited for the purpose of the study), and specifically-designed videos that were developed for the sole purpose of research. To provide a comprehensive summary of the literature, studies that adopted a variety of methodologies were included (cross-sectional correlational studies, prospective and retrospective cohort studies and experiments). However, case study reports were excluded from the review. Finally, this chapter predominantly focuses on the cognitive outcomes; therefore, studies investigating social and emotional outcomes, including aggression, were excluded from this review.

Results

Using the pre-set criteria, the initial search of the relevant databases identified 8,812 studies. Duplicates were removed (1,166) and the exclusion criteria applied to the title and the abstract, which removed another 7,561 articles. After scrutiny of the full text of the remaining 85 articles, 14 further articles were eliminated. The most common reasons for exclusion were: the outcome measure was related to attention to or comprehension of television, rather than the effects of the programme on subsequent attention and cognition, or the outcome measure was outside of the scope of this review (e.g., mental health problems unrelated to attention disorders, imagination or social play). A further five manuscripts were added during review process. This procedure resulted in 76 articles being retained for analysis. Figure 1.1. shows a flowchart of a systematic search. The manuscripts kept for review were divided according to method into three groups: cross-sectional correlation, longitudinal correlation and experimental. For descriptions, see Tables 1.1., 1.2. and 1.3. Where published, study description includes effect sizes, odds ratios and confidence intervals; otherwise p-values are reported.

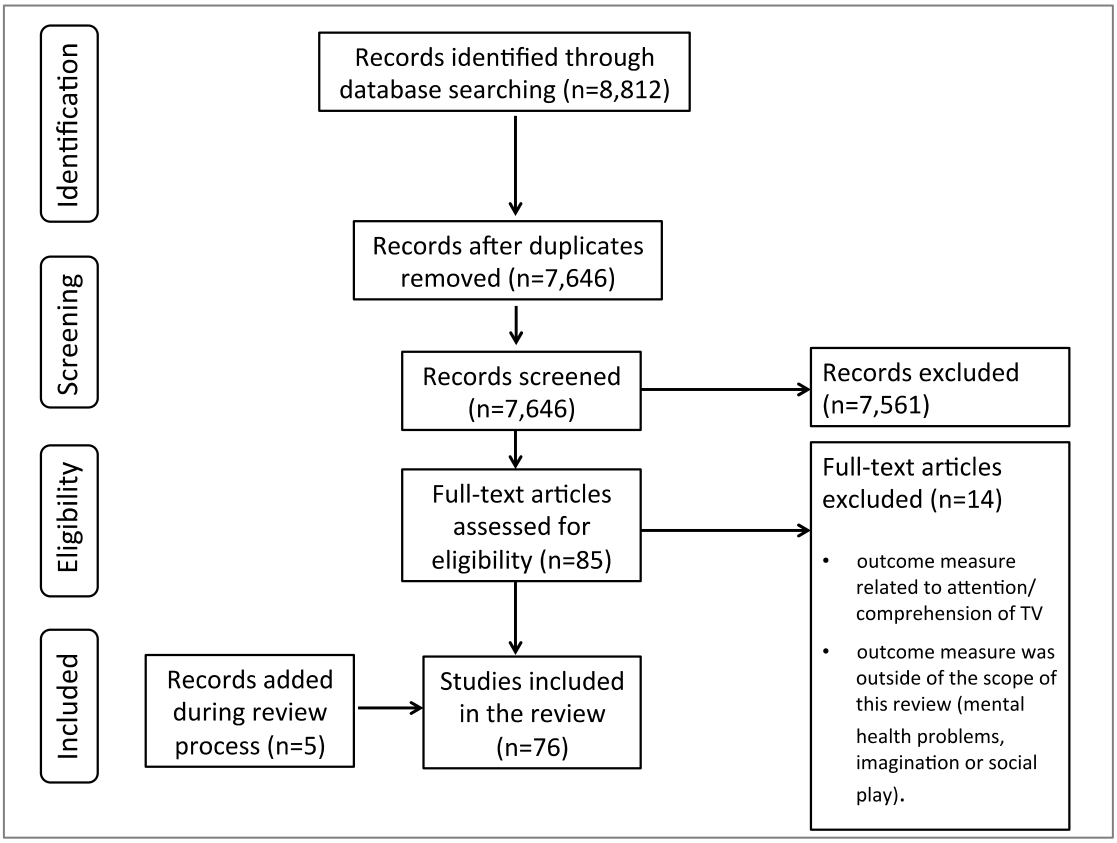

Figure 1. 1. The flow diagram depicting systematic searches process.

The articles in this review have been divided into four broad topics. First, there are studies that examine the relationship between television viewing, executive function and academic performance (sections on 'Executive function and academic performance'). These studies are integrated to reflect current literature, which suggests that effective executive function is associated with academic success, particularly in mathematics and reading (Best, Miller, & Naglieri, 2011; Blair & Razza, 2007; Cragg & Gilmore, 2014; Latzman, Elkovitch, Young, & Clark, 2010; Ponitz, McClelland, Matthews, & Morrison, 2009). Second, there are studies that examine the relationship between television viewing and attention problems. Attention is either measured directly in experimental research (section 'Attention measures') or more indirectly through measures of hyperactivity/inattention associated with attention deficit hyperactivity disorder (ADHD) in correlational studies (sections on 'Attention problems'). Third, sections on 'Language development' review the evidence relevant to the associations between television exposure and language development. Finally, the literature on the influence of foreground and background television on children's play and child-caregiver interactions observed during unstructured play is reviewed in section 'Free-play and child-caregiver interactions'.

Cross-sectional correlation studies.

Cross-sectional design offers a quick and relatively uncomplicated way to examine the differences between groups of participants by concurrent measurement of skills or behaviour of interest (Robinson, Schmidt, & Teti, 2005). The results of cross-sectional correlation studies provide a rationale for subsequent, more thorough longitudinal or experimental research (Kraemer, Yesavage, Taylor, & Kupfer, 2000). For a detailed summary of the studies included in this section, see Table 1.1.

Executive function and academic performance.

Developmental literature provides robust evidence for a relationship between executive function and children's math skills (for a review see Cragg & Gilmore, 2014) word reading and reading comprehension (e.g., Christopher et al., 2012). Therefore, in this subsection, we first review the studies that investigated the relationship between television exposure and executive function and, second, the literature that examined the associations between television viewing and academic performance in early and middle childhood.

Nathanson, Alade, Sharp, Rasmussen, and Christy (2014) tested 4-year-olds on four measures of executive function. In addition, data were collected regarding onset age of television viewing, overall exposure, foreground viewing, genre and channel viewing, vocabulary knowledge and sleep. They found children who started watching television at a younger age, and who watched more television overall, had poorer executive function. Moreover, educational cartoon viewing was negatively associated with performance on executive function assessments. In contrast, Public Broadcasting Service channel predicted better executive function scores, perhaps because, as researchers suggested, children's programmes shown on PBS were not interrupted by fast-paced commercials.

In contrast to performance-based measures of executive function, Linebarger, Barr, Lapierre, and Piotrowski (2014) assessed a group of preschoolers (3 to 5 years) and primary school children with a parent-reported measure. Participants in this study were categorised into "low risk" or "high risk" depending on their family ethnicity, economic and educational background. For primary school children from high-risk families watching educational television predicted higher executive function. Moreover, parenting style moderated this relationship; increased parental responsiveness together with increased amount of educational programmes viewing was associated with increased executive function scores. Conversely, greater exposure to background television predicted lower executive function in high-risk preschoolers and low-risk primary school children. Parenting style moderated the latter relationship; an increase in parental inconsistency together with an increased background television exposure was related to decreased executive function. Finally, foreground watching of children's entertainment programmes predicted higher executive function in low-risk preschoolers. Overall, these results suggest that the potential effects of television on the development of executive functioning depend on the type of exposure (i.e., background or foreground), content (e.g., educational, entertainment) and are further intensified by parenting style.

Together, the results of Nathanson et al. (2014) and Linebarger et al. (2014) suggest children's television habits are related to executive function skills. However, the exact nature of this association is nuanced, and depends on factors such as children's age, socioeconomic environment, and type of programming watched. For example, the negative relationship between background television exposure and executive function skills of preschoolers from high-risk families present in Linebarger et al.'s (2014) study was not replicated by the study of Nathanson et al. (2014). However, the majority of participants in the latter study came from families that might have been considered "low-risk" according to Linebarger and colleagues' classification. Finally, it is worth noting that executive function was assessed by different methods in these studies. Past literature suggests that although both performance-based measures and ratings of everyday executive function are valid, they capture different aspects of performance; the former reflects participants' *optimal* functioning and the latter reflects their *typical* functioning (Toplak, West, & Stanovich, 2013).

Similarly, research investigating the relations between television exposure and academic performance presents mixed findings. In four studies reviewed in this section children's reading and math abilities were measured with selected subtests of different standardised tests of academic achievement. Only one of these articles examined preschool academic skills. The remainder focused on academic achievement during early and middle school years.

Clarke and Kurtz-Costes (1997) examined the associations between television viewing, Home Learning Environment (HLE), parental employment and school readiness of preschool children from African-American families with low socioeconomic background. The authors assessed three components of HLE: number of books owned by a child; frequency of a child being read to by a parent; and frequency of a child receiving educational instruction, such as explanation of new words. Television viewing was negatively associated with children's school readiness and the quality of HLE. Yet, the relationship between HLE and school readiness was not significant.

However, it appears that the negative relation between television viewing and pre-academic skills, documented by Clarke and Kurtz-Costes (1997), may be only relevant to children of preschool age, or children from disadvantaged socioeconomic environment. An investigation by Anderson and Maguire (1978) did not provide support for negative relations between television viewing and academic performance. In this study, children from grades three to six (ages not reported) were tested on numeracy, vocabulary and reading comprehension. There was no significant association between television viewing and the test variables. However, children who participated in this study came from predominantly middle-class families, and were selected based on their superior IQ scores. Schweizer, Moosbrugger, and Goldhammer (2005) demonstrated links between several different types of attention and intelligence, and perhaps higher-than-average IQ moderates the relationship between television viewing and cognitive performance.

Similarly, Roberts, Bachen, Hornby, and Hernandez-Ramos (1984) researched the associations between television viewing and primary school children's reading abilities, and found no evidence that the amount of viewing predicted reading outcomes. The researchers focused their investigation on the relations between television use and motivation for viewing television/reading and reading achievement of children from second, third and sixth grade (ages not reported). The results did not show any significant associations between the variables measured in the study for the second-grade children. Moreover, for older children (third and sixth graders) the amount of television viewing was not a significant predictor of reading achievement. Conversely, children's reading ability appeared to be related to motivation for watching television. Using television to learn was negatively related to reading achievement in both age groups, whereas watching television to unwind predicted better reading, but only in sixth-grade children. However, it is worth noting here that the researchers collected information directly from the children, which should prompt a degree of caution in interpreting the findings from this study. Collecting questionnaire data from primary school children poses many challenges, such as, for example, low motivation and concentration, difficulty with answering ambiguous questions, and young children's unwillingness to give honest personal opinions for fear of giving a wrong answer (Borgers, De Leeuw, & Hox, 2000).

In contrast to the findings of Anderson and Maguire (1978) and Roberts et al. (1984), the results of Shin (2004) study suggest that the amount of television viewing in middle childhood may have detrimental direct and indirect effects on academic performance. The author obtained data from children aged from 6 to 13 years to examine four hypotheses about the relations between television and children's development: (1) *stimulation hypothesis*, watching well-designed educational programming aids learning; (2) *time displacement hypothesis*, television substitutes activities that offer more intellectual stimulation; (3) *mental-effort and passivity hypothesis*, watching television promotes "mental laziness"; and (4) *attention-arousal hypothesis*, viewing fast-paced, action-filled programming increases impulsivity and reduces the ability to sustain attention. The researcher investigated the relationship between television viewing, reading, homework, and whether these variables predicted reading and numeracy skills. Using structural equation modelling, the author demonstrated that the amount of television viewing was negatively associated with time spent doing homework and reading. Conversely, it was positively associated with impulsive behaviour. Moreover, the results showed that these three relations hindered academic performance. Shin (2004) suggested that the results supported hypotheses 2, 3 and 4 but not 1. However, even though the author stipulated that the *stimulation hypothesis* predicted an association between viewing "well-designed" and "informative programs" (Shin, 2004, p.368) and academic achievement, no attempt was made to measure content in this study.

In general, the importance of content has been largely overlooked in the studies that examined the potential role of television in children's academic performance. With an exception of Anderson and Maguire (1978), who analysed the type of programming that children were exposed to, viewing time was the primary predictor in the reviewed literature. This approach, to treat television viewing as an undifferentiated activity, limits the possibility of pinpointing the mechanisms that drive any observed associations. Furthermore, it appears that when researchers included children with a broader range of individual (e.g., IQ) or family factors (e.g., parents' attitudes towards TV), the relationship between television viewing and the measured outcomes was not significant.

In fact, the family context, in which the viewing occurs, may hold the key to explaining some of the results. Somewhat surprised by the lack of a significant association between HLE and school readiness in preschool children, Clarke and Kurtz-Costes (1997) suggested a new variable - *the family value system* - that could explain their findings. Perhaps limitations associated with the low socioeconomic status, such as for example, restricted budget, may prevent parents from buying books. Yet, families, who have high aspirations for their children's future may place more *value* on alternative educational activities, that were not measured in the study, to support children's learning. At the same time, these parents may discourage activities that are thought to have low educational value, such as television viewing. Therefore, as Clarke and Kurtz-Costes (1997) suggest, the family value system may mediate the relation between preschoolers' pre-academic skills and HLE measured in their study.

Attention problems.

Viewing time was the primary predictor in a variety of studies that examined the association between television and attention problems. However, studies reviewed below varied greatly in the number and type of confounding variables included in the analyses, and in the method of assessing television exposure (see Table 1.1. for details).

Based on parental estimates, Miller et al. (2007) calculated the average daily viewing time in a group of 4-year-olds. After controlling for age, gender, and socioeconomic status, an association was found between television viewing and both teachers' reports of ADHD behaviours and a direct measure of motor activity. Conversely, parents' reports of attention problems were not associated with television viewing. In similar research, Ebenegger et al. (2012) examined the association between television viewing and hyperactivity/inattention rated by parents of 4- to 6-year-olds. Higher scores on this measure were associated with more television viewing. Although these studies point to a relationship between the amount of time spent on television viewing and the presence of attention problems in young children, they both utilise parental recall of television viewing. Global measures, such as the estimates of typical weekly viewing time, have been found to be biased and less accurate than, for example, viewing diaries (Anderson, Field, Collins, Lorch, & Nathan, 1985; Rich, Bickham, & Shrier, 2015). Using a more precise estimate of television exposure, Conners-Burrow et al. (2011) failed to demonstrate an association between the amount of viewing and teachers' assessments of hyperactivity, aggression and social skills in 5-year-olds from low-income families. However, viewing inappropriate content was associated with classroom hyperactivity, higher aggression scores and poorer social skills.

Finally, in a carefully designed study, Collins (1990) examined whether television exposure was correlated with preschoolers' cognitive performance and with parental ratings of children's temperament. Parents of participants completed detailed 10-day viewing diaries, which were used to establish the amount, content and pace of programming watched. Children completed a battery of cognitive assessments (including measures of IQ performance, perseverance, impulsivity and sustained attention). Television viewing did not predict children's cognitive performance. Yet, it is worth noting, that children in this study scored slightly higher than average on the IQ measures. Thus, it is plausible the associations between television viewing and children's cognitive outcomes were moderated by their superior intelligence (see section on 'Executive function and academic performance' for a brief discussion). Conversely, parental ratings of motor activity were positively related to the amount of television watched. Moreover, watching entertainment and "action shows" was positively associated with motor activity. It appears that it was the content of programming, rather than pace that explains these results. For example, the researcher found that boys, who watched *Mister Rogers Neighborhood,* were judged as less active than boys who watched more sports. Both *Mister Rogers Neighborhood* and sports shows were slow-paced. Thus, it was suggested that a show's content rather than its pace might explain the results.

Four studies investigated whether television viewing was associated with attention problems in middle childhood and early adolescence. Levine and Waite (2000) collected individual viewing diaries from 8- to 11-year-olds, as well as parental estimates of their child's viewing, to calculate a television-viewing index. Viewing time was positively associated with teachers' ratings of ADHD behaviours in the classroom, but not with any other of the measures used in the study (e.g., Stroop performance and parental ratings of distractibility/hyperactivity).

Controlling for similar variables, Özmert, Toyran, and Yurdakök (2002) collected survey data from the parents of second and third grade Turkish children (ages not reported). Parents provided information about their children's viewing habits, behaviour and social functioning. Watching television for more than 2 hours per day predicted lower social competence and attention problems. Yousef, Eapen, Zoubeidi, and Mabrouk (2014), who examined data from 5- to 15-year-olds reported similar results. Watching television/playing video games for more than 2 hours per day was associated with withdrawn, attention problems, and delinquent and aggressive behaviour. Conversely, using the same outcome measure, Ferguson (2011) did not find a relationship between television viewing or exposure to violent content and the presence of attention problems in 10- to 14-year-olds from low-income Hispanic families. In this study, attention problems were predicted by social and personal variables, such as family environment, male gender, antisocial traits and anxiety. Perhaps the inclusion of these factors might explain the differences between the findings of Ferguson (2011) and the previous two studies, as they controlled for fewer confounding variables.

The link between time spent watching television and occurrence of attention problems was also investigated by three large population-based studies. Twenty per cent of 4- to 12-year-old children taking part in a Scottish health survey watched television for more than 3 hours a day (Shiue, 2015). Watching television for more than 3 hours a day was associated with poorer psychosocial adjustment as assessed by the Strengths and Difficulties Questionnaire. However, this level of viewing was not related to the hyperactivity/inattention subscale of this questionnaire. In contrast to this, using the same outcome measure, van Egmond-Fröhlich, Weghuber, and de Zwaan (2012) found an association between television viewing and the scores on hyperactivity/inattention subscale with 6- to 17-year-olds. Furthermore, Lingineni et al. (2012) performed a cross-sectional study of 5- to 17-year-old children. Approximately 10% of children in this sample had a diagnosis of ADHD. The researchers found that watching television for more than 1 hour a day was one of six factors that increased the odds of the ADHD diagnosis.

Based on the results of these three large-scale studies, it appears that watching television should be considered a risk factor, particularly in relation to children's mental health and psychological wellbeing. However, there are limitations to consider. First, each study had a somewhat different focus, and this was reflected in the wide range of covariates included in the analyses (see Table 1.1. for details). Second, all studies relied on either parental or self-report of television viewing and health-related outcomes, therefore introducing the possibility of recall bias. Finally, none of the studies controlled for content. It is plausible that older children and adolescents, who have less parental supervision, watch more inappropriate content. Thus, the observed associations between television viewing and attention and behavioural problems could be driven by the quality rather than the quantity of television.

This lack of consideration of content may be of particular importance, as a recent study has suggested that children's media content preference may be genetically pre-disposed. Testing a sample of 5- to 9-year-old children, Nikkelen, Vossen, et al. (2014) demonstrated a relationship between the serotonin transporter-linked 5-HTTLPR polymorphism and violent media use. This polymorphism has previously been linked to the development of ADHD (see Gizer, Ficks, & Waldman, 2009 for the meta-analysis). Furthermore, the results of this study showed an association between violent media use and children's attention problems. Finally, there was an indirect significant relation between the genotype and ADHD behaviour mediated through violent media use.

In summary, over 70% of the studies reviewed in this section present evidence for positive associations between television viewing and attention problems. However, the contribution of this evidence to our understanding of the potential role that television viewing might have in the development of children's attention is limited in two ways. First, the researchers largely overlooked the importance of content. Yet, in studies that controlled for content (i.e., Collins, 1990; Conners-Burrow et al., 2011) the relationship between the amount of viewing and measured outcomes was eliminated. Second, with very few exceptions (Collins, 1990; Ferguson, 2011), the authors did not consider the broader individual and family context, in which television viewing occurred. Instead they focused on researching basic links between TV viewing and attention without more detailed consideration of a host of interacting variables "…that lead children on a path from exposure to outcomes." (Barr & Linebarger, 2010, p.555). Thus, the evidence, which came from the investigation of such rudimentary models, appears to be inadequate to explain the complex relationships between television exposure and attentional outcomes (Barr & Linebarger, 2010)

Language development.

The reports of language outcomes in cross-sectional literature are scarce. Only three studies examined the relationship between television viewing and language outcomes in young children. First, Zimmerman, Christakis, and Meltzoff (2007) measured the association between television/film content and infants' (birth to 2 years) language skills. Of four types of content examined (baby TV/DVDs, educational, entertainment and adult), only watching programmes directed specifically at infant audience was negatively related to early language development.

Second, Lin, Cherng, Chen, Chen, and Yang (2015) compared language skills of two groups of 15- to 35-month-olds. The groups were matched for age and gender, but differed in television viewing (137 vs. 16 minutes/day). High exposure to television increased the risk of language delay. Moreover, children with language delay tended to watch more television than their typically developing peers (117 vs. 53 minutes/day). Third, Chonchaiya and Pruksananonda (2008) compared television viewing habits between 2-year-olds with or without language delay. Children with language delay started watching television at a younger age (7- vs. 12-months), and spent more time watching television (3.1 vs. 1.0 hours/day). Watching television before a child's first birthday and watching more than 2 hours/day increased the risk of language delay over six times. Moreover, lone-viewing, lacking child-caregiver interaction during television watching, was associated with eight times greater risk of having language delay.

Although television may be detrimental to infants' development, the three most significant risk factors for language delay in this study were unrelated to television exposure. Neglectful parenting increased the odds of language delay by over 30 times, and delivery by caesarean section or family history of language/developmental delay were both associated with an odds ratio of about 10 times. Similarly, Lin and colleagues (2015) reported that a low level of maternal education was the strongest risk factor for language delay in their study (about four times). Therefore, as with the suggestions made in the concluding paragraphs of sections 'Executive function and academic performance' and 'Attention problems', it appears that family factors should be given serious consideration in the investigation of the mechanisms that underlie the associations between television exposure and children's development. Finally, without random allocation of participants into each viewing group, there is no certainty that the differences observed in the latter two studies are in fact due to television viewing rather than other unmeasured variables. However, they offer interesting comparisons between developmental outcomes of children, who were or were not exposed to high levels of television at a young age, which could not be made experimentally due to ethical considerations.

Summary of cross-sectional studies.

Although the results of many cross-sectional studies report negative associations between television viewing and children's cognitive development and - in particular - attention, questions can be raised about the value of the evidence they provide. On the one hand, it appears that there is a positive association between the amount of television viewing and the presence of attention problems in preschool and older children (e.g., Ebenegger et al., 2012; Özmert et al., 2002). Furthermore, increased impulsivity associated with television viewing, in conjunction with displacing the activities that promote learning (such as reading and homework), may lead to poorer educational outcomes (Shin, 2004). Also, excessive television exposure in infancy (> 2 hours/day) is an important risk factor for language delay (e.g., Lin et al., 2015). On the other hand, these associations are mainly observed in the literature based on the investigation of relatively simple theoretical models.

For example, age, gender and socioeconomic status have been included in most of the investigated models. However, individual, family and social factors that may mediate the relationships between television viewing and developmental outcomes have been largely overlooked in cross-sectional research (Oakes, 2009). Indeed, when these factors were included in analyses, they appeared to be stronger predictors of developmental outcomes than TV viewing per se (e.g., Ferguson, 2011; Linebarger et al., 2014). Moreover, evidence suggests that individual factors, such as IQ, may moderate the associations between television viewing and developmental outcomes (Anderson & Maguire, 1978; Collins, 1990).

Additionally, some methodological concerns raise questions about the robustness of the evidence. First, with few exceptions, most of the cross-sectional research described here used global measures of television viewing, based on parental recall, which may be subject to bias. Average daily viewing time, reported across the various studies ranges from less than 1 hour/day (e.g., Roberts et al., 1984; Ebenegger et al., 2012) to over 3 hours (e.g., Conners-Burrow et al., 2011; Clarke & Kurtz-Costes, 1997). This wide range may be a true reflection of differences between television viewing depending on children's age or cultural factors. However, it may also be a result of inaccurate measurement, arising from the type of response scales used in a study, respondents' bias to give socially desirable answers, or simply poor recall. Another question raised by assessing the amount of viewing is what exactly is being measured. Is it the amount of time a child spends in a room when the television is on? The time a child has her eyes fixed on a screen? Or perhaps the time a child is immersed in watching a programme (Moses, 2008)?

Second, most of the studies reviewed in this section have employed well-validated measures such as the Strengths and Difficulties Questionnaire (Goodman, 1997), Child Behavior Checklist (Achenbach, 1991), or The Bayley Scales of Infant Development -2nd Edition (Bayley, 1993). However, the assessment of complex skills such as attention or language with a single measure (sometimes reduced to several items or a subtest of a particular measure) appears too restrictive (Moses, 2008). Moreover, several studies relied on arguably less reliable parental assessment of ADHD behaviours (e.g., Miller et al., 2007), or on parent-reported ADHD/ADD diagnosis (Lingieni et al., 2012). It is likely that when consent was sought and the information about the study was provided to participants, parents were made aware of the potential negative associations between television exposure and behaviour. As

Russell, Rodgers, and Ford (2013) suggest, parents may be more likely to report the presence of ADHD symptoms if the diagnosis was suggested to them by a healthcare professional, but not yet confirmed. Similarly, parents of children who watched a lot of television may have been more likely to report attention difficulties than parents of children who exhibited similar behaviour, but watched a moderate amount.

Third, most studies did not attempt to account for the content viewed. In fact, findings from the studies where the type of content was controlled for, suggest that *what* children watch rather than *how much* they watch is a better predictor of developmental outcomes. The lack of information about what children watch may be of particular importance when considering findings from large-scale, population-based studies, which included participants from a wide age range. Older children and adolescents have more choice over what they watch and may choose programmes based purely on entertainment value. Moreover, television programming directed at 5-year-old audience differs in content and form to that directed, for example, at 10-year-old viewers. Considering television viewing to be an undifferentiated activity may lead to oversimplifying the possible relationships between viewing behaviour and developmental outcomes.

In sum, although cross-sectional studies have been useful in recognising associations between exposure to television and developmental outcomes, they do not allow us to draw causal inferences or establish a temporal sequence, thus it is impossible to determine when the association developed, or how it may change across time (Robinson et al., 2005). Moreover, the key limitations of cross-sectional research are the lack of precise viewing measures and the potential reporting bias, restricted outcome assessment, and a frequent omission of potential moderators, such as content, or contextual variables, from the investigated models. Nevertheless, the investigation of the literature revealed a number of variables (i.e., content, age of exposure, family context and individual differences, and foreground vs. background exposure) that may play a key role in developing a better understanding of the complex relations between television exposure and children's development.

Longitudinal correlation studies.

Longitudinal design allows the observation of "early-later" relationships (Robinson et al., 2005) and suggestions to be made about the temporal sequence of co-variables; thus it enables plausible inferences about causes and effects. Furthermore, it is a suitable alternative when controlled experiments would be unethical (Mann, 2003), such as, for example, exposing children to high levels of television. This section reviews evidence from 31 studies related to the long-term correlates of television viewing to executive function, academic performance, attention problems and language development. For a detailed description of the studies, see Table 1.2.

Executive function and academic performance.

The cross-sectional literature reviewed in section 'Executive function and academic performance' suggests that programming content and family context may play a role in understanding the mechanisms that underlie the associations between television viewing and executive function. The following two studies provide further evidence for the importance of these variables. In a prospective cohort study, Barr, Lauricella, Zack, and Calvert (2010) investigated whether the television content children are exposed to at young age (child-directed vs. adult-directed) predicted subsequent cognitive outcomes[1]. Parents completed viewing diaries when their children were 1- and 4-years-old, and assessed their children's behaviour at age 4 by completing a questionnaire measure of executive function. The results suggested that the type of content children watched was related to their cognitive skills. Watching adult-directed programmes in infancy was associated with poor executive function at age 4, as measured by the questionnaire. In addition to parental assessment of executive function, 4-year-olds completed a battery of cognitive tests. After controlling for parental education, the results showed that high exposure to adult-directed content at age 4 was associated with poorer cognitive performance (poorer language skills, school readiness skills, and lower scores on executive function measure). Conversely, watching child-directed programming both in infancy and at 4 years was not associated with these negative outcomes. Overall, the results of this study suggest that the relationship between watching television and cognitive outcomes depends on content. Watching child-directed programming was unrelated to both performance and parent-reported executive functioning, whereas exposure to adult-directed content was associated with poor executive function.

Blankson, O'Brien, Leerkes, Calkins, and Marcovitch (2015) used performance-based cognitive measures to examine the relationship between preschool television viewing at 3 and 4 years and vocabulary and executive function at 5 years. The researchers also measured the quality of Home Learning Environment (HLE assessed with a number of books at home, joint reading activities, explicit teaching of new concepts and words and availability of toys and other learning materials at home) and the quantity and quality of parental scaffolding (parent-child interactions measured during a problem-solving task). At baseline (age 3), there was a negative correlation

[1] Although this study has a longitudinal design, one of the investigated hypotheses is cross-sectional. However, for clarity, the results of both longitudinal and cross-sectional investigations are presented together in this subsection of the review.

between the amount of television viewing and the quality of HLE and cognitive scaffolding. However, there was no association between television viewing at age 3 and executive function and vocabulary at age 5 (after controlling for socioeconomic status and ethnicity). Instead, these were predicted by parental scaffolding. Similarly, at age 4, there was a negative correlation between the amount of television and HLE and parental scaffolding. Yet again, television viewing at 4 was not predictive of vocabulary and executive function at age 5. The only significant association was between the level of parental scaffolding and vocabulary.

These two studies had different strengths. Barr et al. (2010) used a more accurate measure of television viewing (a viewing diary), and collected information about content as well as capturing information about viewing at a younger age. However, Blankson et al. (2015) controlled for the level of cognitive stimulation at home. Perhaps the way television is used in the household contributes to the overall educational climate within the home. For example, parents who provided more cognitive stimulation may have also encouraged their children to watch age-appropriate educational programming. Conversely, families, in which parents rarely engaged in educational activities with their children, may have used television purely for entertainment purposes, and in consequence paid little attention to the educational value of the programmes to which their children were exposed.

Two studies, using large population-based samples investigated the relations between viewing in infancy and early childhood and children's school readiness and early educational outcomes. First, Zimmerman and Christakis (2005) examined whether television viewing before the age of 3 and between ages of 3 and 5 years predicted early academic skills and working memory at the age of 6. There was an association between television viewing before the age of 3 and poorer single word reading and text comprehension. Furthermore, early television viewing predicted poorer working memory and early numeracy skills, but only in children from low-income families. Conversely, television viewing between the age 3 and 5 was *positively* associated with reading comprehension scores. Second, Pagani, Fitzpatrick, and Barnett (2013) reported that more time spent viewing television at 29 months was negatively associated with vocabulary scores, early numerical skills and teachers' ratings of classroom engagement at 65 months.

In contrast, Ritchie, Price, and Roberts (1987) failed to provide evidence of a meaningful relation between the amount of viewing and school outcomes. The researchers examined changes in television viewing, leisure reading and reading achievement across a three-year period in primary school children. It appears that neither reading time, nor reading skills were related to the amount of television viewing in primary school children. Yet, caution should be applied to the interpretation of these results. The researchers asked children and not parents to quantify the amount of television viewing and reading at home (see section 'Executive function and academic performance' for a brief discussion). The correlations between children's estimates collected via a questionnaire and viewing diary were only moderate (r-values ranging from .40 to .65), which raises questions about the reliability of the viewing data analysed in this study.

Although the results of Zimmerman and Christakis (2005) and Pagani and colleagues (2013) suggest that television is negatively related to school readiness and early educational outcomes, they tested the amount of viewing rather than the content. A carefully designed study conducted by Wright et al. (2001) provided evidence that content might be critical to these outcomes. They examined patterns of television viewing and their relationship to early academic skills in two cohorts of children (with initial ages of 2 and 4 years) over a period of 3 years. For the younger cohort only, watching educational television at 2 to 3 years was positively related to basic academic skills, vocabulary, and school readiness at the age of 3. Also for the younger cohort only, watching animated cartoons at 2 and 3 years predicted poorer word recognition at the age of 3, and lower vocabulary at the age of 5. For both cohorts, viewing "general audience programmes" was associated with worse outcomes on several cognitive measures (younger - poor numeracy and vocabulary, older - letter/word knowledge). Furthermore, this study provided some evidence for children's cognitive skills driving later viewing. For the younger cohort, better performance on letter-word recognition, vocabulary, and school readiness tests at age 3 predicted less viewing of general audience programmes at 4 to 5 years. For the older cohort, higher scores on the test of letter-word recognition at age 5 were positively related to watching educational television at 6 to 7 years. Finally, low vocabulary scores at age 5 predicted more cartoon viewing at ages 6 to 7 years.

Overall, these findings suggest that watching adult-directed content may have potential detrimental effects during childhood, irrespective of the age of exposure. Moreover, only young viewers (age 2-3) appear to benefit from watching educational television. Finally, this study provides evidence for a bidirectional relationship between content preference and children's cognitive skills.

Further evidence that the relations between television exposure and educational outcomes are complex comes from a study by Sharif, Wills, and Sargent (2010). The authors collected self-reported information to examine relationships between amount of television viewing, watching inappropriate content, and school performance in older children (10- to 14-year-olds). Using structural equation modelling, the researchers tested a model that proposed several potential pathways leading to inferior school performance. The results did not support the direct pathway, from television exposure to educational performance. However, it appears that there was an indirect negative relation between viewing inappropriate content and educational performance. Specifically, viewing inappropriate content predicted poorer school outcomes through an increase in substance use and sensation seeking. Moreover, specifically viewing R-rated "adult only" films increased problem behaviour at school, which in turn resulted in poorer educational outcomes.

Studies reviewed so far in this section have had a relatively short duration; the interval between the baseline and the last wave of data collection varied between one and three years. Thus, their findings cannot provide evidence for persistent associations. The remaining part of this section describes findings from four studies that investigated long-term outcomes of television viewing.

In a population-based study, Pagani, Fitzpatrick, Barnett, and Dubow (2010) investigated prospective associations between television viewing at 29 and 53 months and the level of academic performance and classroom behaviour at 10 years. The amount of television viewing at 29 months predicted lower levels of classroom engagement and mathematical skills (but not reading) at age 10. Viewing at 53 months had no relation to subsequent performance. The latter result implies that the potential effect of television viewing on educational outcomes may be restricted to infancy. This suggestion is supported by results of a study that examined the relationship between changes in television viewing and academic performance between the ages of 6 and 12 years (Hofferth, 2010). Overall, for the majority of children taking part in this study, changes in television viewing were not related to changes in educational performance. Significant findings were restricted and contradictory. For White boys an increase in amount of television viewing predicted higher scores on letter-word recognition, whereas for Black girls an increase in television viewing predicted lower scores on text comprehension.

Although these two studies spanned a relatively long period, they examined children's educational outcomes in relation to the overall viewing time, without considering content. In contrast, Anderson and colleagues (2001) focused their investigation on the long-term developmental correlates of television content watched by preschoolers. The comparison of preschool and adolescent viewing habits suggested that content preferences remained stable across time. Moreover, the type of content watched during preschool years, but not the amount watched, appeared to have long-term associations with educational outcomes.

For girls, the amount of viewing at age 5 predicted poorer high school grades; conversely, boys' preschool viewing time was positively associated with academic achievement during adolescence. However, more detailed analyses showed that these results were explained by content watched. The girls who watched more child-informative programmes at age 5 tended to have better grades at high school, although this relationship was not statistically significant. The boys' results were more conclusive; viewing child-informative programmes during preschool years predicted better high school grades. In contrast, the girls who watched violent cartoons at 5 had lower grades. However, this relationship was partially mediated by teen viewing of violent content. For boys, preschool viewing of violent content did not predict high school grades; however, watching violent content in adolescence was negatively associated with high school grades. Overall, these results suggest that the content of programming watched, rather than the amount, during preschool years predicts teen educational outcomes. Moreover, the only robust long-term association between preschool viewing and teen grades appears to be the positive relation between boys' exposure to child-informative programmes and average grades in adolescence.

Although the findings of Pagani et al. (2010) and Wright et al. (2001) suggest that some associations between television and academic outcomes are long-lasting, they do not allow us making inferences about the potential role of early TV viewing beyond adolescence. Hancox, Milne, and Poulton (2005) examined prospective associations of television viewing and educational attainment through into adulthood. The results indicated that the amount of television viewing in childhood (5 to 11 years) and adolescence (13 to 15 years) was positively associated with leaving school with no qualifications, and negatively related to achieving a university degree. Furthermore, adolescent viewing was a strong predictor of leaving school without qualifications, whereas childhood viewing was negatively related to achieving a university degree. Although these findings suggest that watching television may have far-reaching consequences that extend beyond school years and potentially impact adult life, Hancox and colleagues (2005) did not consider in their investigation important moderating variables such as content and family context.

In sum, the findings from the studies that measured the amount of viewing suggest that infancy TV exposure may have negative consequences for children's later educational attainment. Conversely, the evidence pertaining to older viewers' academic outcomes is less clear. Considering the heterogeneity of the measures used, the varied choice of covariates and a different length of the interval between the study phases, it is likely that the mixed findings stem from the differences in study design rather than reflect a lack of systematic relations. Finally, the findings from the studies that investigated the potential role of content are consistent with the evidence presented in earlier sections of this review. The relationship between watching educational TV and academic outcomes is positive, whereas watching inappropriate adult-directed content predicts lower educational attainment.

Attention problems.

Although useful for identifying associations between television exposure and attention problems, the cross-sectional literature could not provide answers regarding the mechanisms that drive such associations. While longitudinal research has advantages in this regard, its potential to explain the underlying causal mechanisms depends on the complexity of the investigated models and the robustness of the measures used

In a prospective cohort study Cheng, Maeda, Yoichi, Yamagata, and Tomiwa (2010) investigated whether early television exposure was associated with subsequent behaviour in under-threes. Mothers reported their children’s daily television viewing at ages 18 and 30 months. In addition, children’s behaviour was assessed at 30 months. After controlling for child and mother characteristics, there was a positive association between daily television exposure at 18 months and hyperactivity/inattention. Furthermore, there was a significant linear trend indicating that as the number of viewing hours at age 18 months increased, hyperactivity/inattention problems at age 30-months increased and pro-social behaviour decreased.

Although this study provided evidence for the relationship between television viewing and decrease in attention and pro-social behaviour in infants, it did not measure children’s baseline behaviour. Perhaps parents of infants, who demonstrate difficult behaviour early on, turn to television to soothe their otherwise unsettled children. Therefore, the associations between later television exposure and behavioural problems, such as, for example, inattention, might be confounded by children’s early behavioural traits. Radesky, Silverstein, Zuckerman, and Christakis (2014) examined whether infants’ self-regulation at 9 months predicted the amount of television use at 24-months. A questionnaire completed by parents at ages 9 and 24 months measured children’s behaviour regulation. Infants with moderate to severe self-regulation problems watched more television as toddlers than infants who had no or mild behavioural regulation difficulties. Furthermore, children with persistently poor self-regulation were 40% more likely to watch 2 hours of television a day. Likewise, children whose self-regulation skills deteriorated since infancy were at increased risk of watching more television. It is worth noting that researchers did not collect information about television exposure at 9 months. Perhaps the positive relationship between infants’ self-regulation and later viewing was confounded by television exposure in infancy.

Further evidence for an interdependent relationship between behavioural difficulties and television viewing comes from a study conducted by Verlinden et al. (2012). The researchers assessed the *occurrence* (onset of behaviour at 36-months) and *persistence* (a continuous presence of behaviour at both 18- and 36-months) of attention problems and aggression in a large sample of children. Information about the amount of viewing and type of content was collected at 24 and 36 months. Neither the amount of television nor viewing unsuitable content at 24 months predicted the occurrence of attention problems and aggression at 36 months. However, “high television exposure” (a high amount of viewing at 24- *and* 36-months *and* increased viewing between these time points) was associated with the occurrence of attention problems and aggression at 36 months and the persistence of these problems. Finally, an increase in viewing was strongly related to persistence of attention problems and aggression. Therefore, it appears that children with early behavioural difficulties may be particularly drawn to watching television. Acevedo-Polakovich, Lorch, and Milich (2007) suggest that children who demonstrate difficult behaviour, such as children with ADHD, struggle with peer relationships and experience a higher level of conflict in their interactions with caregivers at home. Perhaps, as Acevedo-Polakovich et al. (2007) suggest, watching television offers a mutually enjoyable alternative to social interaction for children with behavioural difficulties and others in their social environment.

Four further large studies examined the relationship between the amount of television viewing and subsequent ADHD behaviours. Christakis and colleagues (2004) examined whether the amount of television viewing at age 1 and 3 was associated with attention problems at 7 years. After controlling for confounding variables, there was a positive association between the score children obtained on the hyperactivity subscale of the questionnaire measuring behaviour problems and the amount of television they watched at the age of 1 year and 3 years. Furthermore, Landhuis, Poulton, Welch, and Hancox (2007) investigated whether attention problems in adolescence were related to childhood (i.e., ages 5 to 11) television viewing. The researchers demonstrated that, after controlling for early attention, cognitive ability and socioeconomic status, the amount of television viewing in childhood was related to attention problems in adolescence. However, this relationship was reduced once adolescent viewing was controlled for.

The data from Christakis and colleagues' (2004) study were subsequently reanalysed in two independent studies. First, to explore the developmental trajectories of television viewing and attention problems across the six-year period (Stevens, Barnard-Brak, & To, 2009), and second, to examine the robustness of the original findings by using a different statistical technique and adding more covariates to the model (Foster & Watkins, 2010). Stevens and colleagues (2009) used the same data as Christakis et al. (2004); however, instead of using two time points (television viewing at ages 1 and 3 years, and attention outcomes at 7 years) to evaluate the relationship between the variables, they mapped the developmental trajectories of television viewing and attention problems between the ages of 4 and 10, and examined the relationship between both. The analysis of changes in television viewing revealed that after a rapid rise in early childhood, there was a steady increase in viewing during the six-year period. In contrast, attention problems and hyperactivity peaked between the ages of 6 and 7, and then gradually declined. The examination of the relationship between the amount of television and attention problems during the time, when the children were 6 years old, indicated that there was no significant association between the increase in viewing and hyperactivity/inattention. Furthermore, although there was a significant association between attention problems at 4 years and the subsequent increase in television viewing, it was deemed weak ($\beta = .05$) and thus of little importance. Finally, there was no significant association between the amount of viewing and attention problems in 4-year-olds.

In the second re-analysis of the data first presented by Christakis and colleagues (2004), Foster and Watkins (2010) used semi-parametric regression, which allowed a more sensitive non-linear approach to investigating the relationship between the amount of television viewing, covariates and attention outcomes. This reanalyse failed to support the original interpretation of the findings. First, the association between early childhood viewing and later attention problems was only significant for children who watched excessive amounts (i.e., between 6 and 7 hours of television a day). Moreover, the inclusion of two additional covariates to the model (maternal achievement and family poverty status) rendered this relationship not significant.

More support for the lack of a meaningful relationship between the amount of viewing and subsequent attention problems comes from a study by Stevens and Mulsow (2006). Using a structural equation model, the researchers examined the data from two samples of children (the second sample was used to cross-validate the model) to test for the association between kindergarten television viewing and the presence of ADHD symptoms (measured by teachers' and parents' ratings) in the first grade (age not reported). Controlling for socioeconomic status, no statistically significant relationship was found between television viewing and subsequent ADHD symptoms. Furthermore, using a large population-based sample, Parkes, Sweeting, Wight, and Henderson (2013) found no association between the amount of television viewing at 5 years and hyperactivity/inattention at 7 years reported (by mothers on a questionnaire measure of behaviour). However, children who watched more than 3 hours of television a day at the age of 5 years demonstrated increased conduct problems between the ages of 5 and 7 years. Finally, Schmiedeler, Niklas, and Schneider (2014) demonstrated that the amount of television exposure (based on the child- and parent-reported viewing amount) did not predict attention problems at school age. Instead, hyperactivity and inattention at school age were related to child's early home learning environment.

It appears that not only the quality of learning environment, but also other aspects of home life may be important for the development of attention. Martin, Razza, and Brooks-Gunn (2012) examined the associations between "chaos in the households" – measured by the lack of routine, family instability, having the television on, noise and crowding – of 2-year-olds and developmental outcomes at 5 years. Having the television habitually on at home was associated with poorer attention and increased aggression. Other measures of household chaos were not associated with the measured outcomes.

All of the studied reviewed so far in this section measured the amount of exposure, overlooking the importance of television content. Yet, as we have discussed above, *what* children watch rather than *how much* they watch may be crucial to subsequent developmental outcomes. However, only two longitudinal studies tried to capture the contribution of content in explaining the relationships between television viewing and attention. Tomopoulos et al. (2007) collected television exposure data (including names of programmes and total viewing time) at 21 and 33 months from Latino mother-child dyads[2]. The programmes watched by children were categorised. Further, children's behaviour was assessed at 33 months with a questionnaire measure. There was a positive association between total television viewing at 21 months, aggressive behaviour and the presence of externalising problems (i.e., unruly, antagonistic and hyperactive behaviour). Moreover, aggressive behaviour was associated with viewing non-educational programmes at 21 and 33 months. Finally, viewing non-educational programmes at 33 months was positively associated with the scores on externalising problems scores. In contrast, viewing educational content at 21 months did not predict subsequent problem behaviour.

Adopting a longer interval between the study phases, Zimmerman and Christakis (2007) investigated the association between the type of content watched in early childhood and later attention problems. Viewing entertainment programmes (both violent and non-violent) before the age of 3 years predicted higher hyperactivity 5 years later. In contrast, no associations were found between the exposure to entertainment content at the age of 4 to 5 years and attention problems 5 years later.

[2] Some analyses performed in this study are cross-sectional. However, for clarity, all results from longitudinal studies are reported in this section of the review.

In addition, viewing educational television at an early age was not associated with subsequent attention problems.

Overall, the longitudinal literature provides some evidence for a bidirectional relationship between television exposure and behaviour (Radesky et al., 2014; Verlinden et al., 2012), which suggests that children with early attention difficulties may be particularly drawn to watching television. There is less evidence for high levels of television viewing simply causing attention deficits. However, when content was considered, the potential negative outcomes associated with watching television were more apparent – with problems observed among children that were exposed to content which was designed to entertain (e.g., cartoons). Conversely, watching educational content was unrelated to subsequent attention or problem behaviour.

Language development.

Some cross-sectional literature suggests that although television viewing is not the most significant risk factor for language delay, it should be considered as an important variable associated with early language outcomes. Three longitudinal studies assessed the relationship between early television exposure and infants' language development. Tomopoulos et al. (2010) examined whether exposure to various media (i.e., television, video/DVD, films and games), and media content, at age 6 months predicted language skills at 14 months in infants from families with low socioeconomic status. The overall amount of television exposure was negatively related to language development. Moreover, exposure to older child/adult-directed content predicted poorer language skills.

Duch et al. (2013) provided further support for the negative relationship between television exposure and communication skills of 12- to 24-month-olds from low-income families. Children taking part in this study were categorised according to viewing time (either “under 2 hours per day” or “over 2 hours per day”). High exposure predicted poorer communication skills a year later. Furthermore, watching child-directed content for more than 2 hours per day decreased subsequent communication skills. High exposure to adult content was not related to communication scores. However, at baseline assessment there were only 19 children who were exposed to more than 2 hours of adult-directed content daily, and so perhaps, as the authors suggested, the study was underpowered to detect a relationship between the variables.

In a carefully designed study, Linebarger and Walker (2005) collected detailed viewing logs from parents every three months between ages 6 and 30 months to examine developmental trajectories of television viewing and language skills. Parents recorded information regarding children’s overall viewing time and names of programmes viewed. Researchers classified programmes listed by parents into three broad categories: child-educational, child-entertainment and adult programming. The overall viewing time predicted lower word production at 30 months. Furthermore, watching child-educational programmes, but not child-entertainment and adult programming, was also negatively related to word production. Conversely, expressive language scores (obtained in a play-based assessment of early communication behaviour) were positively associated with time spent viewing television. Moreover, watching adult programmes, but not those directed to children, predicted expressive language growth. Finally, watching programmes directed at child audiences was unrelated to expressive language outcomes.

These associations appeared to be further qualified by children’s preference for specific kinds of programme. Watching shows with no structured story, such as *Sesame Street* (despite its well-documented benefits for preschool learning), or programmes that provided few or low-quality language examples (e.g., “baby talk” used in *Teletubbies*) predicted poorer language skills. Conversely, watching programmes that may stimulate language development through clear labelling, encouraging vocalizations, and interactions with on-screen characters (e.g., *Dora the Explorer*, *Blues Clues*) was associated with positive language outcomes. Collectively, the negative associations between television viewing and language development are particularly evident for children from low socioeconomic environments (Tomopulous et al., 2010; Duch et al., 2013). However, for children from middle- to high-income families (Linebarger & Walker, 2005), the relationships between television viewing and language outcomes are more nuanced.

In contrast to these findings, Schmidt and colleagues (2009) found no evidence that television viewing before the age of 2 was associated with poorer vocabulary at the age of 3, once maternal and household characteristics were controlled for. Similarly, based on data from older children, Bittman and colleagues (2011) found no relationship between the amount of television viewing and children’s vocabulary knowledge – although other relationships were significant. The researchers examined traditional media (television and print) use, as well as children’s access to new media devices (e.g., computers, games consoles, etc.), co-viewing and parental media monitoring practices in two cohorts of children over a four-year period. For the younger cohort (0- to 5-year-olds), having a television in the bedroom and background television predicted lower receptive vocabulary scores at age 5 years. In contrast, watching television together with parents was associated with increased vocabulary scores of 5-year-olds. For the older cohort (4- to 9-year-olds), having a television in the bedroom predicted lower vocabulary scores at age 9.

The results of this study did not show any evidence for the negative relationship between the amount of television viewing and children's subsequent language outcomes. Although families that took part in this research represented diverse socioeconomic backgrounds, the percentage of highly educated mothers was relatively high (10%), whereas families with low socioeconomic status were underrepresented. Previous research shows that maternal education and family income are strong positive predictors of language outcomes (e.g., Hoff, 2003). Likewise, consistent with the suggestions of other researchers (e.g., Clarke & Kurtz-Costes, 1997; Schmiedeler et al., 2014), home environment and parental characteristics may be stronger predictors of language outcomes than the amount of television children are exposed to. Well-educated parents may have a greater awareness of paediatric media guidelines, and consequently their children are exposed to less television overall, and watch programmes that are age-appropriate and contain educational material.

Indeed, some television may have the potential to support children's language development. Rice, Huston, Truglio, and Wright (1990) investigated the relation between watching *Sesame Street* and vocabulary development in two cohorts of children (with initial ages of 3 and 5). For the younger cohort, viewing the programme at age 3 and 4- to 5 was positively related to vocabulary growth at age 5. Preschoolers, who are the target audience of *Sesame Street*, appeared to benefit from the language-enhancing content of the programme. In contrast, for the older cohort the relationship between watching *Sesame Street* at age 5 and 6-7 was not significant. Perhaps, as Rice and colleagues (1990) suggested, the content of *Sesame Street* is well suited to support the rapid development of vocabulary during preschool years, yet ineffective in enhancing the learning of older children who need to acquire more sophisticated language skills. Moreover, the notion that the potential effects of content may be mediated by a viewer's age is supported by the findings of Linebarger and Walker (2005) described earlier in this section, which demonstrated a negative association between watching *Sesame Street* and infants' language growth. Unlike preschoolers', infants' cognitive skills are too immature to benefit from vocabulary-enhancing content presented on a television screen (for a discussion see Barr, 2010).

Finally, there is a suggestion that television viewing may be associated with anatomical changes in brain structures important for the development of verbal abilities and overall intelligence in children and adolescents. Using functional magnetic resonance imaging, Takeuchi et al. (2015) provided evidence for cross-sectional and longitudinal relations between the amount of television viewing and positive changes in grey/white matter volume in the frontopolar, medial prefrontal, visual cortex, hypothalamus/septum and sensorimotor areas. Although it is unclear whether these observed structural changes in various parts of the brain are detrimental, the same study also reports negative changes in verbal IQ. Specifically, in the cross-sectional analysis the amount of television viewing predicted lower verbal IQ. In the longitudinal analysis, the amount of television viewing predicted a decrease in verbal IQ after 3 years. However, there was no evidence for long-term associations between time spent watching television and performance IQ or full scale IQ. Moreover, the authors suggested that the associations between brain changes and behaviour were not strong and could be explained by other variables, such as the rate of physical maturation.

Longitudinal evidence supports the findings from cross-sectional studies, and suggests that television exposure (both amount and specific content) could be potentially detrimental to infants' language development. The evidence related to older children is too limited to draw any meaningful conclusions. The amount of viewing beyond infancy appears to be unrelated to children's vocabulary development, while exposure to educational content predicts subsequent vocabulary growth - albeit only in preschool children.

Summary of longitudinal studies.

The evidence reviewed in this section suggests that the longitudinal relationships between television viewing and subsequent developmental outcomes are complex and may be mediated by a host of contextual and individual factors. Several studies reviewed in sections 'Executive function and academic performance' and 'Language development' point to negative associations between early television exposure and both cognitive and educational outcomes. These relations are mostly restricted to children who started watching television early (< 3 years), come from disadvantaged socioeconomic backgrounds, or are exposed to content that is inappropriate for their age (e.g., Barr et al., 2010; Tomopoulos et al., 2010; Wright et al., 2001). Conversely, watching television at older age appears to be generally unrelated to subsequent cognitive and educational outcomes. Moreover, age also appears to be an important moderator of the direction in the relationships between viewing educational content and subsequent academic achievement. Depending on the age of exposure, the observed relations were negative (infancy; Linebarger & Walker, 2005), positive (preschool; e.g., Rice et al., 1990), or null (school-age; e.g., Wright et al., 2001).

Similarly, studies reviewed in section 'Attention problems' fail to provide a clear picture of the relationship between television viewing and subsequent occurrence of attention problems. Although the results of smaller scale research point to an association of infant television viewing with attention and behavioural problems (Cheng et al., 2010; Tomopoulos et al., 2007), the results of investigations involving larger samples are less straightforward. For example, initial data analysis suggested that there was an association between exposure to television in infancy and attention problems in early/middle childhood (Christakis et al., 2004). However, this apparent relationship was not robust, as after adjusting for additional confounding variables, and using a more powerful statistical approach to data analysis, the associations found in the original study were no longer significant (Foster & Watkins, 2010). Nevertheless, other factors such as the type of content watched and background exposure to television may influence long-term relations between children's attention and behavioural outcomes (Martin et al., 2012; Zimmerman & Christakis, 2007).

Longitudinal studies seem to be well-suited to address the limitations of the cross-sectional research; however, they are not flawless. Many limitations of longitudinal research, such as relying on imprecise viewing measures, limited outcome assessments and omission of content, mirror the concerns that were raised about the cross-sectional studies in section 'Summary of cross-sectional studies'. The drawbacks of television literature discussed in the following paragraphs are specific to the nature of longitudinal design.

First, in the majority of studies reviewed in this section, data were collected at two time points; yet cognitive and behavioural variables were assessed only once. The authors assumed that the "cause" (i.e., television exposure), preceded the outcome. However, without the simultaneous assessment of cognition/attention, it is neither possible to establish the presence of early indicators of developmental problems, nor to assess change. Indeed, Stevens and colleagues (2009) demonstrated that the trajectories of television viewing and attention problems did not develop in parallel. Thus, further multi-phase longitudinal investigations are needed to map the trajectories and make more robust inferences about the direction of the association between television exposure and developmental outcomes.

It is conceivable that the proposed "causal relationship" between television viewing and developmental outcomes is bidirectional; children with attention difficulties may turn to television more than their typically developing peers (Acevedo-Polakovich et al., 2007; Nikkelen, Valkenburg, et al., 2014). In fact, the results of three studies cited in this review seem to support this suggestion, as they suggest that both the amount and content preferences can be predicted by early behavioural traits and cognitive skills (Radesky et al., 2014; Verlinden et al., 2012; Wright et al., 2001).

The length of the interval between the two study phases varied from one year (e.g. Cheng et al., 2010) to five years (Zimmerman & Christakis, 2007). Although, as Taris and Kompier (2003) point out, it is very difficult to assess the duration of the "causal lag" (i.e., the time required for the causal variable to have an effect on the outcome variable), neither of the studies reviewed here provided a clear rationale for choosing a particular interval between the two study phases. Finally, studies differed in the choice of confounding variables (see Table 1.2. for details), and as demonstrated by Foster and Watkins (2010) adding additional covariates to the model rendered a previously significant association between the amount of television and attention problems non-significant.

Experimental studies.

Controlled experiments allow one to develop an understanding of how particular features of television affect children's cognition and attention. A hypothesis formulated in the literature suggests that fast pace, which characterises children's programming, may over-stimulate developing brains and ultimately lead to deficits in attention (Christakis, 2009, 2011; Singer, 1980). Twenty-five per cent of the studies reviewed in this section investigate the immediate effects of television pacing on children's executive function and attention. Moreover, in line with research providing evidence for the importance of parent-child interactions to young children's cognitive and social development (e.g., Bernier, Carlson, Deschênes, & Matte - Gagné, 2012; Blewitt, Rump, Shealy, & Cook, 2009), several studies included in this section examined parent-child interactions in the presence of foreground or background television. Finally, several articles investigated the educational values of infant programming and the conditions under which under-threes can learn words from televised material. For a detailed description of the studies included in this section see Table 1.3.

Executive function and academic performance.

Correlational literature suggests that programming content and family context of exposure are important in understanding the relations between television viewing and executive function performance. However, controlled experiments have done little to examine the effects of these variables on children's executive function. Nevertheless, the results of two studies suggest that television does affect these processes. Lillard and Peterson (2011) examined the immediate effects of a programme pacing on children's executive function. Four-year-olds were assigned to one of two experimental groups (fast-paced or slow-paced film) or a control (drawing). Children who watched a fast-paced cartoon performed significantly worse on a post-viewing test of executive function compared to the control group. These results suggest that children are sensitive to programme pacing. However, as researchers did not measure children's executive function prior to film exposure, the difference in post-viewing scores could have resulted from either an improvement in executive function following the educational activity, or a decline after exposure to a fast-paced cartoon. Moreover, this difference may have resulted from exposure to different content. One group watched a slow-paced educational programme aimed at preschoolers, whereas the second group watched a fast-paced entertainment show directed at older children.

Building on these findings, Lillard et al. (2015) examined whether pacing or content drove post-viewing differences in executive function. The authors hypothesised that processing fantastic content (i.e., events or characters that defy natural laws) taxed children’s cognitive resources and, consequently, might lead to short-term executive function depletion. To test their prediction, they compared 4-year-olds executive function following viewing of a fast-fantastic entertainment show, a fast-fantastic educational show or story reading. Children who listened to the story performed significantly better on executive function tasks than children who watched either the entertainment show or the educational show (other comparisons were not significant). Thus fast editing and fantastic content may deplete executive function, even when children watch a programme that is broadly categorised as “educational”.

To further investigate fantastic content and pacing, in the second experiment, Lillard et al. (2015) varied the amount of fantastic content and the editing pace across experimental films. The analysis revealed a significant main effect of content, but not pacing. The results of this study support the findings of correlational research showing negative associations between television viewing and executive function development reviewed earlier in this chapter (e.g., Barr et al., 2010). Moreover, they suggest that the mechanisms, which explain how watching television suppresses the development of executive function, are more consistent with content-based theories related to the effects of television on cognitive functioning.

Field experiments are infrequent in television effects research (Oakes, 2009). An early study examined the effects of restricting 6-year-olds daily television viewing time on IQ scores, cognitive performance, and the choice of leisure-time activities (Gadberry, 1980). During the 6-week period, children in the restricted-viewing group had their television time reduced by at least 50%, compared to control children. In addition, parents in both groups were encouraged to engage in daily 20 minutes of joint activities with their children. Restricting television time resulted in the increase in performance IQ scores, reading time, and more thoughtful behaviour. However, one cannot be certain that parents in both groups equally engaged their children in shared activities.

Furthermore, restricting the overall amount of viewing may not be the only way to improve children's academic skills, as correlational research shows the positive associations between exposure to educational content and academic achievement (e.g., Rice et al., 1990; Wright et al., 2001). Two studies investigated the effects of repeated exposure to an educational programme on children's emergent literacy and school readiness. Six- and 7-year-olds either watched 17 episodes of an educational programme designed to foster the development of early literacy skills or continued their usual school routine (Linebarger, Kosanic, Greenwood, & Doku, 2004). Although improvements in literacy skills and reading scores were noted for some children in the experimental group, they varied as a function of age and pre-intervention reading assessment. Exposure to educational content was only beneficial for younger children who were moderately-, or not-at-risk for developing reading problems. There was no advantage of watching the programme for either the 6-year-olds who were at-risk of developing reading problems or for the older children.

In a similar investigation, Baydar et al. (2008) assessed the effects of repeated viewing of an educational programme on the school readiness of 4- to 7-year-old Turkish children who did not have access to formal preschool education. Compared with children who were instructed to watch an entertainment programme, children who watched an educational show improved their skills in early numeracy, literacy and vocabulary. These effects were further qualified by the frequency of exposure to educational content. Children who watched the programme often achieved the biggest educational gains, whereas rare exposure had no effect on improving school readiness. Furthermore, Baydar and colleagues (2008) demonstrated *compensatory effects* of watching educational television; children with low pre-intervention school readiness skills benefited from the programme significantly more than children who had adequate skills prior to the exposure. The results are in contrast to those of Linebarger et al. (2004), who suggested that children at risk of developing reading difficulties did not benefit from exposure to an educational programme. Varied forms of intervention assessment can perhaps explain these differences in relative outcomes: the former study assessed basic skills such as receptive vocabulary, whereas the latter focused on a more comprehensive assessment of complex reading skills. Finally, the medium of television may be inadequate to support the learning of complex literacy skills that go beyond acquiring new vocabulary.

Overall, the evidence from studies reviewed in this section supports findings from correlational research that age-appropriate high quality educational programming can support children’s early learning. However, the learning-enhancing qualities of educational programmes may be diminished by the introduction of fantastic content, which was found to be taxing on children’s cognitive resources.

Finally, the extent to which children may benefit from watching educational TV depends on their baseline skills and the complexity of the assessed competence.

Attention measures.

Correlational literature shows links between the amount of viewing and children's *everyday* attention functioning (but see sections on 'Attention problems' for a discussion of methodological issues). Furthermore, it suggests that programming content may be critical to understanding these relations. However, experimental researchers have not explored these findings further. Instead, they have investigated the effects of programmes' visual and editing features on children's attention. In these studies, attention was either operationalised with children's engagement in a task during free-play or measured directly with a continuous performance test.

Two experimental studies, which examined the effects of editing pace on preschoolers' subsequent play have produced inconsistent results (Anderson, Levin, & Lorch, 1977; Geist & Gibson, 2000). Anderson and colleagues (1977) asked 4-year-olds to watch either a specially edited fast- or slow-paced version of *Sesame Street*, or listen to a story read by a parent. Immediately following this session, children took part in cognitive tests and a 10-minute play assessment. The researchers found no evidence that the pacing of a television programme had an effect on behavioural outcomes.

In contrast, a study by Geist and Gibson (2000) reported negative consequences of watching a fast-paced programme. They investigated whether viewing a fast-paced entertainment programme would result in unsettled behaviour in 4- and 5-year-olds. Children were assigned to one of the two experimental groups: watching *Mister Rogers Neighborhood* – a slow-paced educational show; *Mighty Morphin' Power Rangers* – an action filled, rapidly edited entertainment programme. Control group children took part in educational activities. During the post-viewing play session, children who watched the entertainment show switched between activities more frequently, and spent less time on the task, than children in the control group. These results were interpreted as suggesting that action filled, rapidly edited television causes an immediate shortening of children's attention span, and has a detrimental effect on the subsequent task perseverance. However, it is not clear whether the observed detrimental effects should be attributed to content, pace, or, the combination of both.

To overcome the pace/content confound, Cooper et al. (2009) produced their own experimental videos, which were identical in content, and differed only in the number of edits. The effects of editing on 4-7-year-olds' *optimal* attention were examined with Attention Networks Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002). ANT is a flanker type continuous performance task, which uses cues to test the efficiency of three attention networks: alerting, orienting and executive attention proposed by Petersen and Posner (Petersen & Posner, 2012; Posner & Petersen, 1990). Considering the alternative interpretations of the alerting and orienting scores outlined in the following paragraphs, caution should be applied to the interpretation of Cooper et al. (2009) findings.

Alerting refers to the process whereby presentation of an external warning signal (i.e., a cue) serves to mobilise attention and increase preparedness to respond to the incoming stimulus (Fan & Posner, 2004). The efficiency of alerting network is measured by subtracting reactions times from *double-cued* trials from the reaction times obtained on non-cued trials (Posner, 2008). On the one hand, higher alerting scores may reflect the difficulty in remaining vigilant in the absence of a cue. On the other hand, they may be a manifestation of an increased effort rather than less efficient performance (Fan & Posner, 2004).

In comparison, *single-cued* trials on the ANT serve to measure the efficiency of orienting, the process by which attention is directed towards a stimulus (Posner, 1980). A measure of orienting is obtained by subtracting reaction times from the trials where the cue appears in the same location as the target (spatial cue) from the reaction times on the trials where the cue is in a different location to the target (i.e., centrally; Posner, 2008). Although lower orienting scores should indicate a more efficient orienting network, they may reflect reduced effort associated with use of a valid spatial cue (Fan & Posner, 2004).

Finally, executive attention allows top-down task control in situations requiring conflict resolution or processing of competing information (Fan & Posner, 2004). The ANT measures efficiency of this network by manipulating the direction of the flankers (congruent vs. incongruent) surrounding the target (Petersen & Posner, 2012). The interpretation of the difference between reaction times on congruent and incongruent trials should take into account the error rates (i.e., accuracy) recorded in these trials. If the accuracy across congruent and incongruent trials is the same, the larger difference between reaction times indicates poorer executive attention. However, when slower reaction times on incongruent trials are accompanied with better accuracy, this may be an indication of a more careful responding (Fan & Posner, 2004).

Returning to the study of Cooper et al. (2009), the differences were found between the orienting scores of the fast- and slow-edit groups. Four-year-olds who watched a slow-paced video had higher orienting scores compared to children in the fast-edit group. This effect was reversed for 6-year-olds. This suggests that attention orienting was more efficient among younger children in the fast-paced group and among older children in the slow-paced group. Although due the alternative explanation of orienting scores proposed by Fan and Posner (2004), this interpretation should be considered with a dose of caution. Finally, in all age groups, children who watched a slow-paced video were less accurate, suggesting less careful responding.

To examine whether other visual features of the medium affect children's attention, Bellieni et al. (2010) investigated the differences in the attention-capturing potential of colour and black-and-white film. Ten-year-old children performed an auditory vigilance test. During the experiment, either a cartoon's soundtrack was played, or the black-and-white or colour cartoon was shown. Compared to the soundtrack only, the black-and-white and colour films had a similar effect on the attention. Children made more errors and took longer to respond when either version of the film was played during the task. Taken together, the results of these two experiments suggest that the editing pace, but not the presence of other visual features of the medium (such as the colour), may have an effect on children's sustained attention. Moreover, the results of Bellieni et al. (2010) support correlational findings of the potential negative effects of background television (e.g., Martin et al., 2012).

Free-play and child-caregiver interactions.

A small number of studies have focused on the short-term effects of background and foreground television viewing on infants' play and child-caregiver interactions. Schmidt, Pempek, Kirkorian, Lund, and Anderson (2008) investigated whether background television affected play episode duration and focused attention during play in under-threes. The researchers found that when the television was on, children played less, and the length of focused attention was reduced when they did play. In this experiment, the programme played in the background was directed at adult audiences, and was hard to understand for very young children.

In a similar study, Setliff and Courage (2011) examined the effects of background television on the quality of infants' interactions with toys during a free-play session. In the presence of background television, the mean length of focused attention and the duration of the longest play episode were shorter than when the television was off. Although infants spent more time looking at the toys than the television, irrespective of whether it was on, background television interfered with infants' play. When the television was on, the frequent shifts of visual attention, between the toys and screen, provided evidence that TV "grabbed" infants' attention, and thus disrupted play. However, background television did not hold infants' attention for long, nearly 50% of the looks were shorter than 2 seconds. Again, because the television programme used in this study was directed at older children and adults, it may have been incomprehensible to the infants.

Kirkorian, Pempek, Murphy, Schmidt, and Anderson (2009) provided further evidence supporting the notion that adult-directed background television hinders child-parent interactions. The presence of background television reduced parents' responsiveness to their children's attempts to elicit attention and their involvement in children's play. In contrast, its effect on children's reactions to parental bids for attention was not significant. Overall, the results suggested that the reduction in the quantity of child-parent interactions observed during background television was due to less parental involvement in their child's play.

Courage, Murphy, Goulding, and Setliff (2010) investigated whether any detrimental effects of background television occurred with infant-directed programmes, and compared infants' behaviour during an unstructured play session when the television was either on or off. The results showed that in the presence of a background infant-directed programme, both 6- and 18-month-olds looked more frequently at the toys than the film or parent. However, background television interrupted 18-month-olds' play, as demonstrated by the reduced duration of looking at the toys. Furthermore, when the television was on, parents talked to 6-month-olds infants less. Finally, play interactions between parents and 18-month-olds were shorter in the presence of a background programme. Overall, these results suggest that the presence of infant-directed background television may have a distracting effect on infants' interactions with toys, and it may reduce the quality and duration of parent-child communication and play.

The latter result is particularly important, as previous research provides convincing evidence for the beneficial effects of parental involvement in children's play (e.g., Tamis- LeMonda, Shannon, Cabrera, & Lamb, 2004). Furthermore, the benefits of high-quality parental stimulation during early years have implications for subsequent cognitive development, with research providing evidence for strong links between parental scaffolding and the development of children's verbal abilities and executive function (e.g., Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012).

The studies reviewed so far in this section (with the exception of Courage et al., 2010) used materials that were directed at older children and adult audiences. Perhaps some of the detrimental effects on children's play and interactions with adults could be explained by the incomprehensibility of the shows played in the background. Moreover, it is plausible that background television that emits background noise, which might be disruptive to verbal interactions, could be more harmful compared to foreground co-viewing of age-appropriate material that encourages parents to label objects and actions on the screen.

To address these questions, Pempek, Demers, Hanson, Kirkorian, and Anderson (2011) investigated the effects of repeated home co-viewing of two different infant DVDs on subsequent parent-child interactions. One group was assigned to watch *Sesame Beginnings* - a program specifically designed to demonstrate developmentally appropriate joint activities such as reading, physical play, singing or dancing. The other group received *Baby Einstein*. This programme does not promote shared parent-child activities; however, it emphasises naming of objects and actions. Following a two-week exposure, parent-child interactions were assessed in the laboratory; one session measured dyads' behaviour during unstructured play, another during a DVD presentation. Compared to watching *Baby Einstein*, home co-viewing of *Sesame Beginnings* was associated with increased parent-child interactions in the free-play session. However, the quantity and quality of parent-child interactions were reduced during the video presentation session for both groups. Instead of playing together, parents and infants directed their attention at the screen. These results are in line with findings related to the negative effects of background television on dyadic interactions (e.g., Courage et al., 2010; Kirkorian et al., 2009). Although moderate co-viewing of infant-directed shows may promote an increase in subsequent positive child-parent interactions, television reduces the amount and quality of dyadic interactions, which in the long-term may be harmful rather than beneficial to children's development.

Language.

Paediatricians' recommend that children under the age of 18 months should not watch television at all (AAP, 2016). Furthermore, the findings from the correlational literature suggest that both the amount of TV and watching specific content are negatively related to language development. Despite these concerns, producers of infant-directed programmes market their products as developmentally stimulating and educational (Christakis, 2009).

Two studies investigated this assertion by examining the effects of repeated exposure to *Baby Wordsworth* DVD on infants' knowledge of specific words emphasised in the programme as well as general language skills growth. Robb, Richert, and Wartella (2009) compared the difference in receptive and expressive language of 12-to 15-month infants, who repeatedly watched this DVD at home during a six-week period, to infants who did not watch the show. Exposure to the programme had no effect on early language development. Instead, language growth was positively related to both the amount of time a child was read to, and (weakly) the amount of background television exposure at home.

Building on this research, Richert, Robb, Fender, and Wartella (2010) expanded their investigation to the effects of repeated *Baby Wordsworth* exposure on general language growth in 12- to 25-month-olds. Similarly to the findings of Robb and colleagues (2009), watching the DVD had no effect on learning of the specific words introduced in the programme, or affected general language development in participating infants. The only significant finding in this study was a negative relation between the onset age of baby DVDs viewing and language assessment scores. Furthermore, DeLoache et al. (2010) demonstrated that 4 weeks of repeated exposure to a popular baby DVD did not result in infants' learning the words emphasised in the programme beyond normal age-related growth. Only infants who did not watch the DVD, but whose parents intentionally incorporated new vocabulary in everyday activities, showed substantial language growth. Overall, these three studies suggest that watching infant-directed programming of this type does not benefit early language development.

In fact, the literature provides robust evidence that television has very limited potential to teach new vocabulary to infants and very young children (<3 years). For example, Krcmar (2011) showed that 6- to 24-month-olds, who learned novel vocabulary following one brief demonstration by a parent, did not benefit from a *single* DVD tutorial specifically designed to teach them novel words. In comparison, *repeated* exposure to a DVD featuring novel words did result in new vocabulary learning, but only for infants older than 17 months. Infants younger than 16 months did not benefit from these presentations (Krcmar, 2014).

Moreover, it appears that the inability to learn novel vocabulary following a single DVD presentation persists beyond infancy into toddlerhood. Roseberry, Hirsh-Pasek, Parish- Morris, and Golinkoff (2009) demonstrated that children younger than 36 months were unable to learn new verbs from a single exposure to an instructional DVD. However, when the on-screen content was supported with a live tutorial by the experimenter, children showed evidence of word learning. Although children older than 36 months were able to learn novel verbs from DVD material only, compared with the presentation supported by the experimenter's tutorial, their understanding of the meaning of newly acquired words was superficial.

Strouse, O'Doherty, and Troseth (2013) provided evidence that adult support during the presentation of televised material enhances linguistic ability even for over-threes. The researchers examined the effects of varying levels of parental involvement during co-viewing on children's vocabulary growth and story comprehension. After a month-long co-viewing of a televised storybook, all children learned vocabulary featured in the story. However, children's understanding and general vocabulary growth varied depending on the quality of parental involvement during co-viewing. Children, whose parents elicited a discussion about the content through asking questions about the story, were most successful on the measure of comprehension. These children also showed a significant improvement in their general expressive vocabulary. Interestingly, Strouse et al. (2013) showed that non-parental support (i.e., a recording of an actress directing children's attention to the content presented on the screen and asking questions) improved children's comprehension, but did not result in general vocabulary growth.

The collective evidence from the studies reviewed so far suggests that young children's ability to learn vocabulary from televised content is limited. Appropriate parental support (e.g., questioning, drawing attention to key content, etc.) may reduce some of the limitations inherent in on-screen presentation of educational content. However, considering the evidence showing that television creates an environment that hinders high-quality child-parent interactions (Courage et al., 2010; Kirkorian et al., 2004; Pempek et al., 2011), it is questionable whether parents will provide appropriate support during co-viewing. In fact, the evidence from the three studies reviewed below suggests that successful spontaneous parental support (i.e., not prescribed by the experimenter) is unlikely.

For example, Lavigne, Hanson, and Anderson (2015) compared the quantity and quality of parent language directed at infants during play sessions in the laboratory. Compared to free-play, during viewing of a baby DVD, parents spoke less. Moreover, the quality of parental language decreased during co-viewing; parents uttered fewer new words and their mean length utterance was shorter. Although parents spoke less to their infants when watching a DVD, they used a wider range of vocabulary as evidenced by an increased number of new words per utterance.

Nathanson and Rasmussen (2011) found similar effects when maternal responsiveness and communication with toddlers and preschoolers was compared across three popular childhood activities: television viewing, play and book reading. Consistent with the findings of Lavigne and colleagues (2015), the presence of foreground television had a detrimental effect on parent-child interactions. The quantity of communication when watching television was reduced compared with play and book reading. Moreover, during co-viewing, mothers asked fewer questions, gave fewer responses that were contingent to child's prior communication, and made fewer attempts to elicit further responses from their child or to label objects and events in the shared environment. Finally, Tanimura, Okuma, and Kyoshima (2007) provided further evidence that the presence of television suppresses parental verbal communication with their young children. When the television was on, sentences spoken by parents became shorter and the frequency of parental utterances and the use of explanatory sentences were reduced.

In conclusion, infant programming has very limited potential to "teach" vocabulary to under-threes. Although this is not evidence of negative effects of television on children's language growth *per se*, it appears that the presence of television creates an environment that is unfavourable to fostering early language growth. First, when infants are watching the television they are either not learning (Krcmar, 2011), or their learning is of a lesser quality (Roseberry et al., 2009; Strouse et al., 2013). Second, foreground and background TV diminishes the quality and quantity of parental communication (Lavigne et al., 2015; Nathanson & Rasmussen, 2011; Tanimura et al., 2007), which further reduces infants' opportunities to acquire the new language. Perhaps collectively, these findings could explain the negative associations between screen exposure and language development documented in the correlational literature (e.g., Chonchaiya & Pruksananonda, 2008; Duch et al., 2013; Lin et al., 2015; Tomopoulos et al., 2010).

Summary of experimental studies.

Collectively, the experimental findings related to child-parent interactions consistently point to the potentially detrimental effects of television viewing. Television is effective in grabbing the attention of children and parents, and consequently is disruptive to play and reduces parental verbal communication and responsiveness to children's needs. Moreover, they corroborate the results of correlational research that show a negative association between the amount of television viewing and language development (e.g., Duch et al., 2010; Lin et al., 2015; Tomopoulos et al., 2010; Zimmerman et al., 2007) and suggest that these negative associations might be explained by a reduced quantity and quality of parent-child communication in the presence of television. Finally, under-threes find it difficult to learn from the on-screen presentation of educational material (e.g., Krcmar, 2011; Krcmar, 2014; Roseberry et al., 2009) and exposure to baby DVDs appears to be of no value to infants' language growth (e.g., Robb et al., 2009; Richert et al., 2010; DeLoache et al., 2010). Conversely, during preschool years, high-quality television has the potential to aid learning of pre-academic concepts (Baydar et al., 2008) and improve competence in more complex skills (Linebarger et al., 2004), depending on the child's baseline level of ability.

The results of the studies investigating the effects of pacing on children's cognition and behaviour are less conclusive. The findings from two studies imply that watching fast-paced programming has short-term negative consequences for executive function (Lillard & Peterson, 2011) or task perseverance (Geist & Gibson, 2000). However, both studies failed to control for content. Thus the extent to which these negative effects of television can be attributed to pacing is questionable. In fact, the findings of Lillard et al. (2015) support the notion that content matters more than pacing. Moreover, when content is controlled for, fast pace appears to be inconsequential for children's behaviour (Anderson et al., 1977) or even beneficial for certain tasks (Cooper et al., 2009). Finally, experimental research on the effects of television pacing is limited to the investigation of short-term outcomes. Therefore, it is unclear whether the *cumulative* effects of exposure to fast-paced programming lead to the longer lasting change in children's cognition and behaviour.

General Discussion

The aim of this review was to provide a systematic and comprehensive summary of the literature regarding the associations between television viewing and children's cognition and behaviour. Due to the limited availability of unpublished research, we were unable to compare the findings of unpublished work with the results of published studies that addressed the same questions, which is the most direct method of assessing the potential publication bias (Song, Hooper, & Loke, 2013). However, this review includes a relatively high proportion of studies that reported non-significant findings, thus suggesting a low risk of publication bias. For example, the proportion of negative findings (i.e., where the results did not support the tested hypotheses) reported in the correlational and experimental literature was 19.2 and 12.5%, respectively. In comparison, the proportion of negative findings published in general psychology/psychiatry literature is approximately 8% (Fanelli, 2010).

The selected studies investigated the short-terms effects of viewing in infancy and childhood, as well as the long-term associations that spanned from infancy and early childhood throughout adolescence and into adulthood. The majority of the research reported here focused on behavioural measures. However, two studies (Nikkelen, Vossen et al., 2014; Takeuchi et al., 2013) looked beyond the observable behaviour, and investigated the role of genetic disposition in the preference for violent media content and structural changes in the brain associated with television exposure.

A variety of methodological approaches and a wide range of outcome measures used in the studies summarised in this chapter reflect the complexity of the topic. The overarching finding from this review is that treating television viewing as an undifferentiated activity is inadequate to explain its likely effects. Rather, effects of exposure to television depend on a host of variables that either characterise the child (e.g., age, individual characteristics, family context), are inherent to the medium (e.g., content and editing features), or even the type of exposure (foreground vs. background viewing).

One consistent finding is that age of exposure matters. Educational television appears to enhance preschoolers' learning. Conversely, the evidence of benefits for school-age children is very limited. Moreover, exposure to some educational shows was negatively related to infants' language growth (Linebarger & Walker, 2005). In fact, studies that measured exposure in *infancy* (both with and without content analysis) consistently demonstrated that television viewing is associated with negative developmental outcomes. This is seen with attention (Cheng et al., 2010; Christakis et al., 2004; Tomopulous et al., 2007), educational achievement and executive functions (Barr et al., 2010; Nathanson et al., 2014; Zimmerman & Christakis, 2005) and language outcomes (Chonchiya & Pruksananonda, 2008).

The period from birth to 3 years may be developmentally sensitive due to the rapid growth and maximal plasticity of the brain (Christakis, 2009). Moreover, during infancy, qualitative changes in cortical structures that underpin a brain's functional potential co-occur with the emergence of fundamental cognitive skills (Dawson, Ashman, & Carver, 2000). Neuroscience literature documents the relations between cortical maturation and the development of attention (Ducharme et al., 2012), working memory (Short et al., 2013) and more general cognitive ability (Deoni et al., 2016). However, these associations are likely to be moderated by the interplay of individual genetics and early experience (Walhovd, Tamnes, & Fjell, 2014). Currently, it is not clear whether certain parenting practices, such as allowing infants to watch television, have a lasting influence on the developing brain. In fact, most of the evidence describing relations between early experiences and cortical changes comes from comparative literature and, as such, should be interpreted with caution (Thompson & Nelson, 2001).

There is, however, well-documented evidence that infants and children under the age of 3 years learn less from television than they do from real-life demonstration (Barr, 2010). “Video deficit” describes under-threes’ pervasive difficulty to extend knowledge acquired from “symbolic” sources (e.g., photographs, picture books, films) to real-world objects and situations (Anderson & Pempek, 2005; Barr, 2010; Barr, 2013). Adequate adult support may mitigate some of the constraints on children’s learning from symbolic sources (Roseberry et al., 2009; Strouse et al., 2013). However, achieving enough parental support to enhance the understanding of material presented on screen seems challenging outside of well-controlled laboratory conditions. First, qualitative literature suggests that parents often use the television as a “digital babysitter” when they need some respite from the demands of childcare or have to attend to household chores (e.g., Bentley, Turner, & Jago, 2016; Jago et al., 2016), thus, suggesting much viewing occurs without active parental support. That is, a parent may be in the same room but is not actively involved in supporting their child’s understanding of the televised content. Second, the results of experimental research provide substantial evidence that foreground and background television creates an environment unfavourable to child-parent communication (Lavigne et al., 2015; Nathanson & Rassmussen, 2011; Tanimura et al., 2007).

The latter indicates that television may reduce children's opportunities to acquire and practice language. Moreover, when infants are watching television, they are missing out on other activities that may promote development. Indeed, the finding that the decrease in play equalled the amount of time children directed their attention at background television (Schmidt et al., 2008), may suggest that television directly displaces play. Therefore, the negative outcomes associated with viewing during infancy, documented in the correlational literature, may be explained by (1) children's limited ability to understand and learn from television; (2) direct displacement of developmentally-appropriate activities; and (3) a reduction of high-quality parent-child interactions.

In addition to the negative outcomes associated with early viewing, the overall amount of exposure seems to be associated with unfavourable developmental outcomes. Low to moderate viewing does not predict later attention and behaviour problems; however, high exposure to television in infancy (>2 hours a day) and early childhood (>3 hours a day) is negatively related to attention, and is associated with later conduct problems (Foster & Watkins, 2010; Parkes et al., 2013; Shiue, 2015). It is important to note two limitations concerning this evidence. Firstly, not only the viewing data but also behavioural ratings were derived from responses provided by parents. As Foster and Watkins (2010) point out, relying on parental reports leads to potential problems. First, parents may provide inaccurate information about the amount of television their children watch. Second, when confronted with questions about their children's bad behaviour and attention problems parents may give answers that are more socially desirable, and under report problems. Indeed, Levine and Waite

(2000) and Miller and colleagues (2007) found a positive association between the amount of television viewing and teachers' assessments of hyperactivity/inattention, but not parental ratings of attention problems.

Secondly, confounding variables may influence correlational study outcomes. The studies presented in this review varied greatly in terms of the number and the type of covariates, and in fact Foster and Watkins (2010) demonstrated that the analysis of the same dataset could lead to different interpretations depending on the covariates included in the model. Furthermore, as Nikkelen, Valkenburg and colleagues (2014) point out, individual differences, such as family circumstances, peer relations, gender or temperament might moderate the associations between the measured outcomes and media exposure. This further draws our attention to the importance of the context in which television viewing occurs, as well as to individual-level factors that may mediate the associations between television exposure and developmental outcomes (Oakes, 2009).

With very few exceptions (e.g., Ferguson, 2011; Shariff et al., 2010), television research failed to consider personal variables other than age and gender. Yet, the evidence suggests that amount and content of television viewing may be predicted by one's early behavioural traits or determined by genetic predisposition (e.g., Nikkelen, Vossen et al., 2014; Radesky et al., 2014); whereas personal variables, such as self-control or sensation-seeking, act as mediators of the relationship between television exposure and measured outcomes (e.g., Shariff et al., 2010). Although, being in a high quality home learning environment was related to less viewing (Blankson et al., 2015; Clarke & Kurtz-Costes, 1997), whether the wider socio-family context of viewing (e.g., watching television with friends or alone, at home or in a child-care setting, etc.) is meaningful, we may only guess, as there is no research that addressed this question.

Therefore, more research is needed to identify individual and social environment variables that increase children's sensitivity to screen use, as well as to establish protective factors that can provide a buffer against any negative effects. Moreover, it is currently unknown *how much* television children must watch and *for how long* before it meaningfully affects their development. In consequence, bearing in mind the lack of consistent results of longitudinal studies and the paucity of research that spans over a prolonged period, it is difficult to draw clear conclusions about the long-term effects of television viewing on cognitive and behavioural outcomes.

A further cause of inconsistent findings could be differences in *what* children watch. What children watch may be more important than *how much* they watch. It appears that both foreground and background exposure to programmes that are created for an adult audience (and are thus inappropriate for young viewers) are associated with problem behaviour, poor attention (Conners-Burrow et al., 2011; Schmidt et al., 2008) and other negative cognitive outcomes (Barr et al., 2010). In addition, Zimmermann and Christakis (2007) suggest that there is an association between viewing children's entertainment shows, which are designed to amuse and occupy (rather than to aid learning), and later attention problems.

There are two plausible explanations for why content may be detrimental for developmental outcomes. Firstly, one way that children learn behaviour is through the observation of others (Bandura, 1971). Thus children who watch inappropriate content (especially without an adult present, which could provide a buffer against potentially harmful material – Austin, 2001) may learn and later imitate undesirable behaviours or language observed on the screen. Second, children are mostly incapable of understanding the content of the adult-directed television. Instead, children's attention may be maintained through perceptually salient audio-visual features that elicit an orienting response to what is happening on the screen (Christakis, 2009; Singer, 1980). Over time, this may reduce children's ability to engage in reflective processing, and lead them to develop a preference for a high level of stimulation and frequent change (Wright et al., 1984).

Conversely, beyond infancy, watching age-appropriate educational television not only can enhance children's learning in the short term (Baydar et al., 2008; Linebarger et al., 2004), but also relates to long-term positive academic outcomes (Anderson et al., 2001; Rice et al., 1990; Wright et al., 2001). Yet again, the potential benefits of viewing educational content may be moderated by other variables, such as age of the viewer, pre-existing skill level and the complexity of the measured outcome. On the one hand the literature provides consistent evidence for learning-enhancing benefits of exposure to quality content during preschool years (e.g., Rice et al., 1990). On the other hand, the circumstances under which older children learn from educational TV are more nuanced. For example repeated exposure to educational content has the potential to improve basic literacy and numeracy in children with low-level pre-intervention skills (Baydar et al., 2008); however, it is not as effective in supporting the learning of more complex skills, such as reading (Linebarger et al., 2004).

In addition to content, *formal features* of television programming (e.g., editing actions, such as cuts, camera angle changes, and active motion) may be detrimental to children's cognition and attention. Zimmerman and Christakis (2007) argue that children's entertainment programmes are characterised by a fast pace (with frequent scene and character changes). Not only the speed of events that unfold in front of a child is much faster, compared to real-life events, but also the number of auditory and visual stimuli a child has to process is beyond the capacity of a young brain, and results in overstimulation (Christakis, 2011; Singer, 1980). In fact, there is a growing interest in the effects of editing pace in the current literature. A small number of studies presented in this review provide interesting but inconsistent evidence about the effects of editing features. The presence of a pace/content confound (e.g., Geist & Gibson, 2000; Lillard & Peterson, 2011) may explain these inconsistencies. Designing and producing one's own materials (e.g., Cooper et al., 2009) allows for the manipulation of pace while controlling the content (although this may reduce ecological validity).

The research on which this review is based, investigated a variety of hypotheses about the potential effects of viewing on children's developmental outcomes. However, very few studies attempted to systematically explore the mechanisms underlying the relationship between television viewing and developmental outcomes (Linebarger et al., 2014; Shariff et al., 2010; Shin, 2004). Future research should use the existing empirical evidence to develop and test specific theoretical proposals to establish the mechanisms that underlie the associations between television viewing and particular developmental outcomes. Furthermore, television research employed a wide range of measures, each potentially capturing different aspects of children's cognition and behaviour. For example, attention outcomes have been measured with parents' or teachers' subjective perceptions of children's *everyday* behaviour rated on standardised questionnaires such as the Strengths and Difficulties Questionnaire (Goodman, 1997), or Child Behaviour Checklist (Achenbach, 1991). However, several studies used less rigorous measures, such as selected subscales of these questionnaires (e.g., Christakis et al., 2004; Egmond-Frölich et al., 2012). Conversely, experimental research focused on the investigation of children's *optimal* performance under well-controlled laboratory conditions. Furthermore, collective evidence from correlational literature points to the importance of content. Yet, the efforts of experimental researchers to discern the effects of various types of content on specific developmental outcomes have been limited – particularly in relation to attention and executive function research. Therefore, there is a need for researchers to work collaboratively to develop uniform protocols to address some of the methodological limitations present in the past literature, thus enabling us to answer more detailed questions about the long-term impact of television on developmental outcomes.

Finally, past research focused on examining the correlates and effects of traditional television viewing. Today's children have a variety of different screen media at their disposal and "worries about the effects of TV in the living room seem quaint" (Rich et al., 2015, p.1737). In fact, in the UK 53% of 3- to 4-year-olds use a tablet at home, and this figure rises to 73% for children aged 8 to 11 years (Ofcom, 2015). Moreover, the results of a recent study about children's media preferences and screen multitasking indicate that although traditional television is still favoured by young children, tablets are now equally as popular as long-established DVDs among 3- to 6-year-olds (Kostyrka- Allchorne, Cooper, & Simpson, 2017). Thus, future studies should examine the developmental consequences of this increased exposure to new media.

In conclusion, this review suggests that television cannot be treated as a unitary activity, and collectively, the evidence points to the importance of content over quantity. Moreover, age, content and family context appear to be the key moderators of the direction and the strength of the relationship between television and developmental outcomes. However, the state of the current literature does not allow one to draw clear conclusions about the potential long-lasting effects of viewing, and the detailed mechanisms underlying the associations between particular features of television and different developmental outcomes. Finally, the present review integrates the findings relevant to television exposure on a traditional television screen. However, with the rise in popularity of new media platforms, and availability of new ways of accessing television content, future research should explore how to optimise media use, by identifying harmful features, as well as the potential opportunities and the problems created by the availability of the new interactive devices

Table 1. 1. Description of cross-sectional correlation studies included in the review [*were the Content/Pacing (C/P) variables measured, not measured, or partially measured].

Study	***N***	***TV amount (hours per day)***	***Predictors***	***Outcome measure***	***Population and age***	***Viewing measure***	***Content/ Pacing****	***Main findings***
Anderson & Maguire (1978)	300	N/A	TV viewing measures (preference for news and documentaries, violent, sitcoms and cartoons), number of programmes, SES.	Verbal and non-verbal IQ, math and reading test, behaviour impulsivity.	Children with superior IQ. **Mean (*M*) age** not reported (grades 3 to 6)	Child report	C measured	No association between the viewing measures, the number of programmes watched and academic performance.
Chonchaiya & Pruksananonda (2008)	166	*Delay*: 3.05h *Control:* 1.85h	TV amount and content, onset age, child characteristics, parent characteristics, parenting style.	Speech and language developmental delay.	Children with language delay/ randomly matched control group. *Delay:* ***M* age** = 2.11years *Control:* ***M* age** = 2.23 years	Parent estimate	C partially measured (adult)	Language delay predicted by poor child-parent interaction during TV watching (OR=6.74; 95% CI: 3.24-14.02), watching adult content (OR=1.92, (95%CI: 1.00-3.70), early onset (<12m; OR=3.14, 95%CI: 1.58-6.23), and watching > 2h/day (OR=3.94, 95%CI: 2.00-7.76).
Clarke & Kurtz-Costes (1997)	30	3.13h	TV amount, age, IQ, parental employment, home educational environment.	Metropolitan School Readiness Test.	Low-income African-American families. ***M* age** = 57 months	Parent estimate	C not measured	TV viewing negatively related to school readiness (β=-.311, p< .05), number of books at home (r=-.375, p< .05) and parent instruction (r=-.328, p< .05).
Collins (1990)	328	2.16h	TV amount and content, Peabody Picture Vocabulary Test.	Sustained attention task, Banta's puzzle, Kansas Reflectivity Impulsivity Scale for Preschoolers, parental ratings of child's temperament.	White, middle-class families. ***M* age** = 60 months	Parent-reported diary	C measured P measured	The measures of TV exposure not related to cognitive performance.
Conners-Burrow et al. (2011)	92	3.3h	TV amount and content, maternal education, ethnicity, gender and Early Head Start intervention.	Classroom behaviour (hyperactivity, aggression, social skills).	Low-income White and African American Families. ***M* age** = 61 months	Parent estimate	C measured	Viewing inappropriate content predicted hyperactivity (p= .046, η^2_p= .047), aggression (p= .017, η^2_p= .066), and poorer social skills (p= .003, η^2_p= .097). No association between the amount of TV and the outcome variables.
Ebenegger et al. (2012)	450	0.9h	TV amount, gender, age, parental migrant status, parental education, BMI and per cent body fat, physical activity, eating habits.	Hyperactivity/inattention subscale of Strengths and Difficulties Questionnaire, adiposity.	Families from a European region with a high percentage of migrants (> 40%). ***M* age** = 5.2 years	Parent estimate	C not measured	A positive association between the amount of TV and hyperactivity/ inattention (β=2.90, p= .005, 95% CI: 0.58-4.95).
Egmond-Fröhlich et al. (2012)	11,676	1.6h	TV/video amount, age, gender, physical activity, diet, parental BMI, smoking, migrant status, SES.	Parental ratings of hyperactivity-inattention subscale of the Strengths and Difficulties Questionnaire	A subsample of children from varied socioeconomic background taking part in a panel study. **Age range** = 6-17 years	Parent estimate (6-11); Child estimate (11-17)	C not measured	A positive association between TV/video amount and hyperactivity-inattention (B=0.021, p< .001, η^2_p= .002).

Study	*N*	*TV amount (hours per day)*	*Predictors*	*Outcome measure*	*Population and age*	*Viewing measure*	*Content/ Pacing**	*Main findings*
Ferguson (2011)	603	N/A	TV amount and content, gender, number of children in family, income, negative life events, family violence, depression and anxiety.	Child and parent rated Child Behavior Checklist, Grade Point Average.	Low-income Hispanic families. ***M* age=** 12.35 years	Child estimate	C partially measured (violence)	No association between TV and attention problems or Grade Point Average.
Levine & Waite (2000)	70	1.3-1.7h	TV amount and content, grade, gender and SES.	ADD-H Comprehensive Teachers Rating Scale (ACTeRS), teacher assessed hyperactivity/ attention, Stroop colour and word test, parental rating of distractibility/ hyperactivity.	Predominantly White middle- and working-class families. ***M* age** = 10.3 years	Children's diaries and parental estimates.	C partially measured (action-adventure)	TV amount positively associated with ACTeRS scores (β=1.10, p< .05), but not with any other outcome variable. Watching action-adventure shows not related to outcome measures.
Linebarger et al. (2014)	1,156	*Preschool:* 3.92h background TV and 1.87h foreground TV. *School:* 2.9h background TV and 1.97h foreground TV	Background/foreground TV amount, content, age, gender, ethnicity, birth order, childcare attendance (preschool children) or school grade, vocabulary production (preschool children), literacy skills (school children), mother's age at birth and education, family structure, income, parenting style.	EF measured with parent-reported Behavior Assessment System for Children-2	Nationally representative sample of families. *Preschool:* ***M* age**=46 months. *School:* ***M* age** =84 months	Parent-reported 24h time-use diary	C measured	Watching non-educational TV predicted higher EF in *low-risk* pre-schoolers (B=-.079, p= .021). Negative relation between background TV and EF in *high-risk* pre-schoolers (B= 0.59, p= .003). Watching educational TV predicted higher EF for *high-risk* school children (B= -5.96, p< .001). Higher exposure to background TV predicted lower EF for *low-risk* school children (B= 0.37, p= .014).
Lin et al. (2015)	150	*High:* 2.3h *Control:* 0.3h	TV amount, age, gender, family structure, parental education and employment, income, preschool attendance.	Cognitive and language development assessed with the Bayley Scales of Infant Development-second edition; motor skills assessed with Peabody Developmental Motor Scales-second edition	Opportunity sample of children attending paediatric outpatient clinics. *High:* ***M* age** =24.8 months *Control:* ***M* age** = 24.8 months	Parent estimate	C not measured	High amount of TV predicted developmental delay (OR=3.9, 95%CI: 1.4-5.9), language delay (OR=3.3, 95%CI: 1.5-7.3) and motor development delay (OR=3.7, 95%CI: 1.5-9.3).
Lingieni et al. (2012)	68,634	N/A	TV amount, age, gender, ethnicity, BMI, depression, anxiety, education, family structure, poverty status, healthcare coverage, clubs and sports participation, smoking in family.	Presence of ADHD diagnosis	Randomly selected families taking part in a panel study. **Age range** = 5-17 years	Parent estimate	C not measured	Watching TV for more than 1h a day associated with increased odds of ADHD diagnosis (OR=1.82, 95%CI: 1.55-2.13).
Miller et al. (2007)	170	2.35h	TV amount, gender, age, SES.	Parents' and teachers' ratings of 18 ADHD behaviours listed in DSM-IV, actigraph-measured motor activity assessment	Middle-class families of varied ethnic background. ***M* age** = 4.31 years	Parent estimate	C not measured	A positive association between TV amount and teachers' assessment of attention problems (β= .235, p= .002) and activity level (β=. 208, p= .01). No relation between parents' ratings of attention problems and TV amount.
Nathanson et al. (2014)	107	4.3h background TV; 2.9h foreground TV	Background/foreground TV amount, content, viewing by channel, onset age, age, parental education and income, vocabulary and sleep.	4 EF tasks (grass/snow, whisper task, backward digit span, tower task), Picture Naming.	Predominantly White low- and middle-income families. ***M* age** = 53.4 months	Parent estimate	C measured	Later viewing onset and PBS channel viewing predicted better EF (β=. 03, p< .001; β=. 23 p< .001, respectively). Higher amount of TV and educational cartoon viewing predicted poorer EF (β=-.26, p< .05; β= - .24, p< .001, respectively).

Study	N	TV amount (hours per day)	Predictors	Outcome measure	Population and age	Viewing measure	Content/ Pacing*	Main findings
Nikkelen et al. (2014)	1,612	N/A	Violent media use, genotyping, age, gender, birth order, and SES.	ADHD behaviours assessed on DSM-ADHD subscale of Child Behavior Checklist	Subsample of Generation R study participants consisting solely of children of Dutch ethnicity ***M* age** = 6 years	Parent estimate	C partially measured (violence)	A positive relation between 5-HTTLPR polymorphism and violent media use ($r = .07$, $p=.04$). A positive relation between violent media use and ADHD behaviours ($p= .005$). An indirect association between genotype and ADHD behaviours mediated through violent media use (BCa[3] 95% CI: .001-011).
Özmert et al. (2002)	885	2.5h	TV amount, gender, age and SES.	Child Behavior Checklist	Opportunity sample of children attending schools from high- and low SES areas. ***M* age** not reported (grades 2 and 3)	Parent estimate (all); parent diary (10%).	C not measured	Watching TV for > 2h/day predicted attention problems (OR= 1.138, 95%CI: 1.066-1.213) and was negatively related to social competence scores (OR=0.847, 95%CI: 0.748-0.958).
Roberts et al. (1984)	539	0.8h per week	TV amount, TV on at home, TV rules, parent TV behaviour and attitudes towards TV, print availability, parent-child print interaction, amount of reading, orientation towards TV and reading (e.g., gratification, learning), involvement with TV and reading, SES.	School-assessed reading ability	Opportunity sample of children from varied socioeconomic and ethnic background. ***M* age** not reported (grades 2, 3 and 6)	Child estimate	C not measured	No significant relations for 2nd graders. For 3rd graders, using TV to learn negatively related to reading ability ($p< .05$); involvement with medium positively related to reading outcomes ($p<. 05$). For 6th graders, using TV to learn predicted poorer reading ($p< .01$). Emotional involvement with TV, general responses to medium and involvement with programmes were all positively related to reading ability ($p< .05$, $p <.001$ and $p <.01$, respectively).
Shin (2004)	1,203	4.35h	TV amount, homework and studying, reading for leisure, impulsivity.	Woodcock–Johnson Revised Tests of Achievement	A subsample of children from varied ethnic background taking part in a panel study. ***M* age** = 9 years	Parent diary	C not measured	A negative association between TV amount and homework time ($p < .001$), studying ($p < .001$) and leisure reading ($p < .01$). A positive association between TV amount and impulsive behaviour ($p< .05$).
Shiue (2015)	1,997	79.3% <3h; 20.7% >3h	TV amount, gender, age, BMI, second-hand smoking, physical activity, self-reported health conditions.	The Strengths and Difficulties Questionnaire	A subsample of Scottish children taking part in the panel study. **Age range** = 4-12 years	Parent estimate	C not measured	Excessive TV viewing (>3h/day) associated with the total difficulties scores (RRR[4]=1.88, 95%CI: 1.27-2.78), emotional symptoms (RRR=1.88, 95%CI: 1.27-2.78), conduct problems (RRR=1.88, 95%CI: 1.27-2.78), peer problems (RRR=1.88, 95%CI: 1.27-2.78) and prosocial problems (RRR=1.88, 95%CI: 1.27-2.78), but not with hyperactivity.
Yousef et al. (2014)	197	2.3h	TV and video games amount, medical history, family psychosocial stress (e.g., illness, financial difficulties, work-related problems, etc.), birth order and the number of siblings, age and gender.	Child Behavior Checklist	A representative sample of children from UAE. ***M* age** = 8.7 years	Parent estimate	C not measured	Excessive TV/video use (>2h/day) was positively related to withdrawal (OR=0.275, 95%CI: 0.106-0.712), attention problems (OR=0.480, 95%CI: 0.241-0.956), externalising problems (OR=0.393, 95%CI:0.201-0.771) and the total score (OR=0.441, 95%CI:0.229-0.848).

[3] BCa CI - bias corrected and accelerated confidence intervals

[4] RRR – relative risk ratio

Study	*N*	*TV amount (hours per day)*	*Predictors*	*Outcome measure*	*Population and age*	*Viewing measure*	*Content/ Pacing**	*Main findings*
Zimmerman et al. (2007)	729	*8- to 16m-olds:* Baby: 0.15h; Educational: 0.31h; Entertainment: 0.16h; Adult: 0.10h *17-24m-olds:* Baby: 0.15h; Educational: 0.31h;Entertainment: 0.16h; Adult: 0.10h	TV/DVD amount and content of TV, ethnicity, age, household income, parents' education, day care, preterm birth, family structure, place of birth, parent-child interactions (reading, storytelling, music).	Language development assessed with the Communicative Development Inventory	Predominantly White, well-educated families. **Age range** = 2-24 months	Parent estimate	C measured	For 8- to 16m-olds, viewing baby shows was related to poorer language development (p<.01, 95%CI: -26.20 to -7.77). No other significant relations between the amount of measured content and language outcomes.

Table 1. 2. Description of longitudinal correlation studies included in the review [*were the Content (C) variable measured, not measured, or partially measured].

Study	***N***	***TV amount (hours per day)***	***Predictors***	***Outcome measure***	***Population and age***	***Viewing measure***	***Content****	***Main findings***
Anderson et al. (2001)	570	Preschool: 2.47h Adolescents: 1.59h	TV amount and content, age, gender, parental education and occupational status, family structure.	Grade point average and self-reported grades; book use and homework; achievement motivation.	Predominantly White, middle-class. ***M* age** = 17.45 years	Parent diary (preschool); retrospective estimate (adolescents)	C measured	Overall preschool TV amount and preschool informative content predicted better boys' grades (β= .16, p< .01 and β= .21, p< .001). Overall preschool TV amount and preschool violent content predicted worse girls' grades (β= -.19, p< .01). Watching teen violent content predicted boys' worse grades (β= -.12, p< .05).
Barr et al. (2010)	60	2.02h at 1y 2.33h at 4y	TV amount and content, TV on at home, parental education, gender, ethnicity, SES.	The Behavior Rating Inventory of Executive Function-Preschool Version and block-design subtest from Wechsler Preschool and Primary Scale of Intelligence-Revised, The Peabody Picture Vocabulary Test, The Bracken Basic Concept Scale- Revised.	Predominantly White, middle-class, with highly educated parents. Wave 1: ***M* age** = 15.77 months Wave 2: ***M* age** = 49.42 months	Parent-reported diary	C partially measured (child- and adult-directed);	Longitudinally, a negative relation between watching adult-directed content at 1y and parent-reported EF at 4y (p= .03, η_p^2= .17). Cross-sectionally, TV amount at 4y predicted poorer parent-reported EF (p= .02, = η_p^2.17). High exposure to adult-directed content at age 4 was associated with poorer cognitive performance (p=.03, η_p^2=.26). Specifically, poorer language skills (p<.01, η_p^2=.17), inferior school readiness skills (p<.01, η_p^2=.18), and lower scores on EF measure (p=.05, η_p^2=.10). No relation between watching child-directed programming both at 1y and at 4y and parent-predicted EF.
Bittman et al. (2011)	5,107 4,983	N/A	Media use and media access, media control, household income, maternal education,	Short form of Peabody Picture Vocabulary Test-Third Edition, Language and Literacy Academic Rating Scale	Nationally representative sample of Australian children. Cohort 1: Wave 1: **age range** = 0-1 years; Final Wave: **age range** = 4-5 years. Cohort 2: Wave 1: **age range** = 4-5 years; Final Wave: **age range** = 8-9 years.	Parent-reported diary	C not measured	No relationship between the amount TV and language development; having a television in the bedroom associated with poorer vocabulary for 4-year olds (B=-1.172, p=.005) and 8-year-olds (B=-1.144, p<.001).
Blankson et al. (2015)	263	1.4h at 3y 1.5h at 4y	TV amount, reading, using computers, toys and activities, mother-child interactions and the use of *mental state* language, SES, ethnicity	Peabody Picture Vocabulary Test-Third Edition, Animal Stroop task, number recall test from Kaufman Assessment Battery for Children.	Middle-class families from varied ethnic background. Wave 1: ***M* age** = 3.5 years. Final Wave = approx. 2 years later.	Parent estimate	C not measured	No association between the amount of TV viewing and cognitive outcomes.
Cheng et al. (2010)	316	2.7h at 18m 2.6h at 30m	TV amount, birth weight, gestational age, gender, number of children in family maternal education, family income, maternal stimulation.	The Strengths and Difficulties Questionnaire-Japanese version	Middle-class Japanese families. **Age range** = 4-30 months.	Parent estimate	C not measured	A positive association between TV amount at 18m and hyperactivity/ inattention at 30m (p= .012). A significant linear trend (p= .002) indicating that as the number of TV amount at18m increased, hyperactivity/ inattention problems at 30m increased (p= .002) and prosocial behaviour decreased (p= .039) proportionally.

Study	*N*	*TV amount (hours per day)*	*Predictors*	*Outcome measure*	*Population and age*	*Viewing measure*	*Content**	*Main findings*
Christakis et al. (2004)	1,345	2.2h at 1y 3.6h per week at 3y	TV amount, gender, race/ethnicity, age, gestational age, urban/rural residence, maternal use of tobacco/ alcohol during pregnancy, cognitive stimulation and emotional support, number of children in family, presence of 2 parents, maternal self-esteem, maternal depression, maternal age, maternal education.	Attention problems status as defined by the hyperactivity subscale of Behavior Problems Index	A subsample of children from varied ethnic background taking part in a panel study. Wave 1: ***M* age** = 1.8 years Wave 2: ***M* age**=3.84 years. Final Wave: **age range**= 6.75 to 8.75 years.	Parent estimate	C not measured	A positive association between the scores on the hyperactivity subscale of the Behavior Problems Index and the amount of TV at 1y (p< .05, 95% CI: 1.03 to 1.5) and 3y (p<.05, 95% CI: 1.02 to 1.16).
Duch et al. (2013)	119	3.29h at 21m	TV amount and content, gender, maternal education and age, country of origin, family structure.	Communication skills development assessed by the Ages and Stages Questionnaire: A Parent-Completed Child Monitoring System, Third Edition	Low-income Hispanic families. Wave 1: ***M* age**=21.09 months. Wave 2: approximately 1 year later.	Parent estimate (24h recall diary)	C partially measured (child- and adult-directed)	Watching >2h of TV a day predicted lower communication scores a year later (β= -1.49, p= .008). Exposure to child-directed content >2h a day was negatively related to communication scores a year later (β= -1.15, p= .02). No relationship between watching >2h of adult-directed content and subsequent communication scores.
Foster & Watkins (2010)	1,159	N/A	Same as Christakis et al. (2004) plus maternal achievement, family income.	Attention problems status as defined by the hyperactivity subscale of the Behavior Problems Index.	A subsample of children from varied ethnic background taking part in a panel study. Wave 1: ***M* age** = approx. 1 year. Wave 2: ***M* age** = approx. 3 years. Wave 3: ***M* age** = approx. 7 years.	Parent estimate	C not measured	No association between early TV exposure and subsequent attention problems.
Hancox et al. (2005)	1,037	2.06h at 5-11y 3.13h at 13-15y	TV amount, SES, childhood IQ, parent and teacher assessment of behaviour with Rutter Child Scales.	Highest level of educational achievement in adulthood.	A representative sample of children from New Zealand. Wave 1: ***M* age** approx. 3 years. Final Wave: ***M* age** = approx. 26 years.	Parent estimate (5- 11); child estimate (13-15)	C not measured	Childhood and adolescent TV viewing predicted leaving school with no qualifications (RR=1.34; 95%CI: 1.10-1.62) and was negatively related to achieving a university degree (RR=0.85; 95%CI: 0.75-0.98).
Hofferth (2010)	3,563	1.93h at 6-12y 2h at 12-18y	TV and other screen and non-screen media amount, daily activities, gender, age, ethnicity, maternal education, family income and structure, maternal employment, season of the year	Socioeconomic adjustment measured with Behavior Problems Index; cognitive achievement measured with three subtests of the Woodcock–Johnson Revised Test of Basic Achievement	A subsample of children from varied ethnic background taking part in a panel study. Wave 1: **age range** =6-12 years. Wave 2: approximately 6 years later.	Parent estimate (24h recall diary)	C not measured	For White boys, a positive association between TV amount and scores on letter-word recognition (β= .13, p< .05). For Black girls, a negative association between TV amount and scores on text comprehension (β= -.20, p< .01).

Study	N	TV amount (hours per day)	Predictors	Outcome measure	Population and age	Viewing measure	Content/pacing confound	Main findings
Landhuis et al. (2007)	1,037	2.06h at 5-11y 3.13h at 13-15y	TV amount, gender, SES, childhood IQ, early childhood attention problems measured during a psychometric assessment.	Adolescent-reported scores on Diagnostic Interview Schedule for Children, parent-reported scores on Quay and Peterson Revised Problem Behavior Checklist and teacher-reported scores on the Rutter Child Scale.	A representative sample of children from New Zealand. Wave 1: ***M* age** approx. 3 years. Final Wave: ***M* age** = approx. 15 years.	Parent estimate (5- 11); child estimate (13-15)	C not measured	Childhood TV amount predicted attention problems in adolescence (β= .09, p= .002). However, when adolescent viewing was controlled for the relationship was no longer significant (β= .06, p= .052).
Linebarger & Walker (2005)	51	0.97h at 30m	TV amount and content, gender, age, SES, ethnicity, disability status, quantity and quality of stimulation from home environment, general cognitive development measured with (Bayley Scale of Infant Development-Second Edition).	Vocabulary development assessed by MacArthur Communicative Development Inventory and expressive language production assessed with Early Childhood Indicator	White middle- to upper-middle class families. Wave 1: ***M* age** approx. 6 months. Final Wave: ***M* age** = approx. 30 months.	Parent-reported viewing diary.	C measured	TV amount was associated lower word production at 30m (p<.05). Watching child educational programmes was the only content category negatively related to word production (p<.05). TV amount was positively related to expressive language growth (p<.05). Moreover, watching adult programmes predicted expressive language growth (p<.05).
Martin et al. (2012)	842	N/A	TV generally on, crowding, noise, family instability, lack of routine, gender, maternal age, household income, family size, maternal education and marital status, maternal ethnicity/race, maternal warmth, learning materials.	The Peabody Picture Vocabulary Test, Child Behavior Checklist (attention, aggression and anxiety/ depression items), self-regulation (delay of gratification and motor control).	A sample of families from varied ethnic background. Wave 1: ***M* age** approx. 2.5 years. Wave 2: ***M* age** = approx. 5 years.	N/A	N/A	The TV habitually on at home was associated with poorer attention (B= 0.43, p<.05) and increased aggression (B=1.35, p<.001).
Pagani et al. (2010)	1,314	1.26h at 29m 2.12h at 53m	TV amount, gender, temperament, sleep, maternal education, cognitive ability, impulsivity, emotional distress, physical aggression.	Teachers' rating of academic performance and classroom behaviour; parents' assessment of sedentary lifestyle, dietary choices; BMI.	A representative sample of children from Canada. Wave 1: ***M* age** = approx. 29 months. Wave 2: ***M* age** = approx. 53 months. Wave 3: ***M* age** = 121.83 months.	Parent estimate	C not measured	TV amount at 29m negatively associated with subsequent classroom engagement (β= -0.01; 95%CI:-0.02 to -0.04) and mathematics achievement (β= -0.01; 95%CI:-0.03 to 0.01), but not reading.
Pagani et al. (2013)	1,997	1.8h at 29m	TV amount, gender, maternal education, literacy stimulation, difficult temperament, family dysfunction.	Peabody Picture Vocabulary Test (PPVT), Number Knowledge Test, teacher-rated classroom engagement, gross motor development, victimization, kindergarten anxiety, physical aggression and prosocial behaviour.	A representative sample of children from Canada. Wave 1: ***M* age** approx. 29 months. Wave 2: ***M* age** = approx. 65 months	Parent estimate	C not measured	TV amount at 29m predicted lower PPVT scores (p< .001, 95% CI: −0.29 to −0.15), Number Knowledge Test scores (p<.001, 95% CI: −0.043 to −0.015), and teachers' ratings of classroom engagement (p = .015, 95% CI: −0.004 to 0.000) at 65m.

Study	*N*	*TV amount (hours per day)*	*Predictors*	*Outcome measure*	*Population*	*Viewing measure*	*Content/pacing confound*	*Main findings*
Parkes et al. (2013)	11,014	2.16h at 5y	TV and video game use amount, gender, maternal ethnicity, maternal education, maternal employment, household income, presence of biological father, family structure.	Psychosocial adjustment measured by the Strengths and Difficulties Questionnaire.	Predominantly White low-income families. Wave 1: ***M* age** = approx. 5 years Wave 2: ***M* age** = approx. 7 years.	Parent estimate	C not measured	Positive association between high TV amount and subsequent conduct problems (>3h a day; p= .003, 95%CI:0.05 -0.25). No association between TV viewing and subsequent attention problems.
Radesky et al. (2014)	7,450	2.3h at 24m	Infant Toddler Symptom Checklist (self-regulation items), ethnicity, age, gender, Bayley Mental and Motor scores, birth weight, parent-rated child health, hours in childcare, maternal and paternal age, SES, marital status, maternal physical and psychological health, prenatal alcohol/tobacco use, violence against mother, family structure, language spoken in household, neighbourhood, quantity and quality of stimulation at home.	The amount of TV viewing.	Children from varied ethnic background taking part in a panel study. Wave 1: ***M* age** = approx. 9 months. Wave 2: ***M* age** = approx. 24 months.	Parent estimate	C not measured	Self-regulation problems at 9m predicted increased TV viewing at 24m (95%CI:0.02-0.25). Poor self-regulation at both 9m and 24m predicted high (>2h a day) TV exposure at 24m (a[5]OR=1.40; 95%CI: 1.14-1.71). A decrease in self-regulation skills between 9 and 24m increased the risk of watching TV >2h a day at 24m (aOR=1.27; 95%CI: 1.04-1.56).
Rice et al. (1990)	326	N/A	Viewing *Sesame Street*, gender, starting season, parent education and occupation, maternal employment, family size, cable options, number of TV sets in household, preschool attendance, media preferences and Peabody Picture Vocabulary-Revised scores.	Peabody Picture Vocabulary Test-Revised (PPVT-R) scores.	Predominantly White families with varied educational and occupational background. Cohort 1: Wave 1: **M age** = approx. 3 years. Cohort 2: Wave 1: **M age** = approx. 5 years. Wave 2 (both cohorts): approx. 2 years later.	Family viewing diary	C measured	For Cohort 1, early viewing of *Sesame* Street (age 3-3-.5) and later viewing (age 4-5) predicted better vocabulary scores at 5 (β=.233, p<.01 and β=.213, p<.05, respectively). In contrast, for Cohort 2, neither early (age 5-5-.5), nor later (age 6-7) viewing of *Sesame Street* was related to PPVT scores at age 7. For both cohorts a relationship between early PPVT scores and later *Sesame Street* viewing was null.
Ritchie et al. (1987)	270	N/A	TV and reading amount	Teacher-assessed reading achievement,	Children from varied socioeconomic and ethnic background. *Wave 1:* ***M* age** not reported (grades 2, 3 and 6). Wave 2: approx. 3 years later.	Child estimate	C not measured	No clear relationship between TV viewing, reading and reading achievement.
Schmidt et al. (2009)	872	1.2h from birth to 24m	TV amount, maternal age, income, education, marital status and parity, age, gender, gestational age, birth weight, breastfeeding duration, race/ethnicity, primary language, sleep.	Peabody Picture Vocabulary Test -Third Edition, Wide-Range Assessment of Visual Motor Abilities	White middle-class families. Wave 1: **age range**=0 to 6 months. Final Wave: ***M* age** = approx. 3 years.	Parent estimate	C not measured	No association between early TV viewing and language and visual motor skills development at 3y.

[5] aOR-adjusted odds ratio

Study	*N*	*TV amount (hours per day)*	*Predictors*	*Outcome measure*	*Population and age*	*Viewing measure*	*Content/pacing confound*	*Main findings*
Schmiedeler et al. (2014)	924	N/A	Child and parent television amount, gender, SES, home learning environment.	Symptoms of ADHD assessed with short form of the Conners Scale and the Strengths and Difficulties Questionnaire.	A subsample of German children taking part in a panel study.Wave 1: ***M* age** = 4.1 years. Final Wave: age not reported (grade 2).	Parent estimate	C not measured	No direct or indirect relations between TV amount and symptoms of ADHD.
Shariff et al. (2010)	6,486	N/A	TV amount and content, parenting style, self-control, extracurricular activities, gender, ethnicity, age, family structure, parental education, household income, sensation seeking, problem behaviour, substance use.	Child- and parent-reported school performance.	A representative sample of children from varied ethnic background. Wave 1: **age range** = 10-14 years. Final Wave: 2 years later.	Child estimate	C measured	No direct effects of TV amount and academic performance. Viewing inappropriate content negatively related to school outcomes through an increase in substance use (β= .06, p<.01) and sensation seeking (β= .06, p<.01). Moreover, viewing adult-rated films increased problem behaviour at school (β= .09, p< .01), which in turn resulted in poorer educational outcomes (β= .14, p< .01).
Stevens et al. (2009)	2,717	3.94 per week at 3y	Parental reports of children's TV exposure, ethnicity and gender.	Inattention and hyperactivity subscale of the Behavior Problems Index.	Children from varied ethnic background taking part in a panel study. Wave 1: ***M* age** = approx. 4 years Final Wave: ***M* age**= approx. 10 years.	Parent estimate	C not measured	No association between TV viewing and subsequent attention problems.
Stevens & Mulslow (2006)	2,500	N/A	TV amount, rules about TV, SES, parental involvement with child.	Teachers' reports (approaches to learning, self-control, externalizing problem behaviours), parental assessment of children's impulsivity/ hyperactivity.	Children taking part in a panel study. Wave 1: **age** not reported (kindergarten) Wave 2: **age** not reported (grade 1).	Parent estimate	C not measured	No association between early TV exposure and subsequent attentional and behavioural problems.
Takeuchi et al. (2013)	276	1.93h	Weekday TV amount, full-scale IQ measured with the Japanese version of the Wechsler Adult Intelligence Scale-Third Edition, and the Wechsler Intelligence Scale for Children-Third Editionage, gender, age, family income, maternal and paternal education.	Full scale IQ, regional grey/white matter volume (rGMV/rWMV)	Healthy Japanese children. Wave 1: **age range**= 5.6 to 18.4 years. Wave 2: approx. 3 years later.	Child estimate	C not measured	Negative association between TV amount and and changes in verbal IQ over a 3-year period (β= -.014, p= .032). A positive association between TV viewing and rGMV of the frontopolar and medial prefrontal areas. A positive association between TV viewing and rGMV of the hypothalamus/septum and sensorimotor areas.

Study	*N*	*TV amount (hours per day)*	*Predictors*	*Outcome measure*	*Population and age*	*Viewing measure*	*Content/pacing confound*	*Main findings*
Tomopoulos et al. (2007)	99	1.96h at 21m 2.13h at 33m	TV, video, computer games amount and content, mother's socio-demographic characteristics, household structure, gender, age, day care, child's temperament, maternal depressive symptoms, parent-child reading activities.	Child Behavior Checklist	Children from low-educated Hispanic families. Wave 1: ***M* age** = 21 months. Wave 2: ***M* age**= 33 months.	Parent estimate (24h recall diary)	C measured	At 21m, positive association between total media amount and the Aggressive Behaviour (p= .030, 95%CI: 1.1 - 3.8) and the Externalising Problems subscales scores (p= .046, 95%CI: 1.0 - 2.7). Aggressive behaviour was associated with viewing non-educational programmes at 21- (p= .020, 95%CI: 0.6 - 3.0) and 33m (p= .047, 95% CI: 1.0 - 4.9). Viewing non-educational programmes at 33m was positively associated with the scores on Externalising Problems subscale (p= .03, 95% CI: 1.1 - 4.7).
Tomopoulos et al. (2010)	259	2.5h at 6m	TV amount and content, maternal education, age, primary language, ethnicity, country of origin, marital status, gender and birth order, maternal depression, quality and quantity of cognitive stimulation at home.	Cognitive development assessed with Bayley Scales of Infant and Toddler Development – third edition; language development assessed with the Preschool Language Scale–4.	Predominantly Hispanic families, from low SES background. Wave 1: ***M* age** = 6 months. Wave 2: ***M* age**= 14 months.	Parent estimate (24h recall diary)	C measured	Negative association between the amount of TV at 6m and both cognitive (β= -.15, p= .02) and language outcomes (β= -.16, p< .01) at 14m. Exposure to older child/adult content also negatively associated with subsequent cognitive (β= -.18, p= .006) and language outcomes (β= -.19, p= .001).
Verlinden et al. (2012)	3,913	0.53h at 24m 0.91h at 36m	TV amount and content, pre-existing externalising problems (measured at 18m), gender, age, parents' country of origin, day care attendance, maternal and paternal age, educational level, marital status, monthly income, maternal mental health, parenting stress, and parity.	*Occurrence* (at 36m) and *persistence* (at 24-to 36m) of externalising problems measured with the Child Behavior Checklist subscale.	Dutch children taking part in a panel study. Wave 1: ***M* age**= 18 months. Final Wave: ***M* age**=36 months.	Parent estimate	C partially measured (adult- and child-directed)	For all children, the amount of TV and content type watched at 24m was not related to occurrence of externalising problems at 36m. However, for a subgroup of children, high TV exposure[6] was associated with the occurrence of externalising problems at 36m (OR=2.0, 95%CI: 1.07-3.75) and the persistence of the pre-existing externalising problems (OR=2.59, 95%CI: 1.03-6.55).
Wright et al. (2001)	236	*Educational TV:* 2h per week (preschool); 1h per week (school) *Cartoons:* 7.5h per week (preschool); 5h per week (school) *General audience:* 16h per week (preschool); 10h per week (school	TV amount and content, maternal education, family income, marital status, ethnicity, primary language at home, family structure, child-parent interactions at home.	Reading and number skills (two subtests from the Woodcock–Johnson Tests of Achievement); Peabody Picture Vocabulary Test-Revised; School Readiness Scale from Bracken Concepts Scale.	Low- to moderate-income families, representing a diverse ethnic background. Cohort 1: Wave 1: ***M* age** = approx. 2 years. Cohort 2: Wave 1: ***M* age** = approx. 4 years. Final Wave (both cohorts): approx. 3 years later.	Parent estimate (24h recall diary)	C measured	Younger cohort: educational TV at ages 2-3 predicted better literacy (β= 208, p< .05), numeracy (β= .316, p< .01), vocabulary (β= .202, p< .05), and school readiness (β= 296, p< .01), at 3. Cartoons at 2-3 predicted poorer word recognition at 3 (β= -.204, p< .05), and lower vocabulary at 5. Finally, viewing 'general audience TV' predicted worse numeracy skills (β= -.286, p< .01) and vocabulary (β= -.269, p< .01). Older cohort: watching 'general audience TV at 4-5 predicted poorer letter/word knowledge (β= -.223, p< .05) at 5. Younger cohort: better performance on letter-word recognition, vocabulary, and schools readiness at 3 predicted less viewing of general audience TV at 4-5 (β= -.209, β= -.199, β= -.195, respectively; all significant at p< .05). Older cohort, higher scores on letter-word recognition at 5y predicted watching educational TV at 6-7 (β= .174, p<.05) Finally, low vocabulary scores at 5y predicted more cartoon viewing at 6-7 (β= -.216, p<.05).

[6] High TV group includes two subgroups of children: (1) children with an *increase in TV amount* from < 0.5h/day at 24m to ≥1h /day at 36m and (2) children, who showed *continued high exposure*, i.e., ≥ 05h/day at 24m and ≥1h/day at 36m.

Study	*N*	*Age*	*Materials/intervention*	*Control condition*	*Measure*	*Main findings*		
Zimmerman & Christakis (2005)	1,797	2.2h under-3s 3.29h at 3-5y 3.54h for 6y+	TV amount, cognitive stimulation, parental cognitive ability, mother's intellectual background, race/ethnicity, native language	Peabody Individual Achievement Test (mathematics, reading recognition and comprehension), memory for digit span	Children from varied ethnic background taking part in a panel study. Wave 1: ***M* age** <3 years. Final Wave: age range=5.5 years to 7.5 years.	Parent estimate	C not measured	A negative association between early TV onset (<3 years) and reading recognition (p<.05, 95% CI: −0.61 to −0.01) and reading comprehension (p<.05, 96% CI: −0.94 to −0.21) at 6y. Early onset also predicted a decrease in digit span scores (p<.05, 95%CI: - 0.2 to 0.0), and mathematics score (p<.05, 95% CI: −0.85 to −0.04), but only in children from low-income families. A positive association between watching TV at the age 3 and 5 and reading comprehension scores (p<.05, 95% CI: 0.17 to 0.85), but not digit span scores (p=.16).
Zimmerman & Christakis (2007)	3,563	N/A	Content (educational, entertainment, violent), age, race/ethnicity, sex, region of residence, socioeconomic adversity, birth order, emotional support, cognitive stimulation.	Hyperactive scale of the Behavior Problems Index	Children from varied ethnic background. Cohort 1: Wave 1: **age range** = 0-3 years. Cohort 2: Wave 1: **age range** = 4-5 years. Last Wave: 5 years on.	Parent diary	C measured	Watching entertainment TV before the age of 3 predicted higher scores on the hyperactivity subscale of the BPI at 8 (p= .01, 95%CI: 1.19 -4.08 and p=.04, 95% CI: 1.02 1.28, respectively). No relation between entertainment TV at the age of 4 to 5 and attention problems 5 years later. Watching educational TV not related to subsequent attention outcomes.

Table 1. 3. Description of experimental studies included in the review.

Study	*N*	*Age*	*Materials/intervention*	*Control condition*	*Measure*	*Main findings*
Anderson et al. (1977)	72	*M* age= approx. 4 years.	Specially edited (slow- and fast-paced) 40-min versions of Sesame Street.	Story	Matching Familiar Figure test, Replacement Puzzle Test, 10-minute free play session.	Children's cognition and behaviour did not differ between experimental groups.
Baydar et al. (2008)	399	*M* age = 5.25 years.	Watching an educational programme for 13 weeks Information about the benefits of an educational programme	Watching an entertainment programme for 13 weeks	Early numeracy skills, ability to categorise objects and form mental representations of shapes, early literacy skills and receptive vocabulary.	Compared with control children, frequent exposure to an educational programme was associated with improved numeracy (β=.110, p.<01), literacy skills (β=.122, p<.05) and vocabulary (β=.106, p<.05). Moderate exposure predicted better numeracy skills (β= .107, p<.05) vocabulary (β=.186, p<.01). Low exposure was not predictive of any of the measured cognitive skills. Compared with control children, children from families that were told about the potential benefits of an educational programme and who watched it more than 1 x week improved vocabulary (β= .143, p<.01), but not other cognitive skills. Low or no exposure to the programme was associated with poorer numeracy skills.
Bellieni et al. (2010)	122	*M* age = approx. 10 years.	Voices and music of the animated film, black and white cartoon/colour cartoon	No control group	Auditory vigilance test (AVT)	Compared to listening to the soundtrack only, children made more errors (p<.001), and took longer to respond (p<.001) when either colour or black-and-white film was played during the AVT task administration.
Cooper et al. (2009)	37	*M* age = 5.19 years.	4-min film presenting a narrator reading a children story in fast- and slow-edit version.	No control group	Attention networks test (ANT)	4y-olds who watched a slow-paced film had greater orienting scores compared to children in the fast-edit group (p<.01) and this effect was reversed for 6y-olds (p<.05). In all age groups children who watched a slow-edited film made more errors (p<.05).
Courage et al. (2010)	48 (phase 1) 25 (phase 2)	Phase 1: *M* age= approx. 6 months Phase 2: *M* age = approx. 18 months.	10-min segment of infant-directed programme	10-min of no TV	Infant behaviour during play, and child-parent interaction.	In the presence of a background TV 6m-olds and 8m-olds looked more frequently at the toys than the film or parent (p<.001, η_p^2=.48 and p<.001, η_p^2=.97, respectively). For 18m-olds, TV in in the background reduced duration of looking at the toys (p<.001) and the number of looks to the toys (p<.01). When the TV was on, parents talked to 6m-olds infants less (p< .001, η_p^2= .57). Play interactions between parents and 18m-olds were shorter in the presence of a background programme (p< .03, η_p^2= .23).
DeLoache et al. (2010)	72	*M age* = 14.7 months	Co-viewing of a baby DVD; exposure to a video 5x week for 4 weeks. Solitary viewing of a baby DVD. Exposure as above. Parents taught infants 25 words presented in a DVD.	No intervention.	Knowledge of the words presented in a baby DVD.	Infants in both DVD viewing groups (co-viewing and solitary viewing) did not learn words beyond normal vocabulary growth. Only infants in parent-taught condition performed above chance (p<.05).
Gadberry (1980)	27	*M* age = 78 months.	Restriction of TV viewing for 6 weeks	Unrestricted viewing	Verbal and performance IQ, leisure time use, Matching Familiar Figures Test	Restricting television had a positive effect on performance IQ scores (p< .05), reading time (p <.01), and response times on the Reflective Matching Familiar Figures task (p <.05).
Geist & Gibson (2000)	62	Age range= 4.08-5.58 years.	30-min episode of the slow-paced educational show 30-min episode of the fast-paced action-adventure show	Educational activity	Children's time on task and number of activity changes during 30-minute play period.	Compared to the children, who took part in educational activity, children who watched a fast-paced entertainment show switched between activities more frequently (p= .038, 95% CI: -2.66 to -6.17) and spent less time on the task (p=.046, 95% CI: 2.96 to 379.4).
Kirkorian et al. (2009)	51	Age range = 12-36 months.	30-min of adult-directed programme played in the background	30-min of no background TV.	Verbal stimulation, parent involvement, child behaviour, parent and child responsiveness	Background TV was associated with fewer verbal interactions, less parental involvement during play, and decrease in children's social behaviour (all significant at p<.001). Background TV had no effect on children's speech.

Study	*N*	*Age range*	*Materials/intervention*	*Control condition*	*Measure*	*Main findings*
Krcmar (2011)	60	Age range = 6-24 months.	The 3-minute DVD modelled on a popular baby programme featuring novel objects. Parent-led demonstration of novel objects.	No control group	Knowledge of the words featured in the DVD/parent demonstration measured with the duration of looks at target and distractor object.	Following parent-led demonstration, infants looked longer at target objects than they did at distractor objects, $F(1,59)=10.43$, $p<.001$, $\eta^2=.18$. Conversely, in the DVD condition, infants looked longer at distractor objects than they did at target objects, $F(1,59) = 7.29$, $p<.001$, $\eta^2=.13$.
Krcmar (2014)	70	Age range = 4-24 months.	Co-viewing of one of the two versions of a baby DVD featuring 3 different novel words; exposure 6x over 2 weeks.	Solitary viewing. Materials and exposure same as in experimental condition.	Knowledge of the words featured in the baby DVD measured with the duration of looks at target and distractor object.	Older infants (> 17-months) looked longer at target objects than they looked at distractors (M=5.29 and M=2.81, respectively). For younger infants (<17-months), the duration of looks at target and distractor objects was almost identical (M=2.81 and M=2.85). Further, there was no benefit of co-viewing; the difference in word learning between intervention and control group was not significant (p=.065).
Lavigne et al. (2015)	128	Age range = 12-18 months.	Two-week exposure to either *Sesame Beginnings* or *Baby Einstein* prior to test session. Two experimental sessions; one 30-min free-play session with TV off and one 30-min session of watching the pre-assigned programme followed by 15-min of free-play with TV off.	Parents unfamiliar with the show	Quantity and quality of parent language, the effects of programme familiarity on parental language.	Co-viewing both baby videos number of words per minute (p< .001), new words per minute (p<.001), new words per utterance (p<.001) and mean length of utterance (p<.001; only during Baby Einstein). However, there was an increase in the number of new words per utterance (p< .001 for both videos). The familiarity with the programme did not affect parental language.
Lillard & Peterson (2011)	60	*M* age = approx. 4 years.	9-min episode of fast-paced show entertainment show 9-min episode of slow-paced educational show	Drawing	Tower of Hanoi, Head Toes Knees Shoulders, backward digit span, delay of gratification	Children who watched the fast-paced cartoon performed significantly worse on the EF tests (p=0.004), and on the delay of gratification test (p=.03) compared to the control group.
Lillard et al. (2015) Exp.1	160	*M* age = 55 months *M* age = 76 months	11-min of fast-paced fantastical programme 11-min of fast-paced action-adventure programme 11-minutes of slow-paced realistic cartoon	Free-play	Tower of Hanoi, Head Toes Knees Shoulders, auditory working memory, delay of gratification, functional fixedness	Children who watched fast-paced fantastical programme and fast-paced action adventure programme performed worse on the EF assessment than children who played (p= .041 and p= .047, respectively). Children who watched slow-paced realistic cartoon performed better in delay of gratification test than children who played (p= .03).
Exp. 2	60	*M* age = 55.58 months.	22-min of fast-paced fantastical programme 22-min of fast-paced educational show	Educational audio-book	Tower of Hanoi, auditory working memory, card sorting task, inhibitory control task, vocabulary quiz	Children's performance on the EF tasks differed by condition ((p=.005, $\eta_p^2=.17$); children who watched the fantastical show and the educational show performed worse on the EF tasks than children who listened to the audio-book (p=.02 and p<.01, respectively). There was no difference between the groups in the vocabulary quiz scores.
Exp. 3	80	*M* age = 52.77 months.	Fast- and slow-paced fantastical show Fast- and slow-paced realistic show	No control group	Head Toes Knees Shoulders, auditory working memory, inhibitory control task, delay of gratification, Tower of Hanoi	Controlling for pre-film EF scores, there was a main effect of content on the post-film EF performance (p=.01, $\eta_p^2=.08$). Similarly, controlling for pre-film working memory scores, there was a main effect of content, but not pacing on the post-film measure of working memory (p= .02, $\eta_p^2=.08$).
Linebarger et al. (2004)	79 85	*M* age = 6.02years. *M* age = 7.10 years.	17 episodes of a programme designed to improve early literacy skills development watched in the classroom during school hours	No programme exposure; usual school activities	Learning of the specific programme content (speech to print matching, word recognition, concepts of print, word meaning, word building); The Dynamic Indicators of Basic Early Literacy Skills (DIBELS); The Test of Early Reading Ability-2 (TERA-2).	Children categorised into three "at-risk for later reading outcomes" groups (*at-risk*, *moderately at-risk*, *not at-risk*) based on the pre-intervention reading ability assessed with DIBELS. Compared to the control group, all children who viewed the programme scored better on the word recognition task ($\eta^2=.07$). *Moderately-at-risk* 6y-olds performed better on word building and speech to print matching ($\eta^2=.17$ and $\eta^2=.14$, respectively). Further, *moderately-at risk* and *not-at-risk* 6y-olds performed better on concepts of print task ($\eta^2=.13$ and $\eta^2=.05$, respectively). Finally, *moderately-at-risk* 6y-olds outperformed their peers who did not watch the programme on TERA-2 assessment.

Study	*N*	*Age*	*Materials/intervention*	*Control condition*	*Measure*	*Main findings*
Nathanson & Rasmussen (2011)	73	Age range = 16-72 months.	10-min of reading books 10- min of watching TV 10-min of playing with toys	No control group	Assessment of communication frequency and maternal responsiveness.	The quantity of mother-child communication and maternal responsiveness was reduced during TV viewing compared to reading and playing with toys ($p<.001$ and $p<.01$, respectively).
Pempek et al. (2011)	152	*M* age = 14.33 months *M* age =19.62 months.	Two-week exposure to either *Sesame Beginnings* or *Baby Einstein* prior to test session. Two experimental sessions; one 30-min free-play session with TV off and one 30-min session of watching the pre-assigned programme followed by 15-min of free-play with TV off.	No prior video exposure	Assessment of reading, labelling, praising and making music together.	Quantity of interactions during the first free-play session was positively associated with co-viewing of both videos at home ($\beta= .08$, $p= .015$) and this relationship was stronger for parents who watched *Sesame Beginnings* at home ($\beta= .14$, $p= .021$). Viewing the programme during experimental session decreased quality and quantity of interactions (both significant at $p< .001$). Compared to the pre-film free-play session, the quantity and quality of interactions during a post-film session increased for the *Sesame Beginning* group ($p= .006$ and $p=.002$, respectively).
Richert et al. (2010)	96	Age range =12 - 25 months	Frequent exposure to *Baby Wordsworth* DVD at home (5x 2-week period) for 6 weeks	Normal home routine	Knowledge of the words emphasised in the baby DVD (*word said*, *word understood* and *picture identification*). General language knowledge assessed with MacArthur Communicative Development Inventory (CDI).	No difference in the CDI scores between experimental and control groups. However, watching Baby Einstein DVDs at younger age predicted poorer general language scores ($p=.05$). Further, there was no difference in the assessment scores related to the knowledge of words emphasised in the baby DVD between the two groups.
Robb et al. (2009)	45	Age range = 12 - 15 months.	Frequent exposure to *Baby Wordsworth* DVD at home (5x 2-week period) for 6 weeks	Normal home routine	Knowledge of the words emphasised in the baby DVD (*word said*, *word understood*).	Watching a baby DVD did not have an effect on *word said* scores. However, there was a positive relationship between *word said scores* and the time child was read to and was exposed to background TV at home. Similarly, there was no effect of baby DVD exposure on the *word understood* scores. Finally, there was a positive association between *word understood* scores and the amount of time a child was read to and the amount of background TV exposure at home.
Roseberry et al. (2009) Exp. 1	40	*M age* = 33.74 months. *M age* = 39.36 months.	Exposure to a specially edited baby DVD supported with live action demonstration, during which the experimenter performed target actions with a doll or a puppet.	No control condition	Knowledge of two novel verbs taught in training phase measured with duration of looking at target and non-target actions presented on a screen. *Extension test:* children had to extend their word learning from a puppet to a human and vice versa. *Stringent test:* children had to look away from target action upon hearing a novel word and look back at target action upon hearing previously featured verb.	*Extension test:* For the first verb, there was no significant difference in looks duration at target and non-target actions, $t(39) = .77$, $p > .05$. For the second verb, looks towards the target action were significantly longer than looks to the non-target action, $t(39) = 4.67$, $p < .001$. *Stringent test:* upon hearing the novel verb, children looked equally to target and non-target action, $t(39) = 0.02$, $p > .05$. However, upon hearing previously taught verb, children looked significantly longer toward the target action than the non-target action presented on a screen, $t(39) = 3.23$, $p< .05$. Finally, looking time during extension and stringent tests showed a significant quadratic pattern, $F(1, 39) = 6.16$, $p < .05$, $\eta_p^2= .14$.
Exp. 2	40	*M age* = 33.00 months. *M age* = 39.39 months.	Exposure to a specially edited baby DVD without live action demonstration.	No control condition	Measures were identical to those used in Experiment 1.	*Extension test:* only older children looked significantly longer to the target than to the non-target action, $t(19)= 4.36$, $p < .001$. *Stringent test:* upon hearing the novel verb, older children looked equally to target and non-target action $t(39) = 0.85$, $p > .05$. In contrast, upon hearing previously taught verb, children looked significantly longer toward the target action than the non-target action presented on a screen, $t(39) = 3.59$, $p < .05$. Finally, there was no significant quadratic pattern in visual fixation, $p>.05$.

Study	*N*	*Age*	*Materials/intervention*	*Control condition*	*Measure*	*Main findings*
Exp. 3	16	*M age* = 33.08	Exposure to a specially edited baby DVD supported with televised action demonstration, during which a video recording of the experimenter performing target actions with a doll or a puppet was shown to a child.	No control condition	Measures were identical to those used in Experiment 1 and 2.	*Extension test:* no significant difference between looks duration to the target and non-target actions, p > .05.
Schmidt et al. (2008)	50	Age range = 12-36 months.	30-min of adult entertainment show played in the background	30-min of no background television.	Per cent of time spent in play, play episode length and focused attention during play.	Adult-directed background TV decreased overall play-time (B=-5.08), reduced the length of the average play episode (B=-30.16) and the duration of focused attention during play (B=-5.06).
Setliff & Courage (2011)	60	*M* age = 26.3 weeks *M* age = 51.5 weeks.	10-min of background TV	10-min of no background TV	Direction and duration of infants' looks, focused attention during play	In both conditions, infants spent more time looking at the toys than at the TV (p< .001, η_p^2 = .94). Compared to no TV, background TV reduced the mean length of focused attention episode (p< .01) and the duration of the longest play episode (p<.001). When the television was on, the number of looks to the toys increased significantly (p< .001, η_p^2 = .78), but nearly 50% of the looks were shorter than 2s.
Strouse et al. (2013)	81	*M age* = 42.1 months	Two-week parent-child co-viewing of educational DVD (a televised storybook format). *Dialogic questioning:* parents trained to provide support during viewing through scaffolding, questioning and social feedback. *Directed attention:* parents asked to draw children's attention to televised story and to provide social feedback, but to refrain from asking questions. *Dialogic actress:* a video of an actress using dialogic technique to ask children questions during the programme incorporated into a televised storybook.	Two-week viewing of educational DVD (a televised storybook) as per usual home routine.	Story comprehension and knowledge of vocabulary featured in the story. Expressive vocabulary growth assessed with the Expressive One-Word Picture Vocabulary Test (EOW-PVT).	Children in the dialogic questioning group scored higher on the measure of story comprehension than children in directed attention and control group, t(77) = 2.32, p =.023, d=0.53 and t(77)=3.07, p=.003, d=0.70, respectively. However, there was no significant difference in comprehension scores between dialogic questioning and dialogic actress groups (p=0.71). Similarly, children in the dialogic questioning group had better knowledge of vocabulary featured in the DVD than children in the directed attention group, t(76)=2.74, p=.008, d=0.63, and than children in the control group, t(76)=3.16, p=.002, d=0.72, There was no significant difference in story-related vocabulary scores between dialogic questioning group the dialogic actress group, p=.061. Compared to pre-intervention assessment, post-intervention EOW-PVT scores showed a significant improvement in expressive vocabulary for children in dialogic questioning t(19)=2.15, p= .045, d=0.99 and directed attention group, t(20)=3.40, p= .003, d=1.52. Conversely, for children in dialogic actress and control group, there was no significant expressive vocabulary growth (p=.068 and p=,638, respectively).
Tanimura et al. (2007)	14	Age range = 7-24 months.	12-min of background TV	20-min of no background TV	Frequency and quality of parental utterance, singing to and smiling at the child.	Background TV increased frequency of parental singing (p= .003) and smiling (p=.001), but reduced quality (p<.001) and quantity (p=.02) of parental utterance.

Chapter Two: The immediate effect of video editing pace on preschool children toy-switching behaviour

Abstract

The aim of the present study was to examine whether fast-paced video affects how preschool-aged children interact with toys. Seventy children (aged 2 to 4.5 years) were paired and tested with either a fast- or a slow-paced video. Each dyad took part in two free-play sessions. In between these play sessions they watched one of two specially edited 4-minute videos of a narrator reading a children's story. The number of toys with which children played during the pre- and post-video session was measured. Prior to watching the video, children's behaviour did not differ across experimental groups. However, after watching the video, the children in the fast-paced group shifted their attention between toys more frequently compared to the children in the slow- paced group. Even a brief exposure to differently paced videos had an immediate effect on children's interactions with toys.

Introduction

The ability to maintain attention on objects and tasks has implications for learning and achieving educational potential (Lyon, 1996). Exposure to television in childhood is proposed to influence the early development of attention (Christakis, 2009). However, research focusing on the relationship between the *amount* of viewing and attention outcomes has produced inconsistent results. Several studies suggest that there is an association between the time spent watching television in childhood and hyperactivity-inattention (Cheng et al., 2010) as well as attentional problems more generally (e.g., Christakis et al., 2004; Ebenegger et al., 2012). Conversely, other research shows that the amount of viewing is not a strong predictor of attention functioning (Foster & Watkins, 2010; Stevens & Mulsow, 2006).

In addition to how much television is watched, the nature of the material viewed may also be important. Wright and colleagues (Wright & Huston, 1983; Wright et al., 1984) suggest that in order to attract and hold attention of young children, television employs various audio-visual features, such as visual effects (pans, zooms, fades), high rate of action, auditory enhancement, and pace variability. At the same time, rapid pacing gives less scope to reflect on and process the viewed content, thus potentially delivering cognitive overload (Singer, 1980). Fast pace programming may affect cognitive processes and behaviour in two ways. First, audio-visual features may 'over-stimulate' young brains during a developmental period when environmental influences are crucial, and so ultimately lead to deficits in attention (Christakis, 2009; Christakis et al., 2004). Second, processing of the content is dictated by pacing of the programme. Faster pace requires the viewer to assimilate new stimuli rather than persevere in understanding the old ones (Greenfield, 1984), and integrate numerous scene and character changes in a short time, thus leading to difficulties in understanding of the content (Goodrich, Pempek, & Calvert, 2009). Therefore, watching fast-paced film may encourage superficial processing rather than reflective thought.

Very few studies have experimentally investigated the short-term effects of programme pacing on children's cognition and behaviour. An early investigation by Anderson, Levin and Lorch (1997) examined the effects of different pacing of *Sesame Street* on perseverance, impulsivity and level of activity during toy play, and found no detrimental effects of fast film pace on 4-year-olds. However, compared with more modern children's TV shows, *Sesame Street* has a very slow pace (McCollum & Bryant, 2003). In contrast, Wright and colleagues (1984) demonstrated that primary school children, who watched a fast-paced programme, found it more difficult to integrate the information from the film, and to recall the sequence of still pictures taken from the show, than children who watched a slow-paced programme.

Moreover, there is a suggestion that exposure to rapidly edited cartoons may result in poorer behavioural control and less goal-directed persistence. Indeed, children who watched a fast-paced entertainment cartoon persevered less with subsequent educational activities such as painting, playing board games or listening to the story, than control group children who did not watch television prior to the play session (Geist & Gibson, 2000). Similarly, Lillard and Peterson (2011) demonstrated that watching an episode of a fast-paced film had a detrimental effect on 4-year-olds' executive function. However, these studies confounded pace with content (i.e., fast-paced films had different content from slow-paced films). In fact, using real-life programming with varying editing pace and content, Lillard et al. (2015) found evidence that it was processing of a particular content, rather than the fast pace, which taxed executive function. Compared with children who viewed realistic programming, a group that watched programmes with unrealistic content (i.e., showing events or characters that defy the laws of nature) performed worse on executive function tests. However, despite manipulating unrealistic content and editing, the films employed in this study also varied in other aspects of their content and audio-visual characteristics (e.g., social concepts vs. word learning, different target age, presence of loud music or bright colours).

To avoid the content-pacing confound, Cooper et al. (2009) developed a novel experimental paradigm, in which the same raw footage was edited to produce fast- and slow-paced videos. The results of the experiment suggest that watching differently paced videos affected children's performance on the Attention Networks Task. This continuous performance test (Fan et al., 2002), which integrates cueing and flanker paradigms, measures performance of the three attention components: alerting, orienting and executive control (Fan & Posner, 2004). The study showed that, irrespective of age, children in the fast-paced condition made fewer errors (Cooper et al., 2009). Four-year-olds in the slow-paced condition had higher orienting scores; however, this effect was reversed for 6-year-old children. In addition, 4- and 6-year-old children (but not 5-year-olds) in the fast-paced group had shorter reaction times. Although these findings were somewhat difficult to interpret (for a detailed discussion, please see Chapter 1, pp.76-78), it is evident that even a very brief exposure to a fast-paced video can affect children's attention.

In contrast to television viewing, during which attention is driven by the pace of events presented in a programme, the structure of play is generally dictated by the individual child (Choi & Anderson, 1991). Nevertheless, Choi and Anderson (1991) suggest that there is an important similarity in the attentional processes underlying television viewing and toy play: in both cases orientation towards the object of the child's activity is driven by 'attentional inertia'. This term was originally proposed by Anderson and colleagues (Anderson, Alwitt, Lorch, & Levin, 1979; Anderson, Choi, & Lorch, 1987) to describe the phenomenon observed during their research on children's visual attention to television and was later extended to describe children's attentional engagement during free play (Choi & Anderson, 1991). Anderson et al. noted that the longer the duration of an uninterrupted segment of a respective activity, such as looking at television or playing, the more likely it was that this activity continued further. Thus, attentional inertia appears to bind together the segments of consecutive activity, by protecting from disruptions caused by external distractors and by deepening engagement. It should be noted here that this conceptualisation of attentional inertia is somewhat different to that proposed by Kirkham, Cruess, and Diamond (2003), which refers to children's difficulty in re-directing attention between different dimensions in the card sorting task.

The ability to resist distraction from competing objects or events is one of the several processes that appear to be compromised by attention hyperactivity deficit disorder (ADHD; Barkley, 1997). In children, this tendency to be distracted can be observed during free play. Alessandri (1992) suggested that frequent changes between toys during a free play session implied a shorter attention span, and is a characteristic of ADHD. In fact, playroom observations have been used successfully to distinguish between hyperactive and control children. Compared to the typically developing peers, clinically-referred boys' behaviour has been characterised by greater motor activity, less time on task and increased switching between tasks (Roberts, 1990; Roberts, Ray, & Roberts, 1984). Moreover, Handen, McAuliffe, Janosky, Feldman, and Breaux (1998) found that children with ADHD changed toys more often, and engaged in shorter play episodes than a control group during free play. The potential role of attentional inertia in both television viewing and free play makes an investigation of the effect of editing pace on children's unstructured play of particular interest.

As noted above, previous attempts to understand the role of editing pace have been limited by the confounding effect of content (Anderson et al., 1977; Geist & Gibson, 2000; Lillard et al., 2015; Lillard & Peterson, 2011). Thus, the present study examined whether varying the pace of a short video, while keeping the content constant, would affect the frequency of switching between toys in a subsequent unstructured play session. Specifically, this experiment investigated the effect of pacing on how pairs of children behaved in a 5-minute post-viewing free-play session. The methodology developed by Cooper and colleagues (2009) was adopted. Using materials with *identical content*, but different editing, allowed the effect of pacing to be isolated. It was predicted that exposure to a fast-paced video would reduce attentional inertia, leading to more shifts between toys during playtime.

Experiment 1

Method

Participants.

Sixty-eight (35 girls) children with a mean age of 43.6 months (SD=5.9) and a range of 28-55 months were recruited from an opportunity sample attending preschools in a semi-rural county of England, UK. One further dyad took part but was excluded from the analysis due to very unsettled behaviour of one of the children during the pre-video session. The experiment was approved by the local Ethics Committee. Before the study began, children's parents had received a letter providing information about the project and the procedure, and had an opportunity to withdraw their child from participation. Children were alternately assigned to one of the two experimental conditions.

Apparatus and Materials.

The video stimulus was played on an ASUS laptop computer (ASUSTek Computer Inc., Taipei, Taiwan), using Windows Media Player (Microsoft Corporation, WA, USA). Audio playback was delivered via Sony speakers (Sony Corporation, Tokyo, Japan). The experiment was recorded with Panasonic HD video camera (Panasonic Corporation, Osaka, Japan). A popular children story - *The Snail and the Whale* (Donaldson & Scheffler, 2003) - was used to create the experimental videos. The narrative describes the adventures of a little snail and a humpback whale during their shared journey around the world and it represents a typical story directed at preschool children.

Two 4 minute 12 second versions of a video recording of a female narrator reading a story were produced using the same unedited raw material and audio track. The narrator was filmed with three different cameras (narrator front view, narrator three-quarter view and narrator side-view). This footage was later edited together with the illustrations from the book to produce either a slow- or a fast-paced video. For the purpose of this study, an editing action was specified as a change from the narrator view to a still image or a change between the two different narrator views (e.g., from a head view to a full view). The still images were spliced into the footage to match the content of the story read by a narrator. For example, when the narrator read "A humpback whale immensely long…" an illustration from a book showing a whale half-submerged in the sea appeared on the screen. Further, every effort was made to make sure the editing did not alter the comprehensibility of the content.

The slow-paced video consisted of 22 camera cuts (10.8 sec average scene duration) and four still images (3 sec average duration), which resulted in an average of 6.2 cuts per minute. The fast-paced video consisted of 102 camera changes (average shot lasting 2.3 sec) and 16 still images (2 sec duration); the average number of cuts per minute was 28.1. Table 2.1. shows a comparison in cut frequency between the experimental videos, pop music videos and typical children's programmes available on British terrestrial television channels. In both versions of the video, whale song was played continuously in the background as an additional audio feature.

Table 2. 1. Frequency of camera cuts in the experimental videos (denoted with asterisks), pop music videos and randomly selected five-minute segments of typical children's shows available in January 2015 on UK terrestrial television.

Title	**Average cuts per minute**
Uptown Funk (music video by Mark Ronson and Bruno Mars)	37.5
Blank Space (music video by Taylor Swift)	32.0
The Snail and The Whale (fast-edit study video)*	28.2
Pokemon (children's TV programme)	16.6
Bear Behaving Badly (children's TV programme)	14.4
Old Jack's Boat (children's TV programme)	8.8
Sooty (children's TV programme)	7.6
The Snail and The Whale (slow-edit study video)*	6.2

Design.

The experiment adopted a between-participant design. The independent variable was video pace (fast vs. slow) and the dependent variable was the number of toy episodes during the post-video session. Furthermore, the number of toy episodes during pre-video play and participants' age was included as covariates. Thus, each child contributed two scores: pre-video toy episodes score and post-video toy episodes score.

Procedure and coding.

Two free-play sessions – one immediately before and the other immediately after the video presentation – were used to measure children's attention. The length of each session was 5 minutes. In the post-video session, children were allowed to stay in the test room and play for up to 10 minutes; however, only the first 5 minutes of play were subsequently coded to match the length of the pre-video play session. There were seven age-appropriate toys, such as, for example, a building snail pail, paper and colouring pens, a soft animal toy, available to play with during each experimental session.

The experiment took place in a quiet room that was separate from the main preschool area. To create a naturalistic setting and reduce participants' anxiety associated with being under observation that could constrict their natural behaviour, children were invited to come to the test room in pairs. The assignment to pairs was random. At the beginning of each session, the experimenter greeted the children coming into the test room and said: "I brought my toys to preschool today. Would you like to play with them?" Following this brief introduction, participants were encouraged by the experimenter to engage in play activity, using the variety of toys arranged on the table. Immediately after the first free-play session, the experimenter said: “Let’s watch a video now” and the children were instructed to move over to the next table where they watched either version of the video. During viewing, both children sat in front of a laptop computer, approximately 50 cm away from the screen, and watched the video together on one screen. Following the viewing, children were invited to go back to the toy table and to engage in further play activity. Each session lasted approximately 20 minutes, and the experimenter remained in the testing room throughout the session.

To ensure that no data were lost in case of equipment malfunction, behaviour was first coded ‘on-line’ during the test session by the experimenter who was not blind to the experimental condition. Second observer – blind to the condition – coded children’s behaviour from video recordings, and these scores were used in the analysis. The experimenter and the observers coded two types of behaviours that represented toy episodes: (1) picking up toys, and (2) touching toys. Thus the target behaviour was defined as *physical contact with a toy*. To be counted, the toy had to be physically touched or picked up by a child. In case of concurrent contact with more than one toy (for example, if a child simultaneously picked up or touched two toys), the observer coded behaviour as one toy episode. Furthermore, if a child who was in possession of one toy touched or picked up another toy without putting down toy number one, behaviour was coded as a new episode. Engaging with non-toys (i.e. other objects that were present in the test room) was rare and therefore not coded.

The percentage agreement between the experimenter and the first observer was 67.6%, and the *kappa* coefficient, ƙ =.63. Two further observers independently coded the behaviour of 25% of the children. The percentage agreement between the three observers was 80.6%, the *kappa* coefficient, ƙ =.77. Any discrepancies in coding between the observers were resolved through a discussion, until consensus was reached.

Results

In order to address the interdependent nature of the dyadic data collected in this study and to avoid violating the assumption of scores independence underlying many statistical tests, the data analysis adopted a two-step approach. In the first step, the dyad was treated as a single unit of analysis and the scores of both children were averaged within a pair to obtain a single measure of within-dyad behaviour. This approach allowed running an independent-samples t-test to confirm that there were no differences in the dyads' play between two experimental groups prior to the video exposure. In the second step, hierarchical linear modelling (HLM) was used to analyse dyadic data. Specifically, at Level 1 of the model, individual child variables (pre-video score and age) were nested in dyads (Level 2) to predict the post-video behaviour.

The pre- and post-video scores were calculated for each dyad. For the fast-paced group, the mean number of toy episodes (standard deviation) in the pre-video play session was 4.65 (1.56) and in the post-video play session was 5.09 (2.11). For the slow paced group, the mean number of toy episodes during pre-video play session was 4.39 (2.10) and 3.72 (1.70) during the post-video play session.

The results of an independent samples t-test showed that during the pre-video play session, there was no difference across experimental groups in the number of toy episodes per dyad, $t(32) = .42$, $p = .680$.

The results of the analysis using HLM framework are shown in Table 2.2. A child's pre-video play behaviour and the pace of video watched were significant predictors of post-video play ($b = 0.496$, $p < .001$ and $b = 1.204$, $p = .039$, respectively).

However, age was not significantly related to the number of toy episodes during the post-video play. Thus, both children's baseline behaviour and the type of experimental video had a significant effect on children's attention during post-video play.

Table 2. 2. Fixed effects for post-video play measure.

Fixed effect	***b***	***SE_b***	***df***	***p value***	***95% CI***
Age	-0.009	0.05	67.617	p= 0.841	- 0.103 - 0.084
Pre-video score	0.496	0.13	59.002	p< 0.001	0.246 - 0.747
Video pace	1.204	0.65	37.112	p= 0.039	0.062 - 2.235

Discussion

The aim of this study was to investigate whether the pace of editing affected how pairs of children behaved during unstructured play. Prior to watching the video, the dyads' behaviour was similar across both experimental groups (no significant difference was found in the number of toy episodes during play). Importantly, editing pace affected subsequent play behaviour. Children who watched the fast-paced version of the video shifted their attention between toys more frequently compared to the children who watched the slow-paced version.

Unstructured play provides an opportunity to observe children's natural ability to focus attention and resist distractors during cognitive activity (Ruff & Capozzoli, 2003). Previous studies have demonstrated that children with ADHD engage less in structured activities, and switch toys more often during free-play (Alessandri, 1992; Handen et al., 1998; Roberts, 1990; Roberts, Ray, et al., 1984). In this study, the videos presented to the children between the play sessions had the same content; thus, the observed effects can be attributed to the pace of the experimental videos. This manipulation appeared to have altered children's natural play behaviour, which had been established prior to watching the videos. In comparison to children who watched the slow-paced video, the fast-paced group played with more toys following the viewing of a video that contained a set of rapid edits. Consistent with the findings that more unsettled behaviour during free-play could indicate problems with sustained attention, greater impulsivity and less behavioural control (Alessandri, 1992), it appears that even a very brief exposure to the fast-paced material had adverse effects on children's behaviour.

Our finding that viewing a fast-paced video resulted in greater shifting of attention between toys is congruent with previous studies, which show an immediate detrimental effect of fast pacing on various aspects of cognitive activity (Geist & Gibson, 2000; Lillard et al., 2015; Lillard & Peterson, 2011; Wright et al., 1984). Moreover, these results fit with theories proposing that the audio-visual characteristics of television affect cognition, especially in young viewers (Anderson et al., 2001; Wright & Huston, 1983). Although how these audio-visual characteristics interact with programme content is currently unknown. This is particularly important, as a recent hypothesis proposed by Lillard et al. (2015) suggests that processing of unrealistic content may be particularly taxing for children's cognitive resources. The story presented in our experimental films contains many elements of fantasy (e.g., talking animals). Thus, it could be an interaction between unrealistic content and the fast pace that drove changes in post-video behaviour.

Choi and Anderson (1991) suggested that attention during television viewing and toy play is driven by the same mechanism – attentional inertia – the process that pieces together segments of cognitive activity. It is thus possible that differential pacing affects attentional inertia in two ways: slow pace facilitates orientation to the object of cognitive activity, and leads to deeper engagement during toy play. In contrast, rapid edits, that are inherent to fast-paced programmes, may disrupt attentional inertia, and stimulate the need for novelty and change. This study provides supporting evidence for the negative effects of the fast-paced video. Although the effects demonstrated in this experiment are small, it is important to remember that this research investigated immediate effects of pacing. It is possible that repeated exposure to fast-paced editing over time may have accumulative effects - and consequently - greater negative impact on children's behaviour.

A strength of this study is in the use of Cooper and colleagues' (2009) methodology that allowed the pace to be manipulated while keeping the content constant. However, the use of novel stimuli is also a limiting factor. Professionally produced children's programmes contain a variety of audio-visual characteristics including unrelated shifts, cuts, active motion, auditory changes, active music and talking (McCollum & Bryant, 2003). In contrast, our experimental video employed only two visual features: different camera angles and cuts, and the same audio track played continuously. To counteract the paucity of editing techniques used during the materials production, the number of cuts in the fast-paced video was higher than in much preschool programming. This may have, unintentionally, rendered the video less comprehensible for young viewers. However, children may often be exposed to film with even faster editing pace, such as pop music videos (see Table 2.1.). Moreover, the experimental materials did not allow the examination of the impact of the combination of various editing techniques used in real-life television on children's behaviour. In future, it is therefore important to also explore the effect of other salient features that characterise entertainment programming (such as active motion or frequent scene and character changes) on cognitive activity.

In conclusion, the present study demonstrated that exposure to a short video can have a differential effect on children's play depending on the editing speed used. Specifically, it was found that in comparison to watching slow-paced material, exposure to a fast-paced video resulted in more unsettled behaviour during free play. Considering that play is viewed as such a crucial activity in infancy and early childhood, and that more frequent shifts between toys may indicate deficits in attention and lack of behavioural control (e.g., Alessandri, 1992; Handen et al., 1998), these findings are important. They suggest that even a *very simple* manipulation of editing features can have differential effect on children's play behaviour. Further research is needed to explore how the actual audio-visual features of real-life TV and film interact with each other and affect different aspects of cognition.

Chapter Three: The effects of video editing pace on neural markers of children's inhibition during sustained attention.

Abstract

Despite 40 years of research into the effects of visual media on children's attention and cognition, no research to date has investigated the neural mechanisms behind them. The aim of the current study was to investigate the immediate consequences of watching differently paced videos on cortical activity during a go/no-go task. Event-related potentials (ERPs) were used to examine the neural processes underlying inhibition during no-go trials. Forty 7-year-old children watched either a fast- or a slow-paced video, designed specifically for this study, followed immediately by the Sustained Attention to Response Task. Watching a fast-paced video led to a temporary increase in the number of erroneous no-go responses. Comparison of peak latencies for two ERP components associated with inhibition (N2 and P3) showed an interaction between video pace and response accuracy. For children in the slow-paced group, the timing of N2 and P3 followed the typical pattern: both components peaked earlier when a response was correctly withheld than when it was not. This typical pattern of activation was absent in the fast-paced group. Together, these findings suggest that the pace of video editing affects both overt behaviour and the neural processes involved in inhibition. Thus, this is the first study to demonstrate that watching visual media affects the neural mechanisms associated with children's cognitive performance.

Introduction

Sustained attention, which rapidly develops in early to middle childhood (Betts, Mckay, Maruff, & Anderson, 2006; Greenberg & Waldmant, 1993; Lin, Hsiao, & Chen, 1999), comprises the ability to focus on a particular goal or task and resist interference from distractors over extended time (Coull, 1998; Sarter, Givens, & Bruno, 2001). It has been associated with children's cognitive performance (Aylward, Gordon, & Verhulst, 1997; Choudhury & Gorman, 2000; Lawson & Ruff, 2004), in particular, with the development of the inhibitory component of executive function (Loher & Roebers, 2013; Reck & Hund, 2011). Inhibition helps 'resist' exogenous inputs during sustained attention (Diamond, 2013). Moreover, lower levels of sustained attention have been linked to poor emotion regulation (Gaertner, Spinrad, & Eisenberg, 2008; Graziano, Calkins, & Keane, 2011) and, in more severe cases, have been proposed to underpin the development of attention deficit hyperactivity disorder (ADHD; Barkley, 1997); although see Huang-Pollock and Nigg (2003) .

Despite the rapid rise in the use of touchscreen devices, such as smartphones and tablets (Ofcom, 2016), traditional television viewing remains the most popular screen based activity in early childhood (Kostyrka-Allchorne, Cooper, & Simpson, 2017; Lauricella, Wartella, & Rideout, 2015). This is important, as correlational literature has delivered evidence that the amount of both foreground and background television exposure is associated with poor everyday attention function in childhood and adolescence (Cheng et al., 2010; Christakis et al., 2004; Landhuis et al., 2007; Martin et al., 2012). However, the explanatory value of this research is somewhat limited by the lack of evidence showing a causal path leading from television exposure to attention dysfunction (Barr & Linebarger, 2010), coupled with a limited consideration of the variability in the content of children’s programming (Kostyrka-Allchorne, Cooper, & Simpson, 2017).

Correlational studies have examined the associations between the amount of television and attention. In contrast, experimental research has mainly focused on a particular visual feature of programming, namely editing pace, and in addition to attentional processes, examined executive function (Anderson et al., 1977; Cooper et al., 2009; Geist & Gibson, 2000; Kostyrka- Allchorne, Cooper, Gossmann, Barber, & Simpson, 2017; Lillard et al., 2015; Lillard & Peterson, 2011). Much of children’s television is rapidly edited (McCollum & Bryant, 2003) and the main concern of this literature is that frequent changes on the screen engage children’s attention in a bottom-up perceptual fashion by eliciting orienting responses to frequent changes on the screen. In the long-term this may lead to a habitual cursory style of processing which is reliant on exogenous inputs (Singer, 1980).

Studies (i.e., Anderson et al., 1977; Geist & Gibson, 2000; Kostyrka-Allchorne, Cooper, Gossmann, et al., 2017) investigating the effects of editing pace on children’s behaviour during unstructured play, as a measure of sustained attention, have utilised both commercial television programmes (which varied in *content* as well as pace) and experimental videos (which controlled content but manipulated pace). Although an early study by Anderson et al. (1977) did not provide the support for the hypothesis that fast editing pace is detrimental to children’s attention, two more recent studies suggested that children who had watched a fast-paced programme subsequently struggled to engage in one activity for a longer period (Geist & Gibson, 2000; Kostyrka- Allchorne, Cooper, Gossmann, et al., 2017), perhaps due to weaker sustained attention.

Similarly, the results of investigations that employed formal laboratory measures of attention, and more recently executive function, suggest that editing pace has consequences for children's subsequent behaviour. Lillard and Peterson (2011) demonstrated that, compared to the control children who were drawing, a group who watched a fast-paced cartoon performed significantly worse in a post-viewing assessment of executive function. However, other findings imply that content of the programme may be more important. Lillard et al. (2015) hypothesised that it was the presence of unrealistic content (i.e., the presence of fictional characters with inhumane powers or physically improbable events) rather than the fast pace that temporarily diminished children's executive function. Using several television programmes with different pacing and amounts of unrealistic content, these authors found evidence for the detrimental effects of unrealistic content but not the fast pace. However, as both of these studies (i.e., Lillard & Peterson, 2011, Lillard et al., 2015) used commercially available television shows, which prevented strict control over other programme features, caution must be applied interpreting these findings.

In contrast to the detrimental effects of watching fast-paced programming reported in the literature (e.g., Geist & Gibson, 2000; Kostyrka- Allchorne, Cooper, Gossmann, et al., 2017; Lillard & Peterson, 2011), the findings of Cooper et al. (2009) showed some positive effects of watching a rapidly edited programme. These authors investigated whether exposure to a brief experimental video affected children's attention performance on the Attention Networks Test (Fan et al., 2002). The responses of the children who watched a fast-paced video were *more* accurate than the responses of the children who watched the slow-paced version.

In sum, the past literature suggests that children's attention and executive function are vulnerable to the effects of differential editing pace. However, the conflicting findings between studies mean that the exact nature of these effects is unclear. Thus, despite some positive effects of watching fast-paced videos demonstrated by Cooper et al. (2009), there remains a concern that exposure to fast-paced material might lead to subsequent attention and executive function problems (e.g., Christakis et al., 2004; Lillard & Peterson, 2011).

The first goal of the present study was to examine the effects of editing pace on children's performance on a well-established laboratory task. Specifically, we measured children's responding on the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). The SART is a brief but monotonous go/no-go task, which requires participants to remain vigilant to avoid responding to rare (11% of trials) no-go target stimuli (Smilek, Carriere, & Cheyne, 2010). During the SART pressing a 'go' key becomes a habitual response associated with stimulus presentation making it *prepotent* (i.e., automatically activated by stimulus onset irrespective of the participant's intentions - Simpson & Riggs, 2007). The high frequency of go trials on the SART creates strong inhibitory demands and successful no-go performance requires *both* sustained attention to avoid missing a rare target (Manly, Robertson, Galloway, & Hawkins, 1999) and *inhibition* to suppress the prepotent go response (Nigg, 2000). Thus, in addition to remaining attentive, withholding a press to the target digit "3" requires the engagement of top-down executive processes, and their effectiveness is manifested in the error rate on no-go trials (Manly, Davison, Heutink, Galloway, & Robertson, 2000).

Singer (1980) proposed that frequent on-screen changes, which characterise fast-paced video, might strengthen exogenously-driven, 'mindless' processing. We suggest they may also weaken the application of inhibition as a component of endogenously-driven executive function. Thus, we hypothesised that watching the slow- and the fast-paced videos would differentially affect go and no-go performance on the SART. Specifically, compared with the slow-paced group, the performance of children in the fast-paced group would be characterised by shorter response times on the exogenously-driven go trials and a greater number of endogenously-driven no-go errors.

The second goal of this study was to investigate whether editing pace would modulate the neural activity involved in inhibition, when performing the rare no-go trials of the SART. Bearing in mind the longevity of research into the effects of visual media on children's cognition, it is surprising that no research has previously investigated the neural mechanisms that underpin these changes. Event-related potentials (ERPs) allow examination of changes in electrical activity in the brain that underpin cognition and behaviour with exquisite timing (Kappenman & Luck, 2012). The two ERP components proposed to reflect processes involved in inhibition in adults (e.g., O'Connell et al., 2009; Sehlmeyer et al., 2010; Zordan, Sarlo, & Stablum, 2008) and in children (e.g., Cragg, Fox, Nation, Reid, & Anderson, 2009; Johnstone et al., 2007) are the N2 and the P3. The ERPs are time-locked to the stimulus onset (Hoyniak, 2017) and thanks to the excellent temporal resolution allow the detailed examination of the processes involved in inhibition (Chevalier, Kelsey, Wiebe, & Espy, 2014).

In previous studies which utilised go/no-go tasks, the N2 maximum peak to no-go trials is usually recorded in frontal (in children; Johnstone et al., 2007) and central brain locations (in adults; Dockree, Kelly, Robertson, Reilly, & Foxe, 2005; Falkenstein, Hoormann, & Hohnsbein, 1999; Zordan et al., 2008) occurring at a latency of 200-450 ms after stimulus onset. The P3 in no-go trials is typically found in frontal (Zordan et al., 2008) or fronto-central locations (Falkenstein et al., 1999;

Jonkman, 2006) occurring at a latency of 300-500 ms following the onset of the stimulus.

Moreover, the latency of the N2 and P3 appears crucial for inhibition. First evidence that successful inhibition requires an *earlier* N2 component activation was provided by Falkenstein et al. (1999), who demonstrated that no-go N2 began 30 ms earlier for participants who made fewer errors on no-go trials compared with those whose performance was characterized by a high no-go error rate. Further, Garavan, Ross, Murphy, Roche, and Stein (2002) observed that, relative to errors, correct responses on go/no-go task were characterised by shorter P3 latencies. This finding led the authors to develop a hypothesis proposing that *successful* inhibition was characterized by a specific timing of ERP components activation.

Further support for this proposal was provided by Roche, Garavan, Foxe, and O'Mara (2005), who showed that the N2 and P3 occurred earlier on correct no-go trials compared to erroneous no-go responses. Thus, withholding a response requires N2 and P3 to occur in a set order during a limited time window; the lack of a timely component activation results in an erroneous response (Zordan et al., 2008). Although this hypothesis was developed in relation to studies with adult participants, the results of a recent meta-analysis of childhood N2 component are consistent with this proposal. After controlling for age, shorter no-go N2 latencies were associated with significantly higher accuracy on no-go trials (Hoyniak, 2017).

Considering this literature, the present study aimed to examine whether cortical mechanisms that underpin inhibition would be affected by video editing pace. This study aimed to explore whether children in the fast-paced group would differ from the slow-paced group regarding the strength and the timing of the N2 and P3 component activation on no-go trials. It was expected that for children in the fast-paced group neural activity associated with inhibition would be atypical.

Method

Participants.

Forty (girls, n=25) 7-year-old children (M=84.6 months, SD=4.7) took part in the study. Four further participants had completed the study but were later excluded due to technical problems. Participants were recruited via opportunity sampling at two primary schools located in a semi-rural county of England, UK. The University's Ethics Committee approved the experiment. Before the study began, the children's parents received a letter explaining the experimental procedure and signed individual consent. Children were alternately assigned to one of the two experimental conditions.

Apparatus and Materials.

The experimental videos were presented on a 13-inch Apple laptop computer running QuickTime video player. Audio playback was delivered via Sony speakers. A Dell Optiplex 745 personal computer with a 17" ACER AC713 monitor was used to present the SART.

Experimental videos.

A popular children's story called 'Winnie at the Seaside' (Paul & Thomas, 2005) was used to produce the experimental videos. In the selected story, Winnie the Witch and her cat Wilbur spend a day at the seaside. A female narrator reading a storybook was filmed from three different cameras: narrator front view, narrator side view and hand-held. This footage was edited together with the still images from the book to produce a slow- and a fast-paced video; the material recorded with the hand-held camera was used only in the fast-paced version of the video. An edit was defined as a change from the narrator view to a still book image or change between the two different narrator views (e.g., from a front view to a side view). Each experimental video lasted 3 minutes 51 seconds and was produced from identical raw recordings. The slow-paced video included five still images and had on average 3.7 edits per minute. The fast-paced video contained 14 still images and had on average 12.3 edits per minute.

SART stimuli and procedure.

The stimuli were 225 single digits from 1 to 9 presented in 25 blocks of nine in a random sequence. The digits were white and appeared in the centre of the black background. Each digit was displayed for 300 ms and the length of the inter-trial interval was 1433.33 ms. Participants were required to press a left button on a computer mouse each time a digit appeared on the screen (go trials) except for the target “3”, which required withholding the response (no-go trials).

EEG data acquisition and preparation.

Children were fitted with an electrode cap and the EEG was recorded from six electrodes (FPz, Fz, Cz, Pz, FCz and CPz) arranged according to the International 10-20-system (Jasper, 1958). These six midline electrodes, as well as the individual component time windows specified below, were selected based on the analyses of Zordan et al. (2008), who were the first group of researchers to investigate the ERPs recorded in adults during a random version of the SART.

The recording was acquired with a NeuroScan Synamps2 headbox, a NeuroScan STIM Audio System P/N 105 amplifier, and a Dell Optiplex 755 personal computer running NeuroScan 4.5 software. Data were recorded at a sampling rate of 500Hz, a band-pass filter at 0.15-100Hz and a notch filter at 50Hz. Impedances were set below 10kΩ prior to recording.

For ERP analysis data were average referenced and filtered with a bandpass zero-shift, 12 dB filter between 2Hz and 30Hz and segmented into epochs from -100 ms before to 650 ms after stimulus onset and baseline corrected to -100 ms before stimulus onset. Automated artefact rejection transformation was carried out excluding epochs containing data above or below +/- 75 mV respectively. Data were then averaged across epochs to separately calculate ERPs for correct and wrong responses on no-go trials. For the N2 component, mean amplitude was measured in the 220-350 ms time window post stimulus onset and automatic peak detection was carried out to find the most negative score at Fz electrode. For the P3 component, mean amplitude was measured in the 300-500 ms time window post stimulus onset and automatic peak detection was carried out to find the most positive score at Cz electrode. Further manual adjustment of peaks was not carried out.

The mean number of no-go trials after artefact rejection for the slow- and the fast-paced group was 24.4 and 23.9, respectively (an average loss of 2.4% and 4.4% trials, respectively).

Procedure.

Children were tested individually in a quiet room that was separate from the main classroom area. At the beginning of the session, the experimenter briefly explained the plan for the testing to participants and invited them to take a seat at the table in front of the computer. Children were fitted with an electrode cap and prepared for EEG data acquisition. They were also encouraged to remain still and relaxed. Considering the lengthy time required for electrode cap preparation and exploratory nature of this study, the pre-test of children’s attention was not included in this experiment.

Following the set-up, children watched either a slow- or a fast-paced experimental video. Immediately after they finished watching the video, the experimenter explained the rules of the SART, and following a short practice, which comprised of 27 trials (three of which were the target “3”), children completed the SART. The children completed the whole SART in about 4.5 min; thus, each half took just over 2 min to complete. Upon finishing the test session, each child received a small reward and a certificate for taking part.

Results

Behavioural data analysis.

Consistent with the previous literature (e.g., Marchetti, Koster, & De Raedt, 2012; Seli, Cheyne, & Smilek, 2012) the behavioural SART data were analysed in two blocks; the first block consisted of 113 trials, the second – 112 trials (approximately 50% of trials in each block). The data were analysed with mixed analyses of variance (ANOVAs). The between-participant variable was pace (fast, slow). The within-participant variable was time (1^{st} half of SART, 2^{nd} half of SART). The dependent variables were three indices of performance: proportion of responses on no-go trials (commission errors), correct trial response time (RT) and correct trial RT variability, computed for each participant using reaction time standard deviation. In this task, erroneous responses on the rare no-go trials, particularly, if accompanied with fast correct trials response times, represent ‘mindless’ stimulus-driven responding and a lack of top-down attentional control (Manly et al., 1999; Robertson et al., 1997). Response times variability reflects inconsistency in the speed of responding and has been proposed to stem from a subset of substantially slower responses during a task caused by temporary lapses of attention (Kofler et al., 2013).

Correct responses with RTs of less than 100 ms were treated as random or anticipatory (Conners & Staff, 2000) and, as such, were excluded from the analyses. Participants’ mean SART scores in each experimental group are shown in Table 3.1.

Table 3. 1. Mean (SD) overall and 1^{st} and 2^{nd} SART half scores for the fast- and slow-paced video conditions.

Video Pace	**Variable**	**Overall SART mean score (SD)**	**SART 1st half mean score (SD)**	**SART 2nd half mean score (SD)**
Fast	No-go trial errors (%)	65 (16)	70 (16)	58 (24)
	Correct RT (ms)	462 (90)	440 (97)	487 (96)
	Correct RT variability (ms)	189 (57)	160 (46)	208 (75)
Slow	No-go trial errors (%)	57 (22)	55 (19)	58 (31)
	Correct RT (ms)	457 (82)	444 (85)	454 (94)
	Correct RT variability (ms)	167 (52)	142 (46)	185 (67)

There were no significant main effects of pace on the no-go trials errors (p= .212). However, the analysis showed a significant Pace x Time interaction, $F(1,38) = 4.37$, $p=.043$, $\eta_p^2= .103$ (Figure 3.1.). A follow-up t-test showed that in the first half of the SART the children who watched a fast-paced video made more commission errors on the no-go trials than the children who watched a slow-paced video, $t(38)=2.88$, $p=.007$, 95%CI: 4.62 to 26.54. Thus, watching a fast-paced video resulted in poorer inhibition but only in the first half of the task.

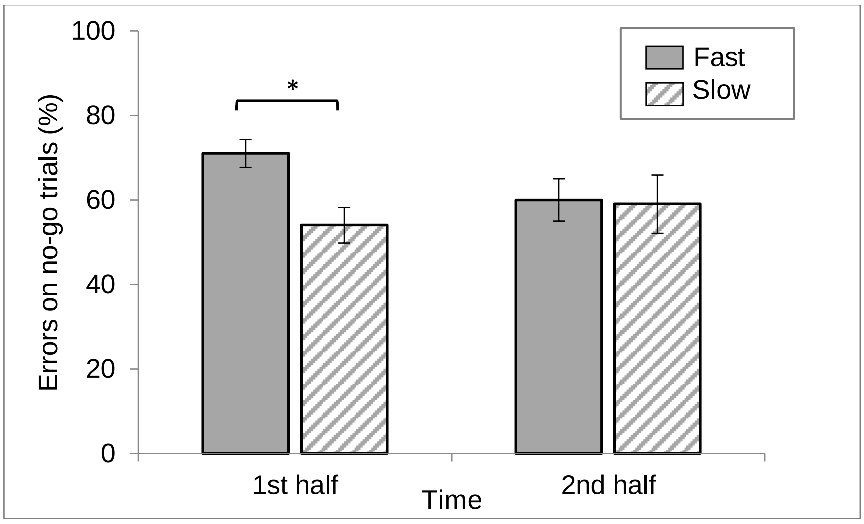

Figure 3. 1. Mean proportion of errors on the no-go trials in the first and the second half of the SART. Error bars represent SEMs (*denotes a significant difference; $p < .05$).

There were no further significant main or interactive effects of pace on the remaining dependent variables. However, time had a significant effect on the two indices of performance. Specifically, correct trials RT and correct trials RT variability showed a significant main effect of time, $F(1,38)= 4.89$, $p=033$, $\eta_p^2= .114$, and $F(1,38)=30.06$, $p<.001$, $\eta_p^2= .442$, respectively. Together, these data show that the children's performance deteriorated as the task progressed, as both correct trials RT and correct trials RT variability increased in the second half.

To compare the reaction times for correct go and wrong no-go responses, an additional mixed ANOVA was performed on the reaction time data. This analysis had trial response (correct, wrong), and time (1st half of SART, 2nd half of SART) as the within-participant variables and pace (fast, slow) as the between-participant variable. The results showed a significant main effect of response, $F(1,38)= 5.98$, $p=.019$, $\eta_p^2= .139$. That is, the reaction times for wrong responses on no-go trials were shorter (M=422 SD=116) than the reaction times for correct responses on go trials (M=460, SD=85). However, there was no significant main effects of pace and time ($p=.331$ and $p=.240$, respectively), nor Response x Pace and Response x Time interactions ($p=.290$ and $p=.214$, respectively).

EEG data analysis.

Mean latencies and amplitudes of N2 and P3 components for no-go trials were analysed in a mixed ANOVA with response (correct, wrong) as the within-participant variable and pace (fast, slow) as the between-participant factor. Due to a concern that analysing ERP data in two blocks would result in too few no-go trials and, potentially, a decreased signal-to-noise ratio (Luck, 2005), the within-participant variable of time was omitted from the N2 and P3 analyses.

N2 peak latency analysis did not show significant main effect of pace ($p=.699$). However, there was a significant Response x Pace interaction, $F(1,38) = 4.88$, $p=.033$, $\eta^2_p =.114$ (Figure 3.2.). A follow-up test revealed that in the slow-paced group, but not the fast-paced group, the N2 peak occurred earlier for correct no-go trials than it did for no-go errors, $t(17) = -2.72$, $p= .015$, 95%CI: -39.1 to -4.9. Figures 3.3. and 3.4. show grand mean N2 waveforms computed for correct and wrong no-go trials in the slow- and fast-paced groups. These data are consistent with the proposal that successful inhibition in go/no-go tasks requires specific timing of N2 activation.

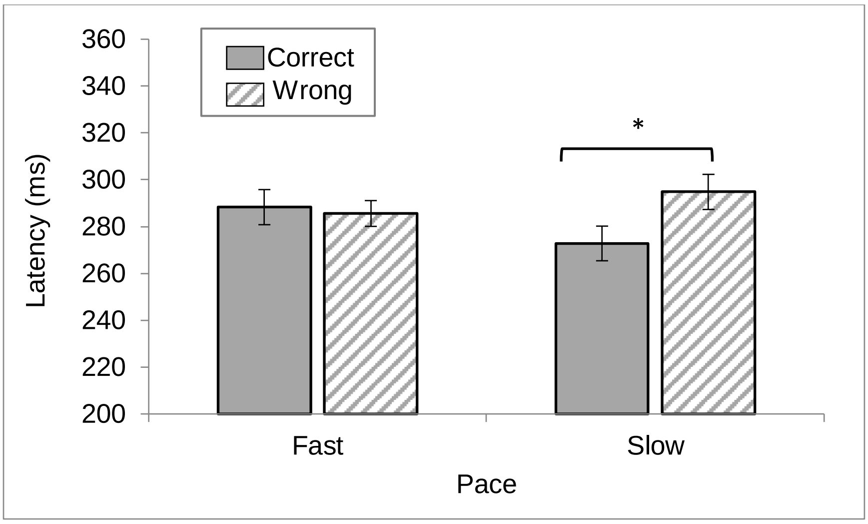

Figure 3. 2. Mean N2 peak latencies for correct and wrong no-go trials in the fast and the slow-paced groups. Error bars represent SEMs (* denotes a significant difference; p < .05).

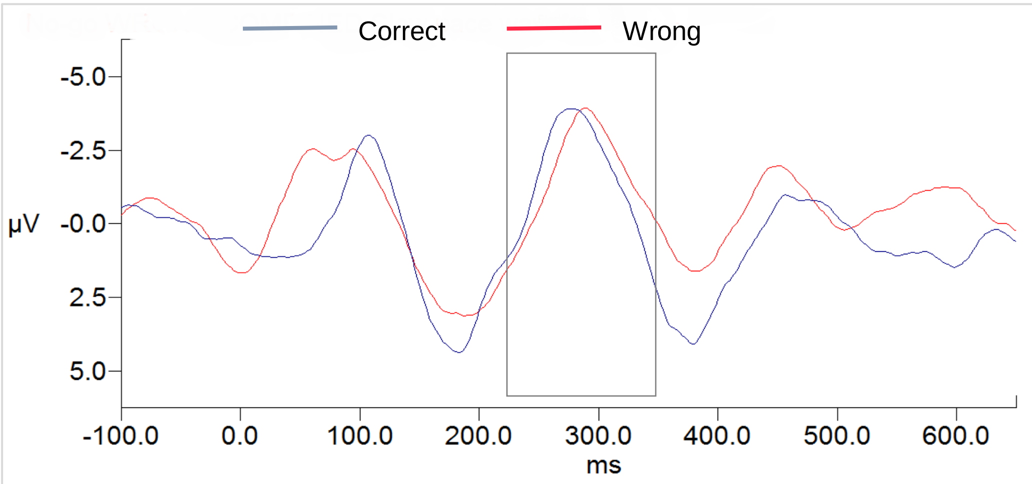

Figure 3. 3. Grand mean N2 (at Fz) waveforms computed for correct and wrong no-go trials in the slow-paced group. The time window of N2 peak is shown in the grey box.

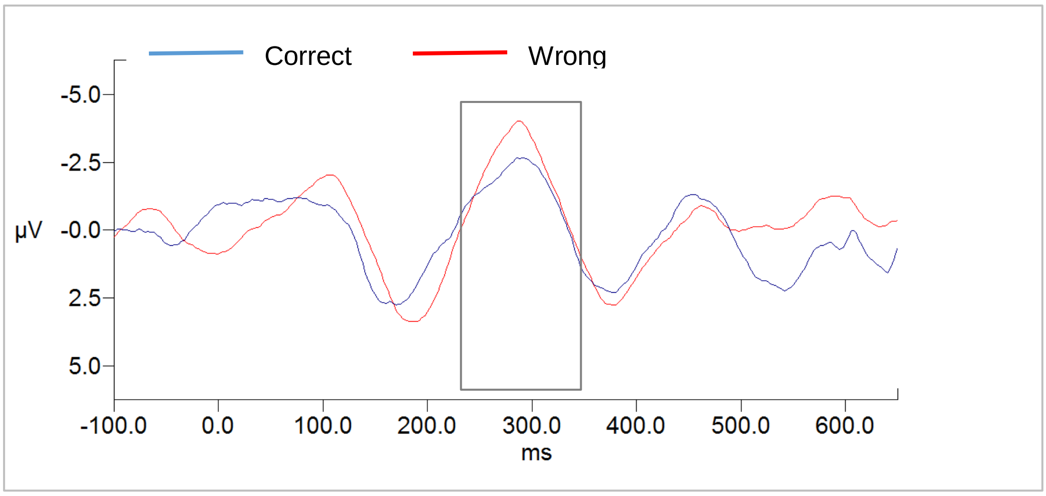

Figure 3. 4. Grand mean N2 (at Fz) waveforms computed for correct and wrong no-go trials in the fast-paced group. The time window of N2 peak is shown in the grey box.

Similarly, there was no significant main effect of pace for P3 component (p= .667) but there was a significant Response x Pace interaction, $F(1,38) = 6.09$, p=.018, η^2_p =.141 (Figure 3.5.). Follow-up t-tests conducted within pace group were not significant. Nevertheless, the significant interaction shows that the correct-wrong difference in P3 latency is reliably more positive in the fast-paced group than in the slow-paced group. In the slow-paced group, the P3 peaks earlier on correct no-go trials than it does during erroneous responses. See Figures 3.6. and 3.7. for the grand mean P3 waveforms computed for correct and wrong no-go trials for the slow-paced group. In contrast, in the fast-paced group the timing of P3 peaks appears to be reversed; the P3 peaks earlier during wrong responses.

The amplitudes analyses did not show any significant main or interactive effects of pace. There was however a main effect of response accuracy for the N2, $F(1,38) = 12.85$, p=.001, η^2_p =.253. The no-go N2 was more negative for wrong responses compared to the correct responses (M=-6.14 mV vs. M=-1.72 mV, respectively).

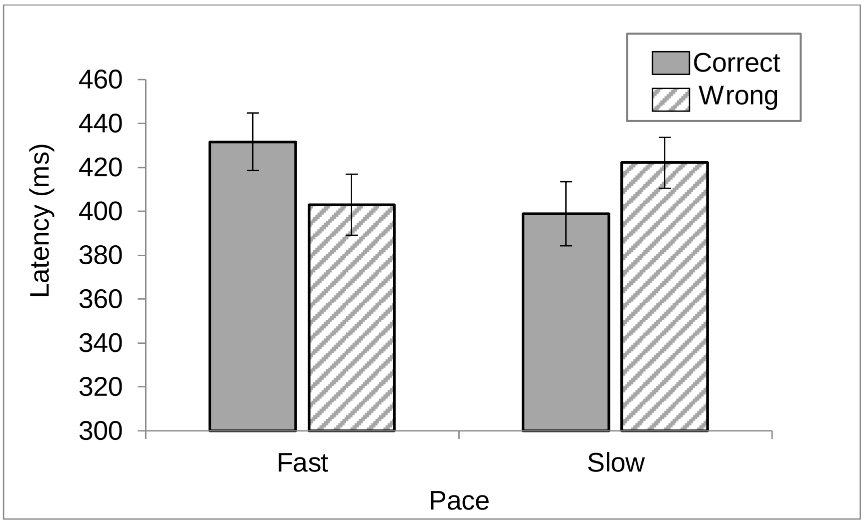

Figure 3. 5. Mean P3 peak (at Cz) latencies for correct and wrong no-go trials in the fast- and the slow-paced groups; error bars represent SEMs.

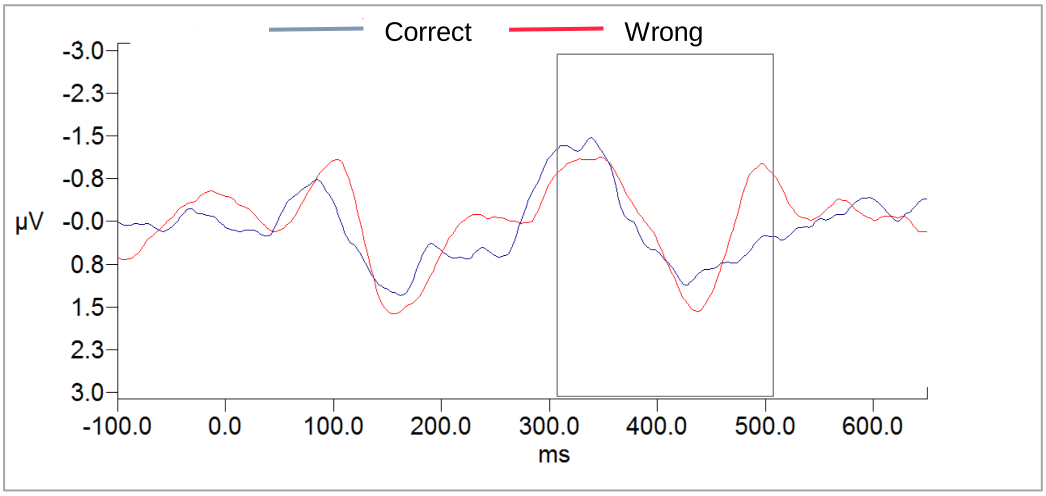

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Figure 3. 6. Grand mean P3 waveforms computed for correct and wrong no-go trials in the slow-paced group. The time window of P3 peak is shown in the grey box.

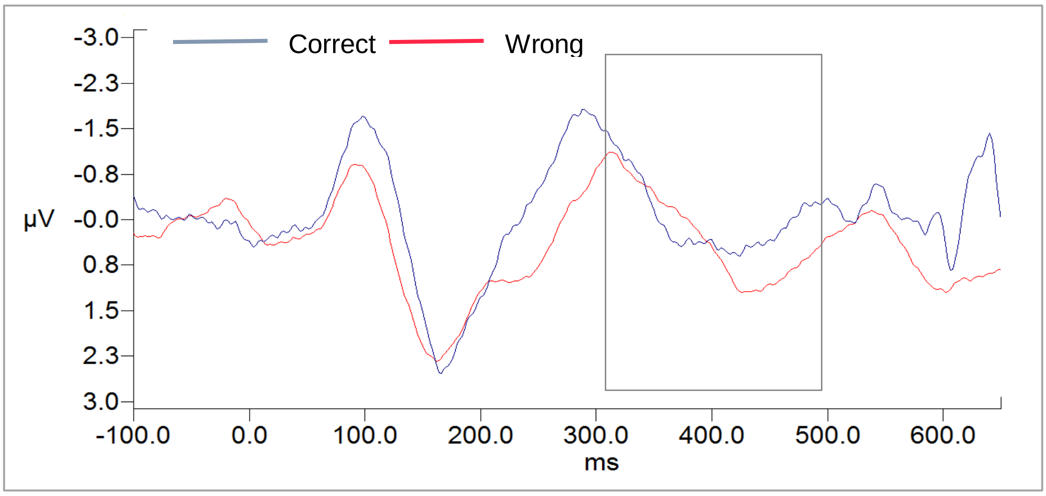

Figure 3. 7. Grand mean P3 waveforms computed for correct and wrong no-go trials in the fast-paced group. The time window of P3 peak is shown in the grey box.

Discussion

This study, which used a short experimental video, had two aims. First, we examined the effect of video editing pace on children's subsequent performance on the SART, which had high inhibitory demands on rare no-go trials. The second goal was to investigate whether editing pace modulated the neural activity involved in inhibition on no-go trials.

The behavioural data supported our prediction about the negative impact of the fast pace for performance on this task. The children who watched the fast-paced video made more errors on the no-go trials than those watching the slow-paced version. Moreover, the use of psychophysiological measures allowed us to demonstrate that editing pace had consequences for the neural processes that underpin inhibition in the no-go trials of the SART: specifically in the timing of the N2 and P3 activation. For the slow-paced group, the timing of these ERP components varied between correct and wrong no-go trials in a typical way (Roche et al., 2005). That is, the N2 and P3 peaked *earlier* when the children correctly withheld a motor response on no-go trials compared to the trials when they made an erroneous press. Conversely, for the children in the fast-paced group, the timing of activation of these cortical processes was atypical, as it did not differ between the correct and wrong no-go trials. Thus, to our knowledge, this is the first study to demonstrate the evidence that watching fast-paced videos has consequences for the neural processes underlying inhibition.

The no-go error data recorded in the present study suggest that immediately following exposure to the video, executive processing of children in the fast-paced group was less efficient. Their performance on the SART was characterized by a higher error rate compared to the children who watched a slow-paced video. However, the increased rate of no-go errors was *not* accompanied by the faster reaction times (measured for both error no-go and correct go trials), which could be an indication of an ‘‘absentminded and insensitive approach to the task’’ (Manly et al., 1999, p. 669). The latter is compatible with the notion that *all* children maintained similar levels of sustained attention to the task, regardless of the video pace. Therefore, the higher rate of no-go errors recorded for the fast-paced group could be attributed to compromised inhibition rather than failures of sustained attention. It might be that despite taking the same amount of time to process the task stimuli as the children in the slow-pace group, these children were unable to stop the execution of the inappropriate prepotent response.

Weaknesses in inhibition may diminish compliance with rules, plans and intentions, and, ultimately, may decrease goal-directed persistence (Barkley, 1997). Thus our interpretation is consistent with the results of previous experimental studies, which showed that following exposure to the fast-paced programme, children’s behaviour was more unsettled and less goal-directed (Geist & Gibson, 2000; Kostyrka‐Allchorne, Cooper, Gossmann, et al., 2017). Moreover, deficits in inhibition are one of the essential impairments in ADHD (Barkley, 1997). Therefore, our data suggest that associations between watching television and the development of attention problems reported in the correlational literature (Cheng et al., 2010; Christakis et al., 2004; Landhuis et al., 2007; Özmert et al., 2002) might be explained in part by repeated exposure to rapidly paced programming.

Although these no-go error data support our suggestion that exposure to fast-paced video may weaken inhibition, the effects observed in the present study were short-lived. In the second half of the SART, the rate of no-go errors in the fast-pace group decreased and did not differ from that of the slow-pace group. This transient character of the detrimental effects of the fast pace may be a result of a very brief exposure to the experimental video (less than 4 minutes) or because the children in the present study were older (7-year-old) than children who participated in the previous experimental studies, and thus, perhaps were less sensitive to the effects of the video pace. Therefore, whether the effects of the editing pace are moderated by the viewers' age and the duration of exposure remain open questions. Moreover, it is essential to establish whether repeated exposure to fast-paced programming leads to persistent deficits in inhibition.

Turning to the ERP findings, the data show that after watching a slow-paced video, incorrect presses on no-go trials differed from correct behaviour in the latency of their N2 and P3 components. Specifically, the peaks of the N2 and P3 were earlier for the correct compared with wrong responses (about 22 ms and 23 ms, respectively). Considering our behavioural data, which suggested that watching a fast-paced video resulted in weaker inhibition, these ERP findings are consistent with the literature showing that the N2 and P3 components play an active role in inhibitory processes (Davis, Bruce, Snyder, & Nelson, 2003; Duan et al., 2009; Falkenstein et al., 1999). Moreover, the differences in N2 and P3 component latencies support the proposal made in the adult (Garavan et al., 2002; Roche et al., 2005) and developmental literature (Cragg et al., 2009) that successful inhibitory processes are dependent on the specific timing of component activation.

Latency data suggest that the timing of the N2 and P3 components is dependent on the editing pace. Specifically, in the slow-paced group, no-go trials N2 and P3 peaked in a typical time pattern (i.e., correct-early, wrong-late), whereas for the children in fast-paced group, this activation of the cortical processes did not follow this typical latency pattern. This is consistent with the prediction about atypical cortical activity associated with inhibition in the fast-paced group put forward in the introduction. Given that this is the first study and the lack of an a priori hypothesis regarding these components, further work is necessary to establish the reproducibility of the specific atypical latency pattern and to allow clear interpretation of these findings.

Further examination of the latency data shows that, irrespective of the video pace, the N2 peak occurred over 100 ms before children made an erroneous press on no-go trials. This supports the suggestions that the N2 may be an index of active inhibitory processes operating at a pre-motor level (Falkenstein et al., 1999). In comparison, the P3 peaked relatively late in relation to the stimulus onset, around the time of the erroneous motor response execution. It is, therefore, unlikely that the timing of the *peak* of this component underpins successful motor inhibition. Instead, as suggested by Kok, Ramautar, De Ruiter, Band, and Ridderinkhof (2004) it might be the P3 *onset* that affects inhibition. Alternatively, P3 may be involved in task monitoring processes (Boucher et al., 2012). Specifically, this component may play an active part in post-response performance monitoring, such as, processing of errors and preparation for the next trial (Roche et al., 2005). Finally, the finding of larger N2 amplitude in unsuccessful no-go trials is consistent with the data reported in the adult (Kok et al., 2004) and developmental literature (Lo et al., 2013). However, due to the alternative explanations present in the literature – larger negativity on failed no-go trials has been interpreted in terms of inhibition (van Boxtel, van der Molen, Jennings, & Brunia, 2001) and error monitoring (Kok et al., 2004) – these findings are somewhat difficult to interpret. Perhaps, as Kok et al. suggested, the difference in N2 amplitudes points to the presence of distinct processes that underpin correct and wrong no-go trials.

The findings from this study provide further evidence for the short-term detrimental effects of watching fast-paced videos on children's behaviour, and also show the first evidence that video pace affects cortical mechanisms that underpin inhibition. Nevertheless, there are two limitations of our study to consider. Firstly, due to the design of the SART, no-go trials are rare. Therefore, ERPs for these trials will have been noisier than for other conditions. Thus, the significant ERP effects in amplitude and timing between correct and wrong no-go trials must be interpreted in this light. Secondly, the use of short, novel experimental videos may have reduced the ecological validity of this experiment. However, it did allow us to maintain strict experimental control over content and other programme features, which is not possible when using commercially available children's TV shows (Kostyrka-Allchorne et al., 2017). Considering the pervasiveness of screen use among young children, it is, therefore, necessary to continue this line of investigation using tasks, which contain a greater number of no-go trials. It may also be useful to investigate electrophysiological correlates of inhibition in children who are habitually exposed to high levels of fast-paced programming.

In conclusion, using specially designed experimental videos, which varied the pace of editing, whilst controlling for the content and other production features, this study showed that children’s behaviour was affected by the editing pace. Following the viewing of the fast-paced video, children made more erroneous responses on no-go trials. These effects were short-lived and the children’s behaviour matched the performance of the group exposed to the slow-paced video before the end of the task. Furthermore, this is the first study to provide evidence that video exposure has consequences for the neural mechanisms that underpin inhibition. Specifically, the no-go peak latencies of the N2 and P3 components were affected by the editing pace. Only for the slow-paced group, N2 and P3 occurred in the typical timing pattern, that is, these components peaked earlier on the correct than on the wrong no-go trials. Together, these findings demonstrate that the pace of video editing affects both internal and overt inhibitory processes.

Chapter Four: Disentangling the effects of video pace and content on children's attention and inhibitory control

Abstract

This study examined the influence of video pace (slow vs. fast) and content (realistic vs. unrealistic) on 4- and 5-year old children's attention and inhibitory control. Using children's television programming, Experiment 3 (n=74) showed that watching a slow-paced story-like video improved the immediate inhibitory control of 4-year-olds. Experiment 4 (n=187) used novel videos, which allowed controlled manipulation of pace and content. Irrespective of the pace, watching the videos with unrealistic content improved children's inhibitory control. Further, exposure to the fast-paced video resulted in faster responding, but only when content was realistic. These results suggest that a video's content, rather than its pace, affects children's inhibitory control. Moreover, certain content can provide a buffer against the negative effects of fast pace.

Introduction

Effective attention is critical to cognitive development. Although typical and atypical attention development is influenced by genetics (Fan, Wu, Fossella, & Posner, 2001; Friedman et al., 2008; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005), there are also characteristics of a child's environment that are thought to contribute to attentional outcomes later in life (Banerjee, Middleton, & Faraone, 2007; Froehlich et al., 2011; Nigg, Nikolas, & Burt, 2010). Television viewing in childhood is one such important environmental influence on the development of attention (Christakis, 2009; Nikkelen, Valkenburg, et al., 2014).

Two aspects of attention have been studied most widely in the context of television viewing: executive attention and attention problems. Executive attention (or interference control) is needed to select and attend to relevant information in the presence of competing information (e.g., Rueda, Posner, & Rothbart, 2005; Rueda, Rothbart, et al., 2005). This kind of attention, together with response inhibition, which involves the suppression of behaviour in the absence of high attentional demands, is a principal component of inhibitory control (Friedman & Miyake, 2004).

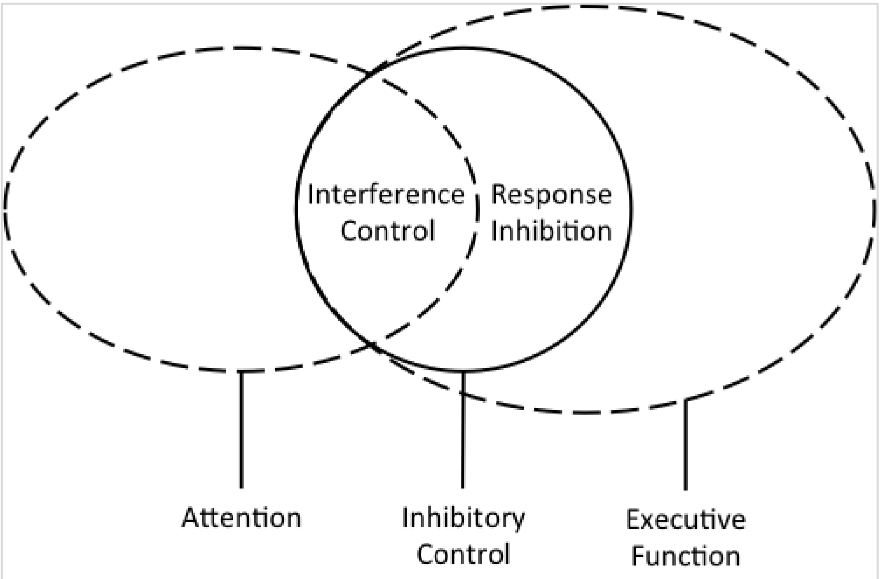

Figure 4. 1. Summary of the relationship between attention, inhibitory control and executive function (based on the analysis of Diamond, 2013).

Along with working memory, inhibitory control underpins the planned behaviour required to achieve goals, and comes under the umbrella term of 'executive function' (Figure 4.1.: see Diamond, 2013, for a review). It has been suggested that deficits in executive function may result in attention problems (challenging behaviours that include hyperactivity, impulsivity and distractibility), and in more extreme cases are associated with the development of attention deficit hyperactivity disorder (ADHD; for a meta-analysis see Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005).

Correlational literature has identified both foreground and background television as risk factors for the development of problems in attention (Cheng et al., 2010; Christakis et al., 2004; Martin et al., 2012; Özmert et al., 2002) and executive function (Barr, Lauricella, Zack, & Calvert, 2010; Nathanson, Aladé, Sharp, Rasmussen, & Christy, 2014). Importantly, these studies have shown a negative association between attention and cognition and both the amount and type (e.g., adult-directed, entertainment) of television watched. This has alerted clinicians and researchers to the potential detrimental effects of television viewing. However, these correlational data are insufficient to explain causal links between television, attention and cognitive dysfunction (Kostyrka-Allchorne et al., 2017).

In contrast, the experimental literature has focused on the effects of programmes' *audio-visual features*, in particular, the pace of video editing (generally operationalized as the frequency of camera editing actions and the rate of scene/character changes; for a discussion see McCollum & Bryant, 2003). The hypothesis that a fast pace is detrimental to children's cognition and behaviour has been tested in several experimental studies (Anderson et al., 1977; Cooper et al., 2009; Geist & Gibson, 2000; Kostyrka- Allchorne, Cooper, Gossmann, et al., 2017; Lillard et al., 2015; Lillard & Peterson, 2011). However, the results are inconclusive.

An early investigation found no evidence that pace affected cognition (Anderson et al., 1977). In contrast, two subsequent studies provided evidence for negative consequences when watching fast-paced programmes (Geist & Gibson, 2000; Lillard & Peterson, 2011). Geist and Gibson (2000) investigated whether viewing a fast-paced entertainment cartoon would lessen the quality of 4- and 5-year-olds' play. Children who watched this programme were more unsettled, evidenced by more shifts between play activities than a control group. More recently, Lillard and Peterson (2011) examined the immediate effects of pace on children's executive function. After watching a fast-paced cartoon, performance on a range of executive tasks was significantly worse compared to a control group.

These findings suggest that pace has negative effects on children's performance. However, these studies did not draw a distinction between pace and content (e.g., a slow-paced educational programme aimed at preschoolers, vs. a fast-paced entertainment programme aimed at older children) and did not account for other differences between the programmes (e.g., slow-paced reality vs. fast-paced cartoons). Finally, researchers did not establish children's baseline behaviour before video exposure. The difference in post-viewing behaviour could have arisen either because the control activities improved performance or because exposure to video worsened it.

Lillard et al. (2015) aimed to address the confound of content and pace. The authors proposed that not only fast pace, but also processing unrealistic content (i.e., events or characters that defy the laws of nature) weakened immediate executive function. To discriminate the effects of content and pace the authors used several television programmes with varied pace and amount of fantasy. The analysis revealed an effect of content, but not pace, and was interpreted as suggesting that exposure to unrealistic content diminished children's executive performance. However, this interpretation overlooked other differences in the content and features of the programmes used in the study (e.g., visual form, learning concepts, narrative structure, humour).

Although it is possible to investigate the effects of pace, while maintaining a strict experimental control over other programme features, such research is rare in the literature. Cooper et al. (2009) examined the effect of pace on 4- to 6-year-old children's attention (rather than executive function) using specially produced experimental videos that were identical in content. In these videos, the same raw footage of a narrator reading a children's story was edited to create a slow- and a fast-paced version. In contrast to other findings (Geist & Gibson, 2000; Lillard & Peterson, 2011), this study showed some benefits of a fast pace. Children who watched a fast-paced video made fewer errors on the Attention Networks Test (Fan et al., 2002) than their peers who watched the slow-paced version. Using the same methodology, Kostyrka- Allchorne, Cooper, Gossmann, et al. (2017) investigated the effects of pace on preschoolers’ unstructured play. During the baseline play session, the children’s behaviour did not differ between the groups. However, post-video, the children in the fast-paced group shifted attention between toys more than the slow-paced control. These findings suggest that watching a fast-paced video unsettled play behaviour and are consistent with the earlier studies (Geist & Gibson, 2000; Lillard & Peterson, 2011). Although the use of novel materials may have reduced the ecological validity of these two studies (Cooper et al., 2009; Kostyrka- Allchorne, Cooper, Gossmann, et al., 2017), the immediate effects of exposure to fast pace on children’s behaviour were evident.

Two theories have been proposed to explain why television may be disruptive to the development of attention (Anderson & Lorch, 1983; Singer, 1980). The key premise of the first proposal is that children are *passive recipients* of television content and their visual attention to the screen is maintained through perceptually salient audio-visual features, for example, fast pace (Singer, 1980). Although intense audio-visual features are very effective in capturing children’s attention, fast pace leaves less scope to reflect on the content viewed (Singer & Singer, 1983), and ultimately may lead to the deficits in attention (Christakis et al., 2004). In contrast to Singer’s (1980) proposition, Anderson and Lorch (1983) proposed that children are *active viewers*, and their visual attention to television depends on the understanding of the content. Thus, the key premise of this theory suggests that viewing is cognitively engaging and the television’s potential to hold attention depends on the viewer’s ability to process and understand what is presented on the screen (Anderson & Hanson, 2010; Anderson & Lorch, 1983; Anderson & Pempek, 2005).

These two proposals are not mutually exclusive. Huston and Wright (1983) suggested that audio-visual features might play an important role in the comprehension of televised material. They are instrumental in conveying narrative meaning (e.g., shifts in time and location). In this way, they make the processing of the content more efficient, which enhances understanding of the events unfolding on the screen. Huston and Wright (1983) suggested that moderate use of audio-visual features is optimal for enhancing this understanding. In contrast, fast pace (which is typical of many entertainment shows) may disrupt the processing of televised content, and ultimately lead to deficits in attention and related functions (Lillard & Peterson, 2011).

These theories were originally developed in relation to attention, but recently have been extended to explain causal links between watching television and executive function (Lillard et al., 2015). Consistent with Singer’s (1980) theory, Lillard and colleagues proposed that watching unrealistic TV, which contained many elements of surprise, elicited increased orienting responses and activated bottom-up processing that persisted in the subsequent cognitive task. Additionally, they suggested that beyond the attention-dependent, initial stage of information processing, comprehension of unrealistic content may require extensive involvement of higher cognitive resources. In consequence, these resources might become depleted for the subsequent cognitive tasks. In the long term, repeated exposure to unrealistic content could lead to impairments in the development of executive function.

The present study

The literature delivers conflicting findings regarding the effects of pace on children’s attention and executive function. Moreover, the recent suggestion that seeing unrealistic events in video impairs children’s executive function (Lillard et al.,

2015) implies that it may be *content* rather than *pace* that affects cognition. However, considering the possibility that other features may have affected Lillard and colleagues' (2015) findings, much uncertainty also remains about the effects of content. Thus, the main aim of the current study was to assess the immediate effects of brief exposure to age-appropriate programming on both the attention and executive function of 4- and 5-year-olds. Specifically, we measured inhibitory control, as it argued to be the core component of executive function in young children (Diamond, 2013) and adults (Miyake & Friedman, 2012). Moreover, these specific ages were chosen to match the age of participants in previous studies (e.g., Anderson et al., 1977; Cooper et al., 2009; Geist & Gibson, 2000; Lillard & Peterson, 2011). Experiment 3 investigated pace with samples taken from British terrestrial children's television. Experiment 4 went on to examine both pace and content in a factorial design using specially produced videos matched for other audio-visual features.

We proposed three non-exclusive hypotheses that could reconcile the inconsistencies from the previous literature. The first hypothesis focused on the effects of pace, and proposed that, consistent with the passive theory of attention to television (Singer, 1980), fast pace elicits an orienting response, increases children's alertness and preparedness for quick responding. Thus, it was expected that children who watched a fast-paced video would respond more quickly and make fewer omission errors in a demanding attention task (in which small stimuli appeared *briefly* on a screen). In contrast, watching a slow-paced video would result in better attentional and inhibitory control. Thus, our second hypothesis predicted that children who watched a slow-paced video would make fewer commission errors and perform better on an inhibitory task. The final hypothesis focused on the effects of content and proposed that, consistent with the suggestions made by Lillard and colleagues (2015), exposure to unrealistic content would temporarily reduce children's executive function. Thus, it was expected that children exposed to unrealistic content would perform worse on the inhibitory task.

Experiment 3

Experiment 3 used two tasks: children's inhibitory control was tested with the day-night task (Gerstadt, Hong, & Diamond, 1994); and their attention was measured with a Continuous Performance Test (CPT) based on the Test of the Variables of Attention (TOVA®; Greenberg & Waldman, 1993). To account for individual variations in cognitive function, and to establish baseline performance, the day-night task was administered in a pre-video assessment. We chose this task as it has high inhibitory demands and offers a relatively pure measure of response inhibition (Simpson & Riggs, 2005; Simpson et al., 2012). The Venn diagram on p. 161 represents this task as a relative complement of Attention in Inhibitory Control - a subset termed Response Inhibition.

The CPT required children to maintain attention to stimuli presented on a computer screen in competing spatial orientations (i.e., target – up, non-target – down), and to make a response when the target stimulus appeared. The Venn diagram on p. 161 represents this task as Attention. The different parameters measured by the CPT (e.g., errors, response times and response time variability) are interpreted as indices of attention (Edwards et al., 2007; Greenberg & Waldmant, 1993). Commission errors represent a lack of inhibitory control when attentional demand is high. The Venn diagram on p. 161 shows this parameter as an intersection between Attention and Inhibitory Control - a subset termed Interference Control. Reaction times index processing and motor response speed (Greenberg & Waldmant, 1993) whereas response time variability is interpreted as a measure of temporary lapses in attention (Kofler et al., 2013).

The CPT contained two blocks. The vigilance block, in which the target was rarely presented (on 22% of the trials), is proposed to capture inattention (Edwards et al., 2007). In contrast, the impulsivity block, in which the target appeared more frequently (on 78% of the trials), measures the ability to withhold a response under conditions that demand higher inhibitory control (Greenberg & Waldmant, 1993). A very monotonous and repetitive nature of responding during this task raised concerns about potentially high participant dropout rate if this task was included in the pre-test. Therefore, a decision was taken to use this task in the post-video test assessment session only.

Experiment 3 sought to examine two of our three overriding hypotheses. The first focused on the effects of pace on alertness and processing of perceptual information, and predicted that the children in the fast-paced group would make fewer omission errors and respond faster in the CPT. The second examined the effect of pace on inhibitory control, and predicted that the children in the slow-paced group would perform better in the day-night task and make fewer commission errors in the CPT.

Method

Participants.

This study included 74 children in two age groups. There were 36 (girls, n=18) 4-year-old children (M=50.06 months, SD = 3.02) and 38 (girls, n=22) 5-year-old children (M=60.37 months, SD=3.77). An additional six children took part but were excluded from the analyses (n=2, did not complete the task; n=1, disengaged after the first block; n=3 identified as outliers based on extremely low attention task accuracy).

Participants were recruited from an opportunity sample attending pre-schools and primary schools located in an economically advantaged area in a semi-rural county of England, UK. Although the data regarding participants' ethnicity were not collected, children were predominantly White. The experiment was approved by a local Ethics Committee. Before the study began, the experimenter provided children's parents with information about the project and the experimental procedure, and obtained individual consent. Children were alternately assigned to one of the two experimental conditions.

Design.

The experiment adopted a mixed factorial design. The between-participant variables were pace (fast, slow) and age (4-, 5-year-old). The two age groups were treated separately in the analyses, as these children differed in terms of their school experience: all 4-year-olds attended preschools, whereas children in the 5-year-old group attended primary schools. Therefore, it is plausible that a difference between these educational environments - a play-oriented preschool and a formal school classroom, where full engagement during specific periods of work is necessary - would be reflected in the differences in attentional and cognitive performance.

For the day-night task the within-participant variable was time (pre-video, post-video). The dependent variable was the proportion of correct responses on the day-night task. For the CPT the within-participant variable was block type (vigilance, impulsivity). The dependent variables were response time latency, response time variability, proportion of omission errors (incorrect withholds on go trials) and proportion of commission errors (incorrect presses on no-go trials).

Apparatus and Materials.

A 13-inch Apple laptop computer running QuickTime video player was used to present the video stimulus. Audio playback was delivered via Sony speakers. The same machine was used to run the attention task programmed in SuperLab5.

Videos.

Randomly selected 5-minute segments of twenty age-appropriate programmes available in January 2015 on British terrestrial children's television channels (CBBC and CITV) were coded for the number of cuts to identify fast- and slow-paced videos. Following this process, the experimenter compiled a short-list of 8 programmes: 4 slow- and 4 fast-paced. A panel of three made the final selection of the two experimental videos: the slow-paced *Old Jack's Boat* and the fast-paced *Pokemon*. *Old Jack's Boat* is a story telling programme combining live production and animation. In each episode the narrator (Jack) tells a story about his past sea adventure. The duration of the episode used in this this experiment was 14m19s and the video contained 7.2 cuts per minute. *Pokemon* is an animated video, based on a popular Japanese video game, about the adventures of a young boy (Ash) who travels around the world of Pokemon with a small group of friends. The duration of the segment used in this experiment was 15m13s and the average number of cuts per minute was 13.6.

Day-night task.

The materials consisted of two laminated cards showing grey-scale pictures of sun and moon used to explain the procedure, and an A4 size flip-book, containing 10 individual grey-scale pictures of sun (S) and 10 individual pictures of moon (M) presented in the following order: SMSMSMSMSSMMSMSSMMSM.

The CPT.

The stimuli consisted of a white square presented on a black background, and a picture of the yellow smiley face that appeared centrally on the white square in either "up" (target) or "down" (non-target) position (Figure 4.2.). Two laminated cards showing the smiley face in target and non-target position were used to explain the rules of the task.

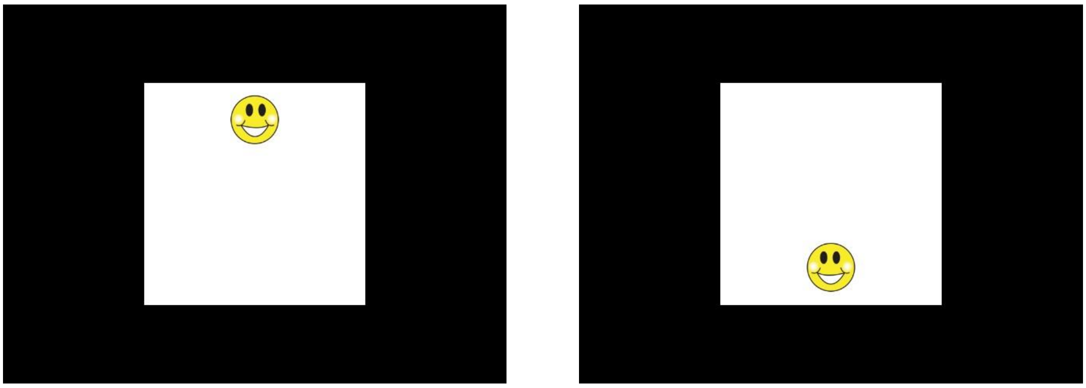

Figure 4. 2. An example of the stimuli presented on the laptop screen during the CPT.

Procedure.

The experiment took place in a quiet room that was separate from the main classroom area. Children were tested individually and each session lasted approximately 25 minutes. Both the experimenter and a child were sat next to each other at a low table. On the table, there were two laptop computers, a flipbook and the laminated instruction cards. A child was positioned in front of an Apple laptop, to the right of the experimenter. At the beginning of the session the experimenter briefly explained the plan for the testing session to each participant. Following this brief set-up, a day-night task was introduced to the children, and the experimenter explained the rules of a "silly game" using two laminated cards. The children were instructed to say "moon" when shown a picture of the sun and "sun" when shown a picture of the moon. The task began with four practice trials (with feedback), followed by 16 experimental trials (no feedback). Once a child finished the day-night task, the experimenter explained that a video was going to be shown on a laptop screen.

Following viewing, the child completed the CPT. The experimenter explained the rules of the "smiley face game" using two laminated cards. The children were instructed to press the space bar on the laptop keyboard every time a smiley face appeared in a target position and to withhold a press when the smiley face appeared in a non-target position on the screen. Participants were then asked to repeat the instructions and show the experimenter which key to press. The experimenter explained that the stimulus would be visible only very briefly and that it was important to keep looking at the screen all time. The task had 126 trials organised into two consecutive blocks. The targets were presented randomly; in the vigilance block there were 14 targets and in the impulsivity block there were 49. The stimulus was presented on the screen for 100ms and the length of the interval between stimulus presentations was 2000ms. There was no break between the two task blocks and the order of block presentation was fully counterbalanced.

Upon completion of the CPT, children took part in the second day-night test. The experimenter briefly reminded each child the rules, and the testing followed with four practice trials and 16 experimental trials. At the end of the session each child received a small reward for taking part.

Results

Day-night task.

A pre- and post-video score was calculated for each participant. The data were analysed in a mixed analysis of variance (ANOVA), with pace (fast, slow) and age (4-years-old, 5-years-old) as between-participant variables and time (pre-video, post-video) as within-participant variable. The results showed a significant main effect of time, $F(1,70) = 7.18$, $p=.009$, $\eta_p^2=.093$ representing an improvement from the pre-video (M=62% SD =23%) to the post-video performance (M=68%, SD=20%). This was qualified by significant Time x Pace, $F(1,70) =4.90$, $p=.030$, $\eta_p^2=.065$, and Time x Pace x Age, $F(1,70) = 9.36$, $p=.003$, $\eta_p^2=.118$ interactions (Figure 4.3).

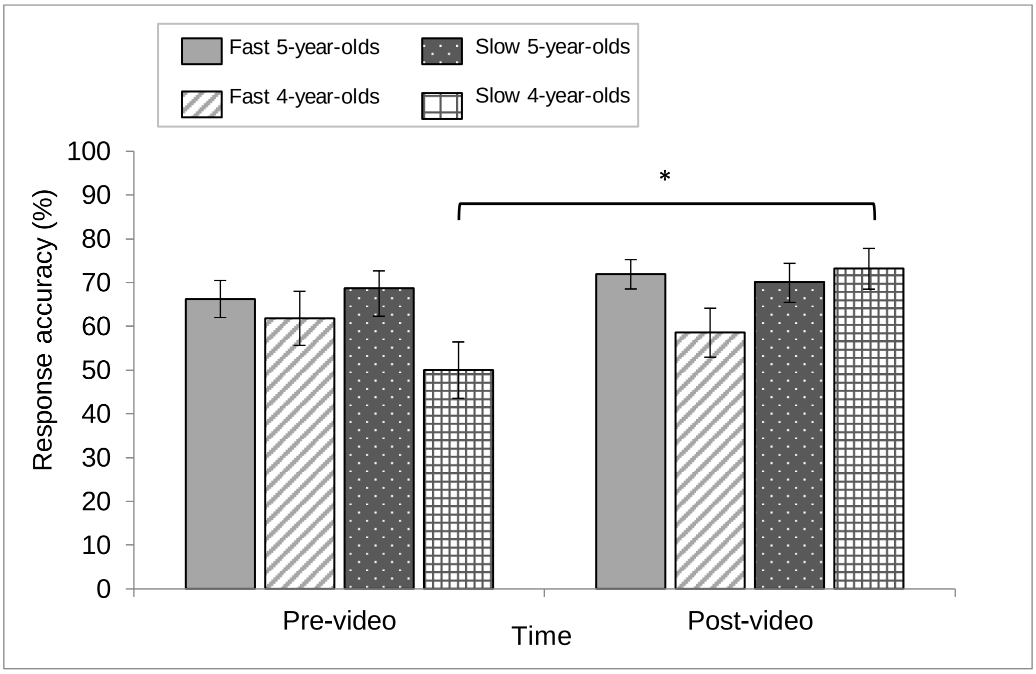

Figure 4. 3. Mean pre- and post-video day-night task scores in fast- and slow-paced conditions for both age groups. Error bars represent SEMs (* denotes a significant difference; p < .05).

Follow-up analysis showed that compared with their baseline scores (M=59.6%, SD=23.6%), children who watched a slow-paced video improved their day-night performance in the post-video session (M=71.6%, SD=18.5%), $t(34)= -2.81$, $p=.008$, 95%CI: -3.30 to -0.53, and this was mainly driven by the changes in the performance of 4-year-olds, $t(16)=-3.67$, $p=.002$, 95% CI: -5.85 to -1.56 (pre-video: M=, SD= and post-video: M=, SD=). For children in the fast-pace group, a difference between pre- and post-video day-night scores was not significant (M=64.1%, SD=22.97% and M=65.4%, SD=21.0%, respectively). Thus, exposure to a slow-paced video resulted in more controlled responding, albeit for the younger children only.

The CPT.

Responses made within the first 100 milliseconds following the stimulus presentation were treated as anticipatory and were removed from the data set (Conners & Staff, 2000). Four scores were calculated for each participant: mean correct response times (RT), RT variability, omission errors and commission errors (Table 4.1).

Table 4. 1. The CPT mean overall (±SD) and mean block (±SD) scores in the fast- and the slow-paced conditions.

Condition	Variable	Overall mean score ± SD	Vigilance block mean score ± SD	Impulsivity block mean score ± SD
Fast	RT (ms)	938 ± 158	970 ± 335	917 ± 167
	RT variability (ms)	331 ± 95	284 ± 153	323 ± 101
	Omission errors (%)	29 ± 18	42 ± 28	25 ± 17
	Commission errors (%)	23 ± 24	18 ± 25	42 ± 28
Slow	RT (ms)	901 ± 168	1049 ± 257	876 ± 169
	RT variability (ms)	327 ± 94	281 ± 144	316 ± 111
	Omission errors (%)	26 ± 15	37 ± 29	24 ± 14
	Commission errors (%)	33 ± 29	29 ± 33	46 ± 24

The CPT performance data were analysed with a mixed ANOVA, with pace (fast, slow) and age (4-years-old, 5-year-olds) as the between-participant variables and block type (vigilance, impulsivity) as the within-participant variable. The pre-video day-night score and gender were used as covariates.

Response time latency.

Response time latency analyses showed no significant main effects of pace ($p=.664$) or block type ($p=.470$). There was also no significant interaction between these variables ($p=.110$). Moreover, there was no significant main effects of age on the speed of responding ($p=.849$). Thus, neither the video's pace nor age had an effect on the speed with which children processed and responded to stimuli presented on the screen.

Response time variability.

There was no significant main effect of pace ($p=.692$) or block type ($p=.133$) on response time variability. There was also no significant interaction between these variables ($p=.972$). However, analysis showed a main effect of age, $F(1,68)=7.72$, $p=.007$, $\eta_p^2=.102$. Five-year-olds' response time variability ($M=289$, $SD=70$) was lower than that of 4-year-olds' ($M=372$, $SD=98$). Thus, younger children appeared to be more prone to lapses of attention during the task.

Omission errors.

Omission errors analyses showed no significant main effects of pace ($p=.317$) or block type ($p=.401$). There was also no significant interaction between these variables ($p=.465$). However, further analysis revealed a main effect of age, $F(1,68)=8.19$, $p=.006$, $\eta_p^2=.107$. Five-year-olds ($M=22$, $SD=15$) made fewer errors of omission than 4-year-old children ($M=34$, $SD=15$). Younger children were more inattentive during the task than the older group.

There was also a main effect of the covariate (i.e., the baseline day-night score), $F(1,68) = 5.79$, $p=.019$, $\eta_p^2=.078$. Children's pre-video day-night score was negatively correlated with the number of omission errors, $r(72)=-.37$, $p=.001$.

Commission errors.

Commission errors analyses showed no significant main effects of pace (p=.309) or block type (p=.430). There was also no significant interaction between these variables (p=.244). Moreover, there was no significant main effects of age on the number of commission errors (p=.444). Thus, neither the pace of the videos nor age affected children's impulsivity.

Interim Discussion.

In Experiment 3, we examined the effects of pace in British terrestrial television children's programmes on attention and inhibitory control. Considering our first hypothesis, performance on the CPT did not provide any support for the prediction about the effects of pace on children's attention. The day-night task, however, did provide partial support for our second hypothesis. Especially for 4-year-olds, exposure to a slow-paced video resulted in an improvement in the post-video performance. Although this finding was consistent with our prediction about the positive effects of slow-paced video on inhibitory control, these effects did not extend to the inhibitory component of the CPT. Despite our prediction, the video's pace did not affect the number of CPT commission errors.

The day-night task makes substantial demands on preschoolers' inhibitory control (Simpson & Riggs, 2005; Simpson et al., 2012). Our data suggest that children engaged their inhibitory control more efficiently after watching the slow-paced video. Deliberate slowing of children's responses during the day-night and other inhibitory tasks improves their performance (Diamond, Kirkham, & Amso, 2002; Simpson & Riggs, 2007; Simpson et al., 2012), possibly because the additional time allows the rapid automatic response to dissipate, which facilitates computing of the correct answer (Simpson & Riggs, 2007; Simpson et al., 2012); although see Barker and

Munakata (2015) and the response of Ling, Wong, and Diamond (2016). Thus, one interpretation of our finding is that watching slow-paced material improved children's inhibitory performance by slowing the speed and increasing the accuracy of their decision-making.

However, attributing the positive effects of the slow-paced video (*Old Jack's Boat*) solely to its slow pace is problematic. This programme had other features, for example, a story-telling format and a low degree of animation, which could have enhanced children's inhibitory control. Thus, although improved day-night performance suggests that certain kinds of video can have positive short-term effects on children's inhibitory control, the presence of the confounding features means they cannot be unequivocally attributed to pace. In addition, contrary to some of the previous literature (e.g., Cooper et al., 2009), we found no evidence of television programme pace affecting children's attention. Therefore, in Experiment 4 we continued to investigate the immediate effects of television on children's attention and inhibitory control; however, this time with strict experimental control of the materials.

Experiment 4

Experiment 4 removed the confound between content and pace by using specially designed and produced experimental videos based on the method developed by Cooper et al. (2009). Further, to address the hypothesis, which predicted that viewing unrealistic content would impair children's inhibitory performance, in addition to varying the pace of video editing, content was also manipulated. Thus, children were assigned to one of four conditions: fast-realistic, slow-realistic, fast-unrealistic and slow-unrealistic. Identical to Experiment 3, children's inhibitory control was assessed with the day-night task and attention performance with the CPT. This experiment sought to disentangle the effects from pace from the effects of content by testing three hypotheses. The first hypothesis predicted that exposure to a fast-paced video would result in fewer omission errors and quicker responding during the CPT. The second hypothesis predicted that watching the slow-paced video would result in better day-night task accuracy and fewer commission errors in the CPT. Finally, we anticipated that children who watched unrealistic content would perform worse on both the day-night task and the inhibitory component of the CPT.

Method

Participants.

One hundred and eighty seven children took part. There were 74 (girls, n=35) 4-year-old children (M=49.28, SD=2.99) and 113 (girls, n=58) 5-year-old children (M= 58.21 months, SD=3.29). A further 24 children took part but were excluded from the analyses due to a failure to complete the CPT (n=6), disengagement from the task after the first block (n=8) or extremely low accuracy scores (n=10). Participants were recruited from an opportunity sample attending pre-schools and primary schools located in a semi-rural county of England, UK. The participants were predominantly White and came from socially diverse families. The experiment was approved by the local Ethics Committee. Before the study began, the experimenter provided children's parents with information about the project and the experimental procedure, and obtained individual consent.

Design.

The experiment adopted a mixed factorial design. The between-participant variables were content (realistic, unrealistic), pace (fast, slow) and age (4-, 5-year-old). For the day-night task, the within-participant variable was time (pre-video, post-video). The dependent variable was the proportion of correct responses on the day-night task. For the CPT, the within-participant factor was block type (vigilance, impulsivity). The dependent variables were response time latency, response time variability, proportion of omission errors and proportion of commission errors.

Apparatus and materials.

The apparatus and the materials used in the day-night task and the CPT were identical to those in Experiment 3. For the experimental videos, two popular children stories were selected: *Charlie and Lola* (realistic content; Child, 2006) and *Room on the Broom* (unrealistic content; Donaldson & Scheffler, 2002). *Charlie and Lola* book series describes the adventures of a little girl and her older brother. In the selected story, "But Excuse Me That Is My Book", Charlie, Lola and their friend Lotta visit a library to find Lola's favourite book. *Room on the Broom* tells a story about the adventures of a friendly witch and her cat.

Before the stories were videoed, their content was tested for the potential differences, for example, in eliciting boredom, amusement, and arousal. During this procedure a teacher read aloud the book to a group of 4- and 5-year-old children and then asked six questions about the book requiring either "yes" or "no" answer. For example, boredom was assessed with two questions: (1) Was the story a bit boring? (2) Did it make you feel sleepy? Children made their response to each question by holding up a laminated picture of a green ("yes") or a red ("no") card. The stories were read on two separate days. Forty children rated the content of *Room on the Broom*, while 47 children rated *Charlie and Lola*.

A series of chi-square tests of association were performed to determine whether children's ratings depended on the story read. Individual tests for each variable (amusement, boredom, enjoyment, arousal and scariness) were computed using an online calculator (http://www.socscistatistics.com/tests/chisquare/Default2.aspx).

Charlie and Lola was rated as amusing by 48% of the children, whereas *Room on the Broom* was rated as amusing by 66% of the children. There was no significant association between the story read and whether or not children found it amusing, $\chi^2_{(1)}$= 3.01, p=.083. When asked about boredom, 44% of children rated *Charlie and Lola* as boring. In comparison, *Room on the Broom* was rated as boring by 45% of the children. A chi-square test of association between ratings of boredom and story type produced $\chi^2_{(1)}$=0.05, which was not statistically significant (p=.818). Further, *Charlie and Lola* was rated as enjoyable by 49% of the children, whereas *Room on the Broom* was rated as enjoyable by 68% of the children. There was no significant association between the story read and whether or not children found it enjoyable, $\chi^2_{(1)}$= 3.04, p=.081. When rating arousal, *Charlie and Lola* was found arousing by 51% of the children and *Room on the Broom* by 55% of the children. There was no significant association between the ratings of arousal and the story type, $\chi^2_{(1)}$=0.13, p=.714. Finally, 49% of children rated *Charlie and Lola* as scary, compared to 43% who found *Room on the Broom* scary, and there was no significant association between the story read and whether or not children found it scary, $\chi^2_{(1)}$= 0.36, p=.548.

Thus, children's ratings indicated that there were no differences between the tested stories.

To produce the experimental videos, a male narrator was videoed reading each story and the same unedited raw footage and audio track were used to create two versions of each video (fast- and slow-paced). The narrator was videoed with three different cameras (narrator front head view, narrator front full view and narrator side view). The recorded material was subsequently edited together with content-relevant cartoon images to produce either a slow- or a fast-paced video. For the purpose of this study an editing action was specified as a change from the narrator view to a still cartoon image that covers between 50 to 100% of the screen, or a change between the two different narrator views (e.g., from a head view to a full view).

Both versions of *Charlie and Lola* had duration of 6m 15s. A fast-paced video contained on average 16.8 editing actions per minute, whereas a slow-paced video contained 6.5 editing actions per minute. In addition to the editing actions, small size cartoon images (covering less than 50% of the screen) and content relevant words/sentences were inserted into each video (Figure 4.4.).

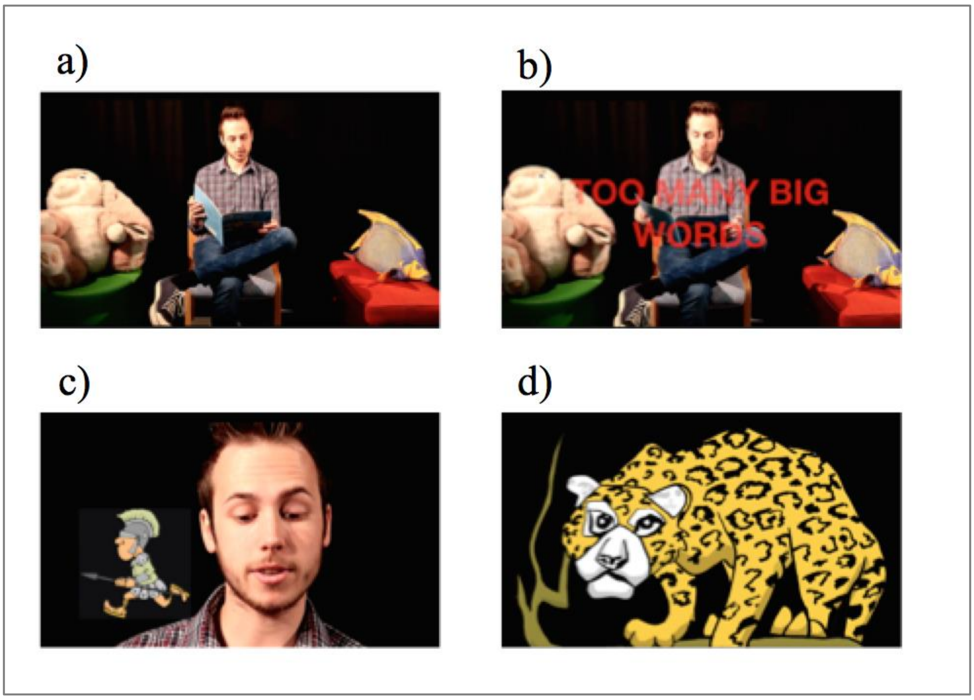

Figure 4. 4. Screen views from *Charlie and Lola*: (a) narrator full view, (b) narrator full view – inserted words, (c) narrator head view – inserted small-size image, (d) cartoon image.

A fast-paced version contained 32 images and 10 words/sentences. In the slow-paced version, there were two cartoon images and one word/sentence. *Room on the Broom* videos had duration of 5m 8s. The average number of editing actions per minute was 18.8 for the fast-edit version and 7.0 for the slow-paced video.

Additionally, the fast-paced video contained 39 images and 14 words/sentences and the slow-paced video contained one image and two words/sentences.

Procedure.

The experimental procedure followed the script identical to that of Experiment 3. However, each session was shorter and lasted approximately 15 minutes.

Results

Day-night task.

A pre- and post-video score was calculated for each participant (Table 4.2.). The data were analysed in a mixed ANOVA, with content (realistic, unrealistic), pace (fast, slow) and age (4-years-old, 5-years-old) as between-participant variables and time (pre-video, post-video) as within-participant variable. The results showed a significant main effect of content, $F(1,171) = 4.20$, $p=.042$, $\eta_p^2=.024$, but no main effect of pace ($p=.789$), and no Content x Pace interaction ($p=.342$). The performance of children in the unrealistic video group was characterised with more controlled responding on the day-night task.

Table 4. 2. Pre- and post-video day-night task scores in each experimental condition.

Pace	**Variable**	**Mean score ± SD (%)**	
Content		*Realistic*	*Non-realistic*
Fast	Pre-video day-night task	61 ± 27	68 ± 19
	Post-video day-night task	70 ± 19	76 ± 18
Slow	Pre-video day-night task	67± 23	69 ± 21
	Post-video day-night task	71 ± 21	76 ± 19

As would be expected, there was also a significant main effect of time, F(1,171) = 16.81, p<.001, η_p^2=.089, indicating that compared to baseline (M=67%, SD=23%), children improved in their post-video assessment (M=73%, SD=20%). There was however, no Content x Time and no Pace x Time interactions (p=.789 and p=.300, respectively). Finally, there was a significant main effect of age, F(1,171) = 7.74, p=.006, η_p^2=.043. This effect was due to 5-year-olds (M=71%, SD=20%) achieving higher scores than 4-year-olds (M=60%, SD=25%) in the baseline assessment, t(178)=3.10, p=.002, 95%CI: 0.60 to 2.72.

The CPT.

Anticipatory responses made within 100 milliseconds of stimulus presentation were excluded from the data analyses (Conners & Staff, 2000). Identical to Experiment 3, four mean scores were calculated for each child: correct RT, correct RT variability, omission errors and commission errors (Table 4.3.).

Table 4. 3. The CPT mean overall and mean block scores in each experimental condition.

Pace	**Variable**	**Overall mean score ± SD**		**Vigilance block mean score ± SD**		**Impulsivity block mean score ± SD**	
Content		*Realistic*	*Unrealistic*	*Realistic*	*Unrealistic*	*Realistic*	*Unrealistic*
Fast	RTs (ms)	862 ± 162	951 ± 190	961 ± 241	1042 ± 297	840 ± 162	950 ± 185
	RTs variability (ms)	346 ± 94	333 ± 87	294 ± 128	314 ± 136	335 ± 95	319 ± 107
	Omission errors (%)	26 ± 13	28 ± 16	34 ± 22	38 ± 25	24 ± 15	26 ± 17
	Commission errors (%)	39 ± 29	32 ± 29	35 ± 32	30 ± 32	56 ± 24	37 ± 25
Slow	RTs (ms)	960 ± 168	886 ± 181	1007 ± 329	946 ± 277	944 ± 165	878 ± 173
	RTs variability (ms)	357 ± 100	356 ± 109	295 ± 152	293 ± 148	349 ± 111	356 ± 120
	Omission errors (%)	32 ± 18	27 ± 17	39 ± 27	34 ± 24	30 ± 18	25 ± 18
	Commission errors (%)	35 ± 28	39 ± 28	32 ± 31	35 ± 32	46 ± 24	51 ± 23

The CPT performance data were analysed with a mixed ANOVA, with content (realistic, unrealistic), pace (fast, slow) and age (4-years-old, 5-year-olds) as the between-participant variables and block type (vigilance, impulsivity) as the within-participant variable. Pre-video day-night score and gender were used as covariates.

Response time latency.

Response time latency analyses showed no main effects for pace ($p= .860$), content ($p= .964$) or block type ($p=.118$) . There was however a significant Content x Pace interaction, $F(1,167) = 8.41$, $p=.004$, $\eta_p^2=.048$ (Figure 4.5.). Follow-up tests showed that the effect of pace was only present in the group that watched a video with realistic content. The children who watched a fast-paced version of the realistic video had faster response times than the children who watched a slow-paced version, $t(91)=-2.86$, $p=.005$, 95%CI: -165.88 to -29.28. Thus, watching a fast-paced video resulted in faster responding, but only when the content was realistic.

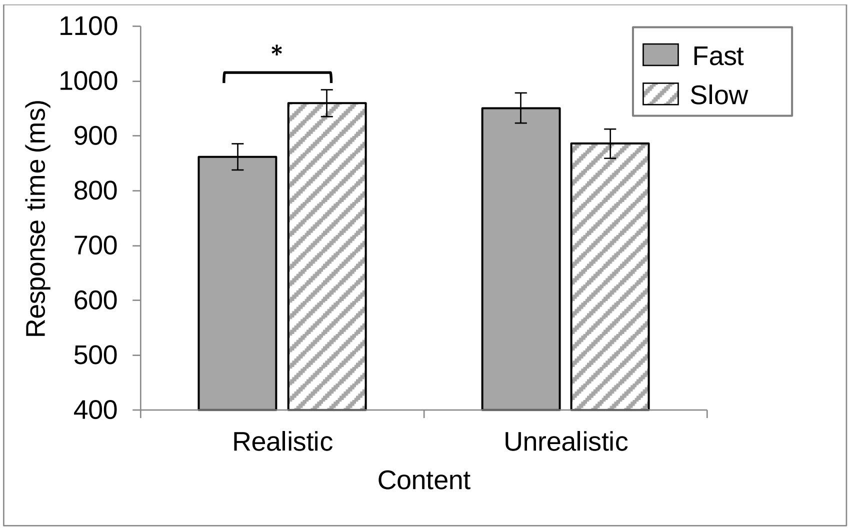

Figure 4. 5. Mean reaction times in the fast- and the slow-paced condition at both levels of content. Error bars represent SEMs (* denotes a significant difference; p < .05).

In addition, there was a significant Content x Age interaction, $F(1,167) = 4.91$, $p=.028$, $\eta_p^2=.029$. The follow-up test showed that 5-year-olds who watched the realistic video responded quicker to the target than 4-year-olds, $t(91)=-2.28$, $p=.025$, 95%CI: -151.47 to -10.52. There was also a significant main effect of gender, $F(1,167)=24.38$ $p<.001$, $\eta_p^2=.127$: Boys (M=876.17, SD=167.79) were faster than girls (M=954.53, SD=182.90). This was qualified by a significant Gender x Block Type interaction, $F(1,167) = 16.81$, $p<.001$, $\eta_p^2=.091$, where girls responded faster during the impulsivity block (M=931, SD=184) than during the vigilance block (M=1093, SD=278), $t(90) = 7.42$, $p<.001$, 95%CI: 118.40 to 205.05.

Response time variability.

Response time variability analyses showed no main effects for pace ($p= .902$), content ($p= .892$) or block type ($p=.311$). There was also no significant Content x Pace interaction ($p=.594$). There was however, a significant main effect of gender, $F(1,167)=5.47$, $p=.021$, $\eta_p^2=.032$ and age, $F(1,167) = 14.92$, $p<.001$, $\eta_p^2=.082$. The girls' response times (M=324, SD=91) were less variable than those of the boys (M= 371, SD = 99), and 5-year-olds' (M=323, SD=99) response time variability was lower than that of 4-year-olds (M=386, SD=83).

Omission errors.

Omission errors analyses showed no main effects for pace (p= .530), content (p= .668) or block type (p=.526). There was also no significant Content x Pace interaction (p=.204). However, there was a significant main effect of age, $F(1,170)=7.66$, $p=.006$, $\eta_p^2=.043$, 5-year-old children (M=25.90, SD=15.17) made fewer omission errors than 4-year-olds (M=31.85, SD=16.86). There was also a significant Block Type x Gender interaction, $F(1,170) = 6.85$, $p=.010$, $\eta_p^2=.039$. Girls (M=23.48, SD = 16.04) made fewer omission errors than boys (M=28.93, SD=17.87) in the impulsivity block, $t(185)=2.19$, $p=.029$, 95%CI: 0.55 to 10.35.

Commission errors.

The analyses of commission errors showed no main effects for pace (p= .901), content (p= .363) or block type (p=.718) . There was, however, a significant Content x Pace interaction, $F(1,170) = 7.45$, $p=.007$, $\eta_p^2=.042$ (Figure 4.6.). However, further analysis did not reveal any significant findings. The trends in the data suggest that the effect of pace was different for the children who watched a realistic video than for the children who watched an unrealistic video. When the content of the video was realistic children in the slow-paced group made fewer commission errors, but when the content was unrealistic the number of commission errors was lower in the fast-paced group.

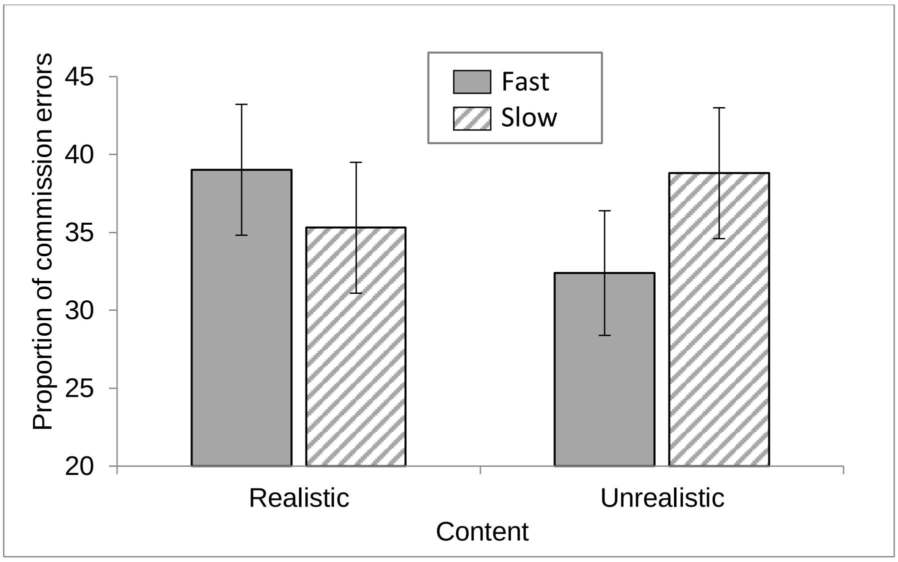

Figure 4. 6. Mean proportion of commission errors in the fast- and the slow-paced condition at both levels of content. Error bars represent SEMs.

Finally, there was also a main effect of age, $F(1,170) = 9.26$, $p=.003$, $\eta_p^2=.052$. The proportion of commission errors made by 5-year-old children (M=31.25, SD=27.07) was lower than that of 4-year-olds (M=44.08, SD=28.83).

Interim Discussion.

Experiment 4 had two aims: to investigate the effects of both pace and of unrealistic content on children’s cognition. Considering our first hypothesis, children who watched a fast-paced realistic video (*Charlie and Lola*) had faster reaction times than their peers who watched a slow-paced version of this video. This finding was consistent with our prediction about the effects of fast pace on attentional performance. However, this effect did not extend to a group that watched the unrealistic video (*Room on the Broom*). It appears that fast pace modulated attentional processing, but only in the presence of realistic content. Moreover, the content interacted with pace to differentially affect the number of commission errors that children made during the CPT task. However, the lack of significant findings in the follow-up tests makes this finding difficult to interpret.

Turning to the second hypothesis, the data obtained in Experiment 4 did not support our prediction about the positive effects of slow pace on children's inhibitory control. There were no differences in the post-video inhibitory control between the children assigned to the slow- and the fast-paced groups. Thus, the video's pace appeared to be inconsequential for inhibitory control. However, inhibitory control *was* affected by the videos' content. Contrary to our third hypothesis, which predicted poorer inhibitory control following exposure to unrealistic content, the children who watched the unrealistic video (*Room on the Broom*) performed better on the day-night task than their peers who watched a realistic video (*Charlie and Lola*). These data suggest that watching unrealistic content can be beneficial for children's inhibitory control, and contrast with the findings of Lillard et al. (2015), who showed that children's executive function (of which inhibitory control is a component) was lower following exposure to unrealistic content. However, it should be noted here that, similarly to Experiment 3, the index of inhibitory performance measured in the CPT remained unaffected by exposure to the video.

In addition to the findings related to the programme pace and content, the results showed age-related differences in performance; compared to 4-year-olds, 5-year-old children were responding more thoughtfully as evidenced by better inhibitory control in the executive task. Similarly, older children's CPT performance was better across all measured indices of attention. Finally, this study found evidence for gender differences in responding on continuous performance tests. Specifically, boys' responding was characterised by shorter and more variable reaction times, poorer attention and response inhibition. Overall, these results are consistent with the past literature and demonstrate age and gender related differences in attention development during early childhood (e.g., Brocki & Bohlin, 2004; Conners, Epstein, Angold, & Klaric, 2003; Greenberg & Waldmant, 1993; Pascualvaca et al., 1997).

General Discussion

Together, the results of the two experiments suggest that watching both real life TV programmes and a short experimental video can affect children's cognitive performance, although support for our three hypotheses was mixed. First, data partially supported our hypothesis about the positive effects of fast pace for children's attention. We found that watching a fast-paced programme was associated with alertness and resulted in quicker responding in Experiment 4, but only when children watched a video with realistic content. Second, consistent with the prediction about the benefits of exposure to a slow-paced video for inhibitory control, performance on an inhibitory task in Experiment 3 improved after watching a slow-paced programme. Finally, contrary to our predictions about the negative effects of exposure to unrealistic content, the findings from Experiment 4 suggest that watching unrealistic content *improved* children's inhibitory control. In the discussion that follows, we consider why video pace and content lead to differential attentional and inhibitory performance.

The effects of pace and content on inhibitory control.

In this study, the inhibitory component of executive function was measured with the accuracy of responding on the day-night task and with the number of commission errors made in the CPT. In both experiments, watching videos affected children's performance on the day-night task, but not the CPT (even though the day-night task was administered after the CPT, which could have weakened the effect of the videos). This may have occurred because, compared with the CPT, the day-night task is a relatively pure measure of inhibitory control with particularly high inhibitory demands (Simpson & Riggs, 2005; Simpson et al., 2012). Thus, the day-night task may have provided a more sensitive measure of changes in inhibitory control after video viewing. Alternatively, the different findings between the day-night task and the CPT may have reflected the different components of inhibitory control tested by these two tasks (Figure 4.1. – Diamond, 2013). Thus, response inhibition (tested with the day-night task) may be more affected by video watching, than interference control (tested with the CPT). This issue aside, the findings from Experiment 3 were consistent with the proposal that exposure to a slow-paced video could improve children's inhibitory control, at least in the short term. However, once the confound between pace and content was removed in Experiment 4, the positive effect of slow pace was not replicated. This speaks against the proposal, made in the discussion of Experiment 3, which suggested that slow pace improved inhibitory control by slowing decision-making. We therefore consider two further possible explanations for why video content might affect inhibitory performance.

First, children's improved inhibitory performance could have resulted from exposure to unrealistic content. In Experiment 4, we specifically selected *Room on the Broom* because of its fantastic content. The episode of *Old Jack's Boat*, used for Experiment 3, also contained fantasy (e.g., a mermaid, sea king and magical trident). Children enjoy watching unrealistic content and research shows that it is positively related to their reception of televised messages (Rose, Merchant, & Bakir, 2012). Moreover, the presence of fantasy in teaching materials increases children's motivation and enhances learning (Parker & Lepper, 1992). Considering this literature, perhaps the fantasy content improved the appeal of *Old Jack's Boat* and *Room on the Broom,* and elicited more positive reception of these two programmes, which increased subsequent task engagement. Therefore, motivational factors may have driven children's improved inhibitory performance.

Our suggestion about the *positive* effects of unrealistic content is contrary to that of Lillard et al. (2015), who proposed that watching fantasy was detrimental to children's executive performance. One explanation for this contrast might be the different tasks used to assess executive function in the Lillard et al. study and the data presented here. In the present study, we used the day-night task, which has particularly high inhibitory demands. In contrast, Lillard et al. used several tasks assessing various executive skills (i.e., delay of gratification, working memory, functional fixedness, inhibitory control, cognitive flexibility). The possibility that video has different effects on different components of executive function needs to be explored in future research. This is now possible because recent studies have identified tasks, including the day-night task, which can be used to distinguish between different components of executive function in early childhood (e.g., Caughy, Mills, Owen, & Hurst, 2013; Gandolfi, Viterbori, Traverso, & Usai, 2014; Lerner & Lonigan, 2014; McAuley & White, 2011).

Second, based on the pattern of findings across our two experiments, we speculate that a previously unconsidered variable may have a role in mediating the effect of video watching on children's executive function: the presence of structured narrative. In Experiment 3 children's inhibitory performance improved after watching the *Old Jack's Boat* video, which has a story-telling format. Unlike *Pokemon,* which has a loose narrative and relies on fast action and fast editing pace to entertain the viewers, *Old Jack's Boat* has a clear, meaningful narrative structure. Likewise, in Experiment 4, children's inhibitory control was also better after watching a video with a stronger narrative. The *Room on the Broom* has a clear narrative structure, and the events unfold in a contingent sequence. In contrast, the narrative of *Charlie and Lola* is quite disjointed; the story line is frequently intermitted by narrative-irrelevant factual information. The processing of narrative in *Room on the Broom* might have activated children's inhibitory control, which then persisted beyond the end of the video, and resulted in more controlled behaviour in the subsequent inhibitory task.

In fact, two of the realistic programmes used by Lillard et al. (2015; *Arthur* and *Little Bill*) adopted an animated storybook format, in which a meaningful narrative was used to convey pro-social messages and show creative problem solving. In contrast, the unrealistic shows were characterised by less prominent narrative. For example, the storyline of *Little Einsteins* was frequently interrupted by the presentation of visual art and classical music, whereas in *Spongebob Squarepants* the adult humour may have obscured the narrative. Arguably, there are many differences between reading a book and watching a video; however, storybook-like videos with a clear and meaningful narrative may improve children's inhibitory performance, at least in the short-term.

We appreciate that this is a post-hoc interpretation of our data, but argue that this field would benefit from future work to determine the effects of narrative in film on children's behaviour and cognition. More fundamentally, research is needed to address the question of whether executive function is enhanced by use (in the same way that using a skill improves it) or depleted by use (in the same way that using a muscle tires it, in the short-term at least)? We have proposed when children deploy their executive function, while watching a video (to process narrative structure), they enhance it: while Lillard and colleagues (2015) suggest that using executive function (while processing fantastic material) depletes it.

The effects of pace and content on attention.

The CPT used to assess attention in this study put children under time pressure. The stimulus appeared on the screen for 100ms and the time to make a response was limited. Thus, to succeed, children had to be alert and prepared to respond quickly. Although our data provide some support for the proposal that editing pace affects some aspects of attention, these effects were moderated by the video's content. Specifically, exposure to fast pace resulted in quicker reaction times, but only when children watched *Charlie and Lola* (realistic content with weak narrative structure). In contrast, reaction times of children who watched *Room on the Broom* (unrealistic content with strong narrative structure) remained unaffected by the pace of editing.

Attention is the result of an interaction between bottom-up (or stimulus-driven) and top-down (goal-driven) processes (Connor, Egeth, & Yantis, 2004; Egeth & Yantis, 1997; Sarter et al., 2001). In the CPT, a small yellow smiley face that briefly appears on the screen is visually salient and stands out from the white background. The colour contrast and the flash-like appearance of the stimulus elicit an orienting response and draw the children's attention towards the source of visual input. This "automatic" deployment of attention is beyond conscious control and does not interfere with simultaneous cognitive activity (Posner & Snyder, 2004). Such involuntarily attention deployment triggered in response to audio-visual input, which is characterised by the lack of conscious cognitive processing is the key premise of the passive viewing hypothesis (Singer, 1980). Frequent scene changes and other audio-visual features automatically activate children's attention to a fast-paced programme. In this way, initial processing of the CPT stimuli parallels processing of a fast-paced video; attention is driven exogenously by visually salient stimuli appearing on the screen.

However, the further allocation of attentional resources during the CPT depends on the particular goal (in this case, the instructions provided by an experimenter, which determined the target) and requires conscious cognitive effort (Egeth & Yantis, 1997). To make a response a child has to *actively* process information about the stimulus (in a similar way, in which a viewer might processes information about the comprehensible content; Anderson & Lorch, 1983). This additional top-down processing slows responding, as more time is needed to assess the relevance of the stimulus in relation to the task goal. Conversely, failure to engage executive processing results in automated responding triggered by perceptual input, which in turn, shortens response times (Manly, Davison, Heutink, Galloway, & Robertson, 2000).

Both the results of Lillard et al. (2015), and our findings pertaining to inhibitory control, indicate that watching realistic content does not activate executive processing. Together, these data suggest that watching the fast-paced realistic video should require little or no cognitive effort. This lack of activation of executive processing during viewing could have further resulted in inadequate attentional processing during the subsequent attention task. The children, who watched a fast-paced version of the realistic video “allowed” their performance to be driven by the visually salient onset of the trial and by bypassing executive processing, were able to make quick responses. However, one would expect that stimulus-driven “automatic” responding should also lead to higher commission error rate; our data *hint* that indeed this was the case for the children who watched a fast-paced version of the unrealistic film.

This interpretation of our findings is congruent with the pattern of results observed in the studies in which attention was operationalised with the frequency of changes between activities during free-play (Geist & Gibson, 2000; Kostyrka-Allchorne, Cooper, Gossmann, et al., 2017). In those two studies, exposure to a fast-paced programme resulted in more frequent shifts between toys, thus suggesting quicker processing of information about a particular toy before moving on to the next activity. Unstructured play activates top-down processing, as during play, children have to set and maintain their own goals. However, unlike a formal attention assessment when children are instructed what to do by an experimenter, during free-play the goals are self-imposed (Barker et al., 2014). Therefore, more frequent changes between the objects of play activity could have been a result of poorer activation of executive processing, which compromised children's ability to engage in goal-directed behaviour.

In sum, we propose a modified passive viewing hypothesis. That is, children's attention to the programme is maintained by the perceptual salience of on-screen stimuli only in the absence of the content that could activate executive processing during viewing. Considering the possibility that some content has the potential to attenuate the detrimental effects of fast pace, future research should explore the relationships between different types of content and children's cognition in more detail.

Implications and limitations.

The findings from our study are important for two reasons. First, they point to the importance of content over pace, particularly for inhibitory performance. We proposed two non-exclusive explanations. Watching unrealistic content could have been more enjoyable, which in turn, resulted in a more positive experience of taking part in the experiment and increased children's motivation to do well in a subsequent task. It is also plausible that the need to follow a meaningful sequence of events unfolding in a video with a clearly structured narrative activated children's top-down processing, which extended to the performance on a subsequent executive task.

Second, maintaining strict experimental control over the stimuli used in the present study, we demonstrated that exposure to the fast-paced video resulted in faster processing of perceptual information. This finding is congruent with the results of previous studies, which showed that children were generally faster in processing information after watching a fast-paced video (Geist & Gibson, 2000; Kostyrka-Allchorne, Cooper, Gossmann, et al., 2017). However, we propose that faster processing speed indicates inadequate deployment of attention and that certain types of content could provide a buffer against the potentially detrimental effects of fast pace.

The present study provides an important contribution to the debate about the potential influence video may have on children's cognition. It adds to the growing body of experimental literature, which consistently delivers evidence that exposure to both real-life television programmes and experimental videos affects children's executive and attentional processes. Producing own materials allowed us to detect more nuanced changes in performance, which depended on both unique and interactive effects of content and pace. However, we also need to acknowledge the potentially limited generalizability of our findings. First, producing these materials limited the choice of editing features and did not allow investigating the effects of animation, which is the staple of children's television. Second, we examined children's attention with a formal laboratory measure, which has been found to be only moderately related to standardised ratings of *everyday* hyperactive-impulsive behaviour (Barker et al., 2014). Third, reaction time variability has been computed using reaction time standard deviation, which due to its typically high correlations with response times, poses a statistical and conceptual limitation (Edwards et al., 2007).

Finally, although traditional television remains the favourite type of media platform for under 6s (Kostyrka- Allchorne, Cooper, & Simpson, 2017), children now have access to a variety of digital devices, which allow convenient access to television content and other kinds of video. Considering that the effects of video may be similar across different digital devices (i.e., traditional television, tablet, smartphone), it is important to continue the experimental investigation of the effects of various content and audio-visual features on developmental outcomes.

Conclusion.

In conclusion, children’s executive function appears affected more by the programme’s content, whereas attention is sensitive to the interactive effects of both content and pace. The results reported in this chapter suggest that watching story-like programmes with embedded fantasy and a low-degree of animation results in greater executive control. Moreover, in the absence of cognitively stimulating content, fast pace results in quicker but less thoughtful responding. Altogether, our results suggest that watching television and video may have consequences for the development of children’s attention and executive function. Further research should aim to tease out further how different components of television audio-visual form and content affect children’s optimal as well as everyday attention and cognition.

CHAPTER FIVE: Attention and cardiovascular adaptation in children: heart rate and heart rate variability during video watching and psychological performance assessment.

Abstract

Despite abundant research into the effects of television on children's attention and executive function, no study to date has directly investigated cognitive effort during television watching. The present study used heart rate and rate variability monitoring to examine changes in cognitive effort during video viewing, while also assessing attention and a component of executive function (inhibitory control). The heart rates of 166 5-year-olds were monitored from a resting baseline through a pre-video inhibitory task, video watching, attention task and post-video inhibitory task. The results showed that, compared to the inhibitory and attention tasks, heart rate during video watching was significantly lower. These data suggest that video watching is very effective in absorbing children's attention. In addition, the post-video inhibitory task heart rate variability was higher then when video watching or participating in the attention task; thus, perhaps video watching is not as cognitively passive, as previously suggested. Finally, the finding that attention task reaction time variability was positively associated with heart rate variability, recorded during this task, was consistent with literature showing links between attentional performance and physiology.

Introduction

Qualitative research suggests that television viewing enables children to rest, unwind and have some “quiet time”(De Decker et al., 2012; He, Irwin, Bouck, Tucker, & Pollett, 2005). Television and other screen media are also used as “digital babysitters”, which allow parents to attend to household chores, have respite from the demands of childcare and as means of distraction (e.g., Bentley et al., 2016; De Decker et al., 2012; He et al., 2005; Holloway, Green, & Love, 2014). These findings are consistent with quantitative research showing that parents have liberal attitudes towards how much screen time their children experience, and that their beliefs about the effects of media on developmental outcomes are mostly positive (Kostyrka-Allchorne, Cooper, & Simpson, 2017). More importantly, the use of television and other media to occupy and maintain interest implies that they may be very effective in cognitively absorbing children, perhaps more so than other age-appropriate leisure activities.

In contrast to much parental opinion, paediatricians and researchers have expressed concern about childhood screen exposure (e.g., AAP, 2016). However, research in to this topic has delivered mixed findings, and clear conclusions about the potential effects of television viewing on developmental outcomes are difficult to draw (for a review see Kostyrka-Allchorne et al., 2017). Moreover, very little is known about *how much* attention children pay to television (Anderson & Burns, 1991). This is particularly important, as engaging with television is regarded as “prerequisite to [the] effects of the media’ (Lang, 1990, p.276).

Traditionally, children’s engagement with television has been measured by the duration of visual orientation towards the screen (Anderson & Burns, 1991; Anderson & Lorch, 1983). Research shows that the length of the episodes of focused attention to the screen greatly varies and depends on a host of individual and contextual variables, for example, the viewer's age, gender or the availability of alternative activities (for a discussion see Anderson & Burns, 1991). Moreover, Anderson and Lorch (1983) proposed that engagement in television viewing, is sustained via "attentional inertia" – a process, which pieces together segments of activity to maintain continuity over time. Choi and Anderson (1991) compared such pleasurable immersion in activity to what James (1890) had described as "passive intellectual attention" – a preoccupation with an enjoyable activity, without a subjective feeling of mental effort.

In addition to measuring overt behaviour, processes that underpin attention and cognition can be investigated by measuring their cardiovascular *concomitants*; that is, the differences in physiological adaptation measured *in parallel* to task performance (Hansen, Johnsen, & Thayer, 2003; Middleton, Sharma, Agouzoul, Sahakian, & Robbins, 1999). Specifically, the assessment of heart rate and heart rate variability has been employed as a measure of the physiological adaptation associated with attention and related cognitive processes in children (e.g., Börger & van der Meere, 2000; Börger et al., 1999; Eisenberg, 2011; Suess, Porges, & Plude, 1994) and adults (e.g., Hansen et al., 2003; Middleton et al., 1999; Porges & Raskin, 1969).

The early heart rate research, with adults, focused on the investigation of physiological changes in response to orienting and attention to external stimuli (Lacey & Lacey, 1974; Porges & Raskin, 1969). It is now well established that the orienting response to novelty or change in the physical environment (Sokolov, 1963) is associated with marked decrease in the heart rate (Bradley, 2009; Bradley, Keil, & Lang, 2012; Graham & Clifton, 1966). Moreover, a series of classic studies (e.g., Lacey & Lacey, 1974; Porges & Raskin, 1969) demonstrated consistent evidence that directing attention to the external environment was associated with slowing of the heart rate, whereas internal processing was accompanied by heart rate acceleration.

Further evidence that heart rate deceleration may be an index of attention comes from infant studies. Casey and Richards (Casey & Richards, 1988; Richards & Casey, 1991) used a modified visual preference paradigm, in which the presentation of a primary visual stimulus was interrupted by a secondary visual stimulus, to measure changes in the heart rate that accompanied sustained attention in infants. The authors demonstrated that following the primary stimulus onset, infants' heart rate decelerated and that infants were less likely to divert gaze to the secondary distractor during a period of heart rate deceleration than when their heart rate returned to the pre-stimulus onset level. This was interpreted as evidence for the proposition that decrease in the heart rate is a physiological marker of sustained attention.

In comparison, the pattern of heart rate changes during tasks which measure executive functions, higher-order cognitive processes which control one's behaviour (Miyake et al., 2000), reported in the adult literature is less clear. For example, Hansen et al. (2003) reported that participants' heart rate was higher during a working memory task relative to the post-task recovery period. Similarly, the examination of changes in heart rate that accompany performance on a Stroop task, showed that participants' heart rate was higher during the task relative to the baseline and to the post-task recovery period (Renaud & Blondin, 1997). However, Silva and Leite (2000) found no evidence of changes in heart rate during a Stroop task, despite noting significant changes in the participants' skin conductivity and extremities temperature.

While the heart rate literature shows the potential importance of examining such physiological processes underpinning attentional and cognitive performance, measuring heart rate variability arguably provides a more effective way of studying the links between physiology and cognition (Berntson et al., 1997). Heart rate variability, which reflects the variance in the intervals between consecutive heartbeats (Camm et al., 1996), has often been interpreted in the literature as an index of attention and mental effort more broadly (e.g., Börger et al., 1999; Fairclough & Houston, 2004; Hansen et al., 2003; Porges & Raskin, 1969). Mulder (1986) distinguished between two types of mental effort: "computational effort" and "state effort". Computational effort refers to task difficulty (e.g. time pressure, high working memory load, or other demands for executive control). State effort is the need to maintain optimum performance, despite the negative states associated with prolonged cognitive activity (e.g., boredom, fatigue or stress).

The results of studies, which have investigated changes in the heart rate variability associated with computational effort, suggest that relative to baseline, variability *decreases* during tasks that require attention and substantial cognitive effort in both children (Calkins & Keane, 2004; Hyde & Izard, 1997; Suess et al., 1994) and adults (Hansen et al., 2003; Hansen, Johnsen, Thornton, Waage, & Thayer, 2007). However, the magnitude of these changes may depend on the executive load associated with the task. For example, Luft, Takase, and Darby (2009) reported a greater decrease in heart rate variability for the tasks with high executive demands relative to the tasks requiring sustained attention. Conversely, Middleton et al., 1999 showed lower heart rate variability during tasks measuring attention compared to planning tasks. These conflicting findings could be explained by the different methods used to compute heart rate variability in both these studies. Finally, heart rate variability may also be sensitive to perceptual demands of the task. Compared to executive tasks with low perceptual load, performance on a psychophysical task, which required discriminating between the lengths of the presentation of two stimuli, was characterised by a significant decrease in the heart rate variability (Luque-Casado, Zabala, Morales, Mateo-March, & Sanabria, 2013).

In contrast, the adult state effort literature suggests that negative states, induced by participating in stressful or tiring tasks (e.g., resisting tasty snacks, driving simulation), are accompanied by *increased* variability (Fairclough & Houston, 2004; Mulder, 1986; Segerstrom & Nes, 2007; Tran, Wijesuriya, Tarvainen, Karjalainen, & Craig, 2009). However, the interpretation of these findings is not clear. On the one hand, it has been suggested that increased heart rate variability may be due to a decrease in cognitive effort or fatigue (Fairclough & Houston, 2004; Mulder, 1986; Tran et al., 2009). An alternative proposal is that it may be a reflection of increased self-regulatory effort in situations requiring emotional restraint, for example, when resisting eating a tasty snack (Segerstrom & Nes, 2007).

In addition to treating heart rate variability as a dependent variable, researchers have used baseline heart rate variability as a predictor of cognitive performance and attention in children (Richards & Casey, 1991; Suess et al., 1994) and adults (Albinet, Boucard, Bouquet, & Audiffren, 2010; Geisler & Kubiak, 2009; Hansen et al., 2003; Reynard, Gevirtz, Berlow, Brown, & Boutelle, 2011; Segerstrom & Nes, 2007). The data reported by Suess et al. (1994) showed that children's higher baseline respiratory sinus arrhythmia (a high-frequency heart rate variability component) was associated with improved attention performance. Moreover, higher baseline respiratory sinus arrhythmia predicted infants' better adjustment in novel situations (Richards & Casey, 1991). Similarly, the data reported in adult literature provide consistent evidence for the positive associations between baseline heart rate variability and attention (Hansen et al., 2003), executive functions (Albinet et al., 2010; Hansen et al., 2003) and self-regulatory strength (Geisler & Kubiak, 2009; Reynard et al., 2011; Segerstrom & Nes, 2007).

Despite the popularity of using cardiovascular measures in psychological research, the literature reporting cardiovascular concomitants of television viewing is very limited. The research with adult participants by Lang and colleagues (e.g., Lang, 1990; Lang, Bolls, Potter, & Kawahara, 1999; Lang et al., 2005; Lang, Zhou, Schwartz, Bolls, & Potter, 2000) focused on the investigation of the effects of audio-visual television features, such as the editing pace, on viewers attention indexed by heart rate. Lang (1990) demonstrated that certain elements of television form (i.e., cuts, edits, movement on the screen) were accompanied by specific physiological changes; that is, an initial lowering of the heart rate followed by acceleration, which were interpreted as physiological markers of an orienting response. Moreover, the data of Lang et al. (2000) showed that the viewers' heart rate was lower when they watched a fast- or very fast-paced programme compared to when they watched a slow-paced programme. The authors interpreted these data, as evidence for increased visual attention during viewing of the fast-paced material. However, the results of other studies failed to show evidence that exposure to fast-paced programming was associated with decreased heart rate (Lang et al., 1999; Lang et al., 2005).

In sum, cardiovascular measures allow an investigation of physiological changes that underpin cognitive activity, and permit inferences to be made about attention and cognitive effort, which are not possible to infer from outward behaviour. However, this method has been underutilised in television research, particularly in the developmental literature. Thus, the main aim of this study was to investigate the task-related cardiovascular changes during three activities characterised by different attentional and executive demands.

Specifically, this study examined heart rate and heart rate variability data recorded in Experiment 4, reported in the previous chapter. It was expected that both heart rate and heart rate variability would fluctuate across experimental session reflecting the task-dependent cardiovascular adjustment. Thus, the first hypothesis predicted a main effect of the task; that is, the different tasks would be accompanied by different cardiovascular adaptations. Additionally, given the findings of Chapters Two, Three and Four, the present study aimed to test whether audio-visual features, such as the editing pace, and the videos' content would affect children's heart rate and heart rate variability. Based on the findings of Lang et al. (Lang, 1990; Lang et al., 2000), it was predicted that cardiovascular responses would be dependent on the editing pace. Specifically, the second hypothesis predicted that compared to the slow-paced video, heart rate would decrease more whilst watching a fast-paced video. Moreover, considering the proposition that processing of the unrealistic content (i.e., improbable events and characters) in television programmes may require greater cognitive effort (Lillard et al., 2015), the third hypothesis predicted that watching a video with unrealistic content would be accompanied by a greater decrease in heart rate variability.

Finally, considering the literature, which showed the associations between heart rate variability, attention and related cognitive function, the second goal of this study was to investigate further the association between heart rate variability and task performance. Thus, a fourth exploratory hypothesis predicted that both baseline and task heart rate variability would be significantly related to the respective indices of task performance.

Experiment 5

Method

Participants.

The participants were 4- and 5-year-old children (M=54.5 months, SD = 5.3) recruited to take part in an experiment, which investigated the effects of video pace and content on attention and inhibitory control (Experiment 4 reported in Chapter Four). The initial sample comprised of 187 children; however, complete physiological data were available for 166 children (girls, n= 84). Four children did not give their permission to use the finger sensor; the data of the remaining 17 participants could not be used due to technical problems. Further details about the participants can be found in Chapter Four (p.181).

Apparatus and materials.

The raw blood volume pulse (BVP) signal was recorded at a rate of 128 samples per second with a Nexus-10 BVP sensor placed on an index finger of a child's non-dominant hand and connected wirelessly to a Dell Latitude laptop computer. This sensor uses photoplethysmography, a non-invasive optical method, to measure blood volume changes at the surface of the skin (Allen, 2007). Finally, BioTrace+ software was used to compute online children's heart rate and, using power spectral analysis, heart rate variability (for a detailed description of this method see Sztajzel, 2004). The activity was examined in the low-frequency band (0.04-0.15Hz) in an entire power spectrum. The raw power was normalised; thus, the spectral index of heart rate variability recorded in this study is expressed as a proportion (Burr, 2007).

A detailed description of the experimental videos and task materials is presented in Chapter 4 (for task materials, see Experiment 3, pp.170-171 and for videos, see Experiment 4, pp.179-181).

Procedure.

The children were tested individually in a quiet room, away from the main classroom area. After a brief description of the activities planned for the test session and upon receiving a child's consent, the experimenter placed a BVP sensor on an index finger of a non-dominant hand and started recording the physiological data.

The procedure followed a protocol introduced in Chapter Four (i.e., day-night task, video, CPT, day-night task). For a detailed description of this procedure see Chapter Four (Experiment 3, pp.171-172). The recording of physiological data was stopped when the children completed the second day-night task. At the end of the session, which lasted approximately 15 minutes, each child received a small reward for taking part.

Design and analysis strategy.

To determine physiological changes during the experimental session, the scores were analysed in a mixed factorial analysis of variance (ANOVA). The between-participant variables were pace (fast, slow) and content (realistic, unrealistic). The within-participant variable was task (pre-video day-night task, video, CPT, post-video day-night task). The dependent variables were heart rate and heart rate variability. Finally, the baseline heart rate and heart rate variability values were used as covariates in the respective analyses.

Physiological data collected in the repeated-measures designs tend to be highly correlated, which can lead to the violation of sphericity (e.g., Giardino, Glenny, Borson, & Chan, 2003; Lang, 1990). Therefore, Greenhouse-Geisser correction was applied to the degrees of freedom. Significant main effects of task were followed with planned contrasts using Bonferroni adjustment for multiple comparisons.

Further, linear regression was used to determine the significant physiological predictors of task performance. Specifically, we examined whether the average heart rate recorded during baseline and the respective task (i.e., pre-video day-night task, the CPT, post-video day-night task) was significantly associated with the following five outcome variables: pre-video day-night task score, post-video day-night task score, reaction time (RT), reaction time variability (RT variability) and commission errors (presses on no-go trials). Participants' gender and age and, with the exception of the pre-video day-night task analysis, the video characteristics (i.e., pace and content) were used as covariates.

Finally, in the present study, we set out to examine cardiac activity across three distinct activities (i.e., the day-night tasks, the CPT and video watching). The complete performance data were previously reported in Chapter Four (Experiment 4) and individual task scores are not analysed again (see Table 4.2. on p.182 and Table 4.3. on p. 183 for the summary of the descriptive statistics). However, briefly, the data showed that watching the videos with unrealistic content improved children's executive performance. Moreover, pace interacted with content to affect children's attention. That is, exposure to the fast-paced video resulted in a faster responding, but only when the content was realistic.

Results

Five heart rate values and five heart rate variability values were obtained for each participant. The mean values (standard errors of the mean; SEMs) are shown in

Table 5.1., with the exception of the baseline heart rate and heart rate variability values, which were evaluated at 98.4 bpm and 44.6%, respectively.

Table 5. 1. Baseline corrected mean heart rate (HR) and heart rate variability (HRV) in each experimental condition (n=166).

Pace	**Task**	**HR (SEM)**		**LF-HRV (SEM)**	
Content		*Fast*	*Slow*	*Fast*	*Slow*
Realistic	Pre-video day-night task	99.2 (1.7)	101.3 (1.5)	41.3 (1.9)	39.2 (1.8)
	Video	100.0 (1.5)	99.4 (1.4)	39.8 (1.5)	38.9 (1.4)
	CPT	100.5 (1.8)	101.4 (1.6)	39.4 (1.7)	39.3 (1.6)
	Post-video day-night task	103.4 (2.1)	104.6 (1.9)	42.8 (2.5)	41.3 (2.3)
Unrealistic	Pre-video day-night task	101.8 (1.5)	100.6 (1.5)	42.0 (1.7)	41. 6 (1.7)
	Video	99.7 (1.4)	97.6 (1.4)	40.3 (1.4)	39.4 (1.4)
	CPT	100.7 (1.6)	99.0 (1.6)	38.6 (1.6)	41.0 (1.6)
	Post-video day-night task	102.0 (1.8)	101.9 (1.8)	44.9 (2.2)	43.8 (2.2)

Heart rate data analysis did not show main or interactive effects of pace or content. However, there was a main effect of task, $F(2.29,368.43) = 6.89$, $p=.001$, $\eta_p^2=.041$ (Figure 5.1.). Pairwise comparisons showed that average heart rate while watching the video was significantly lower than during the pre- and post-video day-night task ($p=.020$ and $p<.001$, respectively) and also significantly lower than during the CPT ($p=.046$). Other pairwise comparisons were not statistically significant.

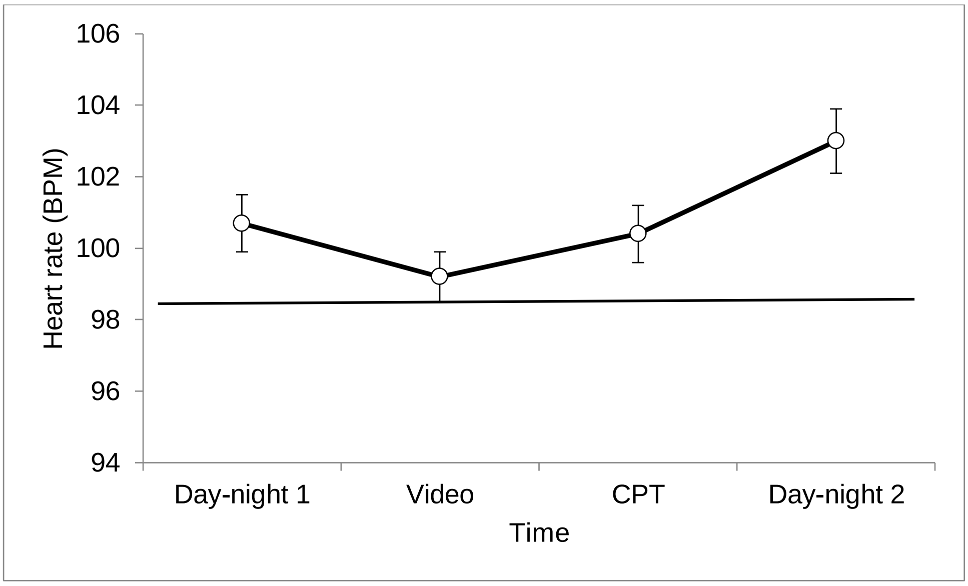

Figure 5. 1. Baseline corrected changes in the children's heart rate during experimental session (dashed line represents the baseline value). Error bars represent SEMs.

The heart rate variability data analysis did not reveal main or interactive effects of pace or content. There was, however, a main effect of task, $F(2.24, 360.45) = 3.79$, $p=.019$, $\eta_p^2=.023$ (Figure 5.2.). Follow-up pairwise comparisons showed that heart rate variability was higher during the post-video day-night task than whilst watching the video ($p=.009$) and during the CPT ($p=.013$). Other pairwise comparisons were not statistically significant.

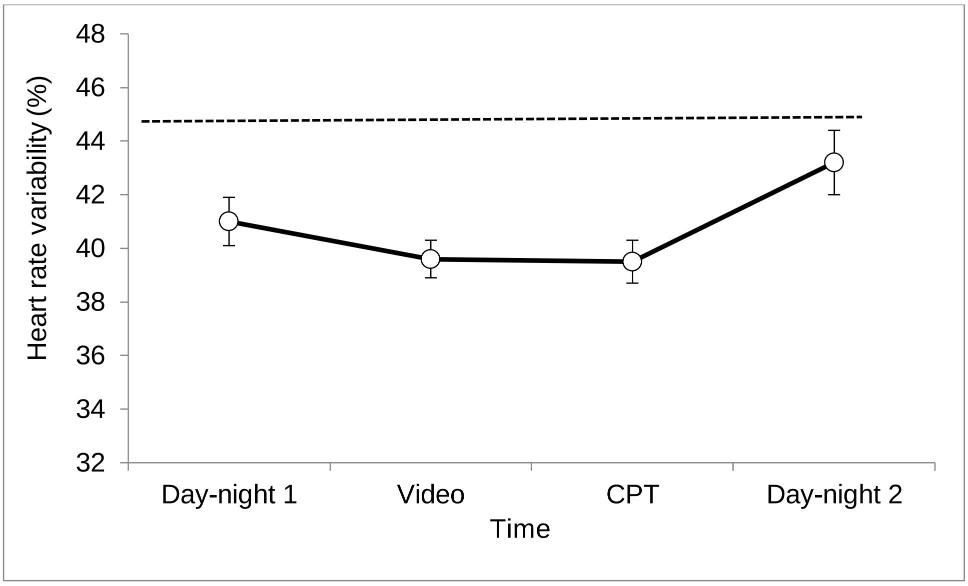

Figure 5. 2. Baseline corrected changes in the children's heart rate variability during the experimental session (dashed line represents the baseline value). Error bars represent SEM.

Table 5.2. shows the summary of regression analysis results. Regression analysis of the pre-video day-night task showed that the first model (including age and gender) accounted for 6% of the variance in performance, with age being the only significant predictor. Adding the baseline and the pre-video day-night task heart rate variability did not improve the model (p=.336). Moreover, the analysis of the post-video day-night data task showed that neither of the models was significant (ps>.05). The only significant predictor of performance was age. Together, these data suggest that increase in age was associated with improved performance on the day-night task.

The regression analyses of the indices of attention measured by the CPT revealed the following pattern of findings. For the reaction times data, the first model (including age and gender) was significant and accounted for 8% of the variance, with gender being the sole predictor of performance. Inclusion of further variables (Model 2: content, pace; Model 3: baseline HRV and Task HRV) accounted for additional 4%

of variance (2% and 2%, respectively) but it did not improve the models (ps>.05). For the reaction times variability data, the first model (including age and gender) accounted for 17% of the variance in performance. Both age and gender were significantly associated with reaction times variability. Inclusion of the additional variables explained an additional 3% of the variance (Model 2:1%; and Model 3: 2%, respectively) but it did not significantly improve the model. However, heart rate variability during the CPT was significantly positively associated with reaction times variability. Finally, for the commission errors data, the first model (age and gender) accounted for 15% of the variance, with gender being the sole predictor of commission errors. Adding pace and content to the model significantly improved it and accounted for the additional 4% of the variance. In addition to gender, the content of the programme was significantly associated with the number of commission errors. The inclusion of the physiological variables explained 1% of the variance in performance and it did not improve the final model.

Table 5. 2. Linear regression models of child individual characteristics, experimental conditions and heart rate variability values predicting scores on the pre- and post-video day-night tasks and the indices of attention measured by the CPT.

Predictor variable	Pre-video day-night task		Post-video day-night task			RT			RT variability			Commission errors		
	Model 1	Model 2	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Age	.236*	.233*	.182*	.168*	.180*	-.123	-.116	-.113	-.334**	-.331**	-328**	-.130$^+$	-.119$^+$	-.120$^+$
Gender	-.040	-.034	-.027	-.034	-.016	-.268*	-.261*	-.264*	.217*	.217*	.211*	.356**	.363**	.364**
Content				-.138$^+$	-.146$^+$		.097	.090		.015	.021		.145*	153*
Pace				-.019	-.013		.115	.116		-.068	-.058		.127$^+$	.129$^+$
Baseline HRV		-.091			.047			-.159$^+$			-.047			.123
Task HRV		.135			-.137$^+$			.083			.154*			-.024
F	5.00*	3.05*	2.90$^+$	2.20$^+$	2.00$^+$	6.94*	4.45*	3.66*	16.96**	8.66**	6.51**	14.33**	9.10**	6.51**
df	2,159	4,157	2,160	4,158	6,156	2,160	4,158	6,156	2,160	4,158	6,156	2,160	4,158	6,156
R^2	.06	.07	.04	.05	.07	.08	.10	.12	.17	.18	.20	.15	.19	.20

$^+$ p<.10, * p<.05, ** p<.001

Discussion

The present study had two aims: first, was to examine the changes in heart rate and heart rate variability across activities characterised by varied executive and attentional demands and, second, to investigate the associations between the children's performance on these tasks and cardiovascular indices. The findings support our first hypothesis, which predicted that distinct activities would be accompanied by changes in heart rate and heart rate variability. Specifically, the data showed that the children's heart rate was lower during video watching compared to taking part in the day-night task and the CPT. Conversely, there was no significant difference in the heart rate between the CPT and the pre- and post-video day-night tasks. Moreover, the data showed that heart rate variability was lower whilst watching the video and taking part in the CPT compared with the post-video day-night task.

Turning to the second hypothesis, which predicted that changes in the heart rate would be dependent on the editing pace, there was no evidence that watching a fast-paced video was accompanied by a greater decrease in the heart rate compared with watching a slow-paced video. Similarly, the data did not support our prediction about the effects of unrealistic content on children's heart rate variability, as there were no significant differences between the children who were watching the video with realistic and unrealistic content. However, the data provided partial support for our fourth hypothesis. Specifically, there was a positive association between task heart rate variability and CPT reaction times variability.

The results of this study are consistent with the literature, which proposes that tasks, which vary in executive and attentional demands, can be distinguished by a different pattern of cardiovascular adaptation (e.g., Hansen et al., 2003; Luque-Casado et al., 2013; Middleton et al., 1999). Specifically, we found that compared with the laboratory tasks measuring children's attention and executive function, watching a video was accompanied by a marked slowing of the heart rate. These data corroborate the previous findings showing heart rate deceleration during periods of exposure to external stimuli (Casey & Richards, 1988; Lacey & Lacey, 1974; Porges & Raskin, 1969; Richards & Casey, 1991). Moreover, considering the proposal that decrease in the heart rate indexes sustained attention (e.g., Casey & Richards, 1998; Richards & Casey, 1991), these findings suggest that watching videos is effective in maintaining children's attention. This interpretation complements parents' qualitative accounts, which suggest that television and other visual media are very effective in absorbing children's interest. It is also consistent with the proposition that children's engagement with television is maintained by attentional inertia, the putative cognitive "glue" holding together pieces of continuous activity, which was described by Anderson and Lorch as "the attentional response to a somewhat unpredictable, meaningful, dynamic stimulus" (1983, p.25).

Furthermore, contrary to the suggestions that television viewing is cognitively passive and promotes "mental laziness" (Singer, 1980), the heart rate variability data suggest that children actively engaged their cognitive resources during viewing. Specifically, heart rate variability recorded during video watching and the CPT decreased relative to the heart rate variability recorded during the post-video executive task. Such decrease in the heart rate variability has been interpreted in the literature as an index of sustained attention (Hyde & Izard, 1997; Middleton et al., 1999; Suess et al., 1994) and cognitive effort (e.g., Calkins & Keane, 2004; Fairclough & Houston, 2004).

Alternatively, these differences in the heart rate variability may be explained by various demands that the experimental activities put on state regulation. Video viewing is regarded as a pleasurable activity, which does not require much conscious effort. Thus, the lower heart rate variability could have been a result of children's relaxed state during this activity. In comparison, the demanding day-night task, particularly, at the end of the experimental session, might have been stressful and fatigue - inducing, which could have led to an increase in the heart rate variability, as proposed by the state effort literature (e.g., Segerstrom & Nes, 2007; Tran et al., 2009)

In addition to making predictions about task-dependent effects on cardiovascular adaptations, this study also aimed to test whether audio-visual features and the content of the experimental videos would affect children's heart rate and heart rate variability. Contrary to our hypotheses, this study failed to provide evidence that either the pace of editing or the videos' content have an effect on children's cardiovascular responses. It may be that the difference in the editing between the fast- and the slow-paced video was insufficient to elicit a differential heart rate response. In the present study, the average number of edits in the fast-paced videos ranged between 17-19 cuts per minute. In comparison, Lang et al. (2000), who demonstrated the effects of the fast pace on the viewers' heart rate used the videos with a substantially higher frequency of the editing actions. The fast-paced videos used by Lang et al. (2000) had on average 16-23 cuts per minute, whereas the average number of cuts in the *very* fast-paced videos used in their study exceeded 24 per minute.

Turning to the lack of effects of the videos' content, it could be that heart rate variability may not be sufficiently sensitive to index complex mechanisms that are involved in processing of the unrealistic content. Processing fantasy involves making sense out of unexpected events and managing conflicting mental representations and thus may involve engaging several executive functions (Carlson, White, & Davis-

Unger, 2014; Lillard et al., 2015; Pierucci, O'Brien, McInnis, Gilpin, & Barber, 2014; Thibodeau, Gilpin, Brown, & Meyer, 2016). In fact, the correlational literature shows that developmental activities involving fantasy or pretense are associated with several distinct executive functions, for example, inhibitory control, attentional shifting and delay of gratification (Carlson et al., 2014; Pierucci et al., 2014). Although heart rate variability may be reactive to individual executive functions, such as working memory (Hansen et al., 2003; Middleton et al., 1999), it may not be sensitive enough to reflect a host of distinct and potentially interacting components of executive functions.

Finally, the data partially supported our hypothesis about the associations between baseline and task heart rate variability and task performance. Specifically, there was a significant association between greater *task* heart rate variability (i.e., heart rate variability recorded during the CPT) and increased reaction times variability. Greater reaction times variability may be caused by temporary lapses of attention, which are manifested as a subset of very slow responses (Hervey et al., 2006; Leth-Steensen, Elbaz, & Douglas, 2000; Vaurio, Simmonds, & Mostofsky, 2009). Thus, our findings support the proposition that increased task heart rate variability reflects poorer cognitive effort and perhaps also, greater fatigue induced by taking part in a monotonous task (Fairclough & Houston, 2004; Tran et al., 2009).

The importance of the current findings is twofold. First, continuous recording of the cardiovascular data across three activities allowed us to compare attention and cognitive effort during video watching and taking part in the formal laboratory assessment. In agreement with the parental perceptions reported in the qualitative literature, our data suggest that video watching is very effective in absorbing children's attention. Conversely, we did not find evidence that watching videos required little cognitive effort. However, it is important to bear in mind that our interpretation is based on the analysis of physiological *concomitants* and not the *correlates* of the respective activities. Second, correlational findings add to the growing body of literature showing associations between cardiovascular activity and children's cognitive and attentional performance.

A main limitation of the present study is the method used to acquire psychophysiological data. Although the BVP finger sensor is very convenient, it is also less accurate and more susceptible to movement artifacts (Peper, Harvey, Lin, Tylova, & Moss, 2007). Moreover, there was a difference in baseline heart rate and heart rate variability (although the latter was not statistically significant) between the children assigned to the different experimental groups. The children in the fast-paced group started the study with a higher heart rate than the children in the slow-paced group and the children who watched an unrealistic video had higher baseline heart rate variability relative to their peers who watched a video with realistic content. Therefore, despite controlling for baseline cardiovascular scores in the respective analyses, the initial physiological differences may have reduced the effects of that experimental manipulation.

In conclusion, using the continuous recording of the children's cardiovascular data, this study showed task-related differences in attentional and cognitive effort allocation. Specifically, our data showed that, relative to other experimental activities, watching videos was accompanied by a decrease in heart rate and heart rate variability. This suggests that video watching may be very effective in sustaining children's attention and cognitively engaging. Moreover, the present study provided further support for the proposition that cognitive performance is associated with heart rate variability. However, the results also suggested that cardiovascular variables were not sensitive enough to differentiate between varied pace and content of the experimental videos. Thus, this field could benefit from future research using other, perhaps more sensitive, psychophysiological methods.

Chapter Six: Touchscreen Generation: Children's current media use, parental supervision methods and attitudes towards contemporary media

Abstract

The aim of this study was to explore media preferences and use among young children, as well as to obtain information about parental supervision methods and beliefs about media. Ninety parents of 3- to 6-year-olds, recruited from a relatively economically advantaged area in the United Kingdom, completed a media opinion survey. The results show that although traditional television remains the favourite type of media platform among young children, touchscreen devices are gaining in popularity, and may promote simultaneous multi-screen use. Moreover, parents believe that the effects of media on developmental outcomes are generally positive. However, they do monitor the content of traditional and new media their children are exposed to. This study shows an emerging evidence of concurrent multi-screen use among very young children. More detailed examination of early media multitasking, and its relationship to cognitive and behavioural outcomes, is necessary.

Introduction

There is no doubt that the rapid development of digital technology has changed how we communicate, work and spend our free time. Although many would agree that easy access to multifunction digital devices, such as smartphones or tablets, and high-speed Internet has improved our lives, brought about more freedom, and saved the time needed to complete many daily tasks, very little is known about the impact that modern technology has on adult cognitive and psychosocial functioning. Even less is known about how digital environment will influence developmental outcomes.

In ‘Western’ culture, today’s older children and adolescents are undoubtedly *digital natives* – children, for whom digital technology is fundamental to daily routine (Prensky, 2001). Their environment is saturated with electronic devices (Rideout, 2013) and children appear to fully embrace opportunities provided by new technology to reduce boredom and to allow efficient use of their leisure time (Jago, Sebire, Gorely, Cillero, & Biddle, 2011). However, there is a paucity of research that addresses the extent of new media use among younger children (< 6 years) and the effects of the digital environment on how they play, learn and interact with others. Traditionally, research has focused on the effects of television on the developmental outcomes, with a particular interest in how television viewing relates to learning, attention and behaviour. Many researchers and clinicians have expressed concern about the potentially deleterious effects of heavy television exposure or viewing inappropriate content (AAP, 2016; Christakis et al., 2004; Conners-Burrow et al., 2011). However, over 40 years of research has failed to provide consistent conclusions about the long-lasting impact of viewing on children’s behaviour and cognition.

Considering that today's youngest digital natives are exposed to a rich multimedia environment on a daily basis, it is questionable whether traditional, single-screen television viewing remains a favourite childhood pastime. Previous literature suggests that adolescents and young adults are extensive media multitaskers, who constantly access single or multiple digital platforms to engage with parallel media activities (Courage, Bakhtiar, Fitzpatrick, Kenny, & Brandeau, 2015; Jago et al., 2011; Ophir, Nass, & Wagner, 2009; Rideout, Foehr, & Roberts, 2010). At the centre of young people's multitasking activity is a computer, a *meta-medium* that allows the simultaneous use of several media streams (e.g., film, text, music) and constant switching from one activity to another (Wallis, 2010). Very young children may lack cognitive and motor skills required to use a computer or operate a keyboard and mouse successfully. However, easy-to-use touchscreen devices such as tablets and smartphones that afford the same multitasking functions may provide a suitable alternative platform to engage in media multitasking from a very young age.

Tablets are becoming increasingly prevalent among preschool children. In the UK, 53% of 3- to 4-year-olds use a tablet at home, with one in seven preschoolers owning their own (Ofcom, 2015). Moreover, qualitative findings show that, unlike TV viewing that usually occurs at set times, young children's touchscreens use is irregular yet frequent (Bentley et al., 2016). However, no quantitative research investigates whether the availability of these devices affects children's media use. Commercial adult media research suggests that touchscreens do not replace but are used in conjunction with traditional screen viewing. For example, 84% of tablet/smartphone owners use these devices for other activities (e.g., web surfing, games, messaging) while they watch TV (Demeritt, 2016). One way, in which children learn behaviour, is the observation of others (Bandura, 1971). Thus, young children who have access to or own a tablet or a smartphone may model their behaviour on their parents or older sibling screen use and engage in a similar form of media multitasking.

However, a decision whether a child can have a tablet, and how she can use it, depends on a parent. Ultimately, parents shape children's home environment, and parents' rules and supervision practices are strong predictors of how much children engage with digital devices (Rideout et al., 2010). Nathanson (2001) proposed three ways in which parents monitor their children's media exposure. "Active" supervision requires parents to discuss media content with children. In contrast, "restrictive" supervision imposes rules relevant to the amount of content or exposure. Finally, "coviewing" involves watching a programme with a child. These different forms of monitoring allow parents to control and shape their children's digital environment across the key domains of media exposure (i.e., content, amount and context). However, their implementation is contingent on parents' beliefs about media effects (Vandewater, Park, Huang, & Wartella, 2005), as well as family factors that may either facilitate or hinder the use of these practices (Jago et al., 2016). Specifically, the literature suggests that, on the one hand, parents seek information about age appropriateness and content of films and electronic games, and comply with industry-imposed ratings (Gentile, Humphrey, & Walsh, 2005). On the other hand, they are reluctant to observe paediatricians' recommendations to reduce children's screen time (Hinkley, Salmon, Okely, Crawford, & Hesketh, 2012) or may even disagree with such advice (Vittrup, Snider, Rose, & Rippy, 2016).

Qualitative research provides some explanation for inconsistencies in parents' approach to supervising children's screen use. Typically, parents use screen devices when occupying children with alternative activities is more challenging, such as, for example, when doing housework or in busy public or constrained spaces (e.g., in a doctor's waiting room, in a car etc.). Moreover, screen devices are used as means of reward and punishment or conflict reduction (Bentley et al., 2016; Jago et al., 2016). Parents also believe that digital media may be beneficial to children's cognitive and social development. For example, educational programmes and games are seen as a good source of learning opportunities (Bentley et al., 2016), whereas video calling applications allow face-to-face communication with extended family (Holloway et al., 2014). Finally, contrary to the concerns about children's media exposure expressed by childhood experts (AAP, 2016), parents believe that, in general, traditional media, such as, for example, television and computers, have a positive role in children's development and that early involvement with technology is beneficial for their children's prospective school achievements and employment (Bentley et al., 2016; Vittrup et al., 2016).

In sum, parental attitudes towards technology and supervision practices appear to play a vital role in determining how children use screen media at home. However, much of the evidence comes from the studies that were either conducted before the rapid expansion in use of touchscreen devices or are qualitative and thus, do not allow exploring the associations between measured variables. Therefore, the overarching goal of this study is to gain more insight into the major domains (i.e., children's and parents media use, supervision methods and knowledge and beliefs about popular media) that shape the family media environment using quantitative methods. Specifically, the first aim of this study is to document young children's (<6 years) current media preferences and use. The second aim is to examine whether young children engage in simultaneous multi-screen activities and whether early ‘multitasking’ with media is related to the use of touchscreen devices. The final aim is to investigate parents’ monitoring methods and beliefs about contemporary media.

Study 6

Method

Participants.

The study was approved by the local Ethics Committee. Before the study began, parents had received a letter providing information about the project and contact details of the Principal Investigator. Participants were 90 parents of 3-6-year old children (boys, n=46; girls, n=39; a further 6 participants failed to provide information about gender); 9% of respondents were fathers. Children’s mean age was 4.23 years (SD= 0.78). Information about parents’ education is provided in Table 6.1. Although the data regarding participants’ ethnicity and income were not collected, the sample was recruited from preschools and schools predominantly attended by children from White middle- to high-income families.

Table 6. 1. The highest level of education reported by parents.

Qualifications level	**Highest educational level (%)**	
	Mother (n=84)	**Father** (n=77)
GCSEs, BTEC and lower level vocational qualifications	34.4	42.2
A-levels and intermediate vocational qualifications	35.6	17.8
Diploma in higher education or a university degree	23.3	25.6
Missing information	6.7	14.4

Materials.

A self-reported questionnaire adapted from Funk, Brouwer, Curtiss, and McBroom (2009; see the Appendix) contained questions about parents' level of education and media habits, child's age and gender. Furthermore, parents answered questions regarding their children's media preferences and media use, media supervision methods, and beliefs about the effects of media on developmental outcomes.

Children's media preferences and media use.

To measure opinion of their children's media preferences, participants were asked to rate the popularity of six common screen media platforms (TV, DVD, computer, tablet, game console and smartphone). Further, three items measured how much time children spent in an average week on watching TV and films, using a tablet &/or a smartphone and using a computer. In addition, parents rated the frequency of their child using a tablet to watch TV and films, play entertainment games and access educational applications (apps). Finally, to assess multi-screen use, parents were asked to rate how often their child simultaneously used more than one screen device.

Parents' media use.

Parents' entertainment media use was assessed with two items that measured how often participants watched TV/films and played tablet/smartphone games.

Supervision methods and ratings familiarity.

Two questions, each comprising of four items, examined *the ways* (i.e., different forms of co-viewing and/or restrictive supervision based on, for example, industry ratings), in which parents supervised children's media content. The first question assessed how parents monitor the appropriateness of TV programmes and films and the second assessed monitoring of games and apps. Further, four items were used to assess *the strictness* of supervision in relation to traditional and new media content. Specifically, two items assessed how strictly parents monitored the content of television/films watched by a child and games/apps played by a child (i.e., *foreground* exposure to media). Further two items assessed how strictly parents monitored the content of TV/film and games/apps played *in the background* when a child was present in the room. Finally, one item measured whether parents monitored the overall amount of screen time. Familiarity with industry ratings for media content was assessed with two items.

Parents' beliefs about popular media.

Two questions investigated parents' beliefs about the effects of popular media. The first question measured how parents perceived the severity of four media features that were understood to be deleterious (i.e., inappropriate language, inappropriate behaviour, violent content, fast editing pace). The second question measured parents' perception of the potential positive and negative effects that different features of media might have on children.

Procedure

Two hundred and ten questionnaires were distributed to parents of 3- to 6-year-old children attending two primary schools and four preschools in a semi-rural county of England. Parents completed the questionnaires at home and returned the forms to the school office or a preschool manager. The schools and preschools assisted in the data collection process by sending text message reminders to eligible parents. The final response rate was 43%.

Results

Children's media use and media preferences.

Adopting the procedure employed by Funk and colleagues (2009), children's average weekly media use was calculated by taking the mid-point of each response option, on a scale ranging from 0 to 15 hours. On average, children spent 13.42 hours per week using different types of media, and most time - 8 hours per week - was spent on watching television and DVDs (see Table 6.2). Independent-samples t-test was used to test gender differences in media use. The results showed that boys used tablets/smartphones significantly more than girls, $t(82) = -3.45$, $p=.001$, 95% CI: -3.56 to -0.96 and there was a trend (not significant) for boys to use more media overall, $t(82) = -1.88$, $p=.064$, 95%CI: -5.19 to 0.15.

Table 6. 2. Children's weekly media use (hours per week).

	TV/DVD		**Tablet/ Smartphone**		**Computer**		**Total**	
	Mean	***(SD)***	***Mean***	***(SD)***	***Mean***	***(SD)***	***Mean***	***(SD)***
All children	8.00	(3.75)	3.98	(3.35)	1.44	(2.80)	13.42	(6.19)
Girls	8.30	(3.54)	2.60	(2.43)	1.00	(2.12)	11.90	(4.74)
Boys	7.70	(3.98)	4.90	(3.41)	1.80	(3.34)	14.40	(7.13)

Figure 6.1. shows a detailed breakdown of children's media preferences (rather than use), estimated by parents. The results of a one-sample t-test (test value = 3, which represents 'neutral' on the response scale) show that television, tablet and DVD mean ratings appear on the 'most favourite' side of the scale, $t(89)=10.52$, $p<.001$, 95%CI: 0.86 to 1.26; $t(88)=4.01$, $p<.001$, 95%CI: 0.22 to 0.67 and $t(87)=3.96$,

p<.001, 95%CI: 0.28 to 0.82, respectively. Moreover, the results of a paired-samples t-test show that, compared with tablets and DVDs, television remains the favourite type of media platform among this age group, $t(88) = 2.76$, $p = .007$, 95%CI: 0.14 to 0.85 and $t(87) = 4.68$, $p < .001$, 95%CI: 0.34 to 0.86, respectively. Finally, the results of a paired-samples t-test reveal that tablets are as favoured as more traditional DVDs, $t(87) = -.54$, $p = .568$.

Conversely, the three remaining media platforms: computer, game console and smartphone have mean ratings on the 'least favourite' side of the scale, $t(80) = -4.49$, $p < .001$, 95%CI: -0.93 to -0.36; $t(83) = -6.12$, $p < .001$, 95%CI: -1.21 to -0.62 and $t(83) = -4.96$, $p < .001$, 95%CI: -0.90 to -0.38, respectively. Therefore, it is reasonable to conclude that they are relatively unimportant/infrequently used by 3- to 6-year-olds. Consequently, preference ratings for these platforms were excluded from any further analyses.

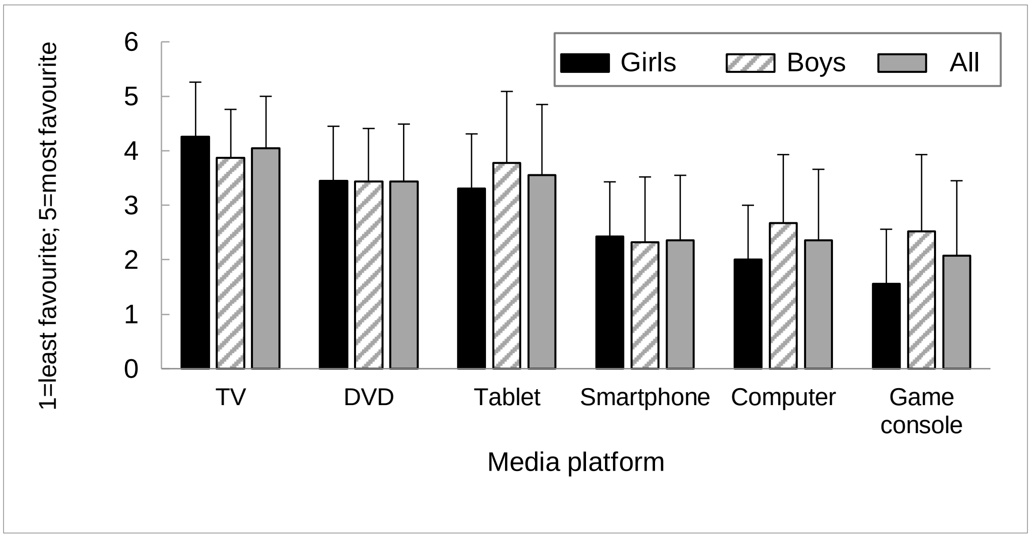

Figure 6. 1. Children's media preferences by platform. Error bars represent standard deviations.

Finally, children's use of tablets was explored (Figure 6.2.). Most frequently, children used tablets to access educational games and apps, followed by playing entertainment games. Conversely, children rarely used tablets to go online. The results of the one-way ANOVA showed that compared with girls, boys used tablets significantly more often to play entertainment games, $F(82) = 8.46$, $p=.005$ and to access educational apps/games, $F(81) = 4.45$, $p=.038$.

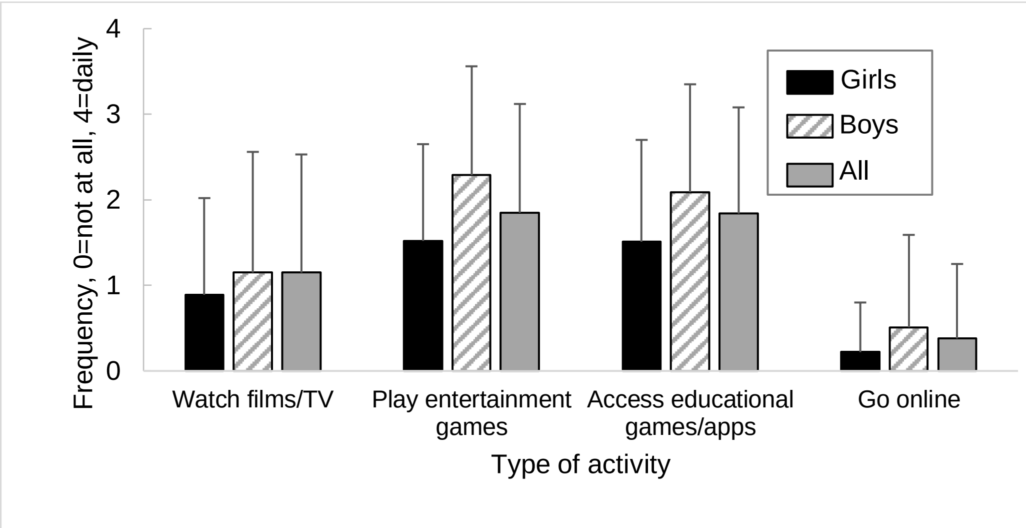

Figure 6. 2. Children's frequency of tablet use for various media activities. Error bars represent standard deviations.

Children's media 'multitasking'.

Over 40% of children in the sample have concurrently used more than one screen device. This breaks down into 23.0% multitasking rarely, 17.8% multitasking sometimes, and just 3.3% multitasking often. There was no significant difference in the frequency of multitasking between boys and girls, $t(82) = -1.30$, $p=.196$. Controlling for child characteristics (i.e., age and gender), multi-screen use was positively associated with the amount of time children spent using *touchscreen devices* ($\beta=.396$, $p<.001$). However, neither the amount of television nor the amount of computer use predicted multitasking. Similarly, entering preference rating scores for the three most favoured media platforms into a regression model showed that a preference for a tablet was positively associated with media 'multitasking' ($\beta=.271$, p=.012), whereas the preference for television and DVDs was unrelated to multi-screen use (both p>.05). These results support our prediction that a preference for tablets and the use of tablets is crucial for early years media multitasking.

Parents' media use.

To assess parents' pattern of media use for entertainment purposes, the parents reported how often they played tablet/mobile games and how often they watched television and films. The frequency ratings of tablet/mobile games use fell on the 'never or hardly ever' side of scale, whereas the frequency of television and film watching fell on the 'often' side of the scale. The results of the paired-samples t-test indicated that, compared to playing tablet/mobile games, parents watched television significantly more frequently, $t(86) = -13.39$, $p<.001$, 95% CI: -1.11 to -0.82.

Media supervision methods and familiarity with the industry ratings.

Figure 6.3. shows that parents mostly rely on industry ratings to judge whether television programme/film or a game/app are appropriate for their child; and they do so equally for monitoring traditional television as well as the new media (i.e. digital games and apps). However, parents' familiarity with the ratings of conventional and new media is not the same (Table 6.3.). Parents appear to be confident in their understanding of television and film ratings; over 70% are 'very familiar' with the ratings. In contrast, only 30.7% of parents are 'very familiar' with the ratings of games and apps and 17.0% are 'not familiar at all'. The results of the paired-samples t-test confirmed that parents are significantly less familiar with the ratings for games and apps than they are with the ratings of television programmes and films, $t(87)=8.10$, $p<.001$, 95% CI: 0.72 to 1.20.

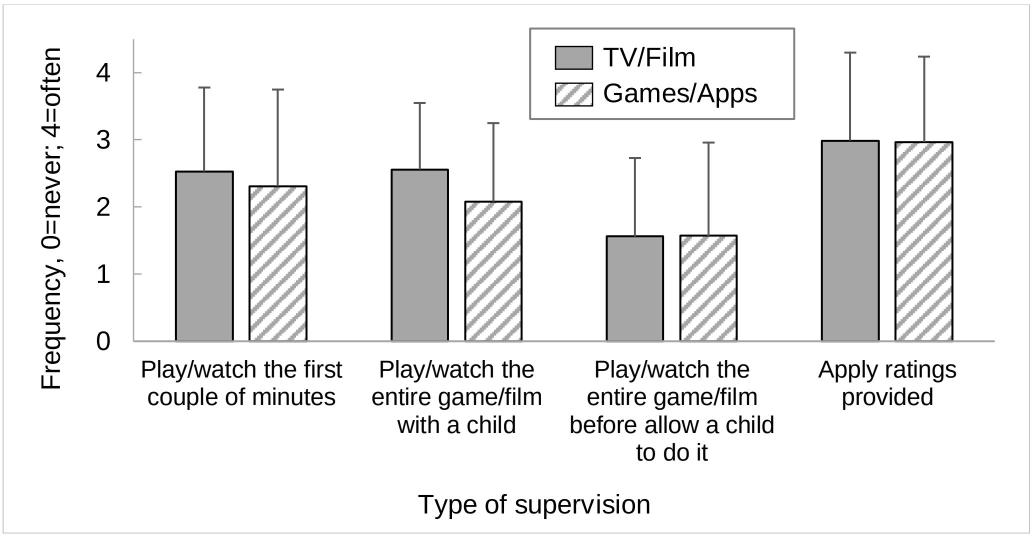

Figure 6. 3. Parents' media supervision methods. Error bars represent standard deviations.

Table 6. 3. The frequencies of parents' familiarity with industry ratings for traditional and new media.

Familiarity rating	Television and film (%)	Games and apps (%)
Not familiar at all	0.00	17.00
Vaguely familiar	5.60	25.00
Quite familiar	20.00	27.30
Very familiar	74.40	30.70

In order to determine which parental characteristics are associated with ratings familiarity, two regression models were built. In a model in which TV ratings familiarity was the outcome variable (controlling for maternal and paternal education) the frequency of television watching was not a significant predictor (β= .046, p=.702). Conversely, games/apps ratings familiarity was positively associated with the frequency with which *parents* played digital games (β= .283, p= .017).

Finally, Figure 6.4. presents how strictly parents supervise children's media exposure. The results of a one-sample t-test (test-value = 2, which represents 'moderately' on the response scale) show that parents' mean monitoring ratings of *foreground* content of TV/films and games/apps fall on the 'strictly' side of the scale, $t(89) = 9.04$, $p<.001$, 95%CI: 0.43 to 0.68 and $t(85) = 9.58$, $p<.001$, 95%CI: 0.46 to 0.70, respectively. Similarly, the mean ratings of *background* TV/films and games/apps content monitoring appear on the 'strictly' side of scale, $t(88) = 6.16$, $p<.001$, 95%CI: 0.32 to 0.64 and $t(84) = 6.50$, $p<.001$, 95%CI: 0.34 to 0.64, respectively.

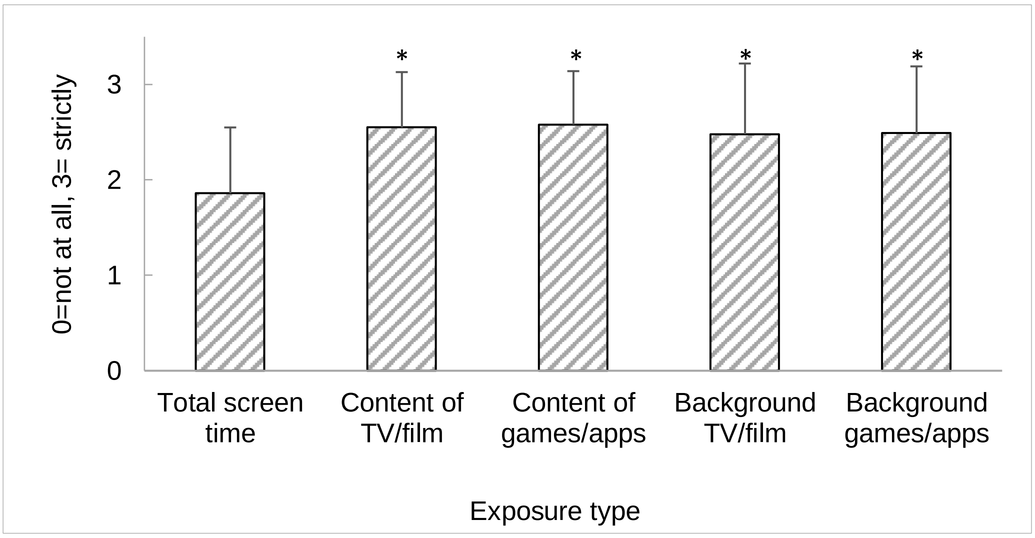

Figure 6. 4. The strictness of media supervision. Error bars represent standard deviations (*denotes where mean ratings were significantly different from the test-value of 2).

Conversely, the overall amount of screen time is monitored 'moderately', as the mean ratings were not significantly different from the test-value of 2, $t(88)=-1.83$, $p=.070$. In addition, pairwise comparisons between four content variables (i.e., foreground TV/film, foreground games/apps, background TV/film, background games/apps) show that parental monitoring of content is equally rigorous for all (all p-values >.05).

Parents' beliefs about popular media.

When asked to rate the *severity* of various features of television and film that are thought to be detrimental to young children's development, parents seem most concerned about the violent content (Figure 6.5.). The results of the paired-samples t-tests show that, compared to inappropriate language, inappropriate behaviour and fast pace, violent content was rated as the most harmful, $t(89) = -6.02$, $p<.001$, 95%CI: -.63 to -.32; $t(89) = -4.09$, $p<.001$, 95%CI: -3.5 to -1.2, and $t(74) = 10.85$, $p<.001$, 95%CI: 1.11 to 1.61, respectively. Conversely, compared to inappropriate language and behaviour shown on the screen, parents appear to be least concerned about the effects of fast editing pace, $t(74)=7.63$, $p<.001$, 95%CI: 0.65 to 1.11 and $t(74) = 9.92$, $p<.001$, 95%CI: 0.88 to 1.33, respectively. Interestingly, 16% of parents did not rate how harmful the editing pace was, some leaving a question mark as a response.

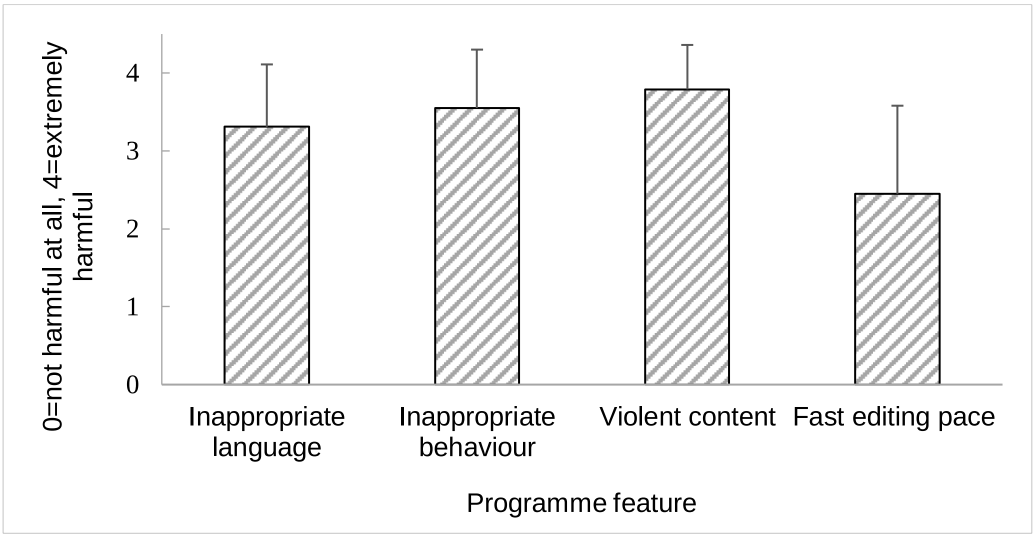

Figure 6. 5. Ratings of severity of harmful programme features. Error bars represent standard deviations.

Finally, parents expressed their beliefs about the effects of the popular media on children's development (Figure 6.6.). The results of a one-sample t-test (test-value = 2, which represents *'somewhat negative'* on the response scale) show parents believe that: (1) overall, the effects of popular media on children's development are somewhat positive, $t(85) = 10.61$, $p<.001$, 95% CI: 0.83 to 1.22; (2) the effects of watching fast-paced programmes are somewhat negative, $t(83) = 1.89$, $p=.063$; (3) the effects of watching educational shows are positive, $t(88)=39.12$, $p<.001$, 95%CI: 2.24 to 2.48; and (4) the effects of watching violent content are very negative, $t(88) = -16.90$, $p<.001$, 95%CI: -1.82 to -1.44.

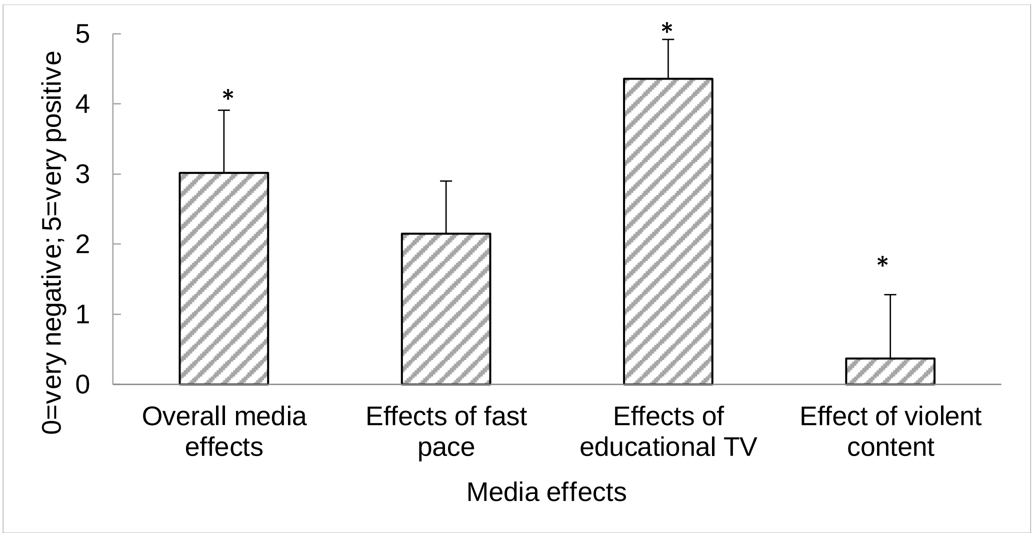

Figure 6. 6. Parents' beliefs about developmental effects of popular media. Error bars represent standard deviations (*denotes where mean ratings were significantly different from the test-value of 2).

Discussion

The aim of this study was to explore and document children's current media preferences and media use. Moreover, we set out to establish if young children (<6 years) engaged in concurrent multi-screen use and whether early years media 'multitasking' was related to a preference for new touchscreen media, for example, tablets. Finally, this study examined how parents supervised their children's media use and their beliefs about the impact of media on developmental outcomes.

Consistent with the previous literature (Gutnick, Robb, Takeuchi, & Kotler, 2010) 3-6-year-olds still prefer television to the newer forms of media. The average amount of weekly television viewing reported by parents in this study appears similar to the amount reported by Funk and colleagues (approximately 8 hours; 2009). However, the overall weekly media consumption is higher; 13.42h per week vs. 12.14h reported by Funk et al. (2009). Moreover, based on parental estimation, tablets have become equally as preferred as more conventional DVDs. Further evidence that young children's media preferences and consumption patterns might be changing is supported by the finding that over 40% of children's reported weekly media time is spent on using digital platforms such as tablets and smartphones and - to a lesser extent - computers. Importantly, this study found an emerging evidence of simultaneous multi-screen use among very young children. Moreover, media 'multitasking' was positively related to children's preference for tablets and the use of tablets/smartphones. It appears that the availability of small touchscreen devices that allow for most of the content to be accessed directly from the home screen with a simple touch or a swipe of a finger (Holloway et al., 2014), facilitates engaging with multiple media streams even at a very young age.

Currently, very little is known about the relationship between media multitasking and cognition. The literature is scarce and presents inconsistent results. For example, some findings point to the detrimental effects of frequent multitasking on the performance in laboratory tests of executive function (Ophir et al., 2009), and a negative relationship between multitasking and self-reported cognitive functioning (Baumgartner, Weeda, van der Heijden, & Huizinga, 2014). Conversely, other studies failed to support the findings that heavy media multitasking is related to poor cognitive performance (Minear, Brasher, McCurdy, Lewis, & Younggren, 2013), or even provided evidence for a positive relationship between media multitasking and the ability to integrate information from multiple sensory systems (Lui & Wong, 2012).

Although there is no convincing evidence for the deleterious effects of multitasking, the changes in children's media preferences and the simultaneous use of the several media streams pose a challenge for parents' supervisory practices. The findings from this study show that, mostly, parents rely on industry ratings to judge whether media content is appropriate for their children. However, their self-reported familiarity with the ratings of digital games and apps is poorer compared to their knowledge of television and film ratings. Perhaps this stems from the finding that over 50% of parents in our sample do not play digital games or if they do, it is infrequent. Although it is reasonable to assume that many of the surveyed parents have adopted various aspects of modern technology at work or personal lives, unlike their *digital native* children, they had spent their formative years before a rapid technology expansion, and as *digital immigrants*, have yet to adapt to the changed environment (Prensky, 2001).

The lack of familiarity with games/apps ratings and the cultural divide between *digital natives*, for whom the use of digital media comes naturally and *digital immigrants*, who still need time to get a full grasp of a new digital environment (Prensky, 2001), are not the only challenges related to media monitoring. Undoubtedly, it is much easier to supervise the use of a family television set in the living room than it is to control children's activity on touchscreen devices that are portable and can be easily taken to the bedroom. Anecdotal evidence suggests that despite the availability of parental control setting, four in five parents do not turn it on, which creates the possibility of children accessing inappropriate content. This is of particular importance, as past research into the relations between television viewing and children's cognition and behaviour suggests that content, rather than the amount of media, is a stronger predictor of developmental outcomes (Conners-Burrow et al., 2011; Linebarger et al., 2014). Moreover, parents appear to be the least concerned about the amount of time their children spend in front of various screens than they are about harmful foreground and background content. Yet, the simultaneous use of several media platforms could mean that the overall amount of media exposure is much higher than what parents perceive to be the appropriate amount for their children. For example, older children manage to fill 7.38 hours physically spent in front of screens with over 10 hours of media content (Rideout et al., 2010).

Finally, the findings from this study show that parents' ratings of harmful media features mostly mirror the concerns of researchers and clinicians. Parents consistently rated violent content and inappropriate language/behaviour presented on the screen as very harmful. However, despite the recently increased interest among media researchers in the effects of fast editing pace on children's attention and executive function (Cooper et al., 2009; Lillard & Peterson, 2011), it appears that many parents may be unaware of the suggestions regarding the potentially deleterious effects of fast pace made in the scientific literature. Alternatively, it may be difficult for parents to objectively quantify what constitutes a 'fast' editing pace and, in consequence, their responses could be biased. Nevertheless, perhaps parents should be made aware of the experts' concerns regarding the potentially harmful effects of exposure to rapidly edited material to allow them to make more informed choices about their children’s media diet.

Although the data reported in this chapter are exploratory in nature, they are important as they point to the evidence of the new type of screen behaviour emerging among 3- to 6-year-olds. It appears that children begin to engage in simultaneous multiple screen use at a very young age, which may influence their cognitive functioning and poses challenges to parental supervisory practices. Yet, the findings from this study are limited by a relatively small number of responses and ethnically non-diverse (White) sample. Moreover, the area from which participants were recruited represents one of the most advantaged locations in the United Kingdom ("English Indices of Deprivation," 2015). Finally, multi-screen use was assessed with a single question, which only allowed a glimpse into children’s behaviour. Further, more thorough, investigation of young children’s media habits is necessary to make more robust inferences.

In summary, this exploratory study documented current media habits of 3- to 6-year-old children. The findings suggest that traditional television remains the favourite type of media platform among this age group. However, new touchscreen devices, such as tablets, are gaining in popularity and facilitate children engaging in multiple screen use, which may create new challenges for parental media supervision methods. Conversely, parents appear to use the new media platforms infrequently (at least for entertainment purposes) and are less familiar with industry ratings for digital games and apps than they are with film and television programmes ratings. Finally, future studies should carry out a more detailed examination of concurrent multi-screen use among pre-schoolers and primary school children to gain a better understanding of its relationship to cognitive and behavioural outcomes.

CHAPTER SEVEN: General Discussion

General Discussion

This thesis examined the immediate effects of watching videos on children's attention and related cognitive processes. This chapter will briefly review Chapter One and summarise and discuss the empirical research reported in Chapters Two to Six. It will also address the limitations and propose ideas that could further advance this field of investigation.

Summary of Research.

Chapter One presents the findings of a systematic review of the 76 studies reporting the associations between exposure to television and children's attention, academic achievement, cognition, language and play. The findings from this comprehensive review highlight that television viewing cannot be treated as a unitary activity; for example, the content, editing pace, and even the type of exposure (i.e., foreground or background) may affect developmental outcomes. Moreover, a host of variables, such as individual child's characteristics, family and social context may mediate the relationships reported in the literature. Finally, there is no robust evidence to suggest that these associations are unidirectional (i.e., that television exposure "precedes" the outcomes) or are stable over time.

Chapter Two reports the results of Experiment 1 that aimed to examine whether exposure to a short video affected the natural behaviour of 2.5- to 4-year-old children. Specifically, of interest were the effects of the differential editing pace (fast vs. slow) on children's distractibility, which was operationalised using the number of shifts between toys during play. Participants assigned into pairs took part in two unstructured play sessions. In between these sessions, the children watched either a fast- or a slow-paced experimental video. Pre-video the children's behaviour was similar across the experimental groups; however, post-video, the children in the fast-paced group changed toy more frequently relative to their peers in the slow-paced group. These data suggested that exposure to the differently paced videos altered children’s natural play behaviour. That is, watching a fast-paced video resulted in greater distractibility and less goal-directed behaviour.

Experiment 2, reported in Chapter Three, sought to extend these findings by investigating whether children’s performance on a go/no-go task was affected by the editing pace. Moreover, to my knowledge, this was the first study to use EEG to examine the effects of pace on cortical mechanisms underpinning inhibition (a principal component of executive function). Seven-year-old children watched either a slow- or a fast-paced experimental video and immediately after completed a go/no-go task (the Sustained Attention to Response Task – SART), during which their electrophysiological activity was recorded. Exposure to the fast-paced video temporarily decreased accuracy on no-go trials. Moreover, the neural activity involved in inhibition during the no-go trials of the SART was modulated by the video’s pace. Specifically, differences were observed in the timing of N2 and P3 ERP components (both of which are proposed to reflect internal inhibitory processes). Only for the slow-paced group did these components peak in the typical manner. In light of the behavioural data showing that this group also made fewer no-go errors in the first half of the SART, these ERP findings are consistent with the literature suggesting that the timing of N2 and P3 activation may be crucial for successful inhibition. More importantly, the data from this experiment indicate that both overt and internal inhibitory processes are susceptible to the effects of the video’s editing pace.

The experiments reported in Chapter Four aimed to unravel the effects of video pace and content. Experiment 3 introduced a new experimental protocol, in which 4-

and 5-year-old children took part in a test session comprising of a pre-video inhibitory control assessment, followed by watching one of the two differentially paced commercial television programmes (fast vs. slow), then a continuous performance test (CPT) and finally, the repeated inhibitory control assessment. The findings showed that watching a slow-paced story-like programme improved the immediate inhibitory control of 4-year-olds. However, the presence of many confounding features, which are inherent to commercial programming, prohibited attributing this positive effect of watching television to one particular feature of the programme, namely its slow editing pace.

Thus, Experiment 4 sought to replicate these findings using experimental videos, which manipulated the editing pace, while strictly controlling the content. Further, to examine a recent hypothesis formulated by Lillard et al. (2015), which proposes that exposure to unrealistic content has detrimental effects on children's executive functions, the video content (realistic vs. unrealistic) was also manipulated in this experiment. Inhibitory control data showed that regardless of the pace, watching the videos with unrealistic content improved children's executive performance. Moreover, pace interacted with content to affect children's attention. Specifically, after watching the fast-paced video, children made faster responses on the CPT, but only when the content was realistic. This was interpreted as evidence of inadequate attention deployment. Together, the results from Experiments 3 and 4 suggest that a video's content, as well as its pace, affect the inhibitory component of children's executive function. Moreover, certain types of content might attenuate the potential detrimental effects of exposure to the fast pace.

Chapter Five reports the findings from Experiment 5 further explored the effects of video on children's cognition. Cardiovascular activity (heart rate and heart rate variability) was measured while watching videos relative to taking part in the assessments of attention and of inhibitory control. Moreover, this experiment sought evidence whether attention and cognitive effort, indexed by changes in heart rate and heart rate variability, depended on the video's pace and content. Finally, a relationship between heart rate variability and task performance was also investigated. Heart rate and heart rate variability had been continuously recorded while testing the participants of Experiment 4. The results showed that compared to the CPT and both the pre- and the post-video inhibitory control assessment, heart rate was lowest whilst watching the video. Moreover, heart rate variability during the post-video day-night task was high relative to video watching and taking part in the CPT. These data suggest that videos efficiently capture children's interest and that watching video is perhaps not as cognitively passive, as previously suggested. However, the cardiovascular variables were not sensitive enough to discriminate between the videos' variable pace and content. With regard to correlational findings, higher heart rate variability recorded during the CPT was positively associated with reaction times variability, which supported the findings of the literature showing links between psychological performance and physiology. This study concluded the experimental investigation of the effects of video exposure on children's attention and cognition.

The study reported in Chapter Six was motivated by the shift in the contemporary media landscape, characterised by the ubiquitous presence of touchscreen devices. Specifically, this study employed a parental survey to document 3- to 6-year-old children's media preferences and use, as well as to obtain information about parents' media monitoring methods and their opinions about the effects of popular media. The results showed that although children under-6 preferred traditional television to other types of media, touchscreen devices are gaining popularity. Moreover, this study found evidence of children as young as three simultaneously using more than one screen device. This early form of media ‘multitasking’ was predicted by the children’s preference for and the use of touchscreens. Finally, parents believed that media had positive effects on developmental outcomes and although they strictly supervised the content of the media their children were exposed to, they were more lenient about the amount of exposure.

That concludes the summary of the empirical research reported in this thesis. The following two sections consider the implications of these findings in the context of the past literature.

Video exposure and attention.

The hypothesis proposing that exposure to fast-paced television could lead to problem behaviour characterised by children’s hyperactivity and poor attentional control is now 40 years old. In fact, it had been developed in the late seventies in response to the criticisms of then novel *Sesame Street* expressed by paediatricians and psychiatrists in the non-scientific press (Anderson et al., 1977). However, initially, empirical evidence that could support this hypothesis was very limited. The paucity of data did not prevent the construction of theories suggesting that the ‘attention grabbing’ properties of fast-paced programming lead to the excessive arousal (Singer, 1980) and passive but superficial processing of the televised content (Singer & Singer, 1983).

Subsequent research remained limited and thus provided little support for these claims. Although Geist and Gibson (2000) found that the children’s behaviour was more unsettled after watching a fast-paced action-filled cartoon, the findings from other experimental studies were either null (Anderson et al., 1977) or even suggested that the fast editing pace could have some positive effects on children's attentional performance (Cooper et al., 2009). Perhaps this lack of consistent findings could be explained by the differences in the programmes that were shown to the children in these studies. Anderson et al. (1977) and Geist and Gibson (2000) used commercial television shows, which varied not only in the pace of editing but also in content and other visual features. In contrast, Cooper et al. (2009) developed a new experimental paradigm, which ensured that content and these other features were kept constant, so that the only variable manipulated in the experiment was the editing pace.

Research in this thesis utilised and further developed Cooper et al.'s paradigm to carefully match the content and other visual features of the experimental videos, which allowed the formulation of clearer inferences about the effects of the editing pace. Taken together, the findings from this thesis consistently show that children's attention is sensitive to the effects of the variable editing pace.

It appears that exposure to fast-paced videos had adverse effects on the children's natural behaviour during play and on attention measured with a formal laboratory test (i.e., the SART). The findings showing more frequent shifts between the toys during unstructured play (Experiment 1) and more errors on no-go trials (Experiment 2) following exposure to the fast-paced videos are consistent with the data of Geist and Gibson (2000), and suggest that fast pace may lead to greater distractibility and less goal-persistent behaviour. More unsettled behaviour during play and the difficulty in withholding a press on no-go trials could also be a demonstration of poor inhibition, which is typical of ADHD (Barkley, 1997). Thus, the findings from this thesis partially corroborate the results of correlational research discussed in Chapter One (sections on 'Attention problems') showing the positive associations between exposure to television and the presence of attention difficulties and ADHD behaviours (e.g., Christakis et al., 2004; Ebenegger et al., 2012; Miller et al., 2007; Özmert et al., 2002).

However, the findings from Experiment 4 show that the effects of pace on attention may also be moderated by the content of a programme. Specifically, in the absence of cognitively stimulating content, which could engage top-down resources, children’s attention to the programme may be passively maintained by the many cuts and other visually salient changes on the screen. Consequently, children rely on bottom-up processing in subsequent activity, which results in inadequate attention deployment driven by exogenous input from the task stimuli. These findings are important for two reasons: (1) they emphasise the importance of maintaining strict control over the video stimuli – using commercial programmes could have made detecting such nuanced effects impossible; and (2) they highlight the role of video content. Finally, these findings led us to develop the modified passive viewing hypothesis (see General Discussion in Chapter Four), which proposes that the absence of cognitively stimulating content in on-screen material leads to bottom-up processing of the video material.

Further, the psychophysiological data obtained in Experiment 2 are the first to show that the editing pace has also consequences for internal inhibitory processes during sustained attention. Specifically, during the SART, the N2 and P3 ERP components, which play a key role in inhibitory processes, occurred in the typical time pattern (i.e., correct response – earlier component peak; incorrect response – later component peak) only after the children watched a slow-paced video. Conversely, for the children in the fast-paced group, this activation of the cortical processes was atypical. Although these data are exploratory and should be corroborated by a replication before robust conclusions can be drawn, they provide an important addition to literature studying the effects of video exposure on children's attention.

So far, the research in this thesis focused on investigating children's attention *after* watching the videos. In contrast, cardiovascular data obtained in Experiment 5 provided a way of measuring attention and cognitive effort *during* exposure to the videos (for an explanation of the relation between attention and executive function see Figure 4.1. on p.163). This study is the first to provide evidence that watching videos is distinguished from other activities by qualitatively different pattern of physiological response. Despite previous propositions that viewing is cognitively passive (Singer, 1980), these data suggest that children actively engaged their cognitive resources during watching the videos. Moreover, the cardiovascular changes recorded while watching the videos suggest that this activity is very effective in engaging children's attention. The latter finding appears crucial, as Lang (1990) proposed that attention *to* the video material determines whether it does or does not exert its effects on the viewer.

Video exposure and executive function.

In addition to measuring children's attention, the protocol developed in Experiment 3 included an assessment of inhibitory control. This change was introduced to account for the proposition of Lillard and Peterson (2011) that fast television pace was detrimental not only to attention but also to children's executive function. The researchers provided evidence that relative to drawing, watching a fast-paced cartoon resulted in poorer performance on a range of executive tasks. Although the data from Experiment 3, which utilised fast- and slow-paced commercial television programmes, failed to corroborate these findings, they suggested that watching slow-paced TV improved children's inhibitory control. However, considering the many other audio-visual and content features that characterised the programme utilised in this experiment, one should be cautious about attributing these positive effects solely to the slow pace.

In fact, the data obtained in Experiment 4, which carefully manipulated both pace and content of the experimental videos, suggest that the editing pace may have limited consequences for inhibitory performance and instead point to the primary role of content. However, contrary to the predictions about the detrimental effects of exposure to unrealistic content made by Lillard et al. (2015) this experiment showed that watching videos with unrealistic content resulted in improved inhibitory control.

This discrepancy in the findings could be explained by the substantial differences in the videos shown to the children in the respective studies. While Experiment 4 used four carefully edited experimental videos, Lillard et al. (2015) used seven different children's television programmes. This methodology introduced a substantial variability, not only in editing and the presence/absence of unrealistic events but also in many other content variables. First, the inclusion of seven different children's programmes weakened experimental control rather than, as the authors suggested, improved it. The control programmes used in the study were intended for different ages with target audiences varying from 4 to 7 years. Younger children may have found some of the content incomprehensible. Second, the shows broadly categorised as "educational" varied in the learning concepts and visual form. For example, *Martha Speaks* (fast-paced, high fantasy) aims to teach children complex words. Such content, although educational, may be difficult to process for young children, especially in the backdrop of fast-paced animation. In consequence, it may be that it is the effort required for processing complex concepts, rather than the presence of fantasy, which temporary diminishes children's executive function. Moreover, *Little Einsteins* (slow-paced, high fantasy) is designed to introduce children to art and classical music, and although the rate of scene changes was low, the programme was rich in other audio-visual features (i.e., bright colours, frequent music, characters' loud and excited speech). In contrast, *Little Bill* (slow-paced, low fantasy) is simple in visual form and focuses on conveying messages relevant to personal and social development that may be easier to process and understand. Finally, the rate of unrealistic events considerably varied among the shows, which were broadly categorised as "fantastic". For example, *Sponge Bob Square Pants,* on average, contained nearly four such events per minute of the show, whereas *Little Einsteins* contained just over one even per minute.

Returning to the data from Experiment 4, although the findings showing positive effects of watching unrealistic content on children's inhibitory control are consistent with correlational research showing the positive associations between engagement in fantasy and pretence and the development of executive function in children (Carlson et al., 2014; Pierucci et al., 2014; Thibodeau et al., 2016), it is also possible that improvements in the children's performance were driven by another variable: that is, the consistent and meaningful narrative present in the unrealistic video.

The results of studies with adult participants suggest that processing narrative engages several components of executive function. For example, working memory is essential for maintaining information about the story's events and characters and for consolidation of new information with the knowledge retrieved from the long-term memory (Cain, Oakhill, & Bryant, 2004; Mar, 2004). Moreover, processing of a narrative requires switching between the different characters' goals and mental states and making causal connections between the events unfolding in the story (Zwaan, Magliano, & Graesser, 1995) and thus involves cognitive flexibility. Finally, as control over prepotent responses is required to suppress mental representations of reality during pretend-play (Carlson et al., 2014), inhibitory control may also be crucial for processing of the unrealistic content in the narrative. It is therefore plausible that watching a video with a strong narrative, particularly, when the content was unrealistic activated children's executive processing, which persisted beyond viewing in the subsequent cognitive task and resulted in improved inhibitory control performance.

It may appear surprising that watching the videos affected the children's performance on the day-night task but was not sensitive to the inhibitory demands of the no-go CPT trials. There are two plausible explanations. First, is the impurity of the CPT. This task lacks specificity, and children's performance on this measure reflects a variety of attentional and cognitive processes (Halperin, 1996). Second, the day-night task is an example of a conflict inhibition task; that is, children not only had to *withhold* the inappropriate prepotent response but also *activate* the competing novel response (Montgomery & Koeltzow, 2010). In comparison, the CPT simply required the children to refrain from responding on no-go trials. Thus, the cognitive processing during the day-night task is more like processing of the unrealistic narrative when children had to suppress their knowledge of reality while activating the incongruent fantastic representations of this reality.

In sum, it appears that inhibitory control component of executive function is not affected by the editing pace. Rather, it is the videos' content that has consequences for children's inhibitory performance. However, contrary to the proposition about the adverse effects of exposure to unrealistic content, the findings presented in this thesis suggest that watching videos with elements of fantasy can be beneficial for inhibitory control, at least in the short term.

Applied relevance of the findings.

The broad topic that is the potential effects of media (including video and television) on developmental outcomes is of interest not only to researchers but also to practitioners and parents. Despite the considerable scientific interest in the effects of the editing pace on children's attention and executive function, the results of the parental survey reported in Chapter Six suggest that parents are either not concerned or not aware of the potential consequences of watching the fast-paced programming. Unlike the apprehension about excessive use of media or exposure to inappropriate content, which attract the attention of the public, the researchers' worries about the effects of the editing pace are little known beyond academia. Considering the findings from this thesis, which consistently show that the editing pace has consequences for children's behaviour, perhaps an attempt should be made to inform parents about the potential implications of exposure to the rapidly edited programming. Similarly, an effort should be made to advise parents about the outcomes relevant to exposure to different types of age-appropriate media content.

It appears that the communication between the researchers and parents works in one-way. We ask parents for consent to engage their children in our research projects. We seek their opinions about the popular media and ask to report their children's media use and habits. However, we rarely feed our findings back to parents. Although in many cases, the data are published in the scientific literature, they remain inaccessible to the wider non-academic audience. Current diverse communication platforms offer an excellent way of connecting with parents to communicate the findings and share the knowledge, which could potentially help them make more informed decisions about their children's media use.

Potential limitations

The research presented in this thesis delivered consistent evidence showing that children's attention and related cognitive processes are sensitive to both the detrimental and the positive effects of the videos' editing pace and content. However, it is important to acknowledge the potential limitations of this research.

First, the production of experimental videos restricted the type of available editing features. Utilising our own videos was essential to isolating the effects of the editing pace from the effects of other visual and content features that characterise commercial television programming. Moreover, careful manipulation of pace and content allowed identifying more subtle changes in children's performance, which depended on both unique and interactive effects of these variables. However, the trade-off between increased experimental control achieved by self-produced videos and using real television programmes may have somewhat reduced ecological validity. Commercially produced television programmes utilise a broad range of editing features, including the use of camera shifts, cuts, active motion, flashing images and various auditory effects (McCollum & Bryant, 2003). In comparison, the experimental videos created for use in this thesis relied mainly on two editing techniques to manipulate the pace of editing: that is, camera angle changes and cuts. In an attempt to enhance the visual form of the experimental videos, in Experiment 4 the camera footage was edited together with cartoon images. Although the inclusion of these additional visual features expanded the editing repertoire, it did not allow creating the editing effects permitted by cartoon animation, which dominates children's programming.

Second, even the careful selection of the stories that were subsequently filmed did not eliminate the possibility that other variables mediated the observed effects of the videos on children's performance. For example, in addition to the already discussed differences in the narrative structure, the presence of temporal or spatial discontinuities (i.e., shifts in time and location; Zwaan et al., 1995) in the realistic story or children's prior familiarity with the content could have affected the subsequent performance.

Third, except for Experiment 1, children's attention and inhibitory control were assessed by performance measures in the highly controlled environment. Such an approach to measuring the effects of video exposure resulted in capturing only the very restricted aspects of behaviour. This is particularly at odds with the broad way attention has been conceptualised in the literature and does not permit making inferences about the effects of the videos' pace and content on children's behaviour in the natural environment, which is not controlled by the experimenter (based on the analysis of Toplak et al., 2013). Finally, the research presented in this thesis focused on examining the immediate effects of video viewing. Thus, it is neither possible to establish what are the *cumulative* consequences of the repeated exposure to fast-paced programming nor whether the effects reported in this thesis are long lasting.

Ideas for future research.

The data presented in Chapter Six provide evidence for the increasing popularity of touchscreen devices among young children. Access to small and portable tablets and smartphones has removed the constraints of watching the programming on a traditional screen at a scheduled time and allowed for 'television content' to be accessed online at any time and place. It is not clear yet, whether the possibility to access television and video 'anytime and anywhere', means that children spend even more time on passive viewing. However, it makes it even more important to develop an understanding of the impact that exposure to television and video has on children's development. This section proposes three potential avenues of research motivated by the findings reported in this thesis.

Considering the conflicting findings regarding the effects of unrealistic content on children's executive function, a clear area for future research should be a further investigation of the role of fantasy in television and video content. As already discussed, the differences between the data presented in Chapter Four and the findings of Lillard et al. (2015) could be a result of the different tasks used to assess children's performance. Lillard et al. employed a comprehensive battery of executive function assessments, including both "hot" (e.g., delay of gratification) and "cold" tasks (e.g., working memory, cognitive flexibility, inhibitory control), while Experiments 3 and 4 focused on measuring only one of the core childhood executive functions, namely, inhibitory control. Thus, it may be useful to investigate the possibility that unrealistic video content has a different effect on the different individual components of executive function.

Another interesting avenue of research is motivated by the interpretation of the findings from Chapter Four and refers to the investigation of the effects of the narrative structure and its interaction with editing pace on children's executive function. Processing the text narrative requires concurrent monitoring of temporal, causal and situational components of the story to construct its meaning mentally. Moreover, even realistic prose is not restricted by the laws of nature (Zwaan et al., 1995). For example, an author may employ temporal shifts to represent the protagonist's past story or future plans (Rong, 2011). Therefore, processing of the text narrative may involve not only working memory but also inhibitory control to suppress information that is irrelevant to the current circumstances (Mar, 2004). It might also involve cognitive flexibility to shift between different mental representations of events and characters portrayed in the story.

However, there is a crucial difference between storytelling in print and screen media; the latter is constrained by the length of time. Specifically, screen media have much less time to spend on telling the intricate details of a story and instead use editing techniques to communicate changes in time and location. Yet, there is a downside; using cuts and changes in visual scene could create substantial temporal or spatial discontinuity. Thus, the consistency of the narrative may be the key to overriding the gaps created by cuts between the visual scenes. Strong and meaningful narrative may help the viewer piece together visually discontinuous fragments of a story and improve the comprehensibility of the programme. Conversely, when the narrative is weak and disjointed, the viewer may rely more on perceptual input to infer the meaning.

Two potential research questions arise from this analysis. The first question has already been introduced in Chapter Four, and it refers to the possibility that processing of the narrative in video activates children's executive function not only while viewing but also in the task that follows immediately after. The second question pertains to the interaction between the narrative and the pace of editing; can the presence of a consistent narrative in the video attenuate for the negative effects of fast pace? Future research should therefore investigate the effects of the video narrative processing on children's attentional and cognitive performance.

The last proposed avenue of research is motivated by the findings from the parental survey which showed that children as young as three engage in media ‘multitasking’. Currently, very little is known about the relationship between media multitasking and cognition. The literature is limited and inconclusive. For example, studies that used self-reported measures showed a negative relationship between multitasking and executive functioning (Baumgartner et al., 2014) and everyday attention (Ralph, Thomson, Cheyne, & Smilek, 2014). Conversely, the findings from the studies that used performance-based measures are mixed. Although media multitasking was negatively related to focused attention (Cain & Mitroff, 2011; Yap & Lim, 2013), the associations with executive processes, for example, working memory, inhibitory control and task switching, were not clear (for a review see Van Der Schuur, Baumgartner, Sumter, & Valkenburg, 2015). Most important however, is that these findings come from studies with adult participants. Thus, it is crucial to examine the associations between media multitasking, attention and other cognitive processes in children.

Final conclusion.

The research described in this thesis was conducted to investigate the effects of video editing pace on young children’s attention and related cognitive processes. To isolate the effects of editing pace, four of five experiments used specially produced experimental videos based on the paradigm developed by Cooper et al. (2009). Additionally, this research provided evidence about the effects of video content and employed psychophysiological methods to thoroughly explore attentional and cognitive processes involved in video watching. Finally, this thesis also documented changes in the way children engage with contemporary digital media.

The key strength of this thesis is the broad range of methodology (i.e., behavioural observation, well-validated performance measures and psychophysiological methods) used to examine the subject. Employing such varied research tools expanded substantially on the previously narrow literature. The findings consistently showed that video editing had consequences for children's attention, supporting the hypothesis about the detrimental effects of the fast pace. Furthermore, this research was the first to use EEG to demonstrate that the pace of editing affected not only observable behaviour but also internal inhibitory processes associated with performance on a go/no-go task.

However, the evidence presented in this thesis did not support the proposition that the pace of editing also affects children's executive function. Moreover, the results ran counter to the recent proposal that it is exposure to unrealistic content rather than the fast pace that depletes children's cognitive resources. On the contrary, the data showed that watching unrealistic videos improved the inhibitory control component of executive function. There is however, a possibility that rather than unrealistic content, the effect of the video was driven by the presence of a strong narrative in the story. Considering the lack of research about the cognitive processing of the narrative in children's videos and television programmes, this proposition has the potential to stimulate a range of further studies.

As a final remark, it is worth reiterating that this thesis focused on examining the effects of traditional non-interactive screen viewing. However, the recent surge in popularity of interactive touchscreen devices, such as tablets, game consoles and smartphones has created a new challenge for researchers to answer a question whether the use of interactive devices promotes or hinders children's attention and cognitive development.

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Appendix

Parent Media Opinion Survey

Please check the answer that best applies:

I am the child's mother (or main female caregiver) ☐ **father** (or main male caregiver) ☐

I play tablet/mobile games: often☐ sometimes☐ never or hardly ever☐

I watch television and films: often☐ sometimes☐ never or hardly ever☐

Highest level of education completed by child's mother/main female caregiver:

____

Highest level of education completed by child's father/main female caregiver:

____

For all the rest of the questions, please answer about your child who is closest <u>to age 5</u>.

Please indicate your child's age and gender:

Age: 3 ☐ 4☐ 5 ☐ 6 ☐ **Gender :** Boy ☐ Girl☐

On a scale of 1 to 5, <u>1=least favourite</u> and <u>5=most favourite</u>, please rate your child's media preferences:

	1=least favourite	2	3=neutral	4	5=most favourite
Television	☐	☐	☐	☐	☐
DVD	☐	☐	☐	☐	☐
Computer	☐	☐	☐	☐	☐
Tablet	☐	☐	☐	☐	☐
Game console	☐	☐	☐	☐	☐
Smartphone	☐	☐	☐	☐	☐

Please select the answer that best applies:

1. In an <u>average week</u>, how much time does your child spend

	No time at all	Less than 5 hours a week	Between 5 and 10 hours a week	Between 10 and 15 hours a week	More than 15 hours a week
Watching TV and films	☐	☐	☐	☐	☐

Using tablet or mobile phone (for games, apps, etc.)	☐	☐	☐	☐	☐
Using computer (for games, going online, etc.)	☐	☐	☐	☐	☐

2. **How often does your child use a tablet to**

	Daily	3-5 times a week	1-2 times a week	Less than once a week	Not at all
Watch TV and films	☐	☐	☐	☐	☐
Play entertainment games	☐	☐	☐	☐	☐
Access educational apps	☐	☐	☐	☐	☐
Go online	☐	☐	☐	☐	☐

3. **Does your child use more than one media devices at the same time** (e.g., plays a tablet/mobile game while watching TV, or listening to the music)**?**

Always	Often	Sometimes	Rarely	Never
☐	☐	☐	☐	☐

4. **When deciding if a new TV programme/film is appropriate for my child, I**

	Always	Often	Sometimes	Rarely	Never
Watch the first couple of minutes to see if it's OK.	☐	☐	☐	☐	☐
Watch it all **with** my child.	☐	☐	☐	☐	☐
Watch it all **before** I allow my child to.	☐	☐	☐	☐	☐
Use the ratings provided.	☐	☐	☐	☐	☐

5. **When deciding if a new game/app is appropriate for my child, I**

	Always	Often	Sometimes	Rarely	Never
Play the first couple of minutes to see if it's OK	☐	☐	☐	☐	☐
Play the entire game **with** my child.	☐	☐	☐	☐	☐
Play the entire game **before** I allow my child to.	☐	☐	☐	☐	☐
Use the ratings provided.	☐	☐	☐	☐	☐

6. **How much screen time (television, DVD, tablets, computers, etc.) per week do you think is recommended for children by early years professionals?**

	None	Less than 2h	2 to 5h	5-10h	10-15h	Unlimited time	I am not aware of any existing recommendations

Children under the age of 2	☐	☐	☐	☐	☐	☐	☐
Children aged 2-5	☐	☐	☐	☐	☐	☐	☐

7. Rate how harmful to children are the following features of TV and films

	Extremely harmful	Very harmful	Moderately harmful	Slightly harmful	Not harmful at all
Inappropriate language	☐	☐	☐	☐	☐
Inappropriate behaviour	☐	☐	☐	☐	☐
Violent content	☐	☐	☐	☐	☐
Fast editing pace	☐	☐	☐	☐	☐

8. Indicate whether you monitor your child's media use

	Not at all	Loosely	Moderately	Strictly
Total time your child spends in front of the screen (TV, computer, etc.)	☐	☐	☐	☐
The content of TV/films your child watches	☐	☐	☐	☐
The content of games apps that your child is using	☐	☐	☐	☐
The TV/film content played in the background when your child is there	☐	☐	☐	☐
The games/apps that are played when your child is there	☐	☐	☐	☐

9. How familiar are you with the ratings for:

	Not familiar at all	Vaguely familiar	Quite familiar	Very familiar
Television and films (U, PG, 12, 12A, 15, 18)	☐	☐	☐	☐
Games and apps (PEGI 3, 7, 16, 18, PEGI OK)	☐	☐	☐	☐

10. Thinking about <u>all children</u>, select the answer that best describes your beliefs about how media affect children's development:

	Very positive	Positive	Somewhat positive	Somewhat negative	Negative	Very negative
The effects of popular media on children's development are	☐	☐	☐	☐	☐	☐
The effects of watching fast-paced action-filled programmes are	☐	☐	☐	☐	☐	☐
The effects of watching educational programmes are	☐	☐	☐	☐	☐	☐
The effects of watching programmes containing violence and threat are	☐	☐	☐	☐	☐	☐

Thank you for completing this survey!