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Understanding the impact of Children's Exposure to Digital Texts on reading related skills

Khela, Parminder Kaur

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By

Parminder Kaur Khela

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Table of Contents

Table of Figures

Table of Tables

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Abstract

Despite the omnipresence of digital technology, little is known about the effects of new media on young children's literacy development. This thesis gives insight into the extent of digital text exposure prior to starting school, and parental attitudes, perceptions and concerns in relation to this. A series of experimental studies compared the reading abilities and visual attention of children with high and low exposure to digital technology and digital texts. Two novel experiments were conducted. The first used eye tracking to compare the visual selective attention (using a change detection task) of high and low exposure groups. Overall, findings showing the effects of exposure to digital technology on children's performance on visual attention tasks were limited. The second compared reading across different types of media. Reading time was longest for paper, followed by tablet and then laptop, suggesting laptops facilitate quicker reading. However, there was no effect on reading comprehension. When digital exposure was also considered, there was no difference in reading time, reading comprehension nor reading accuracy across different media types. Standardised measures of vocabulary, word reading and attention were also compared. The low exposure group had significantly higher vocabulary scores compared to the high exposure group. However, both groups scored within the normal range within their population. No effects of digital technology exposure were found for word reading or attention. Overall, limited differences between exposure groups should help ameliorate parents' concerns regarding their children's digital technology use in including concerns about attention reported by parents in Chapter 2.

Keywords: digital technology, attention, reading, vocabulary, comprehension, young children

Chapter 1: Literature Review

The purpose of this thesis was twofold. Firstly, children's present day use of digital technology was established to allow for the exploration of the effects of digital technology on children's reading and reading related skills. Secondly, the impact of the type of media directly used by children was explored, in which paper and digital device use and reading performance were measured. Together these explorations helped provide key data regarding children's digital device use, their parents' use, and attitudes towards digital technology and the influences of these devices on children's reading and reading related skills. Thus, initially providing a wider scope about digital technology use now and a more focused understanding on the effects digital devices may have on reading.

More specifically, this thesis aimed to examine the effects of exposure to digital technology on young children's reading related skills, including attention, vocabulary and word reading. Additionally, this thesis aimed to compare young children's reading, in terms of reading time, number of reading errors and reading comprehension across different types of media. With the constant advancements of digital technology, it is important to acknowledge and understand changes in technology and the use of technology over the recent year. This first chapter is a literature review, begins with a "screenshot" of children's digital technology use in present day life as well as comparing societal shifts in digital technology use in recent years. This is an important starting point as it provides a wealth of information about the participants who took part in the studies reported in this thesis. This chapter goes on to deal with reading and models of reading, including the Simple View of Reading and the Home Literacy Model (Hoover & Gough, 1990; Sénéchal & LeFevre, 2002). Then the effects of digital technology are discussed in this chapter generally. Followed by a more specific discussion on the effects of digital technology on reading, through the reviewing of studies that explore reading across different types of media. Finally, this chapter reviews a lesser explored predictor of reading which is attention. Attention will be defined, and theories and types of attention will be reviewed. This is followed by an exploration of the impact of digital technology on attention and in turn reading.

One of the most significant changes in recent history has been the societal shift towards the use of digital devices in all areas of life, integration into daily life, and across the lifespan. "Digital natives", a term coined by Marc Prensky, can be defined as a collective term describing people who were born and grew up in an age of new technology, resulting in familiarity with modern digital devices and the internet from a young age (Prensky, 2001). To highlight the huge amount of interest in understanding the impact of being digital natives, it can be observed that Prensky's term has been adopted by many and his article has been cited over 31,000 times (Google Scholar, 2021). Prensky claimed that a single "big discontinuity" has occurred. This singularity is the rapid arrival, distribution and use of digital technology which has changed things to the extent of never turning back (Prensky, 2001).

Prensky identified two groups of individuals, digital natives mentioned above and "digital immigrants". Prensky stated that digital immigrants are the individuals born before new technology, who are not to be considered "native speakers" of the digital language of computers, video games and the Internet" and no matter how much they adapt, they will have a "digital immigrant accent".

Prensky's work seems to have a negative attitude towards these "immigrants", claiming that they "struggle to teach a population that speaks an entirely different language" (Prensky, 2001). Without clear evidence, Prensky claims that digital natives are used to "receiving information really fast", "like to parallel process and multi-task", "prefer graphics before text", "prefer hypertexts", "thrive on instant gratification and frequent rewards" and "prefer games to "serious" work" (Prensky, 2001, p2.). However, for the purpose of this thesis the concepts of digital natives and digital immigrants are unimportant as the present thesis focused on understanding the influence of digital technology in young children in a time where digital technology is omnipresent.

Prensky even stated that he believes brains of digital natives are "likely *physically different* as a result of the digital input they received growing up" (Prensky & Berry, 2001, p.1). Currently, there is no evidence confirming this idea, however, it needs exploration. In particular, the study of digital technology use and brain development may provide further information on the effects that digital technology (usage, delivery and levels of engagement) may have on younger people (Crone and Konijn, 2018).

More recently, research conducted by neuroscientists has begun to explore the effects that digital technology may have on behaviour and how it may be changing brains (Small et al., 2020). In a review of research on the brain health consequences of digital technology use, results showed both potentially harmful and beneficial effects on brain function (Small et al., 2020). Generally, results showed that the harmful effects of frequent digital technology use included potential addictive behaviours, social isolation, worsening of ADHD symptoms and interference with sleep and brain development (Small et al., 2020). Conversely, results broadly showed that the positive effects of frequent digital technology (including specific programmes, online tools and video games) can activate neural circuity, improve cognitive function, increase restful sleep and reduce anxiety (Small et al., 2020). This supports the idea that the use of digital technology may be 'changing brains' but, provides a balanced review of the effects rather than promoting fearmongering.

The idea that young people think very differently from their parents due to growing up in a digital age has been challenged; perhaps the way in which children learn has changed but this does not confirm fundamental transformations, instead, children's preferences of learning may have adapted to the affordance of new technologies (Livingstone, 2009). Although children are not as efficient at reasoning compared to adults, their thought processes and reasoning is the same as that of adults even in early childhood, though less developed and more easily misled as children are not as good at excluding irrelevant information (Goswami, 2008a). Livingstone (2009) claimed that there are many things children are able and unable to do online, this can be a result of socioeconomic factors, resulting in children who have been bought up frequently using digital technology in having very varied chances to engage with digital technology (Livingstone, 2009). Overall, Livingstone's (2009) argument stated that children may have a false sense of confidence with internet use. Livingstone's (2009) argument ended by stating that if it is believed that providing more resources may become a lower priority, this would then potentially create further gaps between individuals who are technologically savvy and those who are not. An issue with this argument is that the focus remains very much on the internet and being online, whereas many aspects and uses of digital technology can be offline, for example, reading, gaming and video content.

Recent evidence suggests that today's students are not fundamentally different from their ancestors due to advances in digital technology (Vincze Ankio, 2015). Moreover, digital natives cannot be treated as a "homogenous group" as there is variation in their access and use of digital technology (Vincze Ankio, 2015). More recently the popular assumption that digital natives are better at multitasking has been refuted, therefore suggesting that the idea of building multitasking into the design of educational practices may be a hindrance rather than a help to learning

(Kirschner & De Bruyckere, 2017). Further evidence exposes issues with multitasking. Thirty-five university students (10 males, 25 females with a mean age of 22.34 years) participated in reading tasks and a questionnaire about their online communication. A negative correlation between multitasking frequency and performance on cognitive tasks (assessing learning and comprehension) was found (Tran et al., 2013). In another study, 262 university students participated in a five-part study with a digital technology use questionnaire and index, three cognitive tasks and an online questionnaire for course credit (Ophir et al., 2009). Using the questionnaire two groups were identified "heavy" and "light" media multitaskers, and it was found that those who tended to engage in multitasking were more susceptible to both environmental and mental distractions (Ophir et al., 2009). This may be due to them being less stimulated in tasks that do not require as much multitasking as they are used to or may be reflective of having a shorter attention span. However, there is a lack of research on cognitive control in young children's digital technology use.

The importance of digital technology and "digital literacy" is clear; for example, in 2006 the European Reference Framework was established to identify key competencies for lifelong learning which included digital competence (European Council, 2006). These key competencies were considered necessary for personal development and personal fulfilment, social inclusion and employment. Digital competence which involves the use of technology for "work, leisure and communication", was listed as a key competence (European Council, 2006), thus, evidencing the importance of digital literacy in all aspects of life. Shortly after, in 2007, the European Commission noted that individuals are living in a "whole new digital world", in which technical skills associated with digital technology are necessary, as is achieving a better understanding of the potential opportunities, challenges and even ethical questions posed by the new forms and types of digital technologies (European Communities, 2007).

Independent of what generation an individual belongs to or what label they are given it is important to note that digital technology has changed and thus people's lives have changed. It is useful to explain what technology is, how it has changed and what the difference between technology and digital technology is. From this, the rapid changes in digital technology in recent years can be explored and put into context for this thesis.

A comprehensive definition of technology is: "something inherently intelligent enough to either function, be used to function, or be interpreted as having a function that intelligent beings—human or otherwise—can appreciate, something devised, designed (by primary intention), or discovered (by secondary intention) serving particular purposes from a secular standpoint without humankind creating it, or a significant beneficiary of rationally derived knowledge that is "used for" a purpose without itself necessarily being translated into something material that "does" autonomously, or dependently when used." (L. S. L. Carroll, 2017, p.1). From this it can be ascertained that a pencil is an example of a simple form of technology (Vittrup et al., 2016). 'Digital' refers to "using a system that can be used by a computer and other electronic equipment, in which information is sent and received in electronic form as a series of the numbers 1 and 0" (Cambridge Dictionary, 2020).

The term digital technology is therefore something that functions electronically by generating, storing and processing data, primarily for humans. The term digital device is a synonym. Many technologies fall under this umbrella. This includes televisions, gaming consoles, computers, laptops, smartphones and e-books. These devices are now omnipresent in the lives of young children. By the time children begin school, the majority will have had exposure to varying types of digital technologies both at home and in homes of family and friends (Plowman et al. 2010).

Research with young children on the effects of new media, which refer to devices such as smartphones and tablets, is limited (Bittman et al., 2011). Previous research has focused on older children and adults, despite the increase in children’s digital technology use and internet access from an increasingly younger age (Chaudron, 2018).

A “screenshot” of young children’s technology use

Digital technology is ubiquitous within the daily lives of young children and their parents. In recent years, there has been a wave of increased mobile device use by or with young children. In 2010 Ofcom (2011) reported smartphone ownership comprised 3% of five to seven year olds, 13% of eight to 11 year olds and 35% of 12-15 year olds. However, more recent data show large increases in ownership across all ages, with 10% of seven year olds, 12% of eight year olds, 65% of 11 year olds 75% of 12 year olds and a staggering 93% of 15 year olds (Ofcom, 2019). Despite this increase, there is currently a lack of guidance for parents, educators and health care workers on young children’s screen time (Livingstone & Franklin, 2018). A journal article titled “Families with young children and ‘screen time’ advice” provides an overview of digital technology use and its effect as well as guidance based on research (Livingstone & Franklin, 2018). It found families have varying and legitimate reasons for their children’s screen time and the negative impacts of screen time for under five year olds is often less than expected. In addition, if a parent is present and interactive during screen time, the benefits increase and potential harm is reduced (Livingstone & Franklin, 2018).

In the UK, a survey conducted by the Department for Education (2018) using face-to-face interviews with a nationally representative sample of 5,922 parents of children aged zero to 14 years old between January and August 2018 found that 76% of children aged zero to five years old used digital technology at home, either jointly with another individual or alone. These children were most likely to use a mobile device, for example, a tablet (64%) or a smartphone (40%), followed by a laptop (16%) then a video game console (15%). The Department for Education (2018) found no statistically significant difference in the proportion of children using digital technology by their family's annual income nor the deprivation level of their local area. Parents reported that most digital technology use was to promote learning (74%), followed by promoting creative play and then to keep children quiet or occupied (44%). In 2019 the UK Department for Education (2019) conducted a similar survey, however this time a sample of 5,057 parents of children aged zero to four years old between January and August 2019 were interviewed face-to-face meaning a larger sample size of children between the ages of zero to four years old. For the 2019 survey only half the parents were asked about their children's digital technology used at home. From this sample, 69% of children aged zero to four years old used digital technology either alone or together with someone (The Department for Education, 2019). There was a considerable variation in digital technology use by age with 20% of children aged zero years old compared to 90% of children aged four years old using a digital device. Tablets (55%) and smartphones (36%) were used most. Similarly, to 2018, parents reported that most digital technology use was to support learning (67%), encourage play and creativity (49%) and to keep children quiet or occupied (45%) (The Department for Education, 2019). Most recently, due to the impact of COVID-19 the Department for Education decided to change both its data gathering and information release practices by concentrating efforts on priority analysis and statistics, thus no report was published in 2020 (The Department for Education, 2020).

In addition to understanding children's digital technology practices, developmental vocabulary and literacy skills in young children need to be assessed as the impact of digital texts on young children's written and spoken language skills has not been explored. The mechanisms through which digital texts might have impact on word learning, vocabulary and reading have also not yet been sufficiently investigated. This is an omission when we consider the literature which has shown that young children's awareness and understanding of text such as letters and words is influenced by their home literacy environment. For example, Neumann, Hood, Ford and Neumann 2011 found that young children's interactions with books, paper and crayons (non-digital items) are consistently found to positively impact emergent literacy).

There is research to suggest that exposure to digital print via computers at home can have a positive impact on emergent literacy skills (Hisrich and Blanchard 2009; Hillman and Marshall 2009). This is supported by Korat and Shamir (2007) who investigated emergent literacy skills of 128 children aged five to six years old from low and middle socioeconomic groups pre and post intervention, with three groups: control group, electronic book group and print book group. They measured emergent literacy measures including vocabulary, word recognition and phonological awareness. It was found that both intervention conditions improved the children's vocabulary development. However, neither word recognition nor phonological awareness was affected by either intervention. Nevertheless, new devices such as touch screen tablets have not been widely researched and relatively little is known about their impact on young children, even though they are frequently used in households around the UK (Neumann 2016; Picton: National Literacy Trust 2014). Children as young as two years of age can use tablet devices independently

(Neumann and Neumann 2014). However, there is a lack of research that explores tablet use in detail within the home environment (Neumann 2016). Neumann (2016) conducted a study with 57 Australian children aged between two to four years old. Results showed a positive association between the frequency of tablet use and sound knowledge, print awareness and print knowledge (Neumann 2016). This shows that there are benefits associated with exposure to digitally based texts; however, there also appear to be potential disadvantages. Disadvantages include a negative impact on communication and social skill, additionally, there are concerns regarding the potential lack of appreciation of print books (Grieshaber et al., 2012; Livingstone et al., 2014)

Reading

Reading is a complex skill and a key component of 'literacy'. A comprehensive definition of literacy reads: "Knowledge and understanding of the literal and intended meanings of cultural symbols and tools which convey meaning, and the ability to make practical and creative use of these symbolic forms to communicate effectively in the widest range of settings and contexts: both synchronous and asynchronous, face-to-face and virtual."(C. Wood, 2017, p. 63). Reading has been defined as "the ability to extract visual information from a page and comprehend the meaning of the text" (Rayner et al., 2012, p.19). Reading is a complex skill where a series of written symbols are decoded to derive meaning (Cornoldi & Oakhill, 1996). It is a form of language acquisition, communication, entertainment and a way to share and acquire ideas and information. In comparison to word reading, comprehension of a passage involves higher levels of both language and cognitive skills allowing the reader to understand mutually the literal and inferential meaning of the passage (Gough et al., 1996). Clearly, the ability to read is very important. In fact, Castles et al. (2018, p.5) wrote "learning to read transforms lives". Successful reading comprehension provides the opportunity for complete engagement in society including education, employment and social activities, all of which rely on the ability to understand written information (Florit & Cain, 2011). This makes the development of children's reading skills a particularly important topic of interest for educational researchers, as children's reading skills are critical for their future academic and personal growth.

Having the ability to read is thought to be essential in finding success in a world where information is often conveyed in written form (Rayner & Reichle, 2010). Word identification ability limits reading comprehension, especially in the early stages of reading development, additionally knowledge of the meaning of words is essential to comprehension and more reading experience positively relates to reading comprehension skill (Perfetti et al., 2005).

It is therefore clear that models of reading comprehension development are necessary to form evidence-based curricula and interventions for developing readers. There are numerous models of reading, all of which try to establish the processes within the practice of reading.

The Simple View of Reading

The Simple View of Reading provides a straightforward overview of skilled reading. As stated by this model, skilled reading is a product of word reading (decoding) and language comprehension, see Figure 1 The Simple View of Reading (Hoover & Gough, 1990). The Simple View of Reading model offers a succinct framework for the description of skills and processes involved when readers comprehend written text, (Kendeou et al., 2009). One-hundred and sixteen, four year old children and 119 six year old children completed a battery of decoding and comprehension assessments, and factor analysis of the measures showed listening comprehension and decoding scores as separate factors (Kendeou et al., 2009). The results showed that in all age groups, decoding and oral language comprehension formed two separate clusters which related to each other. However, over time these relations weakened, as shown in data collected from pre-school, kindergarten and 2nd grade (Kendeou et al., 2009). These results support The Simple View of Reading, as the two clusters are formed from a young age and influence reading comprehension.

The Simple View of Reading model does not exclude other possible factors from the reading process but, does identify word reading and language comprehension as the two key contributors to skilled reading (Kendeou et al., 2009). In the United Kingdom, the Simple View of Reading model has had educational implications with recommendations in the *Independent Review of the Teaching of Early Reading* based on the model (J. Rose, 2006). Catts et al. (2006) identified two types of poor readers, these were children with good language comprehension, but with poor word recognition, and children with good word recognition, but with poor language comprehension. This identification supports the idea of two separate predictors of reading. Further support comes from the notion that although word recognition is essential it is not enough for skilled reading as the ability to pronounce printed words does not assure understanding of the written text. Similarly, the ability of language comprehension is not enough for skilled reading as, if an individual does not recognise the words, they cannot access the necessary lexical information required to apply the language processes that result in comprehension (Gough & Tunmer, 1986).

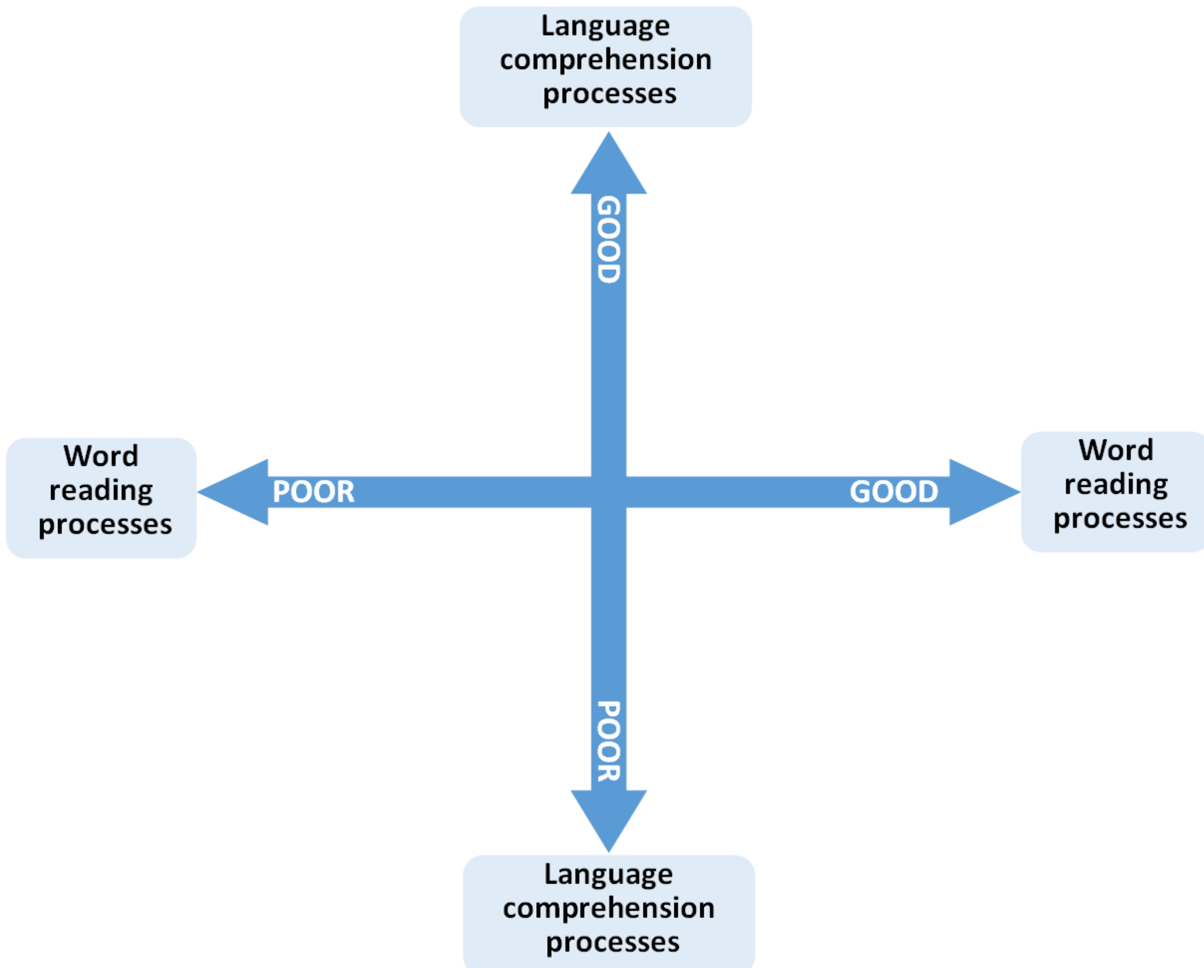

Figure 1 The Simple View of Reading

Further support for the Simple Reading View comes from a five-year longitudinal study of 198 children beginning at the age of seven and a half years old. It was found that word reading and listening comprehension predicted reading comprehension (Lervåg et al., 2018). Together word reading and language comprehension accounted for almost all variance in reading comprehension skills (Lervåg et al., 2018). During early development reading comprehension is greatly restricted by limitations in decoding ability, but the relationship between language comprehension and reading comprehension continues to strengthen across time (Consortium, 2015).

Home Literacy Model

Cartelli (2012) argues that an analysis of changes within learning environments in our society due to technological advances have shown the importance of formal education for young generations, but informal educational experiences are also valuable. Therefore, it is important to understand individuals' use of digital devices not just in educational settings, but in all aspects of life.

A young child's home literacy environment is very important and is a key predictor of the child's language, literacy and reading development (Frijters et al., 2000; Hutton et al., 2020; Sénéchal & LeFevre, 2002). The home literacy environment generally refers to literacy-related activities and interactions between family members in their home. It also refers to available literacy materials, time spent engaging in literacy activities, parental attitudes and levels of encouragement towards literacy, library use and parental modelling of literacy behaviours (Martini & Sénéchal, 2012; Niklas & Schneider, 2013; Phillips & Lonigan, 2009; Puglisi et al., 2017; Rashid et al., 2005).

In the Home Literacy Model, Sénéchal and Lefevre (2002) made the distinction between informal and formal literacy interactions and experiences, which are considered to play different roles in language and literacy development. An informal literacy experience occurs when the focus of the interaction is not on printed text, but the printed text is present (Sénéchal & LeFevre, 2014). An example of informal literacy interaction is shared story book reading (Sénéchal & LeFevre, 2014). In shared book reading it was found that parents tend to focus on either the images or storyline rarely making direct reference to the text (Deckner et al., 2006). Furthermore, children tend not to focus on the text during shared book reading (Evans et al., 2008; Justice et al., 2005). This may be because images are more likely to capture the children's attention and amplify the story (Fang, 1996). However, formal literacy experiences refer to those where attention to printed text is explicit (Sénéchal & LeFevre, 2014). Examples of formal literacy activities include parents teaching the children the alphabet, printing and reading words (Sénéchal & LeFevre, 2014). Informal literacy interactions are linked to the development of oral language skills which include vocabulary knowledge and indirectly affect later reading comprehension, while formal literacy interactions are related to letter knowledge, phonological awareness and decoding skills (Hamilton et al., 2016; Inoue et al., 2018, 2020; Manolitsis et al., 2013; Martini & Sénéchal, 2012; Sénéchal, 2006).

Reading across different media

For many years there has been great interest in how individuals learn to read and comprehend. In recent times, with the advent of digital technology, more research has focused on reading on digital devices, as reading is more frequently taking place on digital devices such as computers, laptops, tablets, e-books and mobile phones. Although, there is a wealth of research on adults' digital reading, less has been conducted with children and there is a lack of research specifically looking at very young children's exposure to reading on digital texts. For example, systematic literature reviews and meta-analyses have reviewed the effects of reading media on reading comprehension, but there is a lack of data from young children (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018). These meta-analyses will be reviewed later in this chapter.

From the above literature and our everyday life experiences, it is clear that the use of digital technology has been on the rise in recent years, and this trend remains on an upward trajectory. It is clear that digital devices are now omnipresent in the lives of young children (Hilbert, 2020; Livingstone et al., 2014). Now more than ever there has been a shift to digital and online resources as remote forms of learning prevail due to mass school closures as a result of the COVID-19 pandemic (Williamson et al., 2020). The educational potential of digital devices and resources has been recognised and promoted during a time when children have had to be home-schooled. This rapid shift has been met with numerous outlets providing information, recommendations, advice and guidance based on existing research (Bulger et al., 2017; Conrads et al., 2017; Higgins et al., 2012; Licata & Baker, 2017; Sonia Livingstone & Third, 2017; Okely et al., 2019). However, there still remains a need for critical reflection and evidence-based practice when understanding this global change to digitally mediated education (Williamson et al., 2020). Therefore, all research regarding children's technology use, whether collected before, during or after the pandemic will provide useful information in understanding the impact of digital technology on the development of children's basic skills.

The Education Endowment Foundation (EEF;2019) stressed the importance of technology being an "active" ingredient, stating there ought to be a clear rationale for how technology will improve children's learning (Stringer et al., 2019). However, without other suitable options, remote digital learning became prevalent across the globe. In contrast with previous guidance, there are now numerous schemes promoting digital technology use, including free laptops and tablets for pupils and students, internet access for disadvantaged children and young people and the Oak National Academy and National Literacy Trust free e-book scheme

(GOV, 2021a, 2021b; TES, 2021). Now with greater reason, research exploring the effects of digital technology on children's educational outcomes is timely, necessary, and of great value.

With sweeping technological changes, the possible effects digital devices might have on individuals' reading must be examined. Alexander & Laboratory's (2012) theoretical paper questions what it means to be a competent reader in the 21st Century. Alexander & Laboratory (2012) suggest that although digital technologies may change, developing readers will still need the same resources and support. This is further supported by earlier changes within our society and more specifically our reading environment. It was stated that reading is "multidimensional, developmental and goal-orientated" in nature rather than merely being a set of bottom-up cognitive processes (Alexander & Laboratory, 2012, p.259). They argue that technology is constantly changing and reading competence skills should not be limited to a certain device because, before long a newer device may potentially take over, therefore the idea behind reading competency should remain relevant now and in the future.

Melhuish & Falloon (2010) note the importance of effective, evidence-driven practices and the evaluation of advantages and limitations of digital devices. From this, it is important to understand fully the effects of digital devices before promoting their use in both home and school life. Melhuish & Falloon (2010) urge the consideration of affordances of digital devices for mobile learning, as a lack of consideration could lead to not capitalising on the potential of the device or forcing an educational experience to fit into a device which it is not suitable for. Yet, Hemmi et al. (2009) stated that there is an "academic repurposing" of technologies that changes the pedagogy by framing devices in suitable forms for the context of use within education. Education has appropriated technologies originally developed for business use (e.g. computers) and social use (e.g. mobile devices) (Traxler, 2010). So, are these technologies suitable for educational settings? How are they affecting children's learning? These unanswered questions still need to be explored.

The widespread rise in tablet popularity has resulted in an increased uptake within educational environments (Haßler et al., 2016). A review of 33 studies exploring the use of tablets by primary and secondary school children found that tablets have mostly a positive impact on children's learning outcomes; no impact on children's learning outcomes and there was little evidence of negative impact (Haßler et al., 2016). The positive impact on learning outcomes included an effect on science related activities, mathematic and economics. This implies that tablets and other mobile technologies including smartphones can feasibly support children in a variety of learning tasks. Therefore, providing support for the increased use of digital technology use in both schools and homes today. However, importantly a negative impact was found on children's reading comprehension. This raises concerns with the promotion of digital technology use as reading is a foundational skill required for academic growth (Stanovich, 2000; Takacs et al., 2015).

If these devices do support learning, it can be questioned if there is evidence that digital devices might support children's reading related outcomes? Dündar & Akçayır (2017) conducted a study with 20 Turkish school children aged between 11 to 12 years old to address this question. Quantitative and qualitative methods were used, including interviews and reading performance tests. Participants were randomly assigned to the reading on a tablet condition (treatment group) or the reading from print condition (control group). Interviews were conducted after the reading test with participants who read on a tablet. The interview included questions regarding children's preference between tablets and books. Independent t-test results showed no significant difference between the treatment group and control group on either reading time or reading comprehension.

This suggests that these digital devices have no effect (positive or negative) on children's reading performance. However, from the interviews two themes were established, that tablets were easy to use, and it was enjoyable to read from a tablet. This is important to note as there is evidence for a positive relationship between an individual's reading enjoyment, reading frequency and reading attainment (C. Clark, 2011; C. Clark & Douglas, 2011). Therefore, if children prefer reading via a tablet compared to paper this may affect how often they read and in turn impact their reading ability. Furthermore, children with the most positive attitudes to reading were more likely to score well on reading assessments (Twist et al., 2007). These results comparing print and screen reading provide useful information which can be applied to young secondary school children. However, there is a lack of similar research conducted on younger, primary school aged children. This is necessary as reading ability changes significantly year on year, as can be seen in five-year longitudinal study conducted on children from the age of seven to 12 years old, which showed significant improvement in reading fluency as time went on (Lipka, 2017). It is, therefore, of interest to understand if reading at a younger age may be more affected by the type of medium used to read.

To reiterate, understanding an individual's attitude towards reading using digital devices and how these attitudes affect their reading behaviour is extremely important. To understand students' use of and attitudes towards technology, quantitative and qualitative survey data was reviewed from 429 university students in Germany, India, Japan, Slovakia and the United States of America (Baron, 2017). From this Baron et al. (2017) noted four physical pros and cons with digital device reading which included concerns regarding annotation, vision, the importance of touch, and ability to search. Students most liked the ability to annotate printed texts in an easy manner by highlighting, underlining and adding notes in the margins. Students preferred print reading due to eyestrain issues when using screens. Students liked physically holding the book and turning the pages. Haptics, which refers to a unification of tactile perception and related active movements, has been found in previous research to be important when reading (Mangen & Velay, 2010). These differences are due to the ergonomics, design and functions that separate print and digital technology. However, there is a lack of research that controls for these differences and allows a comparison where the only difference is whether the text is on print or on a digital device. In such an experiment text would be represented of equal size, using the same colours, fonts, line length and with no need for turning the page or scrolling.

It was found that university students perceived experiencing reduced comprehension when using digital devices in comparison to printed texts (Kirby & Anwar, 2020). This was because the accessing of previous topics was more difficult due to having less opportunity to note their thinking. This resulted in students increasing their cognitive load as more information was having to be held in their working memory. Students did not perceive reduced comprehension when using smaller documents and this may be explained by the idea of having to retain less information as they have less information initially. For a long time, it has been known that annotation including highlighting and underlining has been beneficial for retaining information and comprehension (Fowler & Barker, 1974). Therefore, having the ability to annotate on digital devices would improve individuals' reading comprehension. As devices continue to evolve it is important to take note of how they can facilitate good reading.

Digital technology brings forth both positive and negative possibilities. Powerful advantages of digital technology, generally non-existent in print texts, include "interactivity, non-linearity, immediacy of accessing information, and the convergence of text and images, audio and video" (Liu, 2005, p.701). In addition, large amounts of data can be stored on a single device. For example, when reading on a digital device there is an endless wealth of content and information including access to e-books or a variety of texts available on the internet. However, more negative features associated with digital devices can lead to an increase of cognitive load because digital devices are more demanding of an individual's attention and cognitive processes (Jeong, 2012; Sweller, 1994).

Screen Inferiority

Levy (1997) has claimed that the development of digital libraries is creating a trend towards less concentrated, shallower and more fragmented reading. This could be a significant threat to children's reading engagement and in turn their reading comprehension. Screen inferiority refers to the negative difference between individuals reading from a screen, who performed worse and were more overconfident about their success, in comparison to those who read on paper (Lauterman & Ackerman, 2014). Largely, individuals prefer reading printed text over digital texts (Mizrachi, 2015; Woody et al., 2010). However, more recently it has been found that children prefer to read on screen (Golan et al., 2018). Eighty-two children between the ages of 10 to 12 years old read texts on paper and on a computer screen, and then indicated which medium they preferred. They also answered comprehension questions and rated their confidence in the answers they had given. The results showed a preference for digital reading despite better performance and more confidence during print reading (Golan et al., 2018).

Ackerman & Goldsmith (2011) also found screen inferiority effects in students who preferred print-based learning over digitally mediated learning. However, when students who had only moderate preference for print over digital learning, only under time pressure were similar results of screen inferiority found (Ackerman & Lauterman, 2012). This suggests it is possible for students to overcome screen inferiority effects; however, perhaps not when there is time pressure due to a time limit. As mentioned earlier, young children prefer reading via digital devices, which differs from the older students who participated in this study. Therefore, perhaps they would perform better as those students who had less of a preference for print performed better. Due to this shift in attitudes, research is necessary on potential differences in young children's reading across different forms of print media. Lauterman & Ackerman (2014) discovered that "the consistent screen inferiority found in performance and overconfidence can be overcome by simple methods, such as practice and guidance on in-depth processing, even to the extent that some learners become able to perform as well on screen as on paper" (p. 462). This, therefore, suggests that students can learn to read effectively from screens.

Screen inferiority effects are more prevalent in expository texts compared to narrative texts (Delgado et al., 2018; Delgado & Salmerón, 2021). Expository texts tend not to have a timeline and are written using technical jargon to inform the reader on a topic, whereas narrative texts tend to use everyday vocabulary to describe a character's experience in a series of developmental events (Medina & Pilonieta, 2006; Weaver III & Kintsch, 1991). Expository texts are generally more difficult to understand, resulting in an increase in cognitive effort due to a "large number of ideas, infrequent vocabulary and complex text structures" (Delgado & Salmerón, 2021, p. 1). This finding has been supported by a study in which 61 children aged between eight to 10 years old participated in a reading comprehension task comparing narrative and expository texts (Best et al., 2008). The results showed that comprehension scores were higher for the narrative text than the expository text, and the effects of reader competencies depended on the genre of the text and comprehension of the narrative text was most affected by reading decoding skills (Sidi et al., 2017). By comparison, expository text comprehension was most affected by the children's world knowledge. Therefore, the effect of screen inferiority in children's reading is important to understand as they already find expository texts difficult even when just presented on paper.

Skilled readers report more difficulty comprehending texts when they are presented on screen. For example, Murphy et al. (2003) found that students texts presented on paper to be more understandable compared to those in the computer condition. One hundred and thirty-one American undergraduate students (67 females) read two passages of text. These students likely used a range of strategies to comprehend and to remember the text, and it is possible that the strategies for traditional paper reading are not the same as those essential for processing computer-based texts (Murphy et al., 2003). For example, literature about digital technology would indicate that students need more complex strategic processing abilities when trying to read hypertext and comprehend hypertext (Lawless & Kulikowich, 1996). Additionally, students in the Murphy et al. study reported that they found the digital text less interesting (Murphy et al., 2003). However, due to younger children's preferences towards digital text (as mentioned earlier), it would be of interest to see if these results would be replicated with a younger age group. However, it may be that the screen inferiority effect in skilled readers is driven by their lack of interest or increased effort required. Nichols (2016), summarised previous findings comparing reading from screens and paper and found that reading comprehension performance was not significantly different between screens and paper. However, it was found that reading text from screens was perceived to be more difficult than reading text from paper.

In 1992, a literature review compared the differences between media regarding processes and outcomes of reading (Dillon, 1992). Prior to this review, research had focused on outcomes and aimed to identify a variable to explain differences in reading time. This review examined research to identify issues regarding reading and provided evidence for how single variable explanations do not provide satisfactory answers. It was concluded that digital reading is slower than print reading perhaps due to the awkwardness of digital reading. However, as developments in technology continue, performance between devices can be more directly compared (e.g., print-based tasks can be transferred directly onto digital devices) and more positive attitudes towards digital technology suggest the potential for the differences in reading time and performance to become reduced. A more recent review focused on the issue of equivalence between media by reviewing performance measures (Noyes & Garland 2008). Often when tasks are transferred from paper to a digital format equivalence is assumed, however this is not always the case. It is important to ensure that tasks are presented equally across the different types of media especially when any decrement may affect outcomes. Three types of tasks were identified including: non-standardised, open-ended tasks (e.g., writing about the text), non-standardised, closed tasks (e.g., multiple-choice questions) and standardised tasks (e.g., a standardised test). It was found that not all studies took equivalence into account. This suggests that studies may be confounded due to issues when transferring print text to digital text as the final task may not be the same. For writing tasks individuals in the print reading group spent more time planning compared to those in the digital reading group. Overall, reaching equivalence in digital reading tasks and print reading tasks is difficult, but it is not impossible to construct tasks that can minimize confounds between conditions.

Taking a closer look at the comparison between reading performance on screen and on paper is necessary to establish the effects of each medium. A meta-analysis reviewed 17 studies published from 2002 to 2016 with participants aged 16 or older comparing reading time and comprehension across digital and print reading (Kong et al., 2018). Robust variance estimation

(RVE) based meta-analysis models were used. An RVE differs from conventional meta-analytic methods, which rely on the assumption that effect size estimates from separate experiments are independent and that sampling distributions have known conditional variances (Hedges et al., 2010). The assumption of independence is violated when experiments produce multiple estimates based on the same participants (Hedges et al., 2010). Four RVE meta-regression models were used to study possible effects of some moderators for mean differences in reading time and comprehension digitally and print reading. Findings revealed that there were no significant differences in reading time across digital and print reading. However, reading comprehension was better for print reading in comparison to digital reading. Moderators were not significant. Perhaps there is an advantage of print reading as participants who were post-secondary school age or older have had years of previous experience reading on paper, which has influenced their preference for print media. This shows the importance of conducting studies with young children who are growing in the digital age and have been surrounded by digital technology from a young age as they may not have the same preferences as individuals from older generations.

Clinton (2019) conducted a systematic literature review of thirty-three studies with 2799 participants comparing print reading and digital reading to consolidate research on reading time and reading performance. It was found that reading from digital devices has a negative effect on reading performance compared to reading print, however, this was only found for expository passages and not for narrative passages. This is likely to be because reading expository passages are more difficult than reading narrative passages (Mar et al., 2021).

More recently Støle et al. (2020) examined the effects of reading medium in a large-scale study of 1,139 Norwegian students aged 10 years old. This appears to be the youngest age of children research has been conducted with on this topic. Results showed that these children tended to have lower comprehension scores on the digital test compared to the paper test. The negative effect of reading from a screen was most noticeable in high performing girls. This finding is interesting as previous research has generally found that girls tend to outperform boys in reading assessment, for example in PIRLS and PISA (M. O. Martin et al., 2017; Stoet & Geary, 2013). Perhaps this result was found as boys have been found to be more motivated by computers compared to paper and pencil tests (R. Martin & Binkley, 2009). Støle et al. (2020) state there are still possible uncertainties for the implications of testing and education via technology-based practices as children may not obtain the metacognitive skills required to apply the relevant reading strategies necessary for screen reading. Additionally, a study comparing a group of five year old children and six year old children using phonics-based talking books compared to their matched comparison groups who had adult tuition using paper versions of the same books found no significant difference in phonological awareness scores (C. Wood, 2005). An interesting note is that the younger group were more active in using the talking books, whereas those in the six year old age group used the talking books more similarly to regular reading books, perhaps due to more experience of handling reading books (C. Wood, 2005). However, this could be because the older children found the task easier, they may be less and were, therefore, less likely to use the speech function (C. Wood, 2005).

Research has also compared reading time and comprehension on paper with reading via tablet specifically in children with dyslexia. Secondary school aged participants read 12 successively longer and more complex passages, on paper and digitally (Schneps et al., 2013b). Results showed both speed and comprehension significantly improved in the digital condition (Schneps et al., 2013b). However, this may be attributed to the short lines of text in the digital condition which had an average of 3.4 words per line compared to the paper condition which had

13.9 words per line. There has been evidence to show that shorter line lengths facilitate reading in people with dyslexia, therefore perhaps the use of short lines of text lead to the improved reading rather than the media used to present the text (Krivec et al., 2020; Martelli et al., 2009; Schneps, et al., 2013b). Individuals with dyslexia tend to have oculomotor deficits and make frequent reverse saccades during reading (Bellocchi et al., 2013; Biscaldi et al., 1998; Pirozzolo & Rayner, 1988). This could explain the shorter reading time found in shorter lines as fewer reverse saccades could be made per line, therefore participants complete the line of text faster.

Shallowing Hypothesis

The shallowing hypothesis can be used to explain on-screen inferiority effects (Annisette & Lafreniere, 2017; Delgado et al., 2018). It is proposed that increased experience of reading on digital technologies fosters a superficial way of processing information. This idea has been studied by analysing the attention and meta-cognition of undergraduate students who read print and digital texts. For example, Delgado & Salmerón (2021) aimed to understand the cognitive processes that cause shallower processing during reading from a screen. One hundred and forty undergraduate students were assigned to one of four conditions based on reading medium (paper or screen) and time allowed for the task (a limited time or an unlimited amount of time). Results showed better task adaption to print reading, as the minds of those who read print wandered less on time-sensitive tasks compared to those who read from a screen. Ergo, those who read on screen comprehended less on time-sensitive reading tasks. No differences were found in the readers' 'metacognitive calibration', meaning there was no difference in the accuracy of readers' perceptions of their own performance (Delgado & Salmerón, 2021). Calibration refers to a measure of how accurately an individual is able to assess their own confidence in their own skills and or knowledge (Stone, 2020). These results provide supporting evidence for the shallowing hypothesis when reading on a screen under time limits.

Interestingly, a series of studies explored the calibration of individuals across print materials and computer-based materials (Ackerman & Lauterman, 2012; Lauterman & Ackerman, 2014). During an experimental task, in which participants read passages of text to answer comprehension questions, their accuracy of calibration was inferior on computer based reading compared to print based reading.

The "shallowing hypothesis" stresses the decrease in reflective thought (Annisette & Lafreniere, 2017). Carr (2010; 2020) suggested that the frequent use of social media e.g. texts and brief messages may promote swift and shallow thought. Annisette & Lafreniere (2017, p.145) interpret this as a threat, because regular usage of such media can "be associated with a decline in the use of reflective thought, a decrease in importance placed on life goals related to morality and aesthetics, and an increase in the importance placed on life goals related to hedonism and image".

Additional empirical support for the shallowing hypothesis comes from the first eye tracking study directly accessing the hypothesis in reading across media. One hundred (82.4% female) undergraduates from Norway were randomly assigned to a print or digital reading condition, during which they read whilst their eye movements were tracked and then completed comprehension questions (Latini et al., 2020). Although there was no main effect of reading medium on participants' reading comprehension performance, participants engaged in more consolidative processing of text and picture information when reading print material compared to those who participated in screen reading, which affected their integrated understanding of multimedia content through "cross-representational processing" (Latini et al., 2020, p.2). A strength of this study was the detail in which texts were as similar as possible across the two conditions, with size 11 text all on one A4 sheet of paper and a pdf of this sheet displayed on a 24" screen allowing the entire document to be seen without the need of scrolling. However, due to the sample being older (advanced readers), results cannot be generalized results to young children, thus, leaving a gap in the literature.

Support for the shallowing hypothesis also comes in the form of participant self-reports. Specifically, undergraduate students have reported having more sustained reading on paper in comparison to screen reading where they tend to multi-task, which adds a layer of user-based intricacy to the already complex process of reading (Daniel & Woody, 2013). Therefore, if digital technology influences attention there will in turn be an effect on reading. This will be discussed in more detail further along in this chapter. Perhaps electronic devices give contextual cues which result in shallower processing, causing lower cognitive performance (Sidi et al., 2016). Contextual cues indicate what to expect and guide eye movement (suggesting where to look) additionally they facilitate search and recognition of objects in a scene (Chun, 2000).

There are very specific differences between print and digital reading. Digital reading can potentially also affect sustained attention and can promote a style of fragmented reading (as noted earlier), due to the non-linear reading nature of some digital texts (Liu, 2005). This type of reading is more common on digital devices as you can skip text by clicking a hyperlink, which results in individuals jumping around the body of text. Due to these differences, people are more likely to pay less attention and consequently, their processing of what they are reading may be shallower.

In addition to shallow reading, researchers have posited different types of reading including hyper-reading and close reading. Hyper-reading may be considered the opposite of close reading. Hyper-reading which usually takes place on digital devices is the rapid jump in text reading which can be facilitated by hyperlinks (Liu, 2005). It has been suggested that hyper-reading reduces sustained attention, as well as causing disjointed reading (Liu 2005; Liu 2012). Close reading is a sustained and thorough interpretation of a text (Adlington & Wright, 2013). However, deep reading goes further. Deep reading is an "array of sophisticated processes that propel comprehension and that includes inferential and deductive reasoning, analogical skills, critical analysis, reflection, and insight" which occur in milliseconds for expert readers (Wolf & Barzillai, 2008, p.32). Deep reading is very important and is a standard that educational practices aim towards achieving, however, due to a digital shift the nature of this norm is in question (Mangen & Van der Weel, 2016). Furthermore, due to the immediacy and information overload associated with digital devices, there is a fear that these devices encourage speed whilst discouraging deep reading and reflection (Wolf & Barzillai, 2008).

As a result of the evidence that technology has an influence on reading performance, which is also influenced by various other factors including ergonomic, psychological, cultural, social and evolutionary, Mangen & Van der Weel (2016) developed an integrative, transdisciplinary framework for reading research, see Figure 2 An integrative framework for reading research (Mangen & Van der Weel, 2016). The framework amalgamates and aligns existing knowledge whilst allowing space for growth through further research. The framework suggests reading preparation is influenced by the text, the reader and the reading environment (Mangen & Van der Weel, 2016). In the framework, reading is defined along the dimensions of ergonomics, attention, cognition, emotion, phenomenology, cultural-evolution and sociocultural dimensions (Mangen & Van der Weel, 2016). Here, the term ergonomics refers to the physical aspects of reading and the necessary multisensory engagement which would differ across media.

For example, comparing a book to a tablet, having read a page in a book you must turn the page physically, whilst on a tablet this is done through touch usually using a scrolling motion or by tapping/ clicking the screen. The dimension of attention refers to allocating attentional resources to the text. Cognition which involves mental processes associated with reading and language processing is important. Reading can lead to an emotional impact. Reading can be personally meaningful, and a reader's interpretation of text can be influenced through prior constructs. This idea of phenomenology in reading suggests readers should take into account both the actual text and the steps involved in understanding and responding to that text (Iser, 1972). Cultural evolution would suggest that reading was acquired due to the overload of informational demands of a continuously advancing cultural environment. The sociocultural dimension suggests reading is a historically contingent practice that is necessary for human life within society. Reading is thus clearly multidimensional and multifunctional. These dimensions alongside mediating variables of reading are presented in the integrative framework for reading research, see Figure 2 An integrative framework for reading research (Mangen & Van der Weel, 2016) (Mangen & Van der Weel, 2016).

Figure 2 An integrative framework for reading research (Mangen & Van der Weel, 2016)

Using Mangen & Van der Weel's (2016) integrative framework for reading research to take into consideration the reader and the purpose of their reading, reading across different types of media can be explored. It has been found that digital reading is best suited for fast and shallow reading e.g. text messages (SMS), emails, the news and online forums including university forums with schedules and assignment descriptions (Jones & Lea, 2008; Spencer, 2006; Tewksbury & Althaus, 2000). Sidi et al. (2017) hypothesised that the medium, print, or digital, gives contextual cues consequently leading to shallower processing on screen irrespective of the length of text. The hypothesis was supported as utilising a screen for work was highly sensitive to task characteristics which indicate the legitimacy of the shallow processing hypothesis. This was found for both cognitive and metacognitive processes. This study highlights the value of differentiating cues that activate shallow processing from those which activate deep processing. These cues may help in overcoming screen inferiority by promoting deep reading whilst using digital devices.

Compared with screens, when reading print individuals are perhaps more aware of their performance and more efficient, as their reading is less shallow (Clinton, 2019). However, intuitively Wolf (2018) has hypothesised a worrying "bleeding over effect" which claims when switching between digital and print media, digitally literate individuals who have a tendency for surface-level skim reading, will continue to process print media more shallowly thus impairing the potential for reflective, deep reading. However, this notion has not been tested empirically and is currently speculation. The above evidence seems to suggest that only in limited circumstances digital text presentation negatively impacts reading comprehension. It appears that the rest of the time that evidence does not seem to favour either medium in overall reading performance. Thus, support for the screen inferiority effect is limited and driven by those with less experience of digital technology and digital texts. Thus, the idea that digitally literate individuals would be more vulnerable to shallowing does not stack up. However, it could be suggested that if from the start an individual reads more shallowly on a digital device, they will continue to do so and as their usage of that device increases their shallow reading is reinforced.

Attention, reading and digital technology

Concerns regarding the influence of digital technologies have increased in recent years, with concerns expressed about digital technologies having a negative impact on the brain (Greenfield, 2015). These worries include potential negative effects on cognitive function including attention and memory, and social dynamics including social interaction (Lodge & Harrison, 2019). Given that purpose of this thesis was to explore the effects of digital technology on children's reading and reading related skills. This thesis will investigate attention and digital technology, as visual attention is employed for reading (Stevens & Bavelier, 2012).

Visual attention refers to "the ability to prepare for, select and maintain awareness of specific locations, objects or attributes of a visual scene" (Deyoe, 2002, p.709). This differs to visual attention span which is defined as "the amount of distinct visual elements which can be processed in parallel in a multi-element array" (Bosse et al., 2007, p. 198). During reading these distinct visual elements are orthographic units including letters, letter clusters and syllables that can be processed in parallel.

It has been noted that visual attention span can predict variation in the ability to learn to read, phoneme awareness (ability to recognise and manipulate phonemes which are the smallest unit of sound in speech), and orthographic knowledge (which refers to information that is stored in memory which is represented by spoken language in written form) (Bosse & Valdois, 2009).

Therefore, it is important to understand the impact that reading via digital technology may have on individual differences in attention, due to its potential knock-on effects on reading processes.

Visual attention can be divided into two stages pre-attention and attention (Hoffman, 1975; Neisser, 1967; Neisser et al., 1963; Treisman & Gelade, 1980). Pre-attention processing is unconscious, automatic, very high speed, involuntary and works independently of attention (Andreoli et al., 2014; L. Zhang & Lin, 2013). At the pre-attention stage, low-level visual information is in parallel, extracted and roughly expressed by retina cells into clusters and then form into separate objects (M. Zhang et al., 2014). Pre-attention processing has no capacity limitation and uses features such as shape, colour, size, orientation, motion and depth cues during operation (Bartram et al., 2003; Hoffmann et al., 2008; Roda & Thomas, 2006; Treisman et al., 1986; Wolfe, 1994; L. Zhang & Lin, 2013). Next after analysing the visual field, objects are serially processed in the attention stage, attention is performed slower and specific sweeping of a scene occurs demanding higher cognitive resources (Andreoli et al., 2014).

Overt and covert attention together are a mechanism of visual attention. Overt visual attention is the process of actively directing sight towards an object through eye movement, whereas, covert visual attention occurs without eye movement and is a mental shift, e.g. noticing the motion of an object that is in peripheral areas of vision (Engelke et al., 2014; L. Zhang & Lin, 2013).

Cognitive theories of attention

Attention has been broadly defined as the allocation of cognitive resources amongst other ongoing processes (B. A. Anderson, 2013; J. R. Anderson, 2005). More specifically, attention "is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalisation, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatter-brained state which in French is called distraction" (James, 1890, p. 403-404). Below theories of attention are briefly considered, before being discussed further in Chapter 4.

Broadbent's Theory of Attention (1958)

This model proposes a serial concept starting from perception to recognition (Zivony & Eimer, 2021). Broadbent (1958) suggested that physical characteristics e.g., loudness are used to select one message from numerous messages, which have entered an unlimited capacity sensory register/ sensory buffer. These messages pass through the selective filter for further processing, whilst the remaining inputs are discarded. This implies information is temporarily stored in immediate memory, but due to limited capacity, a selective filter selects stimuli for further processing and filters out the remaining irrelevant stimuli (Lachter et al., 2004). After selection, stimuli are processed semantically, and this is then used to create a suitable response or stored in the long term memory (Lachter et al., 2004). The selective filter is designed to prevent an overload in the information-processing system because there is a limited capacity to process information. Inputs that have not been selected remain in the sensory register for a short period of time and if they do not get processed, they quickly decay. Broadbent suggested all semantic processing occurs after the selective filter stage; therefore, unselected messages are not understood. Broadbent (1958) conducted dichotic listening tasks, in which two different three-digit number sequences e.g., 5, 2, 1 were presented to each ear at the same time after which participants were asked to repeat what they had heard. Results showed most participants decided to recall the digits ear by ear instead of pair by pair. Therefore, if 5, 2, 1 were presented to one year and then 6, 7, 3 the other year recalled would be 5, 2, 1, 6, 7, 3 rather than 5, 6, 2, 7, 1, 3. These findings were explained as two stimuli presented simultaneously access the sensory buffer in parallel. One input goes through the filter whilst the other remains for processing later. The filter prevents any overloading. However, the idea that unattended messages rapidly decay is debatable. The original studies used participants who had very little knowledge of shadowing, thus they found the task difficult. It was found that naïve participants had a detection rate of 8% compared to an expert in the shadow messaging field who detected 67% correctly (Underwood, 1974). Participants responded after hearing the entire message therefore it is possible that participants simply forgot even though the message was initially analysed. Furthermore, it has been found that individuals can process meaning without awareness, therefore unconsciously (Von Wright et al., 1975). Another finding which cannot be accounted for by Broadbent's theory (as it suggests unattended messages are filtered out) is when a participant's own name is played on an unattended message, 33% still report hearing it (Moray, 1959). This suggests some analysis of the stimuli meaning happens prior to reaching the selective filter. This inflexibility in Broadbent's model does not account for the variability in the analysis of non-shadowed messages. See Figure 3 Models of attention (Bundesen, 1990; Deutsch & Deutsch, 1963; Treisman & Gelade, 1980) including Broadbent's Theory of Attention (1958).

Treisman's Attenuation Theory (1960)

Similar to Broadbent's Theory of Attention (1958), Treisman's Attenuation Theory (1960) suggests serial processing. However, the unattended sensory outputs (i.e. the stimuli not selected by the filter) remain in a sensory buffer and they are attenuated by the filter instead of being discarded (Driver, 2001; Lachter et al., 2004). It was suggested that input analysis continues through a hierarchy, beginning with physical cues, specific words, and syllable patterns, then meaning and grammatical structure (Treisman, 1964). This model explains the possibility of some analysis of the stimuli meaning happening prior to reaching the selective filter. However, there is no explanation of precisely how semantic analysis occurs. Treisman argued some words including people's names could be considered to have lower perceptual thresholds and therefore may be activated even when attenuated (Lachter et al., 2004). An example of this is the "cocktail party effect", which is where an individual's attention is suddenly drawn to someone else's conversation if that their name is mentioned, even though the individual was not previously consciously paying attention to that someone (Cherry, 1953).

Treisman & Riley (1969) conducted a study in which participants were initially told to shadow one out of two audio messages, then stop shadowing and detect a target in the audio message. If in line with Treisman's theory, there would be attenuated processing of the non-shadowed message resulting in less detection of the targets. Deutsch & Deutsch (1963) believe there should be no discrepancy in the detection rate between both messages. Results support Treisman's theory as the effect of attention in a dichotic task was restricting the perception of the stimulus in the verbal secondary messages, instead of limiting memory (Treisman & Riley, 1969). However, an issue with dichotic tasks generally is that researchers cannot be completely sure that participants have not essentially switched attention to the supposedly unattended stimuli. See Figure 3 Models of attention (Bundesen, 1990; Deutsch & Deutsch, 1963; Treisman & Gelade, 1980) including Treisman's Attenuation Theory (1960).

Deutsch and Deutsch's Late Selection Model (1963)

In comparison to Broadbent's Theory of Attention (1958), Treisman's Attenuation Theory (1960) which argues that attention activates in early perception before the stimuli are identified, Deutsch and Deutsch's Late Selection Model (1963) argues that attention occurs later during the identification process (Lachter et al., 2004). Selection is said to be based on object properties and is influenced by cognitive representations (Yantis & Johnston, 1990). However, through neuroscience research this model has been found to be unlikely (Driver, 2001). See Figure 3 Models of attention (Bundesen, 1990; Deutsch & Deutsch, 1963; Treisman & Gelade, 1980) including Deutsch and Deutsch's Late Selection Model (1963)

Figure 3 Models of attention (Bundesen, 1990; Deutsch & Deutsch, 1963; Treisman & Gelade, 1980)

Bundesen's Theory of Visual attention (1990)

This theory is a computational theory that defines visual attention as a combination of the processes of attentional selection and visual recognition that are "racing" in parallel processing (Bundesen, 1990, 1998). This occurs as there is limited storage capacity within visual short-term memory (VSTM) (Bundesen, 1990). Stimuli are concurrently recognised and selected against each other to be symbolized in the VSTM (Bundesen, 1990). This theory differs from alternatives that suggest recognition and selection happen in sequence (Posner & Rothbart, 2007), such as Broadbent's (1958) mechanical bottleneck model which suggests attentional selection precedes recognition and Deutsch and Deutsch's (1963) model which suggests instead that recognition occurs before selection.

According to Bundesen's theory, people's visual attention spans can be identified and measured by five parameters: visual processing speed, efficacy of attentional control, storage capacity of visual short-term memory, visual perception threshold and spatial bias of attention (Bundesen, 1990). This model offers a contemporary account of visual attention, which has been found to be supported by theoretical and empirical studies, as a result, it has been utilised as a theoretical foundation by researchers who have investigated visual attention, including those who explore visual attention during reading (Bundesen & Habekost, 2008, 2014; Habekost, 2015; Prieler, 2018).

Types of attention

Attention is not a unitary mechanism (Chun et al., 2011). Instead, attention can be described as a network of interrelated processes which provide functions such as alerting, orienting, and executive function in different regions of the brain (Petersen & Posner, 2012). Coull (1998), suggested attention can be divided into four functions: orienting attention, selective attention, sustained attention and divided attention. Similarly, attention has been described in research as having these four functions: orienting attention, selective attention, sustained attention and executive attention (Tsal et al., 2005). Orientation of attention is the direction of attention to a stimulus (Coull, 1998). Selective attention is the prioritization of one stimulus of other stimuli, thus focusing on one stimulus whilst filtering out other distractions (Coull, 1998). Sustained attention is the attending of one stimulus over a length of time without distraction (Coull, 1998). Divided attention is when attention is split over two or more stimuli simultaneously (Coull, 1998).

For many years it was argued that executive function appeared to have no agreed upon definition (Jurado & Rosselli, 2007). However, it is considered to be essential to human cognition and achievement (Doebel, 2020). Executive functioning is comprised of a set of general-purpose cognitive control processes that regulate an individual's thoughts and behaviours (Miyake & Friedman, 2012; Snyder et al., 2015). More specifically lower-level processes including motor response and perception enable self-regulation and self-directed behaviour towards a goal, allowing an individual to make decisions, evaluate potential dangers, plan for the future, break out of a habit, prioritise and deal with new situations. It is generally agreed that there are three core executive functions, which have been specified as updating working memory, shifting between tasks and inhibitory control, which includes behavioural inhibition and interference control which refers to selective attention and cognitive inhibition (Diamond, 2013; Lehto et al., 2003; Miyake et al., 2000). In addition, from these executive functions, higher order executive function are created included planning, problem solving and reasoning (Collins & Koechlin, 2012; Diamond, 2013; Lunt et al., 2012).

Executive function has been used to explain the control in top-down attention, including attention to stimuli in an environment and keeping one's attention without distraction from irrelevant stimuli, for example in Eriksen & Eriksen's (1974) flanker task (Oberauer, 2019). Hence, there is an overlap between attention and executive function, as shown by measures of attention also being considered measure of executive function e.g., flanker task (Zelazo et al., 2013). The construct of attention that includes attentional process which are under cognitive control significantly overlap with the construct of executive function (Zelazo et al., 2013).

Executive function has also been used to explain attention as the identification of a required reaction including a person's goals and their resulting actions and the ability to switch from one task to a different task (Oberauer, 2019; Szmalec et al., 2005). For example, readers tend to be more attentive and spend more time processing segments of text that are relevant to the types of questions that they will be asked (Reynolds & Anderson, 1982).

The impact of digital technology on reading and attention

Reading is a complex skill that involves the application and coordination of many cognitive processes, regardless of the medium in which the text is presented (Wylie et al., 2018). These cognitive processes, which can be low-level (e.g., word recognition) or high-level (e.g., inference-making), require the allocation of attention (Wylie et al., 2018). Research shows various precursors of reading, on being individuals phonological skills which have been shown to be closely associated with the development of reading (Snowling & Hulme, 2021). Studies have shown that visual spatial attention development occurs alongside the development of literacy skills in the early years and throughout childhood (Olulade et al., 2013; White et al., 2019). There is evidence to support the notion that visual spatial attention affects reading acquisition, performance and fluency (Franceschini et al., 2012; Lobier et al., 2013; Valdois et al., 2019). However, the relationship between digital technology use and attention remain relatively unexplored (Rosenqvist et al., 2016).

There are concerns that increased digital technology use in childhood could result in a reduced attention span (Subramanian, 2018). For example, a persistent concern with early exposure to video material is the formation of attention problems, due to a negative effect on the development of children’s attention processes (Courage & Setliff, 2010). It is speculated that excessive video exposure can cause attention deficit hyperactivity disorder, through to it causing restlessness and potentially affecting social interaction during play by interfering with information processing (Courage & Setliff, 2010). This idea is supported by a study in which visual attention was higher after a storytelling intervention, but not after screen time exposure (Zivan et al., 2019). Moreover, it was found that screen exposure was linked to electroencephalogram (EEG) patterns that were related to alterations in attention abilities, and attention difficulty scores obtained from parental reports also related to EEG patterns that were related to changes in attention abilities. Overall, in typically developing preschool children Zivan et al’s (2019) results showed a negative relationship with screen time and attention-related EEG patterns. However, a between participants design was used and participants’ EEG measures were not taken before the storytelling or before screen time activities.

However, additional support comes from a longitudinal study of 1,037 participants aged between five and 11 years old (48% female) in New Zealand in which parents estimated the time their children spent watching television. Attention issues were also teacher-, parent- or self-reported (Landhuis et al., 2007). The results showed that the amount of time individuals spent watching television was associated with signs of attentional issues in later adolescence, this association was found to be independent of television viewing time during adolescence

(Landhuis et al., 2007). This does show just how profoundly children's minds can be influenced during their younger years of development with long-lasting impacts. However, a limitation of this study was that all data was based on parent reports or other third-party perceptions. A direct cognitive measure of attention or inhibition would have been more objective.

Attentional processes are involved in all aspects of and reading, including fluency and reading comprehension (LaBerge & Samuels, 1974). From being able to select the text (through selective attention) good readers will need to sustain their attention to allow "an active preparation process" in which the reader can complete the text (Yildiz & Çetinkaya, 2017).

However, the impact of digital device used on attentional processing and reading performance has not been researched until very recently. For example, Delgado & Salmerón (2021) examined the effects of types of reading media and reading time pressure on attention and reading comprehension. One hundred and forty Spanish undergraduate students were allocated to one of four conditions, in which the independent variables were reading medium with two levels: print and on screen and reading time-frame also with two levels restricted time period and no time restriction (Delgado & Salmerón, 2021). The text used was an expository transcript that contained 3010 words, in a textbook style format and the dependent variables measured were mind-wandering while reading, prediction of comprehension scores and comprehension scores on a multiple-choice test (Delgado & Salmerón, 2021). Results found that during the print condition minds wandered less than the on-screen condition in the free time condition therefore, attention was better on print (Delgado & Salmerón, 2021). This supports the shallowing hypothesis. However, there was no significant effect for the time restricted condition (Delgado & Salmerón, 2021). It is important to note that to date there is a lack of research exploring the impact of digital reading on attention in young children. Presently, the only study to examine this was a longitudinal study on 140 children, in which initial data on both a whole report and partial report task was obtained when children were four years old and reassessment occurred when children were seven years old (Prieler, 2018). Results showed that children's early exposure to digital texts as reported by their parents was not related to their performance on a task of attentional processing. However, no experimental study has examined the impact of digital texts on either children's reading or on their attentional processing during reading-like tasks.

Rationale

In summary, over the last 20 years, digital technology has become a pervasive feature of human communication, and concerns have been expressed about its potential negative impact on attentional processes, especially in children. Year-on-year there has been an increase in digital device use by young children and this remains relatively under-researched compared to adult use. Therefore, the studies presented in this thesis aim to provide a more complete "snapshot" of the effects of digital technology on children's attention and reading. This thesis begins with a greater insight into how much exposure to digital texts children get before they start school, and what parental attitudes, perceptions and concerns are in relation to this. This frames a series of experimental studies that will systematically compare children who have experienced high exposure to digital technology and digital texts to those who have had less exposure in the early years on a number of tasks exploring their reading abilities and visual attention.

In line with some adult research and earlier claims, it is argued that one would expect to see evidence that children who have been heavily exposed to digital texts during early childhood may show signs of impaired or maladaptive attentional processing when presented with texts on screen, and that their attentional performance on such tasks will be related to their performance on measures of reading. However, evidence of adverse effects can be expected to be small, because of earlier research which has shown that those with a preference for digital media did not experience screen inferiority effects in the same way that those who disliked it did. Furthermore, digital texts represent an important part of the home literacy environment.

The first research question explored was 'What does a child's home digital environment look like?' To answer this, we report findings from a parental questionnaire that aimed to get a complete understanding of young children's digital technology use immediately prior to starting school, as well as the parents' own use of technology and attitudes.

The questionnaire was subsequently used as the basis of cluster analyses, which had the purpose of verifying whether there were distinctive profiles of early digital text exposure in each group of participants and enabled the separation of children into high and low exposure groups based on their digital technology use before starting school.

A further question of interest was 'Is there a difference in attentional abilities between high and low digital technology exposure groups?' To answer this research question, a task was designed using the flicker paradigm, in which participants were shown an original page from a story book and a modified image of that page with either a small colour change or the absence of a small object in the image. Participants had to use selective attention to spot the change whilst their eye movements were tracked. Accuracy, eye movement measures and reaction times were recorded, in what was the first experiment to collect eye tracking data on young children with differing levels of digital technology exposure and compare their attention skills.

As in previous literature with older participants, another question of interest was: is there a difference in reading time, reading comprehension and reading errors across different reading media? Is there a difference in reading time, reading comprehension and reading errors between high and low digital technology use, across different media? These research questions aimed to find out potential differences in young children's reading across the paper and on-screen formats, and whether this interacted with the children's early digital exposure levels. This was the first experiment to use a national reading scheme text across different media to examine differences between high and low digital exposure groups in young children.

Chapter 2 will provide a complete methodological overview of the designs, samples and measures used to address the above-mentioned research questions.

Chapter 2: Methodology

The previous chapter argued that there were unanswered questions regarding children's use of digital technology prior to starting school, and how that digital technology might impact children's reading abilities and attentional processes. This chapter describes the methodology used in four studies designed to explore these gaps in the literature, which were conducted across four phases of data collection from August 2017 to July 2019.

Within these four phases of data collection all surveys and experiments were conducted. These surveys and experiments go on to form Chapters 3 to 6 of this thesis. Phase 1 comprised of an online survey; the data collected during this phase was used in Study 1a which explored young children's and parental perceptions of digital technology use.

Phase 2 data was collected at an event held at Coventry university; the data collected during this phase was used in both Study 1a and Study 2. The data collected for Study 1a were survey data that again explored young children's and parental perceptions of digital technology use. The data collected for Study 2 were the results of a change detection task that explored the relationship between digital exposure and selective visual attention.

Phase 3 data were also collected at an event held at Coventry University; the data collected during this phase was used in both Study 1b and Study 3a. The data collected for Study 1b was from a shortened survey that again explored young children's and parental perceptions of digital technology use. The data collected for Study 3a were collected to explore the effect of digital technology during reading across different types of media.

Lastly, Phase 4 data were collected in primary schools across the Midlands. The data collected in Phase 4 was used in Study 1b, Study 2, Study 3b and Study 4. The data collected for Study 1b was from a shortened survey that again explored young children's and parental perceptions of digital technology use. The data collected for Study 2 were the results of a change detection task that explored the relationship between digital exposure and selective visual attention. The data collected for Study 3b were collected to explore the effects of digital technology use on print reading versus digital reading. Furthermore, during Phase 4 the data collected for Study 4 was used to compare the results of children in high and low to digital technology across standardised background measures. These four phases are described in further detail below

Data collection phases

Data for the various studies were collected in four phases using three types of sampling methods: online sampling, event sampling and school sampling. The use of a combined approach allowed for a more varied sample. The sampling methods are explained further within the descriptions of each phase below.

Phase 1 data collection: The relationship between parental attitudes towards digital technology and children's exposure to digital technology.

Phase 1 of data collection aimed to understand the relationship between parental attitudes towards digital technology and their children's exposure to digital technology before having started school. In Phase 1, 64 adult participants took part in an online survey. These data were combined with survey data obtained from parents who participated in Phase 2 to form the basis for Study 1a. This survey explored parental attitudes towards their children's use of digital technology, their own use of digital technology, and the extent to which their children used digital technology in the six months prior to starting school. Once the survey was validated through data collection in Phases 1 and 2 (Study 1a), it was then adapted for use in Phases 3 and 4 of data collection (Study 1b). For Study 2, Study 3 and Study 4 the questionnaire was used to enable the grouping of participants into high or low digital exposure groups using cluster analyses.

Phase 1 data were collected using an online survey from October 2017 to July 2018. Sixty-four adult respondents were recruited using opportunity sampling. This type of sampling increased the pool of potential participants by including a range of opportunities to advertise the survey. Participants were recruited online via social media (including Facebook and Twitter), online forums including Mumsnet, a primary school in Leicester advertised the link in their school newsletter, and posters were displayed in public areas of Coventry University. Eligibility criteria included being a parent of at least one child aged four to eight years old. If parents had more than one child in this range, they were asked to focus on the oldest child within the age range. Respondent's (parents – see Table 3) and their child(ren)'s demographic information (see Tables 1 and 2) is described below.

The children of survey respondents in Phase 1 had a mean age of five years and six months (SD: 1 year and 3 months). See Table 1 for further demographic information. The number of female and male children of respondents was roughly equal with 53% being female. Eighty-nine percent of children were not reported to have a disability. The remaining 11% comprised seven children whose disabilities included "ASD" referring to autism spectrum disorder, "dyslexia", "partial complex epilepsy", and a "diagnosis of attachment disorder/childhood trauma". The majority (77%) had siblings. See Table 2 for further information regarding siblings. The survey was mostly answered by female respondents (87%

mothers). See Table 3 for further information regarding parent respondents' demographic information.

Table 1 Online survey: children's demographic information

Variable	**Response**	**%**
Gender	Female	53
	Male	47
Disability	Yes	89
	No	11
Vision (Does your child have normal vision?)	Yes	79
	No	3
	Corrected with glasses	16
	Did not respond to question	2
Language (Does your child speak another language?)	Yes	10
	No	90

Table 2 Online survey: children's sibling information

Variable	**Response**	**%**
Sibling	Yes No	77 23
Number of siblings	0 1 2 3 4	33 39 27 9 2
Order of birth among siblings	First Second Third Fourth	61 23 11 5

Table 3 Online survey: parent respondents' demographic data

Variable	**Response**	**%**
Gender	Female	87
	Male	13
Relationship	Mother	87
	Father	13
Level of education	Secondary School	2
	Post-secondary School	2
	Vocational	11
	Undergraduate	41
	Post-graduate	25
	Doctorate	20
	Other	0

Phase 2 data collection: The relationship between digital exposure and selective visual attention.

Phase 2 of data collection aimed to explore whether exposure to digital technology in the early years was related to selective visual attention. Twenty-eight parent-child dyads took part. Parents completed the online survey for Study 1a, while, their children completed a novel experimental change detection task using the flicker paradigm as a measure of selective attention (Study 2), and standardised background measures (see Study 4).

Phase 2 data collection took place during an event at Coventry University called Coventry Young Researchers (CYR), from 31st July to 4th August 2017. CYR was an annual, week-long event where families with children aged six to 12 years of age were invited to participate in and learn about research as well as complete fun educational activities. The event was advertised via social media platforms and fliers handed out within the Coventry area. Opportunity sampling methods were used; however, due to the nature of the event, a broader sample was achieved with children participating from a range of backgrounds. Task administration took place in 30 minute sessions between 10:30 am – 1:00 pm and 2:30 pm – 5:00 pm. Twenty-eight parent respondents completed Study 1a and their children participated in Study 2. Data from five of these child participants were removed from analysis for Study 2 because participants scored less than 50% accuracy, hence a total of 31 participants from this phase of data collection are included in the study reported in Chapter 3. These children were therefore excluded from Table 4. Upon the completion of the study, participants were rewarded with a stamp in their CYR activity booklet. Participants were later rewarded with a book or t-shirt once completing all the studies and activities in their CYR activity booklet.

Child participants were aged between four to eight years old with a mean age of five years old and standard deviation of 2 months. See Table 4 for child participants’ demographic information and Table 5 for parent respondents’ demographic information.

Table 4 Phase 2 children's demographic information

Variable	**Responses**	**%**
Age	4 5 6 7 8	36 25 25 6 8
Gender	Female Male	61 39
Disability	Yes No	11 89

Table 5 Phase 2: parents' demographic data

Variable	**Responses**	**%**
Gender	Female Male	56 44
Relationship	Mother Father Guardian	50 44 6

Phase 3 data collection: The relationship between digital exposure and reading across media

Phase 3 of data collection aimed to explore whether reading performance differed depending on the medium used to present the stimuli (media: paper, tablet or laptop). Thirty-one parent-child dyads took part. Parents completed the survey for Study 1b while their children completed Experiment 3a and standardised background measures (see Study 4). Data were analysed from twenty-seven parent-child dyads with complete datasets because three children did not complete Experiment 3a and one parent did not complete Study 1b.

Phase 3 data were collected during CYR, from 6th August – 10th August 2018. The experiment was administered between 10:30 am – 1:00 pm and 2:30 pm – 5:00 pm and it took roughly 15-20 minutes for parents to complete the survey (Study 1b) and 20 minutes for their children to complete the experimental task (Study 3a). Responses for the vocabulary and reading standardised assessments were collected in a separate 20 minute session on the same day. Data were collected from 27 parents and their children, who were between the ages of six to twelve years old. Participants ranged from seven years old to 12 years old with a mean age of 9.51 years old and an SD of 1.57 years. Four children had disabilities, one had cerebral palsy and three had autism. See Table 6 Phase 3: children's demographic information for child participant's demographic information.

Table 6 Phase 3: children's demographic information

Variable	Response Categories	%
Gender	Female Male	56 44
Disability	Yes No	15 85
Handedness	Right Left	89 11
Vision (Does your child have normal vision?)	Yes No Corrected with glasses	74 0 26
Language (Does your child speak another language?)	Yes No	15 85

Phase 4 data collection: The relationship between digital exposure and reading print versus digital

Having developed and validated the online questionnaire and experimental measures through Phases 1-3, the aim of the final phase of data collection was to use a cross-sectional study to understand children's digital technology use in relation to parental perceptions and attention and reading ability in a more circumscribed age range. Sixty parent-child dyads took part. Parents completed study 1b when they provided consent. Their children later completed Study 2 and 3b as well as standardised background measures assessing vocabulary, reading and attention skills for Study 4. This phase enabled the researcher to explore and combine research questions raised in Phases 1, 2 and 3.

Phase 4 data were collected from participants recruited from seven different primary schools in the Midlands from February – July 2019. This data set includes data from 60 children aged six to seven years old at Key Stage level 1 (M: 6 years 11 months, SD: 3 months). Sixty-two percent of child participants were female. 90% of child participants were right-handed. Two participants were reported to have disabilities. However, the parents reported the nature of these disabilities, and these did not affect the children's ability to participate in the study therefore they were included. 79% of children were reported by their parents to have good vision; 3% were reported to not have good vision, 16% were reported to have corrected vision with glasses and 2% of parents did not answer the question. It is important to note that all children who were required to wear glasses to read did wear them throughout the study. 90% of children only spoke and understood English, however, the remaining 10% spoke additional languages. This included one child who spoke Tamil, four children who spoke Punjabi (for one of these children Punjabi was their first language) and one child who spoke Greek (Greek was the child's first language). A screening question ensured that none of the participants had epilepsy, which was an exclusionary criterion for participation for ethical reasons due to flashing images in the experimental design of Study 2. Table 7 below provides a clear representation of participants' demographic information. All participants scored 100% on Ishihara's Design Chart for Colour Deficiency of Unlettered Persons (2016), suggesting none of them had colour-blindness.

89% of parents who responded to allow their child's participation in the present study were female. Parents were aged between 26 years old to 46 years old (Mean: 37.4 years old, SD: 4.5). Parents' level of education varied from secondary school level to doctorate level with most parents completing education at undergraduate level. See Table 8 below for further demographic information and a breakdown of parents' level of education. This sample was voluntary; seven schools out of many that were contacted chose to participate. Out of these seven schools, 60 parents agreed to their child's participation through opt-in consent. None of the children withdrew themselves.

Table 7 Phase 4: child participant's demographics information

Variable	**Response**	**%**
Gender	Female Male	62 38
Handedness	Left Right	10 90
Disability	Yes No	3 97
Vision (Does your child have normal vision?)	Yes No Corrected with glasses Did not respond to question	79 3 16 2
Language (Does your child speak another language?)	Yes No	10 90
Epilepsy	Yes No	0 100

Table 8 Phase 4: parent respondents' demographic information

Variable	**Response**	**%**
Relation to child	Mother	89
	Father	11
Gender	Female	89
	Male	11
Level of education	Secondary School	17
	Post-secondary School	7
	Vocational	18
	Undergraduate	40
	Post-graduate	17
	Doctorate	2
	Other	0

Ethical considerations

Overall, the potential risk of physical and/or psychological harm/distress to participants was considered low due to the nature of the studies. Ethical approval was granted by Coventry University Research Ethics Committee to conduct the studies. The following steps were conducted to ensure high ethical research standards set by the British Psychological Society and Coventry University were followed for the online study. In all data collection phases, parents/guardians were presented with the participant information sheet and then completed two informed consent forms (1: for their own participation and 2: for their child's participation). A verbal description of the studies was given to the child in a child appropriate manner after which written assent was obtained from the child participants before commencing a phase of data collection. Parents/guardians and child participants were aware that participation was voluntary. It was carefully communicated by the experimenter to ensure the potential risk of children feeling the obligation to participate in the experiment was avoided. Verbal assent was further obtained from child participants before beginning each study. Parents/guardians and child participants were aware that they had the right to withdraw from the experiment at any time, if they felt that they no longer wanted to partake in the study, without explanation or penalty. Parents/ guardians and child participants were fully debriefed at the end of the experiment both verbally and in writing. The experimenter had an enhanced disclosure certificate from the Disclosure and Barring Service. The experimenter's prior experience of working with young children provided a good ground to ensure that participants were well looked after. Due to the nature of Study 2, which presented flashing images, it was important to check that participants did not suffer from epilepsy, prior to starting the task. This was achieved by asking parents and children prior to testing and including this information in the participant information sheet and the demographic questionnaire.

Study design and procedures

This thesis consists of four studies, described below. Study 1 explored pre-school children's and parents' digital technology use. Study 2 explored the effects of digital technology on young children's visual selective attention. Study 3 explored the effects of digital technology on young children's reading and reading comprehension. Study 4 used standardised measures to explore the effects of digital technology on young children's word reading, vocabulary and attention skills.

Study 1a: Survey exploring young children's digital exposure and parental perceptions of digital technology

An online survey was used to explore young children's digital technology use and that of their parent's. It also examined parental attitudes to, and perceptions of, digital technology. This survey was validated using the data collected during Phase 1 and 2 (and subsequently shortened for use in Phase 3 and 4 (this is explained later). The results of this survey are presented in Chapter 3 and were also used to form the between-subjects independent variable "Digital Exposure" in Studies 2 and 3 (the results of which are presented in Chapters 4 and 5).

The hypothesis was that parents with positive attitudes towards digital technology will allow their pre-school children more exposure to digital technology compared to children of parents who have negative attitudes towards technology. Parents who have positive attitudes and perceptions of digital technology generally will believe that digital devices have a positive effect on reading skills.

Survey design

A mixed-methods approach, using both quantitative items and qualitative methods was used to collect data to assess the relationship between parents/guardians' perceptions and attitudes towards digital technology and how this influences how their children use digital devices. The quantitative items included the use of Likert scales. The qualitative methods included open-ended questions analysed using content analysis. Data were collected during Phase 1 and 2 of data collection.

Parents of children aged between four to eight years old completed three questionnaires (Digital Technology Use, Parental Perceptions of Digital Technology, and Social Desirability). These questionnaires were presented (and completed) consecutively using Qualtrics to ensure that the online survey was compatible with completion on PCs, Macs, tablets and smartphones. The questionnaires are described below.

Digital Technology Use questionnaire

The Digital Technology Use questionnaire was based on a paper-based survey initially provided by Sheffield University (Prieler, 2018). This questionnaire comprised four qualitative and 16 quantitative questions that focused on understanding how parents/guardians and their children used digital technology, when their children used different types of digital technology and how frequently these different devices were used. The Digital Technology Use questionnaire is provided in Appendix 1. An example question is: Do you limit the amount of time your child spends on digital devices? (Yes or No) If yes, please specify how you limit the amount of time your child spends on digital devices?

Parental Perceptions of Digital Technology Questionnaire

The Parental Perceptions of Digital Technology Questionnaire included questions selected from the Parent Perceptions of Technology Scale (PPTS -Sanders et al. 2016) and the Technology-related Parenting Scale (TPS - Sanders et al. 2016), see Appendix 1**.**
Parents'/guardians' perceptions, attitudes and parenting methods when dealing with digital

technology were assessed with a two-part questionnaire. Part one contained 13 five-point Likert scale questions. The Likert scale ranged from always me/usually me/sometimes me/occasionally me/never me (1-5). Part two contained 16 five-point Likert scale questions. The Likert scale ranged from strongly agree/ agree/ neither agree nor disagree/ disagree/ strongly disagree (1-5).

Some questions in part 1 addressed the rules they have in place when dealing with digital technology. These questions were presented to see if there was a variation in how parents/ guardians' felt about digital technology and how they parented their children. An example question is: To what extent do you agree with the following statement? I encourage my child to use the Internet and other digital media to learn about things he or she is interested in.

Other questions in part 1 addressed parents/ guardians' personal use of digital devices. An example question is "I use digital devices with my child". This type of question was asked to further understand parents/ guardians' usage of digital technology and confirm their responses to questions asked in the Digital Technology Use questionnaire.

Part 2 questions addressed parents' beliefs, perceptions and attitudes towards digital technology. An example question is "I would be concerned if my child did not know how to use digital devices by the time, they left primary school." See Appendix 1 for the questionnaire.

Social Desirability Scale (not administered in phase 3 and 4)

Social desirability is a potential bias that refers to a tendency for participants to portray themselves in a more positive way than they really are. As such, this presents a potential threat to the validity of the parents' responses. Crowne and Marlowe's (1960) Social Desirability Scale was used to access the validity of parents/ guardians' responses for the Digital Technology Use questionnaire and the Parental Perceptions of Digital Technology. The Social Desirability Scale contained 33 items (see Appendix 1). The participants were instructed to respond "true" or "false" to the list of statements.

Qualitative Data Analysis

A bottom-up, deductive method of qualitative analysis was used. This method was content analysis which is "a research method that uses a set of procedures to make valid inferences from text" (Weber 1990, p. 9). It was used to examine the results to the following open-ended questions: What are the benefits of your child using a digital device (if any)? What are the downsides of your child using a digital device (if any)? Please specify how you limit the amount of time your child spends on digital devices? From the content analysis, the present study made validated inferences from parents' digital technology questionnaire responses. Content analysis was used because of the often-brief responses to the questions prohibited to use of more sophisticated forms of qualitative analysis.

Study 1b: Shortened survey exploring young children's digital exposure and parental perceptions of digital technology

Following validation of the survey through Study 1a, a shortened version of the questionnaire was used in Study 1b (i.e., during Phases 3 and 4 of data collection), in order to reduce the burden on participants. Responses to this version of the survey are reported in Chapter 3 and were also used to form the between-participants independent variable "Digital Exposure" for Study 3 (reported in Chapter 5).

Survey design

The three open-ended questions used in Study 1a were removed for Study 1b. The option to add additional comments was also removed. The Social Desirability Scale was removed entirely due to the results of Study 1a indicating that there was no significant association between participants' responses and social desirability scores, indicating minimal bias in their responses. These changes reduced the time taken to complete the survey from around 30 minutes to around 15 minutes. In Phase 3 questionnaires were completed online. In Phase 4 paper copies of the questionnaire were provided for the schools that agreed to take part. These were forwarded to parents alongside a Parent Information Letter, Informed consent form and an envelope. Parents who agreed to their child's participation in Studies 1b, 2 and 3b (Phase 4) enclosed their questionnaire alongside their informed consent form in the envelope provided and returned it to their school. See Appendix 2 for shortened version of the questionnaire.

Study 2: Change Detection Task

The purpose of this study was to explore differences between children with high and low exposure to digital technology in their selective visual attention abilities. The change detection task was validated in Phase 2 and then also administered without any amendments in Phase 4 of data collection. It was hypothesised that there would be a significant difference in change detection performance measured by accuracy scores and reaction time between low and high exposure to digital technology participant groups. It was also hypothesised that there would be a significant difference in change detection performance measured by eye movement measures between low and high exposure to digital technology participant groups. These hypotheses were formed based on research presented in Chapters 1 and 4. Results are reported in Chapter 4.

The experimental change detection task is also referred to as the flicker paradigm task. This is a well-established specific type of visual search task that requires the use of focused attention (Rensink et al. 2000). In the change detection, task participants view two alternating overlaid images with a small difference between the images, and their task is to spot the difference.

Design and Stimuli

The change detection paradigm was applied here in a 2 x 2 x 2 mixed experimental design. The between participants independent variable was the individuals' level of digital exposure (defined by responses to the Digital Technology Use Questionnaire – see Study 1a and 1b): high exposure and low exposure to digital technology. There were two independent variables tested within participants: the type of alteration to an object within the image (colour change (CC) or absence and presence (A/P)) and the location of the change (central or marginal). There are multiple dependent variables these include: accuracy, reaction time, and eye movement measures (time to first fixation, first fixation duration, gaze duration and total duration). See the analysis section below for dependent variable descriptions.

The stimuli were digitised pages selected from the Rising Stars Reading Planet's books, which were part of a new children's reading scheme. These books were chosen as it is very unlikely that the children would have read these books before, and permission to use them in this research was granted by Rising Stars. Images were selected from books aimed at children between the ages of four to seven (see Figure 4 Examples of original and modified images presented to form the variable type and location of change in Study 2). The images contained a short line of text. The twenty-four images used to create the stimuli were digitally scanned. The images illustrated familiar scenes for children such as a group of school children in a playground. Each image initially measured 3510 x 2552 pixels; this was rescaled by ExperimentBuilder ™ to 1407 x 1025.

To form the independent variable "type" of change for 24 images an alternate version of the image was created using Adobe Photoshop CC 2017. This resulted in 48 paired images. The absence/presence category of images was created from 12 images (half of the original 24 images) for which an alternate version of the image was created by removing a single object. The category of colour change was created using the 12 remaining images, which were altered by changing the colour of a single object. See Figure 4 Examples of original and modified images presented to form the variable type and location of change in Study 2 for example images.

To form the variable "location" of change for both absence/presence and colour change sets of stimuli half of the alterations were within the central region of the image and half of the alterations were in the marginal region. Although in previous research (Rensink et al. 1997; Maccari et al. 2013), central changes did not always occur in the centre of the image, but instead at a focal point of the image (e.g., a toy in an otherwise empty space); it was possible to have central changes located geographically at the centre to the image. Marginal changes occurred outside of the image's focal point (e.g., a colour change on a poster located in the background of a classroom setting). Therefore, the central region was an area of 50% of the image (from the central axis (0, 0) equally spaced a quarter width round. The marginal region was the remaining 50%. The mean of the size of the interest areas where changes took place was 30290 pixels, with a standard deviation of 2368 pixels. See Figure 4 Examples of original and modified images presented to form the variable type and location of change in Study 2 for example images.

Figure 4 Examples of original and modified images presented to form the variable type and location of change in Study 2

Procedure

Prior to participating in the change detection task, the participants completed the Ishihara's Design Chart for Colour Deficiency of Unlettered Persons (2016)**.** This Ishihara Colour Blindness Test was used to ensure participants were not colour blind as this would affect the results of the change detection task in which the participant must spot an object which is rapidly changing colour. The test is suitable for children from the age of four years old. The test contained eight trials (each known as a plate) which consisted of geometrical shapes, such as circles, squares and curved lines. The test was administered in accordance with the instructions in the manual. The test was conducted indoors in a bright room with the plates held at a distance of about 50 to 75cm. Participants were asked to trace the shape within the plate. If they got more than three incorrect their result was considered abnormal. This test was used as exclusion criteria for the present study because if a participant was colour blind they would not be able to complete the task. None of the participants accessed scored abnormally, therefore no participants were excluded on this basis. All participants scored 100% on the test.

The stimuli were presented on a BenQ XL2420-8 monitor (Screen Size of 55cm x 29cm) with 1920x1080 pixel resolution and 60Hz refresh rate. Orientation was landscape. To minimise eyestrain all images were displayed centrally on a light grey background, with an RGB of 195, 195, 195. Eye movements were recorded using an SR Research Eyelink 1000 Plus eye tracker and ExperimentBuilder ™ software v 1.10.1630 with a sample rate of 1000Hz.

Participants were tested individually. Viewing was binocular but only the right eye was tracked. A combination forehead/chin rest was used to minimise head movements which could affect the quality of the calibration of the eye tracker. The combination forehead/chin rest was centrally in line with the monitor. The monitor was approximately 70cm away from the participant's eyes. The eye tracker camera was positioned approximately 55cm away from the participant's eyes. To ensure accuracy of eye tracking a 9 - point calibration was performed to match the eye position to screen coordinates followed by a recalibration to ensure validation. This was always performed prior to beginning the experimental task and was repeated every 6 trials, or more frequently if deemed necessary by the experimenter. Responses were collected via the computer keyboard.

The combination forehead/chin rest was adjusted for the participants to ensure optimal comfort. When it was possible, participants were advised to keep their feet flat on the floor to reduce any movements that may affect the quality the eye tracking. Participants were instructed to move their eyes only and not their head or body when viewing the images.

In Phase 2 data collection, prior to the experiment parents/guardians completed a demographic questionnaire and during the experiment parents/guardians completed the Digital

Technology Use questionnaire, the Parental Perceptions of Digital Technology questionnaire and the Social Desirability Scale (Study 1a). These questionnaires were usually completed in the same room as the experiment on a Toshiba Satellite Pro laptop using Qualtrics with the parent/guardian sitting next to the child. This seating format was prepared to ensure that the child was comfortable and would not feel any distress or nervousness. Although the parent/guardian was near the child they were not in direct view. It is important to note that the child could not see the laptop screen. During Phase 4 data collection parents were not present and questionnaire data was collected prior by using the school system of sending letters home.

Participants were tested individually indoors in a quiet room with fluorescent lighting and some ambient light. Before the start of each trial, participants fixated on a small smiley face in the centre of the screen followed by a gaze contingent crosshair after which the experimenter initiated the trial. The present study uses the flicker paradigm (Rensink et al., 1997). For each trial an original image and a modified version of an image alternated repeatedly, separated by a blank light grey screen (see Figure 5 Representation of flicker paradigm cycle used in Study 2 (adapted from Resink et al., 1997)).

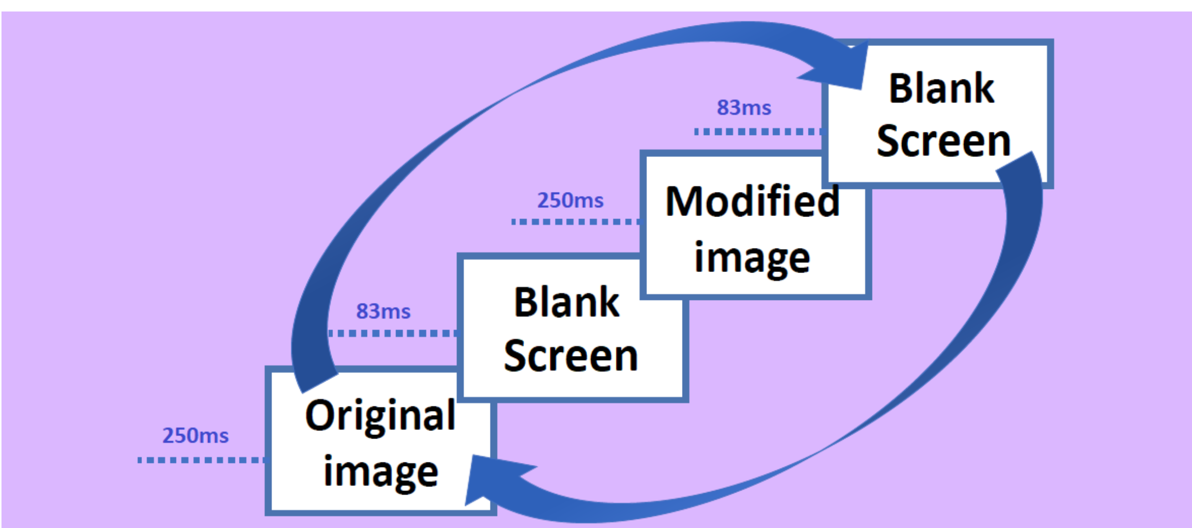

Figure 5 Representation of flicker paradigm cycle used in Study 2 (adapted from Resink et al., 1997)

The original image was presented for 15 frames which is equivalent to 250 milliseconds (ms) followed by a light grey screen displayed for 5 frames which is equivalent to 83ms followed by the modified image for 15 frames and the light grey screen for 5 frames. This cycle was repeated up to 80 times or until the spacebar is pressed.

Two overt behavioural responses were recorded as dependent variables, change detection reaction time and accuracy. Participants were instructed to press the “spacebar” as soon as they detected that an object within the image had disappeared and reappeared or changed colour, and then they were told to verbally describe the change to the experimenter who sat at the side of them out of direct view. Participants used their dominant hand to press the spacebar. Using a score sheet, the experimenter noted whether the participant accurately named the changing object. If an incorrect response was given by the participant, the experimenter noted down exactly what was mentioned by the participant.

There were no practice trials. This was to avoid practice effects due to task repetition. Practice trials can be used to establish that participant’s understand task instructions. Instead, this was achieved using fixed adjacent images rather than alternating images - the examples in Figure 4 Examples of original and modified images presented to form the variable type and location of change in Study 2 and Figure 5 Representation of flicker paradigm cycle used in Study 2 (adapted from Resink et al., 1997).

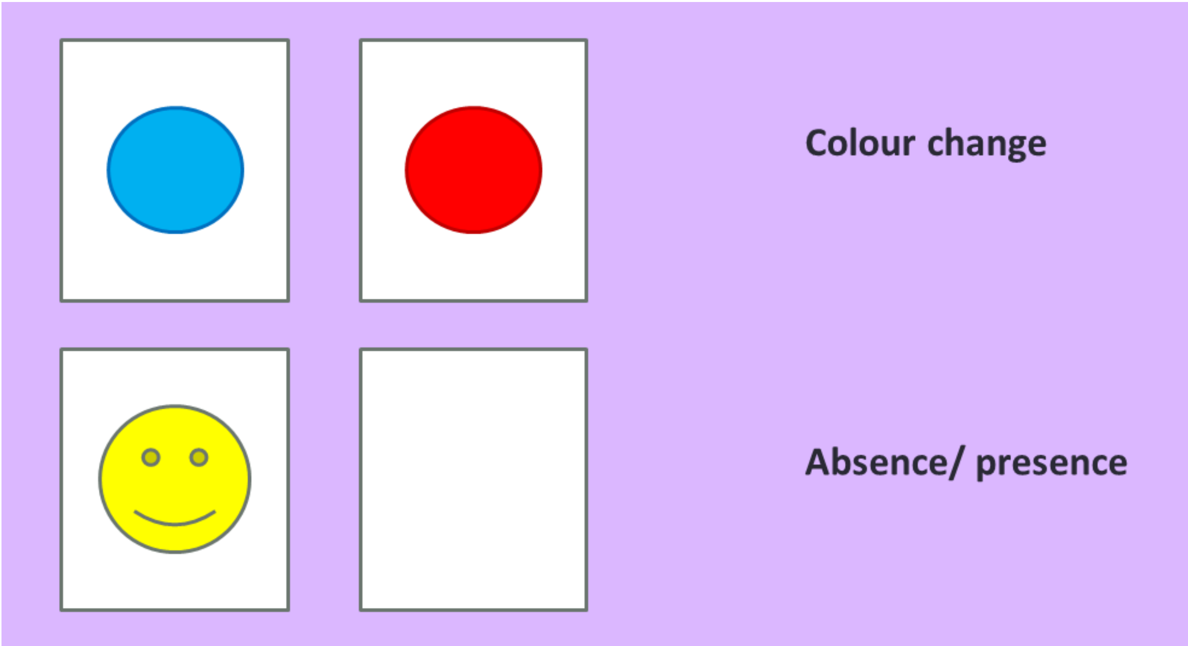

Figure 6 Representation of images used to describe the types of changes in Study 2

These were presented on screen accompanied with a verbal discussion. There were two examples explaining each type of change (A/P and CC), to ensure the participants understood the nature of the task before starting the experimental trials (see Figure 6 Representation of images used to describe the types of changes in Study 2 for examples of the explanations given). No participant failed to identify the types of changes in the examples which were identified verbally by the children. After the examples, the experimenter confirmed that the participants understood the task and had their fingers ready and resting on the keyboard.

All twenty-four sets of trials were presented in random order to each participant. After every six trials participants were offered a break in order to prevent fatigue or boredom. After a break, the experimenter would calibrate and then recalibrate the eye tracker to ensure validity. Participants were also aware that if required breaks could be taken more frequently between trials. Participants received supportive feedback throughout the trials, regardless of response accuracy.

Analysis of Eye Tracking Data

Dependent measures analysed were accuracy, reaction time and eye movement measures (time to first fixation; first fixation; gaze duration and total duration). Accuracy refers to the percentage of correct trials per participant, measured using the oral responses recorded by the experimenter. Reaction time refers to the time taken to respond to change, measured by the time from initial display of an image to the keyboard response (spacebar press). Several eye movement measures were extracted, the process for which is described below.

Eye movement measures were extracted by setting interest areas and interest periods. Interest areas refer to the location or target regions of the screen that displayed the stimuli – the whole screen, the area containing the change, and the text. Time to first fixation (TTFF) is the amount of time the participant takes before they first look at the interest area. First fixation is the duration of the first fixation on the interest area. Gaze duration is the sum of all first-pass fixations on the interest area; thus, it is the sum of all the fixations made in a region until the point of a fixation is made outside the region. Total duration time is the sum of all fixations made on the interest area including re-fixations after leaving the region.

Trials were only included in analyses of reaction time and eye movement measures if the participant correctly detected the change. Therefore, trials were removed if the participant failed to detect a difference or perceived a different change (e.g., if a ball in the image changed colour and the child believed that a person's top changed colour). Further, on a few trials, participants accidentally pressed the spacebar, thus unintentionally terminating a trial prematurely. These error responses were excluded from all analyses.

Trials were also removed from analysis if the participant anticipated the change within the stimuli by making a fixation with a reaction time shorter than 80ms or if the participant was improperly fixated on the central crosshair fixation point (with a deviation larger than 1°) at the beginning of the trial. A four-step automatic software procedure was run in DataViewer to clean the data prior to extraction. Fixations shorter than 80 ms within a distance threshold of .5 were pooled together. Fixations of 40 ms or less within a distance threshold of 1.25 were pooled together. All other fixations less than 80 ms were eliminated as during these fixations viewers rarely extract any information (Rayner and Pollatsek 1989). Fixations longer than 800 ms were excluded.

Once extracted, eye tracking data was combined with accuracy data and exposure group data in R. Means and standards deviations were calculated for eye tracking measures. Outliers were removed by trimming data that was over a value of 2 standard deviation from the mean. Two standard eye movement measures were calculated including first fixation duration (the duration of the first fixation within the interest area) and total duration (the sum of all fixations made within the interest area including both forward and regressive fixations) (Clifton, Staub and Rayner 2007; Radach, Kennedy and Rayner 2004). Results from Study 2 are reported in Chapter 4.

Study 3: Reading on Different Media

The purpose of this study was to examine differences in children's oral reading, reading errors and reading comprehension dependent on their exposure to digital technology. Study 3 was a novel experimental task, validated in Phase 3 (Experiment 3a) and then adapted for Phase 4 (Experiment 3b). Study 3a explored the difference in reading between the three types of media (paper, tablet and laptop), while study 3b explored differences on two types of media (paper, tablet). The studies were concerned with identifying whether the children's reading times, reading accuracy and reading comprehension were affected by the presentation of text: whether it was presented digitally on tablet or laptop compared to being printed on paper? It was predicted that there would be significantly lower reading accuracy and comprehension scores, and slower reading times for the laptop and tablet condition compared to the paper condition. It was also predicted that there would be significantly lower reading accuracy and comprehension scores for children in the high exposure condition compared to the low exposure condition. These hypotheses were formed based on research presented in Chapters 1 and 5. Results are reported in Chapter 5.

Experiment 3a

A novel experimental task to explore the effects of reading on different media was developed and used during Phase 3 data collection.

Design and Stimuli

A mixed design with two independent variables (type of media and level of difficulty) was conducted. Stimuli were presented on three different types of media: paper, tablet and laptop. The two levels of difficulty of the text were easy and difficult, which are defined below. Dependent variables were reading time, reading accuracy (and nature of errors) and reading comprehension. The between-subjects factor was the level of digital exposure: high or low. Participants were presented with the texts at all levels of difficulty for all conditions. All participants were presented with texts on all types of media, but the order of the type of media was counterbalanced between participants to avoid order effects (see Table 9 which shows counterbalancing for participants 1-6 (this pattern was repeated for the following participants).

Table 9 The order of counterbalancing

Participant	**First medium**	**Second medium**	**Third medium**
1	Paper	Tablet	Laptop
2	Paper	Laptop	Tablet
3	Tablet	Laptop	Paper
4	Tablet	Paper	Laptop
5	Laptop	Tablet	Paper
6	Laptop	Paper	Tablet

For each condition participants read six passages. All participants read all the passages however they were presented on different devices. In total participants read aloud 18 passages.

Dependent variables

Reading time was the time taken to read the passage in milliseconds (ms), starting from when the participant was first presented the text and ending once the participant had completed the passage.

Reading accuracy was scored in accordance with the standardised instructions for scoring reading accuracy on the York Assessment of Reading Comprehension (YARC) (C. Martin, 2011). This enabled the researcher to examine not only reading accuracy for the passages, but also to consider the nature of the errors that children made. For each passage, errors were scored as either omissions, substitutions, mispronunciations, reversals, refusals and additions. An omission is when a word is omitted by the participant. A substitution is when an incorrect real word is said in place of a word in the passage e.g., "palace" is replaced by "place". A mispronunciation is a word that is a word that is pronounced incorrectly or is only decoded partially. Differences in dialect and accent are not marked as errors. A reversal is a type of substitution errors in which a word is said backwards e.g., "on" is read as "no". A refusal is when the word is not attempted after five seconds. An addition is when a participant inserts part of a word in the text e.g., "it is out the bag" is changed to "it is outside the bag." An addition is also when a participant inserts a whole word in the text. Self-corrections and omissions or repetitions of a line or chunk of text were not counted as errors. Following the YARC procedural guidelines if this happened the experimenter read the word. Additionally, corrections were made only if the participant misread in a way that altered the meaning of the passage.

Levels of difficulty

For the easy condition, passages were selected from the red band of the Rising Stars Planet, a reading scheme recently introduced in the UK. Permission was granted by the publisher to adapt these texts for experimental use. Red band books are categorised for the Early Years Foundation Stage of the English National Curriculum in which children are age three to five years old. These passages all contained three sentences and between 15 and 27 words with a mean of 20.7 words and had a mean Flesch-Kincaid readability rating of 100. See passage data for easy texts. The Flesch–Kincaid readability tests indicate how difficult a passage in English is to understand, scores between 90-100 mean the text is very easy to read. See Table 10 Passage data for easy texts. In total 9 passages were easy texts (see Appendix 3).

Table 10 Passage data for easy texts

	Number of sentences	Number of words	Number of words in sentence one	Number of words in sentence two	Number of words in sentence three	Number of words in sentence four	Number of words in sentence five	Number of words in sentence six	Mean number words in a sentence	Flesch Reading Ease Rating	Flesch-Kincaid Grade Level
	3	16	6	6	4	5.3	100	0.8	3	16	6
	3	20	7	6	7	6.7	100	1.1	3	20	7
	3	15	7	4	4	5	100	1.4	3	15	7
	3	15	4	7	4	5	100	0	3	15	4
	3	22	8	7	7	7.3	100	0.1	3	22	8
	3	19	7	7	5	6.3	100	0.5	3	19	7
	3	19	5	5	9	6.3	100	0	3	19	5
	3	21	6	8	7	7	100	0.6	3	21	6
Total means	3.0	18.4	6.3	6.3	5.9	6.1	100.0	0.6	3.0	18.4	6.3

For the difficult condition, passages were selected from the green and orange bands of the Rising Stars Planet reading scheme. Green and orange books are categorised as Key Stage 1 for children aged five to seven years old. These passages all contained six sentences. These passages contained between 59 and 76 words with a mean of 66.3 words and had a mean Flesch-Kincaid readability rating of 82.3. See Table 11 for passage data for difficult texts passage data for difficult texts. In total 9 passages were difficult texts (see Appendix 3).

Table 11 Passage data for difficult texts

	Number of sentences	Number of words	Number of words in sentence one	Number of words in sentence two	Number of words in sentence three	Number of words in sentence four	Number of words in sentence five	Number of words in sentence six	Mean number words in a sentence	Flesch Reading Ease Rating	Flesch-Kincaid Grade Level
	6	68	11	12	14	7	17	8	11.5	78.3	5.1
	6	74	14	16	13	11	11	9	12.3	79.9	5.1
	6	60	12	8	8	11	10	11	10	92.3	2.8
	6	76	10	16	9	22	9	10	12.7	81.3	4.5
	6	62	12	14	11	12	5	8	10.3	76.2	5.1
	6	70	15	14	14	15	5	7	11.7	83.4	5.3
	6	62	12	9	9	14	8	10	10.3	82.8	4.1
	6	59	7	13	11	10	7	11	9.8	88.3	4.1
Total means	6.0	66.1	11.7	12.9	10.7	13.6	7.9	9.4	11.0	83.5	4.4

Type of media

For all conditions (paper, laptop and tablet) text was left-justified. A monospaced font whose letters and symbols each occupy an equal amount of horizontal space named Droid Sans Mono was used with one-inch margins and single line spacing. The font was black. This ensured that the format was the same across all conditions. The number of letters on a line for the same stimuli across the different conditions remained equal. However, the visual size of the text varied for each device (laptop and tablet) due to differences in screen resolution. The laptop was larger than the tablet. The tablet had a display screen of 8.3 inches whilst the laptop display screen was 15.6 inches. On both laptop and tablet stimuli were displayed using the OpenSeasme programme, version: 3.2.4 (Mathôt et al., 2012)**.** The visual size of the text was equal for the laptop and paper conditions. In the paper condition text was presented on a white background, however, in the digital conditions, a light grey colour background was used to reduce potential glare. A light grey screen reduces glare and helps minimize eye strain (Breadmore & Carroll, 2018)

Paper

In the paper condition, text was printed on normal white A4 sized paper (210 x 297 mm). Text was left-justified. The paper was usually placed on the table, but it was occasionally held by the participant at a distance that was normal and comfortable for the participant (usually between 30 - 40cm).

Laptop

Stimuli prepared for the laptop condition were displayed on a Toshiba Satellite Pro C50-A-1E6 laptop using the OpenSeasme programme, version: 3.2.4 (Mathôt et al., 2012). The laptop had a 15.6 inch, HD non-reflective High Brightness display and LED backlighting with a screen resolution of 1,366 x 768 / 800 x 768. The laptop display was placed around 30 – 40cm away from the participant.

Tablet

Stimuli prepared for the tablet condition were displayed on a Hudl 2 using the OpenSeasme app, version: 3.2.4 (Mathôt et al., 2012). The Hudl 2 had an 8.3-inch IPS panel, LCD display with a screen resolution of HD 1920 × 1200 / 800 x 768 and a pixel density of 273 ppi. The device dimensions are 128 mm (5.0 in) height, 224 mm (8.8 in) width, 9 mm (0.35 in) depth. Text was presented centrally and was left-justified. A grey background was used as this reduces glare often associated with white backgrounds on digital devices. A light grey screen reduces glare and helps minimize eye strain (Breadmore & Carroll, 2018). The tablet was usually placed on the table, but it was occasionally held by the participant at a distance that was normal and comfortable for the participant (usually between 30 - 40cm).

Procedure

During Phase 3 experiment parents/guardians completed the Digital Technology Use questionnaire and the Parental Perceptions of Digital Technology questionnaire. These questionnaires were usually completed online in the same room as the experiment on a Toshiba Satellite Pro laptop using Qualtrics with the parent/guardian sitting near to the child. This seating format was chosen to ensure that the child was comfortable and would not feel distressed or nervous. The child could not see the laptop screen, therefore would not be distracted by its content. During Phase 4 parents were not present and questionnaire data was collected prior, using the school system of sending letters home.

Child participants were tested individually in a room with fluorescent lighting and some ambient light. To ensure the child was looking at the screen before the start of each trial, participants fixated on a small crosshair. Participants were instructed to read the passages aloud and were given the following instructions: "I'd like you to read some passages for me. Some of them are very short and some are longer. You will read them on three different things: paper, tablet and laptop. Please try to understand what you read and read the passages aloud. If you come to a hard word, try to sound it out. After you have read the passage, I will either flip over the paper or on the screen the passage will disappear. After each passage, I will ask you a question about what you have read. So please read carefully". Participants were not given time to re-read after completing the passage. Participants were given the opportunity to have a break after the 6 passages (3 easy and 3 hard) between the changes of devices and paper. If required, the participant could take a break in between any passage.

After reading each passage children were asked one comprehension question. Therefore, after reading all passages, reading comprehension was scored as out of 18. Reading comprehension questions were all designed to be literal interpretations rather than inferential thus, did not draw on any background knowledge.

Experiment 3b

Following task validation, the design was simplified for use in Phase 4 data collection. The key change was the removal of the laptop condition. The removal of the laptop for Phase 4 was due to the following reasons. Lack of difference between both reading time and reading score between the laptop and tablet condition. Furthermore, in Chapter 3 results from the questionnaire show tablets are used more frequently by children compared to computers and/or laptops, thus providing ecological validity. Research has also shown children are more likely to use tablets over laptops. One reason for this is tablets are easier to use, a higher level of fine motor skill development is needed to use a keyboard furthermore a higher level of cognitive development is required to understand the symbols on the keyboard and use them effectively (Geist, 2014). Additionally, due to time restrictions when testing in school it was most efficient to remove the laptop condition.

Stimuli and design

A mixed design with two independent variables (type of media and level of difficulty) was conducted. Stimuli were presented on paper and on a tablet. The two levels of difficulty were easy and difficult, which are defined below. Dependent variables were reading time, reading accuracy (and nature of errors) and reading comprehension. See stimuli and design in Experiment 3a for more information.

The same stimuli were used, apart from one passage which was removed to allow an equal number of passages per device (See Appendix 3 for sentences). Half the trials were presented via tablet and half paper this was counterbalanced between participants.

Procedure

The same procedure was followed as in Experiment 3a where possible. However, parents were not present as data was collected at schools. Additionally, counterbalancing differed with the paper and tablet conditions being presented in an alternating order across participants (e.g., if the first participant read from the paper and then the tablet, the second participant read from the tablet then the paper and so on.

Study 4: Standardised background measures

In Phase 4 of data collection, children completed standardised background measures in addition to the experimental tasks. These were administered as per their respective manuals. Results from these standardised measures are reported in Chapter 6.

British Picture Vocabulary Scale III (BPVS III) (Dunn, et al., 1997)

The British Picture Vocabulary Scale III (BPVS III) (Dunn, et al., 1997) was individually administered in accordance with the standardised instructions to measure receptive vocabulary. In this task, the experimenter said a word, and the participant was shown four images on a page. The participant was instructed to point to one of four images that corresponded to the meaning of the word. The words increased in difficulty as the task continued. The assessment consisted of 14 sets, with each set containing 12 items. As instructed by the BPVS III manual, the appropriate starting set was determined on the day of testing as it depended on the child's age. Up to eight errors were allowed for participants to move on to the next set. If more than one error was made in the participant's starting set, the sets were administered in a backwards order until the participant reached a set in which they made zero or one error, after which forward testing continued. The manual reports high reliability (.91) and validity (criterion validity -.76 for W.I.S.C. and .80 for Schonell).

Diagnostic Test of Word Reading Processes (DTWRP) (Forum for Research in Literacy and Language, 2012) (Stainthorp, 2012)

The Diagnostic Test of Word Reading Processes (DTWRP) (Stainthorp, 2012) was used to measure written word recognition and wording reading processes through single-word reading. The DTWRP involves three sections: non-word reading, exception word reading and regular word reading. A non-word is a word that does not exist in the English language but is formed from a string of pronounceable letters, an example is "meckton". An exception word is one that does not follow grapheme-phoneme correspondence language rules, thus cannot be broken down into sounds, an example is "yacht". A regular word is one that does follow, grapheme-phoneme correspondence language rule, an example is "meet". Each section contained 30 words that increased in level of difficulty. The DTWRP test was individually administered in accordance with the standardised instructions with no time limit. Participants started at the first word and continued to the end unless the participant made five consecutive reading errors. For each correctly read word participants were given one point, resulting in a score out of 30 for each section. The DTWRP had high levels of reliability with a Cronbach's alpha of .99 for the complete test, .96 for the non-word reading, .97 for the exception word reading and .97 for the regular word reading. Concurrent validity was also high with a correlation of .89 between the DTWRP and the Single Word Reading Test (E. M. Foster, 2007), .82 between the DTWRP and York Assessment of Reading for Comprehension (YARC) Reading Accuracy and .87 between the DTWRP and the YARC Early Word Recognition. In comparison to the Test of Word Reading Efficiency (Torgesen et al., 1999) which provides a measure of word reading fluency (N words read in x time), the DTWRP is a test without timing which provides a measure of accuracy of reading different types of words.

Test of Everyday Attention for children (TEA-Ch 2) (Manly et al., 2016)

The Test of Everyday Attention for children (TEA-Ch 2) (Manly et al., 2016) uses a comic-based format which is partially presented via a paper booklet and partially presented via a laptop. The computerised elements of the assessment result in a highly standardised presentation of stimuli including auditory stimuli, accurate test timings and automated scoring. Participants completed the assessment in stages but always chronologically starting with two selective attention tasks and then four sustained attention tasks.

The first selective attention task was the Balloon Hunt. In this task, the participant would mark as many balloon targets as possible find within a series of 15 second trials. The maximum number of targets was always 48. There was a practice to ensure the participants understood the nature of the task. There were four trials, two trials contained only balloon targets (Balloon Hunt 1 and 3) and another two with balloon targets and distractors (Balloon Hunt 2 and 4). In a fifth Balloon Hunt trial, a stopwatch was used to measure how long it took participants to mark all the balloons on the page without a time limit being imposed.

The second selective attention task, Hide & Seek Visual Search, did not require a motor response. The participant was asked to inspect a series of panels and report whether a target is present or absent within 60 seconds for two trials. This was a red ball amongst blue balls, red balloons and rectangular shaped distractors. This provided a measure of a participant's ability to detect a visual target amongst distractors, within a limited time. There was a practice trial with eight panels, this ensured the participants understood the task and gave the examiner an opportunity to correct the participant. The task contained two trials with 20 panels each.

The sustained attention tasks were all computerised. The first sustained attention task was Barking Vigil which measured the ability of the participant to maintain their attention on a slow, dull task. The trial began with an ascending sound, indicating that the trial had started, then a series of repeated dog barks that were to be counted by the participant (in their head – not out loud), and the descending sound, indicating the end of the trial. Due to the long gaps between the sounds, the task does not ‘grab’ the examinee’s attention thus examining the participant’s ability to self-sustain their attention.

The second sustained attention task was Hide and Seek Auditory in which the participant listened to short sound clips and pressed the spacebar as quickly as possible if a barking sound occurred. Distractor sounds in the form of other animal noises could also be heard, but these should have been ignored. Sometimes a dog bark would be heard, and sometimes not.

The third sustained attention task was the Simple Reaction Time where a reliable estimate of simple reaction time by measuring responses to the onset of a visual target was obtained. Participants were instructed to press the space bar as soon as they see a blue blob appear on the screen.

The fourth and final sustained attention task was the Sustained Attention Reaction Time (SART) task in which the participant’s ability to maintain attention to the task without absentminded responding was measured. In the SART, a set of shapes were presented in sequence in the centre of the monitor. The shapes were presented at a regular pace that was independent of the participant's response. Participants had to respond to each of the shapes by hitting a response key in time with an on-screen cue but to withhold the response to one of the shapes.

The TEA-Ch2 manual reports good reliability. For consistency within the scores on a subtest, internal consistency coefficients for the TEA-Ch2 range from moderate (>.5) to good (>.8), with most subtests being good. However, for consistency between scores, test-retest stability coefficients were lower for the TEA-Ch2 with a range from lower (>.3) to acceptable (>.7), with most subtests being adequate (>.6). The TEA-Ch2 manual also reports good validity. Criterion validity which used special group studies compared a matched group of children without problems to children who had been referred to a UK clinic for children with problems in attention and behaviour. The children referred for attention/behaviour problems showed weaknesses affecting several subtests significantly their scores were lower for Balloon Hunt, Barking and Simple RT tasks. Concurrent validity looked at the relationship of the TEA-Ch2 with the Strengths & Difficulties Questionnaire (SDQ) (a measure of emotional and behavioural problems in children and young people). The results showed that TEA-Ch2 subtests and indices were correlated with a number of SDQ scores including the inattention, conduct problems and peer problems subscales. Contrast validity which looked at the test's internal structure using structural equation modelling (SEM) found that the individual subtests contributed unique variance thus, addressed different abilities and two common underlying factors emerged, supporting the construct validity of the Selective Attention and Sustained Attention indexes and these factors were correlated, therefore supporting the Everyday Attention Index.

Developing digital technology exposure groups

Another important function of the parental questionnaire was to see if it was possible to use parental responses to derive meaningful groups of children who differed in terms of their exposure to technology in the early years. These groups would form the basis of the 'early digital exposure' independent variable that would be used in subsequent experimental studies. We wished to avoid the use of arbitrary cut-offs, in favour of a data-driven approach, and so cluster analysis was used for this purpose.

For data collected in Phase 2 and reported in Chapter 4, a hierarchical cluster analysis using Ward's Method was conducted on data from 28 participants to develop a between-subjects factor of digital technology exposure level (for the results reported in Chapter 4). Squared Euclidean distance was selected as the interval. Variables used were total device use; total activity use and rules and regulations.

For the school data, a hierarchical cluster analysis using Ward's Method was conducted on data from 60 participants from Phase 4 data collection to develop a between-subjects factor of digital technology exposure level (for the results reported in Chapter 4-6). Squared Euclidean distance was selected as the interval. The same variables used in Study 1a were used in Study 1b, these included: total device use; total activity use and rules and regulations.

From both cluster analyses outputs the dendrogram was used to identify the clusters of groups of participants. In both sets of data, there were two obvious groups. These were defined as low exposure and high exposure groups based on the means of the two groups identified. The larger mean indicated higher exposure. For data collected in Phase 2 and reported in Chapter 4, 18 participants fell into the high exposure group and 11 participants fell into the low exposure group. Please see Table 12 Percentages of demographic information by exposure group for data collected in Phase 2, for the demographic information of the child participants broken down by exposure group for school data collected in Phase 2. In the high exposure group, the mean age was 5.9 years old with a standard deviation of 1.4 years. In the low exposure group, the mean age was 6.8 years old with a standard deviation of 1.6 years. A limitation for conducting a cluster analysis on the data collected in Phase 2 is that the sample size is relatively small, however despite this, two groups were still identified. Two groups were also identified in the larger sample consisting of 60 children. However, there is a possibility that future studies accessing even larger samples might identify a more nuanced set of clusters.

Table 12 Percentages of demographic information by exposure group for data collected in Phase 2

Variable	**Variable levels**	**High %**	**Low %**
Gender	Female	66.6	72.7
	Male	33.3	27.3
Handedness	Right	72.2	90.9
	Left	27.7	9.1
Disability	No	88.8	100
	Yes	11.11	0
Vision (Does your child have normal vision?)	Yes	100	100
	Corrected with glasses	0	0
	No	0	0
Language (Does your child speak another language?)	Yes	100	100
	No	0	0

For the school data collected in Phase 4 and reported in Chapters 4-6, 32 participants fell into the high exposure group and 28 participants fell into the low exposure group. Please see Table 13 Percentages of demographic information by exposure group school data collected in Phase 4 for the demographic information of the child participants broken down by exposure group for school data collected in Phase 4. In the high exposure group, the mean age was 6.9 years old with a standard deviation of .54. In the low exposure group, the mean age was 7.1 years old with a standard deviation of .49. A t-test revealed there was not a significant age difference between the exposure groups $t(58) = -.572$, $p = .570$. In the high exposure group, the parent respondents' mean age was 37 years old with a standard deviation of 5.18. In the low exposure group, the mean age was 38 years old with a standard deviation of 4. A t-test revealed there was not a significant age difference between both exposure group $t(57) = -1.339$, $p = .186$. However, it is interesting to note that parents of the children in the high exposure to digital technology group tended to be younger.

Table 13 Percentages of demographic information by exposure group school data collected in Phase 4

Variable	**Variable levels**	**High %**	**Low %**
Gender	Female Male	53.1 46.1	75 25
Handedness	Right Left	87.5 12.5	96.4 3.6
Disability	No Yes	93.8 6.3	100 0
Vision (Does your child have normal vision?)	Yes Corrected with glasses No	84.4 12.5 3.1	75.0 21.4 3.6
Language (Does your child speak another language?)	Yes No	87.5 12.5	92.9 7.1
Parent's gender	Female Male	90.6 9.4	89.3 10.7
Parent's level of education	Secondary School Post-secondary School Vocational Undergraduate Post-graduate Doctorate Other	15.6 0 25.0 40.6 18.8 0 0	14.3 14.3 18.7 42.9 14.3 3.6 0

Summary

This chapter has explained the four phases of data collection and the methodology of the studies conducted. **Error! Reference source not found.**4 presents a summary description of each study and its associated phases of data collection.

Table 14 Study map with research questions

Study	**Data Collection Phase**	**Research Questions**
Study 1a	Phases 1 and 2	What devices do children use and for how long? Is there a difference between children with high and low exposure? Do parents with positive attitudes towards digital technology allow their children more exposure to digital technology compared to children of parents who have negative attitudes towards technology? Do parents who have positive attitudes and perceptions of digital technology generally will believe that digital devices have a positive effect on reading skills? (This questionnaire will be used to create groups dependent of levels of exposure to digital technology).
Study 1b	Phases 3 and 4	A shorter questionnaire was developed to answer the same research questions above from Study 1a.
Study 2	Phases 2 and 4	Is there a difference between children with high and low exposure to digital technology in their selective visual attention abilities through a change detection task via the flicker paradigm?
Study 3a	Phase 3	What are the differences in children's reading, reading errors and reading comprehension dependent on their exposure to digital technology across three different media?
Study 3b	Phase 4	Two media were used to answer the same research questions as above from Study 3a.
Study 4	Phase 2 and 4	Standardised measures of vocabulary, word reading and attention were taken.

To summarise, the novel methodological contributions included the development of an online questionnaire that can be used to identify high and low exposure groups and the use of cluster analysis to derive those groups (rather than using arbitrary cut-offs to determine group membership). Moreover, the present study was the first of its kind to develop and use an eye tracked flicker paradigm with young children to assess their visual attention in the context of understanding its relationship to reading and early exposure to digital texts. These important contributions will be further explored in each relevant chapter discussion. The next chapter will explore children's and parents' digital technology use and analyse the results from the Digital Technology Questionnaire.

Chapter 3: What are the effects of digital text exposure on young children?

This chapter aimed to understand children's and their parents' use of digital technology and their parents' attitudes toward these devices. This chapter provides a "snapshot" of what children's digital home learning environment looks like in the years before they start school and explores this in relation to the technology-related behaviours and attitudes of their parents. This initial study serves as a contextual background in which to locate and interpret the later experimental studies that examine whether high exposure to digital technology in the early years impacts children's later developing attention skills or reading abilities.

Compared to their parents' childhoods, young children today are exposed to a very different technological world. By the time children begin school, the majority will have had exposure to various digital devices, both at home and at the homes of family and friends (Plowman et al., 2010). As noted in Chapter 1, 'digital device' is an umbrella term that encompasses many different technologies. These range from televisions and gaming consoles, through to computers, and mobile devices such as laptops, tablets, smartphones and e-books. In recent years, there has been a wave of increased mobile device use by or with young children. For example, Ofcom (2017) reported an increase in mobile phone use for children aged five to seven years old, rising from 28% in 2016 to 43% in 2017. This increase was also found for children aged three to four years old (28% to 43%). Tablet use was also found to increase for children aged three to four years old (55% to 65%). Most recently, the COVID-19 pandemic has led to the widespread introduction of online schooling. For children across the world, video and messaging tools have been used to enable children to maintain social relationships with peers and family members (Williamson et al., 2020).

However, there is debate regarding the impact and developmental suitability of digital technology for very young (i.e., pre-school) children. On the one hand, research has found that allowing children access to such technology can have developmental benefits. For example, a systematic literature review by Marsh (2010) suggested that children's use of digital devices may promote creativity. Additionally, an online survey of 2,000 parents of zero to five year olds in the UK found that tablet use by young children promoted their motor development and digital skills (Marsh et al., 2015). Chaudron et al., (2015) have suggested that touchscreen devices (e.g., tablets) could help to foster autonomy and independence. Similarly, Bedford et al (2016) found that for children agreed 6 to 36 months, scrolling on a touchscreen was positively correlated with fine motor skills and there were no negative correlations between the age the children first used a touchscreen and other developmental milestones. There is also some evidence that specific apps have the potential to benefit children's working memory development (Huber et al., 2018). Such research findings point to the potential benefits that enabling access to digital technology may have for children in the early years.

Significant concerns have also been expressed about allowing children and young people access to digital technology (e.g., Greenfield 2014, although also see Bell, Bishop & Przybylski, 2015), although little of this concern has been specifically about preschool children (e.g., see Zeigler, Mishra, & Gazzaley, 2015). Yet it is possible that increased use of digital technology in the home may represent a threat to young children's development indirectly, depending on how parents use it and the wider context of that use. For example, the 2017 Nielsen Book Research's annual consumer survey into the reading habits of UK children (*Understanding the Children's Book)* demonstrated a 20% decrease in the number of pre-school children being read to daily since 2013, with only 58% of parents doing so. The survey also found an almost 20% increase in the percentage of children viewing video content online every day. It is therefore possible that in the context of decreased shared storybook reading, the increase in young children's passive viewing of online videos may represent a threat to children's early literacy skills. Although this is less to do with the video and viewing it itself and more related to parental behaviours around engaging with old and new 'narrative' technologies.

Although the Education Endowment Foundation recently published information on the use of digital technology to improve children's learning, this report was intended to provide evidence-based guidance for schools (Stringer et al., 2019). There is still a lack of guidance for parents regarding young children's use of digital devices (Livingstone & Franklin, 2018). Yet, parents are the gatekeepers of digital technology in the early years. Parents can set rules and regulate their children's technology use when they are very young, but mobile devices can make supervision more difficult as children become more technologically competent, and potentially as children's device use becomes more advanced than that of their parents (Livingston & Byrne, 2018).

A significant gap in understanding relates to what children's use of digital technology is like before they start school, and how much parents either regulate or model different levels of technology use when their children are in the early years. It seems likely that shared use of technology will be an important factor in maximizing the potential developmental benefits of such resources. It is known that the adult support provided by shared story book reading is an important factor in reading development (Flack, Field & Horst, 2018). It seems likely to be just as important that parents do not assume that 'technology teaches' and leave very young children alone to explore and make sense of such digital resources and expect benefits to automatically emerge from the resulting interactions. A study of how parents initiate pre-school children into use of digital resources at home revealed the importance of how parents scaffolded and valued digital literacy in their children and were engaged in family digital literacy practices (Marsh et al., 2017). However, this detailed account was focused on four case studies of families who saw digital literacy as "the way forward" (Marsh et al., 2017, p.58). Better understanding is needed of how representative this view is, what pre-school children are using technology for, who are they using it with, and what devices they have access to.

Although there is some research examining parental attitudes to technology, this is concerned with the parents of school age children rather than pre-schoolers. This work has shown that elementary school parents see computer use as vital for their children's academic success and employability (Ortiz et al., 2011) but addiction is a significant worry for other parents (Lampard et al., 2013), with concerns that internet use may also increase the chance of exposure to improper content, and impact social skills negatively (Pavez & Teresa, 2018). It has been suggested that people are on the brink of a cataclysmic change of the brain, in which the way individuals think will change forever (Greenfield, 2004, 2015). Another concern has been that a preference for digital activities will result in reduced participation in physical activity (e.g., Edwards et al., 2016; Wartella et al., 2014). Greenfield (2014) also claimed that social networking sites may worsen an individual's communication skills and negatively affect personal empathy and personal identity, a reliance on web search engines and a preference for surfing the internet may result in superficial processing, thus forfeiting deeper understanding and further knowledge. Greenfield (2014) also claimed excessive use of computer games could result in impulsiveness, an increasingly aggressive disposition and a shorter attention span. However, despite multiple calls for the publication of these claims in peer reviewed scientific journals in which research can be supported or refuted by researchers; this has not happened (Bell et al., 2015).

A meta-analysis showed a significant effect of computer games on information processing including improvements in auditory processing and visual processing domain (Powers et al., 2013). Research has revealed a link between violent content in video games and aggressive behaviour and delinquency (C. A. Anderson & Dill, 2000; Doğan, 2006). A meta-analysis revealed playing violent video games is linked with higher levels of overt aggression over time, even when previously having accounted for levels of aggression (Prescott et al., 2018).

These contradictory positive and negative beliefs will influence the way in which parents regulate, mediate and control their children's use of digital devices. One method of digital technology regulation by parents is 'restrictive mediation'. This involves parents' establishing rules, supervising, and regulating their child's digital technology use (Livingstone & Helsper, 2008). Research on restrictive mediation of digital technology has mainly focused on gaming for adolescents (Holtz and Appel, 2011). It was found that children are more likely to follow rules that limit activities on digital devices (e.g., you cannot use this app) compared to rules that limit the use of digital devices in certain contexts (e.g., no devices at dinner time). Context limits are more difficult for children to follow and more difficult for parents to enforce. This study found that both parents and children agreed that parents should also avoid digital technology use when spending time with family. Radesky et al. (2015) and Petegem et al. (2019) have argued that more research into parents' rule setting when guiding young children's digital technology use is needed. Coyne et al. (2019) suggest that understanding family dynamics and attitudes regarding technology use is central in understanding the effects of digital technology, developing policy and the targeting interventions to improve children's health and their development.

The present study aimed to both characterize the nature of pre-school children's use of technology in the six months before they started school (including shared technology use with parents), and to explore the relationships that might exist between children's use of technology in the early years and their parents' attitudes towards technology. It is still not fully understood what young children's use of technology before school looks like, and whether the technology use of young children is simply a function of parental attitudes and behaviours in relation to it. Given the lack of guidance for parents, it may be found that parental attitudes to technology are unrelated to how they parent in relation to technology. Therefore, consideration of whether parents' attitudes and behaviours in relation to their children's use of technology were related to either the frequency of their use of digital devices, or how often the children engaged in digitally mediated activities in the six months before they started school is needed.

Method

A survey was conducted to explore the relationship between parents/guardians' perceptions and attitudes towards digital technology and how this influenced their children's use of digital technology. See Chapter 2 for full methodology of data collected in Phase 1 and 2 for Study 1a.

Participants

One hundred parents or guardians were recruited to complete an online questionnaire. The questionnaire was designed to provide both qualitative and quantitative data on parental views of technology (both positive and negative) and their children's use of technology during the six months before starting school. The majority of parents (N=64) responded via a survey link circulated via social media. The remaining participants were recruited during a public engagement event called Coventry Young Researchers in which children and their parents participated in psychology experiments and activities held at Coventry University. This event was advertised via social media platforms and fliers handed out within the local area. It should be noted that the survey was distributed and completed in 2017, before the COVID pandemic.

The respondents were primarily the mothers of the children (87.5%), with a mean age of 38 years old and a standard deviation of four years and five months. Most were educated to degree level (26%) or higher (29%) and a diverse range of professions were represented. With respect to the gender of the children concerned, there were 57 girls and 42 boys, with one individual not specifying. The average age of the children was reported to be 5.5 years old with a standard deviation of one year and four months.

Materials

Parents completed a survey, which comprised three questionnaires (Digital Technology Use in the Early Years, Parental Perceptions of Digital Technology, and Social Desirability). These questionnaires were presented (and completed) consecutively, online using Qualtrics.

Digital Technology Use in the Early Years

The Digital Technology Use questionnaire was based on a paper-based survey initially developed by (Prieler, 2018), but expanded to provide more detailed responses. The present version of the questionnaire contained four qualitative and 16 quantitative questions that focused on understanding how parent/ guardians and their children used digital technology in the six months prior to school entry (children start school in the academic year in which they are five years-old), where their children used different types of digital technology and how frequently these different devices were used (see Appendix 1).

Parental Perceptions of Digital Technology Questionnaire

Parents' own use of technology, their regulation of their children's access to technology, and their attitudes to digital technology were assessed within this two-part questionnaire, which was an adaptation of The Parent Perceptions of Technology Scale (PPTS) (Sanders et al. 2016) and the Technology-Related Parenting Scale (TPS) (Sanders et al. 2016).

Part one was concerned with the parents' own use of digital devices, and their use of rules in relation to their children's own use of technology. This section comprised 13 five-point Likert scale questions, where respondents were asked to indicate the extent to which a statement was 'always me' through to 'never me'. Part two was concerned with the parents' own attitudes towards digital technology and consisted of 16 five-point Likert scale questions. These were written as statements which the participants responded to by indicating 'strongly agree' through to 'strongly disagree' (for example: "To what extent do you agree with the following statement? I would be concerned if my child did not know how to use digital devices by the time, they left primary school"; see Appendix 1).

Social Desirability Scale (Marlow and Crowne, 1960)

A social desirability scale was used to provide a measure of the participants’ tendency to respond to questions in a socially desirable way. This was used to determine whether there was evidence of parents’ responding to the digital use questionnaires in ways that they felt were ‘appropriate’ rather than answering openly and honestly.

Design

A mixed-methods approach, using both quantitative items and qualitative methods was used to collect data to assess the relationship between parents/guardians’ perceptions and attitudes towards digital technology and how this influences how their children use digital devices. The quantitative items included the use of Likert scales. The qualitative methods included open-ended questions analysed using content analysis

Results

Characterising Pre-School Children’s Use of Digital Technology

In most cases parents reported that their children were exposed to print media before using digital devices, with 91% of children being read to from a book before the age of one compared to 14% of children being exposed to a digital device before the age of one. Most parents (71%) waited until the age of two before allowing their children access to digital device.

The children’s use of different devices and engagement in different technologically mediated activities in the six months before school was assessed on a six-point Likert scale, which was scored as follows: 0=Never; 1=Less than once a week; 2=Once a week; 3=3-4 times a week; 4=Once a day; 5=More than once a day. The parents' responses to these questions are presented below in **Error! Reference source not found.**. Printed Books are included in the 'Devices' section because a particular interest for us was to use shared book reading as a benchmark for the frequency of the other digital activities.

Error! Reference source not found. shows printed books to be used most frequently, averaging at being used once a day, followed closely by television, also averaging at being used once a day. All children had access to television, with no parent reporting "never" as a response. The frequency of tablet and smartphone use followed television use: tablet use was once a week and smartphone use nearly once a week, on average. E-readers were the least frequently used device with most children never using them.

Table 15 Summary Statistics for the Frequency of Pre-School Technology Use

	Mean	**SD**	**Minimum**	**Maximum**
Devices				
Smartphone	1.75	1.48	0	5
E-Reader	0.37	0.96	0	4
Tablet	2.46	1.63	0	5
Computer / Laptop	1.24	1.49	0	5
Gaming Console	0.44	0.66	0	2
Printed Books	4.41	1.04	0	5
Television	4.24	0.86	1	5
Uses				
Playing games for fun	2.39	1.61	0	5
Playing Educational Games	2.53	1.60	0	5
Watching Videos / Programmes	3.41	1.43	0	5
Watching / Listening to Music	2.15	1.69	0	5
Communication with Others	0.90	1.24	0	5
Children's Gaming Websites	0.32	0.78	0	3
Using Children's Educational Websites	0.81	1.28	0	
Reading e-books	0.42	0.93	0	
Finding things out	1.59	1.73	0	

The most popular digitally mediated activity was watching videos or programmes which is understandable as both televisions and tablets were used frequently and these devices facilitate a viewing experience. Using devices for watching videos or programmes averaged at a frequency of 3-4 times a week. Devices were frequently used to play games, both educational and fun ones, around once a week. Reading e-books and using children's gaming websites were engaged with the least often, with most pre-school children never doing these activities.

84% of parents surveyed exclusively used print books compared to 14% who mostly used print books and 2% who used print books and e-books equally often with their preschool children. However, 45% of parents agreed or strongly agreed that e-books were more interactive than print books. However, 97% of parents believed that their children would pay attention to print books for a longer period of time compared to e-books.

The parents reported that they tended to set rules for their children's screen time. Fifty-eight percent of parents limited the amount of time their children spent on digital devices, 61% limited when their child could use a device, and 72% controlled the content that their children could access. Parents mostly agreed with their partner regarding digital media usage with 42% stating they 'usually' agreed when it came to making decisions about their child's media use.

Parents were asked about how often they engaged with technology together with their child, or on their own. These responses were measured on the same Likert scale of frequency as before. The pattern of device use by parents broadly mirrored that of the devices that the parents used with their children, with a few notable exceptions (see **Error! Reference source not found.**). That is, parents read printed books with their children more often than they read themselves, and parents were more likely to use smartphones and computers / laptops alone than with their children.

Table 16 Summary Statistics for the Frequency of Parental Technology Use and Shared Use

	Mean	**SD**	**Minimum**	**Maximum**
Devices used by Parent				
Smartphone	3.13	2.41	0	5
E-Reader	.48	1.15	0	5
Tablet	1.21	1.74	0	5
Computer / Laptop	1.85	2.03	0	5
Gaming Console	.14	.45	0	5
Printed Books	1.87	2.08	0	5
Television	2.20	2.20	0	5
Devices used with Child				
Smartphone	1.22	1.71	0	5
E-Reader	.17	.73	0	5
Tablet	1.07	1.53	0	5
Computer / Laptop	.78	1.30	0	5
Gaming Console	.26	.65	0	5
Printed Books	2.23	2.18	0	5
Television	2.16	2.11	0	5

The parents were also asked to indicate how much they enjoyed engaging with certain types of activities together as a family, and this was scored as follows: 0=Never, 1=Occasionally, 2=Sometimes, 3=A lot. **Error! Reference source not found.** shows that parents reported engaging in more “traditional” activities with their children than digitally mediated ones. The most frequent type of family activity parents enjoyed doing as a family was outdoor activities. This was followed by cooking and eating, then reading. Watching TV/ movies together was the next most frequent activity and the most frequent one that required the use of a digital device.

Table 17 Summary Statistics for the Frequency of Family Activities

Activity	Mean	SD	Minimum	Maximum
Watching TV / Movies Together	2.10	.718	1	3
Reading	2.40	.804	0	3
Outdoor Activities	2.62	.584	1	3
Playing with Gaming Consoles	.67	.829	0	3
Playing Sport / Attending Sports Events	1.35	1.167	0	3
Participating in Clubs or other Groups	1.35	1.058	0	3
Singing / Making Music	1.57	1.035	0	3
Cooking and Eating	2.53	.658	1	3
Using Computer, Tablet, Smart Phone	1.55	.857	0	3

Parental Perceptions of Impact of Digital Technology on Child Development

Parents were asked about their perceptions of the impact that different types of digital technology could have on aspects of their child's development. For each skill they had to select an option from a five-point Likert scale, which was scored as follows: 0=Very Negative, 1=Somewhat Negative, 2=Neither Positive or Negative, 3=Somewhat Positive, 4=Very Positive. These responses are summarised blow in **Error! Reference source not found.**.

Table 18 Summary of the parents' ratings of perceived impact of devices on children's skills and behaviour

	Mean	SD	Minimum	Maximum

Television				
Reading Skills	1.98	.604	1	3
Speaking Skills	2.54	.861	0	4
Maths Skills	2.40	.727	1	4
Social Skills	2.05	.560	0	3
Physical Activity	1.40	1.035	0	3
Attention Span	1.52	.904	0	3
Creativity	2.21	.967	0	4
Behaviour	1.95	.892	0	4
Sleep	1.62	.738	0	4
Computer / Laptop				
Reading Skills	2.21	.895	0	4
Speaking Skills	2.39	.780	0	4
Maths Skills	2.51	.761	0	4
Social Skills	2.20	.903	0	4
Physical Activity	1.23	.797	0	3
Attention Span	1.58	.861	0	3
Creativity	2.16	.966	0	4
Behaviour	1.99	.898	0	4
Sleep	1.67	.670	0	3
Gaming Console				
Reading Skills	1.62	.829	0	3
Speaking Skills	1.56	.939	0	3
Maths Skills	1.64	.984	0	3
Social Skills	1.58	.938	0	4
Physical Activity	1.18	.934	0	4
Attention Span	1.34	.917	0	3
Creativity	1.65	1.046	0	4
Behaviour	1.44	.862	0	3
Sleep	1.26	.833	0	3
Smartphone / Tablet				
Reading Skills	1.98	1.00	0	4
Speaking Skills	2.22	.864	0	4
Maths Skills	2.22	.868	0	4
Social Skills	1.95	.952	0	4
Physical Activity	1.31	.888	0	3
Attention Span	1.44	.992	0	4
Creativity	1.90	.964	0	4
Behaviour	1.70	.886	0	4
Sleep	1.53	.776	0	4

The perceived impact scores suggest that overall specific devices were seen as typically quite neutral in terms of their impact, in so far as many of the mean scores suggest a 'neither agree nor disagree' response. Computers were seen as potentially having a mild positive impact on mathematical ability, and televisions perhaps benefitting speaking abilities. Gaming consoles were seen as the most negative relative to the other devices. In all cases the biggest negative impact was related to the potential to negatively impact children's physical activity levels, something that was also borne out in the parents' open-ended responses to the questionnaire. In the section that follows, the parents' open-ended responses to the questions about potential benefits versus risks of digital technology are explored.

Understanding Parental Accounts of Risks Vs. Benefits of Digital Technology

The parents' open-ended questionnaire responses with respect to potential benefits and risks linked to allowing pre-school children to use digital devices were analysed using content analysis, in order to give a more detailed picture of parental views and assumptions in this area. The author independently coded all responses obtained to the open-ended questions. Content analysis was conducted in the present study. Content analysis is "a research method that uses a set of procedures to make valid inferences from text" (Weber 1990). Content analysis was conducted in the present study to make justified inferences from parents' digital technology questionnaire responses. For analysing the responses of the parents, content analysis was used rather than the grounded theory (Strauss and Corbin 1994) approach. Research suggests that grounded theory is more suitable for longer narrative texts such as diary entries or interviews. The sparsity found within the nature of open-ended items makes content analysis the more favoured method.

There are two key issues regarding the use of predefined coding schemas/ ideas in content analysis. Firstly, these coding schemas/ ideas may be interpreted differently by different researchers. Thus, one research study independently analysed the data set including all response to open-ended questions. Secondly, predefined coding schemas/ideas may not be extensive causing the researcher to overlook significant unexpected issues developing in the data. Therefore, for the present study a deductive, bottom-up approach that built upon the strength of classical content analysis, while trying to lessen its weaknesses by not using researcher-driven predefined coding schemas/ ideas. Participant responses were reviewed and then these statements were sorted into categories. This analysis resulted in seven unique clusters (e.g., "digital literacy").

Participant responses were reviewed, and their statements were sorted into categories which captured a common idea or concern. For the question, "What are the benefits of digital technology?" the analysis resulted in 11 unique categories or themes (see **Error! Reference source not found.**). For the question, "What are the downsides of digital technology?" the analysis resulted in 10 unique themes (e.g., "online danger", see **Error! Reference source not found.**). The reported benefits of technology use were considered first.

Table 19 Content analysis of parents' responses to "What are the benefits of your child using a digital device (if any)?"

Schema	Sub-schemas	% of parents who stated each sub-schema	% of parents who stated each schema
Digital Literacy	Digital/ computer literacy	5	35
	Confidence with technology	3	
	Getting used to/ experience/ familiarity/learning	11	
	Keep up to date	6	
	School	2	
	Future	8	
Education	Education/Learning	22	47
	Research/Knowledge	7	
	Improve intelligence	1	
	Problem solving	3	
	Educational apps/games	7	
	Letters, Phonics and Reading	6	
	Dyslexia	1	
Technology/Device feature	Access	6	23
	Interactive	10	
	Versatility	3	
	Only available	1	
	Assistive	1	
	Portable	2	
Attitude/ Behaviour	Calm/relaxed/settled	3	9
	Engaged/Enthused/Attention	5	
	Motivated	2	
Parenting	Occupied	6	7
	Feedback	1	
Pleasure	Entertaining	8	14
	Fun	5	
	Creative play	1	
Motor and coordination skills	Hand-eye coordination	2	4
	Fine motor skills	2	
Theory of mind		2	2
Independent		2	2
Communication		2	2
None		2	2

Table 20 Content analysis of parents' responses to "What are the downsides of your child using a digital device (if any)?"

Schema	**Sub-schemas**	**% of parents who stated each sub-schema**	**% of parents who stated each schema**
Behaviour	Moody/grumpy	2	10
	Bad behaviour when removed	1	
	Not wanting to put device away	1	
	Copy negative behaviour	1	
	Excited	1	
	Tired	1	
	Lazy	1	
	Irritable	1	
	Lacks perseverance	1	
Eyes	Eye strain	4	14
	Bad for eyes	4	
	Close/ short distance	2	
	Blue light	1	
	Itchy	1	
	Tearful	1	
	Painful	1	
Online dangers	Inappropriate content	3	5
	Contact with strangers	2	
Lack of communication	Interaction	6	16
	Not talking to other/ isolating/ not social	6	
	Hinders social skills	3	
	Americanisms	1	
Attention/Addiction	Addictive		37
	Harm/loss of attention		
	Attention focused (absorbed/fixated/ zone in)		
	Removing device (difficult/upset)		
	Overuse/too much screen time		
	Everything about tech		
	Temptation to watch vids		
	Gravitate to tech		
	Damage concentration		
	Quick changes between topics		

Activity	Lack of outdoors/ other activities	10	9
	Less understanding of "proper" books	1	
Development	Brain development	2	3
	Melatonin production	1	
Device feature	Hard to police	1	3
	Hard to replace	1	
	Less tactile	1	
Reliant on device		1	1
None		1	1

A key perceived benefit of digital devices appears to be their educational / skills-based development potential, as 47% of parents perceived devices as educational and 35% of parents perceived devices to be useful in improving digital literacy. Within the 35% of parents who perceived digital devices to improve digital literacy, 11% believed that familiarity and experience with digital devices would be beneficial for their child. This was reiterated by 8% who specified the importance of digital technology use for their child's future. As one parent put it, it is "good to be competent in using them in this digital age for future life". Within the 47% of parents who believed digital technology to be educational, 22% specifically referred to the benefit for education and learning of digital device use. Furthermore, 7% acknowledged the benefits digital technology has on their child's knowledge and 6% believed that digital technology has a positive effect on children's letter knowledge, phonics and reading.

Fourteen percent of parents believed that digital devices are fun, entertaining and encourage creative play (this was categorised as "pleasure"). Parents believed that digital technology "allows children to explore their interest" and "engage in creative play". Four percent of parents believed that digital technology had positive effects on their children's motor and coordination skills. Twenty-three percent interpreted the question in terms of device features with

10% of parents viewing digital technology as interactive and 6% identifying the benefit of being able to access "a wider range of material".

The most prominent negative opinion parents had towards digital technology was the effect it had on children's attention and the cause of addiction (see **Error! Reference source not found.**). Thirty-seven percent of parents were concerned about negative impacts on attention or the potential for digital technology to become 'addictive'. Five percent of parents were also concerned about their children accessing inappropriate content and 16% of parents surveyed were concerned about their child's lack of communication when using digital technology. However, despite previous research showing links between digital technology and aggression and violence, this was not a concern for parents, perhaps due to the fact that most children did not use video games and the association with violence and digital technology is often with video games (C. A. Anderson & Dill, 2000; Doğan, 2006).

Notwithstanding the earlier finding that the most popular family activity type was outdoor activities, 9% of parents were concerned about the impact that digital technology might have on their children's activity levels. Ten percent of parents believed that digital media had negative effects on their children's behaviour, including being moody/ grumpy, irritable, lazy and tired. Fourteen percent of parents were also concerned about the effect that digital devices could have on their children's eyesight.

Understanding the Relationships between Behaviour and Attitudes

The parents' Likert scale-based questionnaire responses were scored to provide quantitative measures of (1) their attitudes towards technology in general (a high scores indicates a more positive opinion), (2) the extent to which they regulated or restricted their children's access to technology (a high score indicates more regulation), (3) how much they used technology with their children (a high score indicates more use), and (4) the extent to which they encouraged their children to engage with technology (a high score indicates more encouragement). There is clear interest in the extent to which these factors might explain how much the children used digital technology in the six months before they started school, both in terms of range of activities undertaken and range of devices.

The original 16-item scale on parents' attitudes towards technology in general was reduced to a 10-item scale to improve internal reliability. Initially, the 16-item scale resulted in a Cronbach's Alpha of .525, by removing six items a Cronbach's Alpha of .614. Initially, three items were removed, resulting in a Cronbach's Alpha of .593. The three items removed were (1) My child is more likely to use digital print (e.g., e-books) than printed books. (2) My child is more likely to use printed books than digital print (e.g., e-books). (3) Smartphones and tablet devices make parenting easier. Following this a further two items were removed, resulting in a Cronbach's Alpha of .606. The two items removed were (1) Digital devices are more interactive than books. (2) Television helps my child's language development. One final item was removed resulting in a Cronbach's Alpha of .614. The final item removed was (1) I think the right apps have huge educational potential. The remaining 10 items used were, to what extent do you agree with the following statements? (1) Digital devices make people lazy. (2) My child will be exposed to illicit material if they use these devices. (3) My child would be better off without digital devices in schools. (4) Digital devices are hard to use. (5) It's difficult to set control and rules for my child regarding digital devices. (6) My child knows more about digital devices than me. (7) I am confident in my ability at using digital devices. (8) I would be concerned if my child did not know how to use digital devices by the time, they left primary school. (9) I find new technology intimidating. (10) I believe you need to be technology literate.

The 9-item scale which assessed the extent to which parents regulated or restricted their children's access to technology had a Cronbach's alpha of .708 (see Appendix 3 for 9-item scale). How much parents used technology with their children was based on just two items ("I use digital devices with my child." and "I use media as a way to connect with my child.", as did the measure of the extent to which parents encouraged their children to engage with technology. As shown in **Error! Reference source not found.**, the Social Desirability Bias scores were not significantly correlated with participants' responses to all six variables, suggesting minimal influence of socially desirable responses in the measures.

Table 21 Zero Order Correlations for Technology Use Variables

	2.	3.	4.	5.	6.	7.
1. Attitudes towards Technology	.063	.232*	.332**	.022	.027	.044
2. Regulated Access to Technology	-	.203*	.071	-.052	.032	-.065
3. Technology Use with Child		-	.544**	.129	.129	-.115
4. Encouraged Use of Technology			-	.294**	.294**	.084
5. How often children completed digital activities before starting school.				-	.473**	.120
6. How often children used digital devices before starting school.					-	-.135
7. Social Desirability Bias Score						-

A multiple regression was conducted to see which of the first four variables could account for individual differences in how often children engaged in different types of digitally mediated activities before starting school (this measure was computed from the parents' responses indicated in **Error! Reference source not found.**). The model was found to be significant, predicting around 13.5 % of the variance in preschool technology use, $R^2 = .135$, $F(4, 91) = 3.554$, $p = .01$. When considering the predictor variables individually, it was found that this effect is driven by the extent to which the parents reported that they encouraged their children to use technology (see **Error! Reference source not found.**).

Table 22 Multiple Regression Results for Child's Pre-School Engagement with Digitally Mediated Activities

Variable	B	SE	Beta	t	P
Attitudes towards technology	-.158	.159	-.103	-.997	.321
Regulated Access to Technology	-.052	.115	-.044	-.451	.653
Technology Use with Child	-.076	.426	-.021	-.178	.860
Encouraged Use of Technology	1.403	.420	.399	3.341	.001

The same group of predictor variables was used to see if they could account for individual differences in how often the children used different types of digital devices before school (responses about books were not included in the scoring for this variable). The model was not able to account for significant variance in this case, $R^2 = .069$, $F(4,91) = 1.682$, $p = .161$, although again, the extent to which the parents reported that they encouraged their children to use technology was found to be the only predictor significantly related to the outcome measure (see **Error! Reference source not found.**).

Table 23 Multiple Regression Results for Child's Pre-School Use of Digital Devices

Variable	B	SE	Beta	t	P
Attitudes towards technology	-.063	.106	-.064	-.591	.556
Regulated Access to Technology	.036	.077	.047	.464	.644
Technology Use with Child	-.046	.284	-.020	-.162	.872
Encouraged Use of Technology	.631	.280	.279	2.250	.027

Discussion

From this questionnaire a wealth of information was obtained. Despite digital technology being very prevalent in everyday life as mentioned in Chapter 1, the majority of parents reported that their children were exposed to print before being exposed to any form of digital technology. Passive forms of digital technology use were most popular with television being reported as the most used digital device. Therefore, it is not surprising that the most reported digital activity was watching a programme, as this usually takes place via television or a tablet. Parents' perceptions of digital technology were generally neutral, with parents noting the benefits of television on their children's speaking abilities and computer use on their children's mathematics ability. Parents were, however, worried about the negative effects of digital technology use, (especially those associated with gaming) of which one was the lack of physical activity. Parents noted the potential education benefits of digital technology use but were concerned with the effects on attention and the potential addiction to digital devices. This provides further rationale for exploring the effects digital technology has on young children's attention which will be reported in Chapters 4 and 6.

This study aimed to capture the nature and extent of pre-school children's access to and use of technology, and to understand how parents' own digital technology use and attitudes might influence their children's media use.

Firstly, it was observed was that pre-school children's home learning environment was still typically characterized by frequent shared storybook reading and television watching. What was new is that this was now supplemented by weekly use of tablets and smartphones. In this way children's early exposure to digital devices may be better seen as augmenting children's home learning environment than detracting from it. It can also be noted that the most frequent activity type that parents enjoyed engaging in as a family was outdoor activities. This suggests that concerns about children leading more sedentary lives due to technology (e.g., Edwards et al. 2016; Wartella et al., 2014) are not necessarily supported by the data in this age group.

In terms of literacy-related behaviours, it was found that parents were more likely to read with their children than on their own (for pleasure), but they were more likely to use their smartphone on their own than share it with their preschool child. Although encouraging in some ways (i.e., the maintenance of shared book reading), this observation does represent a potential threat, as it is clear to see that parents are more orientated towards smartphone use than book reading in terms of their own behaviours. Children learn through observation, and it can be argued that they need to see book reading modelled in the home if they are to recognize reading for pleasure as potential leisure activity (Wollscheid, 2014). The way parents use their devices in the presence of their children might also be important and is worthy of further research. For example, perhaps parents can model literacy positive behaviours by using their devices to read the news or e-books in the presence of their children, and this might have positive outcomes as this has been shown with books.

Perhaps consistent with the finding that parents used technology regularly themselves, the parents in this survey generally did not perceive technology use to represent a significant cause for concern, and only just over half reported limiting children's screen time. However, a more significant majority of parents (72%) reported that they did limit the type of content their preschool children were exposed to online. This suggests that parents may have a more nuanced understanding of the threats and affordances of technology, and are sensitive to the need to monitor and restrict certain types of content rather than access to the technology per se.

The most prominent negative opinion parents had towards digital technology was the effect it had on children's attention and the potential for addiction: 37% of parents were concerned about negative impacts on attention or the potential for digital technology to become 'addictive', which is consistent with earlier studies with parents of older children

Again, supporting previous findings 14% of parents believed that digital devices are fun, entertaining and encourage creative play (this was categorised as "pleasure"). Parents believed that digital technology "allows children to explore their interest" and "engage in creative play". 4% of parents believed that digital technology had positive effects on their children's motor and coordination skills. This is supported by Bedford et al. (2016) who found a positive correlation between scrolling on a touchscreen device and fine motor skill in children 6 to 36 months old. 2% of parents in the present survey also state the positive impact digital technology has on developing children's independence (Marsh et al., 2015). The finding that frequency and amount of device use in the early years was explained by the extent to which the parents encouraged such use is logical. It is perhaps more surprising that neither parental attitudes nor the extent to which parents attempted to restrict their children's access to technology did.

It is acknowledged that this study has a number of limitations – a more stratified sampling approach would have enabled not just a larger sample of parents, but insights based on parents and children from different backgrounds and contexts. The sample is modest in size, but the data benefits from the inclusion of a measure of socially desirable response bias, and it was found that parents' answers did not correlate with that tendency, which validates the responses that were received from them. Even so, the survey design relied solely on parental self-report and future research should further explore the extent to which parental attitudes are related to more direct observation of device use.

Given the impact of recent the COVID-19 pandemic, and the centrality of technology-mediated communication and education for children that has formed part of the response, there is also a need to re-examine parental attitudes and concerns. This necessary shift in children's technology use is likely to have also impacted parental attitudes and practices. Its impact on oral language skills and interpersonal communication within specific subgroups is likely to be of significance and needs particular attention, especially given the tension between increased home working and childcare needs in the homes of young children during the pandemic. Parents of school age children are likely to have relied on technology to support their child's education more than ever before (Williamson et al., 2020). This might also have encouraged parents to explore the educational benefits of technology. The temptation to exploit digital devices to keep very young children occupied whilst parents work or support the home-schooling of siblings is something that parents will be acutely aware of and empirical work in this area may allay concerns or heighten them.

Chapter 4: Understanding the Impact of Early Exposure to Digital Technology on Children's Visual Attention

As noted in Chapter 1, the current effects of digital technology still lack a scientific consensus in regard to whether digital technology is good or bad for young children (Vedechkina & Borgonovi, 2021). Perhaps this is due to the sheer number of factors that need to be taken into consideration. This chapter aims to understand the effect that parental-reported exposure to digital technology in the early years has on children's later developing visual attention.

Reading is an essential skill, which is required for successful learning. It is clear that learning to read implies children have a good grasp of language skill, however in addition to good language skills the development of good oculomotor and visual attention skills is necessary (Vernet et al., 2021). This is because the process of reading is a visual task which requires the analysis of features of visual patterns, in the case of reading these features can be considered the letters of a word that can be recognized and understood (Williams & Bologna, 1985).

There is some research evidence that digital technology can affect attention; for example, students who often use digital technologies for distraction reasons including multitasking and other off-task activities show a significant reduction in their educational performance compared to control group (Aagaard, 2015a; Ravizza et al., 2014; E. Wood et al., 2012). However, the introduction to this thesis showed that there is a gap in the literature, as research has explored the effects of attention on reading separately from the effects of digital technology use on attention, with less research directed at the latter topic. However, there is a need to combine these two independent areas of research because, if digital technology is found to have a negative effect on attentional processes, then we need to understand whether (and how) it may, in turn, negatively affect children's reading development. This is concerning especially as there is now clear evidence that visual spatial attention is important in reading acquisition, performance and fluency (Franceschini et al., 2012; Lobier et al., 2013; Valdois et al., 2019).

Parents are faced with quite a predicament with conflicting guidelines regarding children's digital technology use. Education, industry and government authorities encourage the use of digital technology whilst, contrastingly, public health organisations call for minimal digital technology use (Straker et al., 2018). The benefits of digital technology include enhanced learning, the development of children's digital skills, preparation for work and competent social interaction (Clarke & Abbott, 2016; Herodotou, 2018; Lieberman et al., 2009; Radich, 2013; UK Department for Digital Media and Sport, 2017). However, there are potential negative consequences of inappropriate use of digital technology on emotional, mental, physical, social and cognitive health (D. R. Anderson & Subrahmanyam, 2017; Mougharbel & Goldfield, 2020; Peper & Harvey, 2018; Robidoux et al., 2019; L. M. Straker et al., 2008; Swing, 2012; Tremblay et al., 2017; Vincent, 2016).

Attentional Processes and Reading

Attention is a cognitive skill that has found to be both positively and negatively affected by digital technology. Attention is the focus of the mind on one object or thought out of several concurrently occurring objects and thoughts through concentration (James, 1890, p. 403-404). In addition to this definition James (1890) differentiated between "passive" and "active" models of attention. Attention is passive when managed by bottom-up processing including external stimuli, for example an unexpected noise. Attention is active when managed by top-down processing. A persistent concern is that too much exposure to digital technology is detrimental to developing attentional processes; although currently there is no link, research has shown excessive digital technology use can lead to poor executive function in infants and toddlers (Courage, 2017).

Reading is a complex skill which involves the application and coordination of many cognitive processes, regardless of the medium in which the text is presented (Wylie et al., 2018). Attention is one of the cognitive processes required to be able to read, as it is the mental ability to select specific information in the forms of stimuli, objects, reactions, memories or thoughts and ideas that are relevant amid various others that are irrelevant (Corbetta, 1998). Selection is required because human brain capacity has "computational limitations", when processing information to ensure behaviour is relevant to the information provided (Corbetta, 1998). Selective attention therefore requires two simultaneous key processes, enhanced processing of relevant information and the suppression of irrelevant information (Desimone & Duncan, 1995). Visual selective attention occurs when the information processed is obtained visually, through sight. In childhood, visual spatial attention develops together with literacy skills (White, Boynton, & Yeatman, 2019; Olulade, Napoliello, & Eden, 2013). This may be because, reading requires the analysis of features of visual patterns in a space (Williams & Bologna, 1985), before relating them to auditory and semantic representations in memory.

Attention comes in different forms, including selective attention, sustained attention, divided attention and focused attention. There is a causal link between interest, attention and learning (Renninger et al., 2014). Furthermore a link between visual selective attention and reading was established when children with low performance scores in an attention-based cancellation task read significantly slower and with significantly more visual reading errors than children with higher performance on the attention task (Casco et al., 1998).

Frey & Bosse (2018) argue that reading is chiefly a visual task that uses the ocular motor system, although it is clear that reading also has a major linguistic component, as there is a wealth of research that shows letter-sound mapping ability and prior phonological processing skills are required in reading acquisition and morphology knowledge further along (Castles et al., 2018; Castles & Coltheart, 2004; Enderby et al., 2021; Goswami, 2008b; Hulme et al., 2005; Melby-Lervåg et al., 2012). There is evidence that visual spatial attention does has some effect on reading performance, which will be discussed in further detail later (Bosse & Valdois, 2009; Franceschini et al., 2012; Lobier et al., 2013; Valdois et al., 2019). Generally, visual processing is said to be the most important processing system in the human brain, as over 70% of external information comes from our sense of vision (L. Zhang & Lin, 2013). While people tend to believe that they can process all available information when viewing an object or scene, experiments have shown that people overestimate their visual ability and can only focus on a small central area, due to an over-representation of their field of central vision within the cortex (Horton & Hoyt, 1991; L. Zhang & Lin, 2013).

Bundesen's Theory of Visual Attention (TVA) is a computational theory which defines visual attention as a combination of the processes of attentional selection and visual recognition that are "racing" in parallel processing (Bundesen, 1990, 1998). This occurs as there is limited storage capacity within the visual short term memory (VSTM) (Bundesen, 1990). Stimuli are concurrently recognised and selected versus each other to be represented in the VSTM (Bundesen, 1990). This theory differs from alternatives which suggest recognition and selection happen in sequence (Posner & Rothbart, 2007), such as Broadbent's (1958) mechanical bottleneck model, which suggests attentional selection precedes recognition, or Deutsch & Deutsch's (1963) suggestion that the opposite is true, and recognition occurs before selection.

Individual's visual attention based on Bundesen's TVA, is typically tested through the use of the whole report paradigm. This involves the brief presentation of objects after which participants must report as many items as they remember (Cattell, 1885; Duncan et al., 1999; Kyllingsbæk & Bundesen, 2009). A partial report paradigm is also used, this involves the brief presentation of objects or text after which participants must recall some information based off a cue (Duncan et al., 1999). These tasks are used to access parameters of attention, associated with TVA. These include: attentional selection, VSTM storage capacity, visual processing speed and visual perceptual threshold (Bundesen, 1990; McAvinue et al., 2012; Wiegand et al., 2014). However, an issue with whole report and partial report is the requirement of familiarity to convey recall (Kyllingsbæk & Bundesen, 2009). This can be avoided through the use of change detection studies (Kyllingsbæk & Bundesen, 2009). Thus, the present study uses a type of change detection task.

One component of attention is the visual attention span, which is described as the amount of distinctive visual elements that can be processed in parallel at a glance in a display of elements (Bosse et al., 2007; Lobier et al., 2013). During reading these distinct visual elements are orthographic units including letters, letter clusters and syllables that can be processed in parallel. Lobier et al., (2013) hypothesised that in children with and without dyslexia, visual attention span would predict reading time. Assessments of children's reading time and visual attention spans supported the hypothesis, thus suggesting that reading time in children could be limited by their visual attention capacity (Lobier et al., 2013). Lobier et al., (2013) identified the use of words as stimuli in visual attention span studies with children as a limitation because during reading acquisition children may have varying levels of visual processing of letters within words. Therefore, the present study used images rather than letters, words or text for stimuli.

Research has shown an association between low scores in visual selective attention tasks and reading performance (e.g., Casco et al., 1998), usually comparing visual attention scores in dyslexic readers with chronologically age matched non-dyslexic/ typical readers. Dyslexia is a difficulty in reading in individuals who generally have the education and intelligence required to develop reading (Lyon et al., 2003). More specifically, dyslexia's core mechanism can be explained as an impairment in phonological processing which results in a difficulty in identifying, decoding, storing or receiving the separate sounds in printed words (Vellutino et al., 2004).

Pre-school children's performance on visual attention tasks can be used to identify children who will go on to experience difficulties learning to read. A three year longitudinal study assessed pre-reading in 96 (44 female) native Italian-speaking five year old kindergarten children using visual spatial attention tasks, phonological awareness tasks and RAN tasks (Franceschini et al., 2012). The first visual spatial attention task was a serial visual search task in which participants had to find and mark a target symbol across five lines of 31 symbols (5 symbols were targets and the remaining 26 were distractors) line-by-line starting from left to right (Franceschini et al., 2012). The second visual spatial attention task used an eye tracker and was a spatial cueing task based on Posner's (1980) task in which target symbols preceded by spatial cues which were not always valid (Franceschini et al., 2012). These cues tend to get the participant's attention to focus on that side of the display, then the target symbol appears (Gabrieli & Norton, 2012). When the symbol is on the side of the cue performance is typically better than were the symbol appeared to the opposite side of the cue (Gabrieli & Norton, 2012). By grade one participants who were considered poor readers already performed more poorly in the serial visual search task compared to typically developing readers (Franceschini et al., 2012).

Sixty percent of poor readers had visual attention deficits as prereaders. In the pre-reading phase poorer readers made double the number of errors made by typically developing reader in the serial visual task, showing a deficit in visual spatial attention before having acquired the skill of reading (Franceschini et al., 2012). This suggests that their visual spatial attention affected their reading ability and not that their reading ability affected their visual spatial attention because at this stage they could not read.

Even without directly stimulating phonology and/ or orthography, playing video games have been found to improve reading in children who have dyslexia, a finding which is interpreted as further evidence of visual attention impacting reading processes (Franceschini et al., 2017). Twenty-eight dyslexic children (8 female) with a mean age of 10 years old participated and were randomly allocated to either play action video games or non-action video games (Franceschini et al., 2017). A battery of assessments was administered including a reading task, an auditory-phonological working memory task, a focused and disseminated visuo-spatial attention task and a visual, auditory, audio-visual processing and cross-sensory attentional shifting task (Franceschini et al., 2017). Results showed a positive effect of action game play on attentional processing however, not specifically in visuo-spatial attention. Word recognition speed increased and phonological decoding improved, as well as reading time, although reading accuracy was not impacted (Franceschini et al., 2017). This is an important finding as reading time and word identification ease are considered as the most important factors in skilled reading (Share, 2008).

Research has shown that eye movements are preceded by visual attention (Lachter et al., 2004; Rayner & Reichle, 2010). This is shown through research that indicates without eye movement individuals can shift the focus of attention, however eye movements cannot move spatial location whilst focusing fully on another location as eye movements require attention

(Roelofs, 2011). Thus, it is useful to conduct eye movement measure as eye movements represent shifts in attention. Typically reading children with larger visual attention spans make fewer fixations during reading as per fixation they are processing more letters (Prado et al., 2007). This shows that visual attention spans reflect visual attention capacity. One hundred and twenty-six children (70 females) participated in a longitudinal study in which data was collected on visual attention during kindergarten, fluid intelligence and pseudo-word and irregular word reading during Grade 1 (Valdois et al., 2019). Positive associations between visual attention and reading were found, and visual attention span in kindergarten predicted reading fluency in grade one (Valdois et al., 2019). Similarly, de Jong & van den Boer (2021) examined the relationship between reading and visual attention span by examining the retrieval of verbal codes and serial and parallel processing. One-hundred and eighty third grade children completed a visual attention span task, word reading tasks and rapid automatized naming tasks (RAN), which assess speed and fluency of phonological access and articulation. Visual attention span was found to correlate with serial RAN, and both serial and discrete word reading (de Jong & van den Boer, 2021).

Further support for the notion that an individual's visual attention span is important for reading comes from a cross sectional study of 417 typically developing children recruited from grades one, three and five, using a battery of assessments (Bosse & Valdois, 2009). This study found that visual attention span predicted reading acquisition independently of phonological awareness. Both phonological awareness and visual attention were related to reading performance from the beginning of school.

Visual attentional problems have been found to co-occur with dyslexia. Marendaz et al., (1996) compared the visual attention of 10 children with dyslexia to 10 children of the same age and 10 with the same reading ability. A serial attention task showed visuo-attentional deficits in the children with dyslexia compared to control groups (Marendaz et al., 1996). Another study showing the co-occurrence of visual attention difficulties with dyslexia was conducted with 35 non-dyslexic and 35 dyslexic children aged seven to 14 years old (Slaghuis et al., 1993). This found that visual attention processing was a significant predictor of group membership, as 91% of dyslexic participants had visual attention scores compared to only 10% of non-dyslexic individuals with low attention scores. These findings emphasise the importance of finding out if visual attention processing is negatively impacted by technology use, as it seems likely that if it does it would have important implications for children's reading development, especially for children with conditions like developmental dyslexia.

In addition to individual differences in visual attention explaining reading acquisition and reading fluency, visual attention span has also been found to explain variance in text comprehension (C. Chen et al., 2016). One-hundred and five secondary school children with dyslexia (39 female, mean age of 17 years old) completed a battery of assessments evaluating reading comprehension, word reading, pseudo-word reading, phonological awareness and visual attention span (C. Chen et al., 2016). There was a significant effect of visual attention span in more difficult reading comprehension, but not in easier level reading comprehension passages (C. Chen et al., 2016). Therefore, if a passage of text is difficult, deficits in visual attention can result is poorer reading comprehension.

The Impact of Digital Technology on Visual Attention

Having demonstrated that reading can be affected by visual attention it is important to examine whether children's early use of digital technology might impact aspects of their visual attention. In today's society worries regarding the effects of digital technology are common (see Chapter 2). However, the relationship between digital technology use and certain regions of neurocognitive functions including attention remains relatively unexplored. In one study Rosenqvist et al. (2016) explored the relationship between television viewing, computer use, reading and performance in attention tasks and visuospatial processing in 381 five to 12 year old children . Results showed negative effects of attention and visuospatial processing for television viewing but, effects of attention and visuospatial processing positive for computer use. Results also showed a positive effect for reading between the type of digital device and attention and visuospatial processing scores. However, there are limitations to this study as it is unknown what the children viewed on the television, what they did on the computer and the type and content of the material they read and thus, perhaps the type of content influenced the results.

Children's television viewing habits have been negatively linked to attention outcomes in other studies. For example, Christakis et al., (2004) used data from 1,278 grade one children and 1,345 grade three children from the National Survey of York. They found that 10% of children had attention problems and there was an association between television exposure and attention problems (Christakis et al., 2004), and suggested limiting television viewing in the early years. However, using the same survey, Foster & Watkins, (2010) analysed television viewing in 1,159 children aged one and three years old and found no significant correlations between television exposure and attention problems, although very high levels of exposure to television were linked to attentional problems (E. M. Foster & Watkins, 2010). In a longitudinal study, six-hundred and seventy-eight American families participated in interviews when offspring were aged 14, 16 and 22 years old (Johnson et al., 2007). High levels of television exposure were associated with attention difficulties even when family prior cognitive difficulties and family traits were controlled for (Johnson et al., 2007). Individuals who watched one hour or more of television a day were found to have poorer educational outcomes, a negative attitude, poor completion of homework, poor grades and potential academic failure (Johnson et al., 2007). Effects on attention were found when individuals watched three or more hours of television per day (Johnson et al., 2007).

The content and context of digital technology use is important; for example, the viewing of educational television is positively linked to academic achievement (Schmidt & Vandewater, 2008). Schmidt & Vandewater (2008) go as far as saying that the content shown on a digital device has more of an impact on the user than the specific digital device itself. Similarly, the negative effects of television viewing on young children's language and executive functioning are observed in children under the age of two years old; however, older pre-school children who view educational television programmes appear to experience positive impacts on their cognitive development (D. R. Anderson & Subrahmanyam, 2017). The idea that context matters is further supported by findings that showed that appropriate screen time and increased verbal interaction during digital technology use is associated with better cognitive development found in the results of a longitudinal study with 274 infants aged six months old to four years old (Supanitayanon et al., 2020). Studies have also shown that having the television on in the background interferes with cognitive processing, including reading comprehension (D. R. Anderson & Evans, 2001).

A systematic review of research assessing the associations between use of digital technology, time spent in contact with nature, and psychological outcomes, including academic achievement, cognitive functioning and academic achievement was recently conducted by Oswald et al., (2020). The review examined 186 studies and found that in general high exposure to digital technology was negatively associated with cognitive functioning (including attention) mental health and academic achievement, whereas time spent outdoors had a positive effect on these psychological outcomes (Barlett et al., 2012; Oswald et al., 2020; Swing et al., 2010). A more recent review of research identified three main bodies of literature regarding the effects of digital technology on attention, these were: the impact of television, the impact of video games, and the impact of digital multitasking (Vedechkina & Borgonovi, 2021). This review stated that the effects of television viewing are still inconclusive. For example the fast paced stimulating nature of some television programmes can have immediate negative effects on children (Lillard & Peterson, 2011; Vedechkina & Borgonovi, 2021). However, a study of 1,156 children aged between two and eight years old, found that parenting style mediated the risks of background exposure of television and exposure to educational television programmes also reduced the negative effects of television exposure on attention (Linebarger et al., 2014). This highlights that it is not just the use of digital technology per se that has an impact, but the content it provides is also an important factor to consider. Again the review found mixed effects of digital technology exposure on attention, with action games having a positive effects on visual spatial attention and selective attention, particularly in older children (Vedechkina & Borgonovi, 2021). Task switching, which involves shifting back and forth between tasks, requires attention (Longman et al., 2014; Monsell, 2003). It is interesting to note that children who started playing video games from an earlier age performed better in task switching activities compared to those who started at a later age (Hartanto et al., 2016). The review found generally that digital multitasking does not negatively affect attention (Vedechkina & Borgonovi, 2021). For example, a four study series, examined the effects of digital multitasking on sustained attention ability, and the results showed no relation between digital multitasking scores and reaction times on a sustained attention response task, nor was there a relation between digital multitasking and sensitivity and response times on a vigilance task (Ralph et al., 2015). Thus, it appears there is no link between engagement in digital multitasking and sustained attentional processes. From this review Vedechkina & Borgonovi (2021) assert that although some forms of digital technology may cause issues, these issues are dependent on context and only for certain users. The use of digital media is mediated by individual differences in when, how and why these digital devices are used. Clearly these differences must be taken into account when understanding how digital technology is beneficial or harmful (Vedechkina & Borgonovi, 2021).

Many studies have focused on the effects of television on attention, further research must explore the effects of new forms of digital technology on attention. A three yearlong longitudinal study of 3034 children and adolescents aged between eight to 17 years old in Singapore was conducted to explore the effects of video game exposure on attention (Gentile et al., 2012). Average weekly video game time was used as a measure of video game exposure. Participants complete an 18-item self-report questionnaire to measure inattention at two time points. Results showed that more frequent video game use resulted in subsequent attention problems even when taking into account prior attention problems and measures of impulsiveness. In addition, a small effect was found which showed beyond the total amount of playing time, time spent playing violent video games was shown to uniquely predict problems in attention. It is possible, that the self-report nature of the study could affect results. In a comparison, children's self-report of their attention and their parent and teacher report of the child's attention differ, with children underestimating their attention problems in their self-reports (Owens et al., 2007).

Assessing Visual Attention in Children: Change Detection

In this study visual attention was assessed using a change detection task. Rensink et al., (1997) argued that the visual perception of a change in a scene only occurs when concentrated attention is given to the part of the scene that is changing. Rensink et al., (1997) developed a "flicker paradigm" which allows the examination of whether two types of change blindness occur because of the same attentional mechanism. In the flicker paradigm, an original image is repeated alternated with a modified image with short blank screens placed between each consecutive image. There are various possible types of changes e.g., colour change and the size of the change may vary. Once the trial begins the participant views these flickering images and must press a key once they detect the change. To ensure the participant has not randomly pressed the key he/she must report the change that they saw.

Change blindness is a phenomenon in which people fail to notice larges changes to visual scenes that would normally be easy to see (Simons & Levin, 1997). The change blindness literature established four key findings. Firstly, change blindness happens whenever attention is diverted from the change (Simons & Levin, 1997). Secondly, changes which are visually distinctive and changes which occur to objects central in the meaning of a scene are more easily identified than other types of changes (Rensink et al., 1997; Simons & Levin, 1997). Thirdly, unattended changes to objects go undetected, therefore, attention is necessary for change detection (Simons & Levin, 1997). Fourthly, attention to a changing object may not be adequate for change detection as experiments have shown, for example, individuals have not detected changes to an actor in film including the transformation into another person after a shift in camera angle (Levin & Simons, 1997; Simons & Levin, 1997). Simons & Levin (1997) suggested that perhaps to detect the changes, individuals need a before and after to compare.

In Rensink et al's., (1997) initial flicker paradigm experiments it was found that change detection can take a long time and the change detection occurred much quicker if a verb cue was given, suggesting that poor visibility was not an issue. In addition, they found the change detection occurred much quicker if objects that changed were mentioned in a brief verbal description of the scene. This suggests that the participant did not form a full representation of the scene. Furthermore, it is important to note that attention is required to identify a change. This difficulty in change detection was not due to disruption of the information received nor because of a disruption of its storage. However, it is influenced by the significance of the object being changed, with detection occurring the quickest for the objects of greatest interest. Consequently, a flicker paradigm was used for the present study to ensure visual attention was being tested.

The flicker paradigm method has been used in previous studies. Using the flicker paradigm, a change detection task was conducted on 35 male undergraduate students with a mean age of 19.93 year old (SD: 1.69) to explore attentional performance (K. Clark et al., 2011). Participants were grouped based on their results on a video game questionnaire which assessed their video games experience across genres. From this, 15 participants were established to be avid video game players and 20 participants were classified as non-video game players (K. Clark et al., 2011). Results showed that avid video game players had enhanced visual attention abilities; they detected changed more quickly therefore, with fewer exposure to the changing stimuli (K. Clark et al., 2011). This is supported by similar findings Green & Bavelier (2003, 2006a, 2006b) who found significant differences across various aspects of visual attention in video game players in comparison to non-video game players. In one task, with 16 male participants, video game players performed better in visual spatial tasks in both central and peripheral attentional tasks compared to non-video game players (C. S. Green & Bavelier, 2006a). This again supports the idea that digital technology can improve visual attention.

Rationale

The study aims to understand whether children's performance on a visual attention task was related to their levels of exposure to digital technology in the early years. Research findings discussed above show a differing mix of the effects that digital technology use has on attention. These studies have focused on one specific type of digital device and therefore found different effects on attention. Research on television exposure has mainly found negative effects on attention skill, whereas video game exposure was shown to have a positive effect on visual attention. The present study takes into account the exposure to various digital technology including television, video games, computers, smartphones and e-books (see Chapter 2: Methodology). The present study hypothesised that children with high levels of digital exposure will perform better in the change detection attention task.

Method

For this study data was collected in two phases (Phase 2 and Phase 4) as reported in Chapter 2. Methodology is fully explained in Chapter 2: Methodology and have been presented in a more condensed format below.

Participants

In Phase 2, there were 28 participants aged between four to eight years old with a mean age of five years and a standard deviation of two months. 61% of participants were female. See Chapter 2: Methodology,

Phase 2 data collection: The relationship between digital exposure and selective visual attention.In Phase 4, 60 participants aged between six to seven years old with a mean age of six years and 11 months and a standard deviation of three months. 62% of participants were female. See Chapter 2: Methodology, Phase 4 data collection: The relationship between digital exposure and reading print versus digital for a full report of participant information.

Materials

The stimuli were formed from twenty-four pages selected and digitised from books from the Rising Stars Reading Planet reading scheme. The images selected were from books within the reading scheme aimed at children aged between four to seven years old. An alternate version of each image was created using Adobe Photoshop CC 2017, resulting in 48 paired images. One of two types of changes were applied to each of the 24 alternate versions. The two types of changes were either absence/ presence or colour change. The absence/presence category of images was created from 12 images (half of the original 24 images) for which an alternate version of the image was created by removing a single object. The category of colour change was created using the 12 remaining images, which were altered by changing the colour of a single object. For both absence/presence and colour change sets of stimuli half of the alterations were within the central region of the image and the other half of the alterations were in the marginal region, creating the variable of location of change.

Design

The change detection paradigm was applied here in a 2 x 2 x 2 mixed experimental design. The between participants independent variable was the individuals' level of exposure to digital technology (defined by responses to the Digital Technology Use Questionnaire – see Study 1a and 1b) with two levels: high exposure and low exposure to digital technology. Exposure groups were created using a cluster analysis method, see Chapter 2: Developing digital technology exposure groups for more information. The two independent variables tested within participants were the type of change to an object within the image with two levels: colour change (CC) or absence/ presence (A/P) and the location of the change, with two levels: central or marginal. There are multiple dependent variables these include: accuracy, reaction time, and eye movement measures (time to first fixation, first fixation duration, gaze duration and total duration). Accuracy refers to the percentage of correct trials per participant, measured using the oral responses recorded by the experimenter. Reaction time refers to the time taken to respond to change, measured by the time from initial display of an image to the keyboard response (spacebar press). Several eye movement measures were extracted, the process for which is described below. See the analysis section below for dependent variable descriptions.

Procedure

Prior to participating in the change detection task, the participants completed the Ishihara's Design Chart for Colour Deficiency of Unlettered Persons (2016). This Ishihara clour blindness test was used to ensure participants were not colour blind as this would affect the results of the change detection task in which the participant must spot an object which is rapidly changing colour. All participants scored 100% on the test, therefore no participants were excluded on this basis.

The stimuli were presented on a computer monitor. Eye movements were recorded using an SR Research Eyelink 1000 Plus eye tracker and ExperimentBuilder ™ software v 1.10.1630 with a sample rate of 1000Hz.

Participants were tested individually. Viewing was binocular but only the right eye was tracked. A combination forehead/chin rest was used to minimise head movements which could affect the quality of the calibration of the eye tracker. The combination forehead/chin rest was centrally in line with the monitor.

In Phase 2 data collection, prior to the experiment parents/guardians completed a demographic questionnaire and during the experiment parents/guardians completed the Digital Technology Use questionnaire, the Parental Perceptions of Digital Technology questionnaire and the Social Desirability Scale (Study 1a). During Phase 4 data collection parents were not present and questionnaire data was collected prior by using the school system of sending letters home. Questionnaire data was collected in order to be grouped into high and low digital technology exposure groups, see Chapter 2.

Participants were tested individually indoors in a quiet room with fluorescent lighting and some ambient light. Before the start of each trial, participants fixated on a small smiley face in the centre of the screen followed by a gaze contingent crosshair, after which the experimenter initiated the trial. Participants took part in an eye tracking study in which change detection performance was measured using a similar method to that developed Rensink et al., (1997). For each trial paired images (an original image and an altered version of an image) were displayed one at a time with a blank screen in between.

Two overt behavioural responses were recorded as dependent variables, change detection reaction time and accuracy. Participants were instructed to press the “spacebar” as soon as they detected that an object within the image had disappeared and reappeared or changed colour, and then they were told to verbally describe the change to the experimenter who sat at the side of them out of direct view. This was to ensure that the participants had spotted the change and were not just pressing the button to move on. Using a score sheet, the experimenter noted whether the participant accurately named the changing object.

All twenty-four sets of trials were presented in random order to each participant. After every six trials participants were offered a break in order to prevent fatigue or boredom. After a break, the experimenter would calibrate and then recalibrate the eye tracker to ensure validity. Participants were also aware that if required breaks could be taken more frequently between trials. Participants received supportive feedback throughout the trials, regardless of response accuracy.

Results and Discussion

Phase 2 and Phase 4 data is analysed below.

Phase 2 Analysis

Prior to data analysis, data was cleaned in DataViewer software according to standard procedures, see Chapter 2 for full cleaning procedures. Two 2x2x2 mixed ANOVAs were conducted.

Differences were observed between the low and high exposure groups, with fixations in the interest area differing between types of changes, as shown in **Error! Reference source not found.**. The longest fixations in the interest area, meaning the longest time take to recognise the change once looking in the correct area were for central changes in the colour condition for the high exposure group. However, the shortest time of fixations within the interest area was also found in the high exposure group, for the central changes in the absence/ presence condition. For both the high and low exposure groups, fixations within the interest area were longer in the central condition compared to the marginal condition for the colour change condition. However, the fixations within the interest area were shorter for the high exposure group, with a mean of 1117.31ms in the low exposure group and a mean of 778.67ms in the high exposure group. Both the high and low exposure groups had shorter fixations within the interest area for the central condition compared to the marginal condition in the absence/ presence type of change.

Table 24 Means and standard deviations of fixations within the interest area by exposure, type and location

Exposure	**Type**	**Location**	**Mean (ms)**	**Standard deviation (ms)**
Low	**Colour**	**Central**	1340.15	115.18
		Marginal	1117.31	79.82
	Absence/ Presence	**Central**	802.90	43.33
		Marginal	938.39	93.48
High	**Colour**	**Central**	1574.88	154.53
		Marginal	778.67	107.09
	Absence/ Presence	**Central**	644.09	58.13
		Marginal	1006.31	125.41

There was not a significant main effect of type of change in total trial duration $F(1,27) = .523$, $p = .476$, $\eta_p^2 = .019$. However, there was a significant main effect of type of change in fixation duration within in the interest area $F(1,26) = 38.01$, p = .001, $\eta_p^2 = .594$. Fixation duration within the interest area in the colour condition was significantly longer than in the absence/presence condition with means of 1202.75ms (SD: 58.46ms) and 847.92ms (SD: 46.27ms), respectively. There was not a significant main effect of location in total trial duration $F(1,27 = .402$, $p = .531$, $\eta_p^2 = .015$, nor in fixation duration within in the interest area $F(1,26) = 3.865$, $p = .060$, $\eta_p^2 = .129$. There was not a significant main effect of exposure in total trial duration, $F(1,27) = .024$, $p = .879$, $\eta_p^2 = .001$, nor in fixation duration within in the interest area $F(1,26) = .304$, $p = .586$, $\eta_p^2 = .012$.

There was not a significant two-way interaction between type of change and exposure group in total trial duration $F(1,27) = .087$, $p = .771$, $\eta_p^2 = .003$, nor in in fixation duration within in the interest area $F(1,26) = .003$, $p = .955$, $\eta_p^2 = .000$. There was not a significant two-way interaction between type of change and location in total trial duration $F(1,27) = .005$, $p = .946$, $\eta_p^2 = .000$. However, there was a significant two-way interaction between type of change and location in fixation duration within in the interest area $F(1,26) = .25.38$, $p = .001$, $\eta_p^2 = .494$. As illustrated in Figure 7 Means of fixation duration within the interest area by location and type this interaction seems to be as a result of longer fixations duration within the interest area in the colour condition for the central with means of 1457.51ms (SD: 96.36) compared to the absence/ presence condition 723.49ms (SD: 36.25ms). However, in the marginal condition differences between the conditions were minimal with means of 947.99ms (SD: 66.78) for the colour condition and 937.35ms (SD: 78.21ms) for the absence/ presence condition.

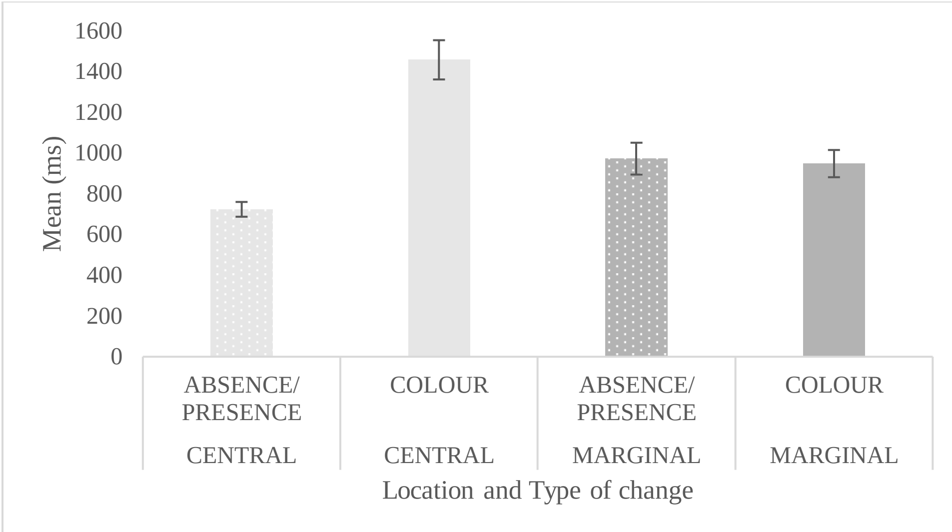

Figure 7 Means of fixation duration within the interest area by location and type

A post hoc test was conducted, and a Bonferroni correction was applied resulting in a new threshold criterion for significance of $p < .025$. Comparing colour change with absence/ presence in fixation duration within in the interest area results showed a significant effect of type of change $t(1,28) = 5.920$, $p = .001$. Colour changes took significantly longer to see with a mean of 1203.56ms (SD: 314.96), compared to absence/ presence changes with a mean of 860.73ms (SD: 228.11ms).

There was not a significant two-way interaction between location and exposure group in total trial duration $F(1,27) = .015$, $p = .902$, $\eta_p^2 = .001$, nor in fixation duration within in the interest area $F(1,26) = 1.709$, $p = .203$, $\eta_p^2 = .062$.

There was not a significant three-way interaction between location of the change, the type of change and level of exposure to digital technology in total trial duration $F(1,27) = 1.307$, $p = .263$, $\eta_p^2 = .046$. However, there was a significant three-way interaction between location of the change, the type of change and level of exposure to digital technology in fixation duration within in the interest area $F(1,26) = 7.062$, $p = .013$, $\eta_p^2 = .214$. For both the high and low exposure groups, fixations in the interest area are longer for a colour change in the central condition compared to the marginal condition, however for and absence/ presence change for both high and low exposure group fixations in the interest area are longer for a colour change in the marginal condition compared to the central condition, see **Error! Reference source not found.** for means and standard deviations.

To summarise, the only significant main effect was found for the type of change in fixation duration within the interest area. Main effects for location of the change or level of digital exposure were not found. This suggests that the amount of digital exposure a child receives does not affect their selective attention ability. Fixation duration within the interest area in the colour condition was significantly longer than in the absence/presence. This may be because an absence/ presence image completely disappears change making it a more obvious change. The only significant two-way interaction found was between the type of change and the location of the change for fixation duration within the interest area. For the central conditions colour changes took significantly longer to see, compared to absence/ presence changes. However, this was not found in the marginal condition, where there was no significant difference between the types of changes. Thus, in the central condition participants spent a longer time looking specifically in the interest area for the colour condition even though there was not a significant difference in the overall time they spent looking at colour compared to absence/ presence both centrally and marginally. Perhaps the colour change was more difficult to spot. A significant three-way interaction was found for fixations within the interest area for fixations within the interest area. Fixation durations were found not to be significant for all main effects and interactions, thus reaction time between participants was not significantly different between all variables.

Due to the lack of a pattern in significant findings in Phase 2 potentially as a result of the study being underpowered, additional eye movements were collected in Phase 4. Additionally, the second set of data was collected in Phase 4 to ensure a narrower age range in the sample, to help reduce individual differences. This second set of data was also collected to ensure a larger sample and because data was collected in schools there was more ecological validity as participants were in a more familiar setting compared to data collected in Phase 2 in which they were visiting Coventry University. Children in Phase 4 were on average older than those in Phase 2 and had started formal education. This age range was selected as children aged six have begun reading acquisition, therefore have had more exposure to text which could influence their attention and where they look on the screen. For example, English is read from left to right therefore, English readers tend to scan a page from left to right and even when looking at an image English speakers will make more fixations on the left (Smith & Elias, 2013).

Additional eye movements were also recorded in Phase 4 to allow a better understanding of the allocation of participants' attention. In addition, to fixation duration in the target interest area and total trial duration, four additional eye movements were recorded. These were first fixation duration within the target interest area; time taken to first fixation in the target interest area; count of fixations in the target interest area and count of total trial fixations. These measures provide more information between the stages of noticing the change and allocating attention to an area of change and ultimately confirming the change by pressing "spacebar" on the keyboard. This information allows for further comparisons between high and low exposure groups. Furthermore, this sample participated in battery of assessments which required participants to have the ability to read and comprehend (see Chapter 5 and 6) therefore, an age range of six to seven years old was chosen.

Phase 4 Analysis

The same design was used for Phase 4. Prior to data analysis, data was cleaned in DataViewer software according to standard procedures, see Chapter 2 for full cleaning procedures. 2x2x2 mixed ANOVAs were conducted. The dependent variables were the following eye movement measures: first fixation duration within the target interest area (the location of the change); time taken to first fixation in the target interest area; count of fixations in the target interest area; fixation duration in the target interest area; total trial duration and count of total trial fixations. The between-subjects factor was level of exposure to digital technology, with two levels: high or low based on the responses to the digital technology questionnaire (see Chapter 3). The within-subjects' factors were location of change, with two levels: central and marginal and type of change: colour and absence/presence.

The target interest area is the location in which the change occurred. First fixation duration within the target interest area is the length of time in ms on the target interest area in the first fixation. Time taken to first fixation in the target interest area is the length of time in ms from the start of the trial to the participants' first fixation in the interest area. Count of fixations in the target interest area in the number of fixations a participant makes within the target interest area. Fixation duration in the target interest area is the mean time spent in ms for fixations within the target interest area. Total trial duration is the time spent in ms from the beginning of the trial to the end where the child has spotted the change and pressed the spacebar, this is equivalent to reaction time. Count of total trial fixations is the total in the number of fixations a participant makes in the trial from start to end of the trial.

There was no significant main effect of the type of change for first fixation duration $F(1,57) = .276$, $p = .601$, $\eta_p^2 = .005$; fixation duration within the interest area $F(1,57) = .463$, $p = .499$, $\eta_p^2 = .008$, total trial duration $F(1,57) = .005$, $p = .946$, $\eta_p^2 = .000$ and count of total trial duration fixations $F(1,57) = .013$, $p = .910$, $\eta_p^2 = .000$. However, for time taken to first fixation and count of first fixations there was a significant main effect of the type of change. There was a significant main effect of type for time taken to first fixation $F(1,57) = 7.535$, $p < .01$, $\eta_p^2 = .117$. Although, there were fewer fixations in the absence/ presence condition, these were longer than those in colour. The mean for the absence/ presence condition was 345.33ms (SD: 6.22ms) compared to 341.45ms (SD: 6.23ms) for the colour condition. There was a significant main effect of type for count of fixations $F(1,57) = 5.701$, $p < .05$, $\eta_p^2 = .091$. The mean number of count of fixations for the absence/ presence condition was 5.82 (SD: .26) and 6.61 (SD: .25) for the colour condition, thus more fixations made in the colour condition compared to the absence/ presence condition.

For all eye movement measures except first fixation duration, there was a main effect of location. There was no significant main effect of location on first fixation duration $F(1,57) = 2.671$, $p = .108$, $\eta_p^2 = .045$. There was a significant main effect of location on total trial duration $F(1,57) = 12.32$, $p < .001$, $\eta_p^2 = .178$. With a total trial duration mean of 15160.05ms (SD: 721.64ms) centrally and 12595.97ms (SD: 602.96ms) marginally, central fixations were longer than marginal fixations. There was a significant main effect of location on count of fixations in the interest area $F(1,57) = 4.783$, $p < .05$, $\eta_p^2 = .077$. There were also more fixations centrally compared to marginally, with respective means 6.53 (SD: .25) and 5.90 and (SD: .24). There was a significant main effect of location on fixation duration within the interest area $F(1,57) = 10.197$, $p < .01$, $\eta_p^2 = .152$. For fixation duration within the interest area, central fixations were shorter than marginal fixation, with a mean of 585.55ms (SD: 40.93ms) centrally and a mean of 798.47ms (SD: 62.65ms). There was a significant main effect of location on time taken to first fixation $F(1,57) = 4.93$, $p < .05$, $\eta_p^2 = .080$. Time taken to first fixations were shorter for central changes compared to marginal changes with respective means of 337.85ms (SD: 5.28ms) and 348.93ms (6.73ms). There was a significant main effect of location on count of total trial duration $F(1,57) = 11.075$, $p < .01$, $\eta_p^2 = .163$. There were more counts of total trial fixations centrally compared to marginally with respective means of 44.09ms (SD: 2.12ms) and 36.98ms (SD: 1.76ms).

The main effect of exposure was not significant in all eye movement measures: first fixation duration $F(1,57) = .118$, $p = .733$, $\eta_p^2 = .002$; fixation duration within the interest area $F(1,57) = .165$, $p = .687$, $\eta_p^2 = .003$; total trial duration $F(1,57) = .006$, $p = .937$, $\eta_p^2 = .000$; time taken to first fixation $F(1,57) = .259$, $p = .613$, ηp2 = .005; count of first fixations $F(1,57) = .536$, $p = .467$, $\eta_p^2 = .009$ and count of total trial fixations $F(1,57) = .041$, $p = .841$, $\eta_p^2 = .001$.

There were no significant two-way interactions between the type of change digital and the level of exposure to digital technology: fixation duration $F(1,57) = .046$, $p = .830$, $\eta_p^2 = .001$; time taken to first fixation $F(1,57) = .624$, $p = .433$, $\eta_p^2 = .011$, $\eta_p^2 = .023$; count of fixations $F(1,57) = .881$, $p = .352$, $\eta_p^2 = .015$.; fixation duration within the interest area $F(1,57) = .031$, $p = .861$, $\eta_p^2 = .001$, $\eta_p^2 = .041$; total trial duration $F(1,57) = .022$, $p = .882$, $\eta_p^2 = .000$ and count of total trial fixations $F(1,57) = .001$, $p = .974$, $\eta_p^2 = .000$.

There were no significant interactions between the location and type of change, for total trial duration $F(1,57) = .020$, $p = .888$, $\eta_p^2 = .000$; count of fixations $F(1,57) = 3.677$, $p = .060$, $\eta_p^2 = .061$; time taken before first fixation $F(1,57) = 3.210$, $p = .079$, $\eta_p^2 = .053$ and count of fixations for total trial duration $F(1,57) = .098$, $p = .755$, $\eta_p^2 = .002$.

However, for first fixation duration and fixation duration within the interest area there were significant interactions between the location and type of change. For first fixation duration, there was a significant interaction between the location and type of change $F(1,57) = 13.713$, $p < .001$, $\eta_p^2 = .194$. As illustrated in Figure 8 Means of first fixations by location and type, this interaction seems to be as a result of longer first fixations in the absence/ presence condition compared to first fixations in the colour changing condition. However, when changes were marginal the opposite was true with first fixations in the colour condition being longer than those in the absence/ presence condition, see **Error! Reference source not found.**.

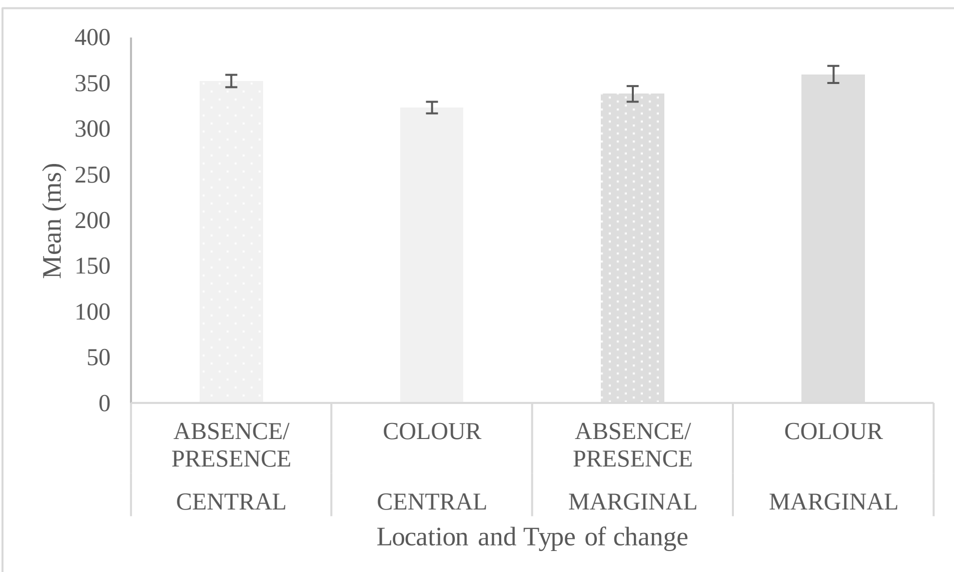

Figure 8 Means of first fixations by location and type

Bonferroni corrections were applied, resulting in a new threshold criterion for significance of $p < .0125$. A paired samples t-test not split by exposure group found a significant difference between central and marginal trials for fixation duration within the interest area in the colour changing condition, $t(58) = -3.898$, $p = .001$. With central trials being significantly shorter than marginal trials with means of 444.85ms (SD: 261.93ms) and 884.25ms (SD: 826.61ms) respectively in the colour changing condition. However, a paired samples t-test not split by exposure group did not find a significant difference between central and marginal trials for fixation duration within the interest area in the absence/ presence condition, $t(58) = -.023$, $p = .982$. With central trials being shorter than marginal trials with means of 720.20 (SD: 516.38ms) and 722.13ms (SD: 607.43ms) respectively in absence/ presence condition, but not significantly. A paired samples t-test not split by exposure group found a significant difference between colour and absence presence trials for the central condition, $t(58) = 4.081$, $p = .001$, but, not for the marginal condition, $t(58) = -1.155$, $p = .253$. For the central condition, the colour changing condition was significantly shorter than the absence/ presence condition with means of 444.85ms (SD: 261.93ms) and 720.20 (SD: 516.38ms), respectively. Again, in the marginal condition the colour changing condition was shorter that the absence/ presence condition, however this was not a significant difference with means 722.13ms (SD: 607.43ms) and 884.25ms (SD: 826.61ms), respectively.

For fixation duration within the interest area, there was a significant interaction between the location and type of change $F(1,57) = 9.992$, $p < .01$, $\eta_p^2 = .149$. Again, individuals spent a longer time when looking marginally compared to looking centrally. However, when the central change was an absence/presence type of change individuals spent fixated for longer compared to colour, but the opposite is true for marginal individuals who spent longer fixating at the colour type change compared to the absence/ presence change, see Figure 9 Means for fixation duration within the interest area split by location and type.

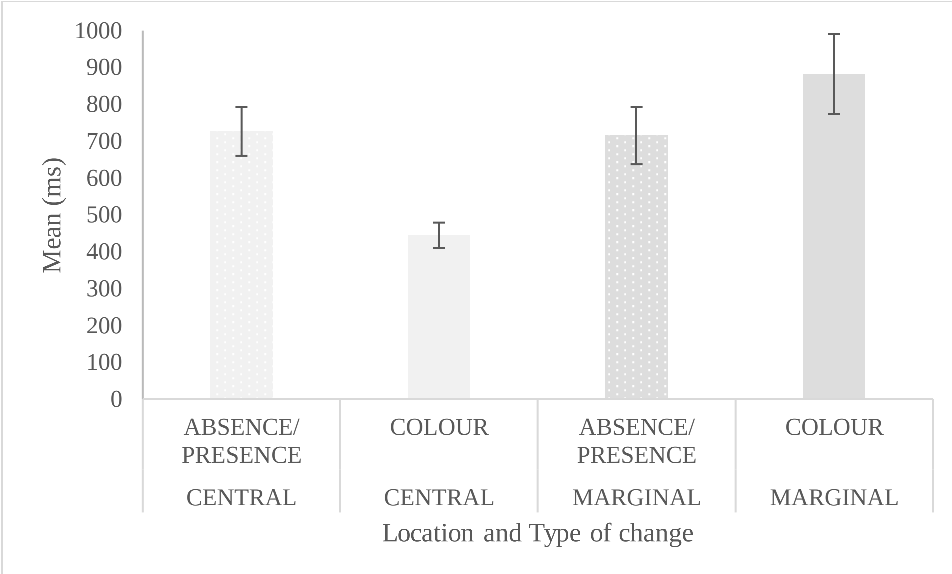

Figure 9 Means for fixation duration within the interest area split by location and type

Bonferroni corrections were applied, resulting in a new threshold criterion for significance of $p < .0125$. A paired samples t-test not split by exposure group found a significant difference between central and marginal trials for fixation duration within the interest area in the colour changing condition, *t(*58)= -3.654, *p* = .001. With central trials being significantly shorter than marginal trials with means of 323.24ms (SD: 48.36ms) and 359.56ms (SD: 71.17ms) respectively in the colour changing condition.

However, a paired samples t-test not split by exposure group found no significant difference between central and marginal trials for fixation duration within the interest area in the absence/presence condition, *t*(58) = -1.524, *p* = .133. With central trials being insignificantly, shorter than marginal trials with means of 352.13 (SD: 51.80ms) and 338.27ms (SD: 65.15ms) respectively in absence/ presence condition. A paired samples t-test not split by exposure group found a significant difference between colour and absence presence trials for the central condition, *t*(58) = -3.654, *p* =.001, but, not for the marginal condition, *t*(58) = -1.534, *p* = .133.

For the central condition, the colour changing condition was significantly shorter that the absence/ presence condition with means of 323.24ms (SD: 48.36ms) and 352.13 (SD: 51.80ms), respectively. Again, in the marginal condition the colour changing condition was shorter that the absence/ presence condition, however this was not a significant difference with means 359.56ms (SD: 71.17ms) and 338.27ms (SD: 65.15ms), respectively.

There were no significant interactions between the location and exposure group for total trial duration $F(1,57) = .413$, $p = .523$, $\eta_p^2 = .007$; first fixation duration $F(1,57) = .182$, $p = .672$, $\eta_p^2 = .003$ and count of fixations in total trial duration $F(1,57) = .270$, $p = .605$, $\eta_p^2 = .005$.

However, for count of fixations, fixation duration within the interest area and time taken to first fixation there were significant interactions between the location and exposure group. For count of fixations there was a significant interaction between the location and exposure group $F(1,57) = 7.404$, $p < .05$, $\eta_p^2 = .115$. For the high exposure group more eye movements are made in the marginal trial compared to the central trials, but the opposite is true for individuals in the low exposure group who make fewer counts of eye movements in the marginal condition to the central condition, see Figure 10 Means for count of fixations split by exposure and location.

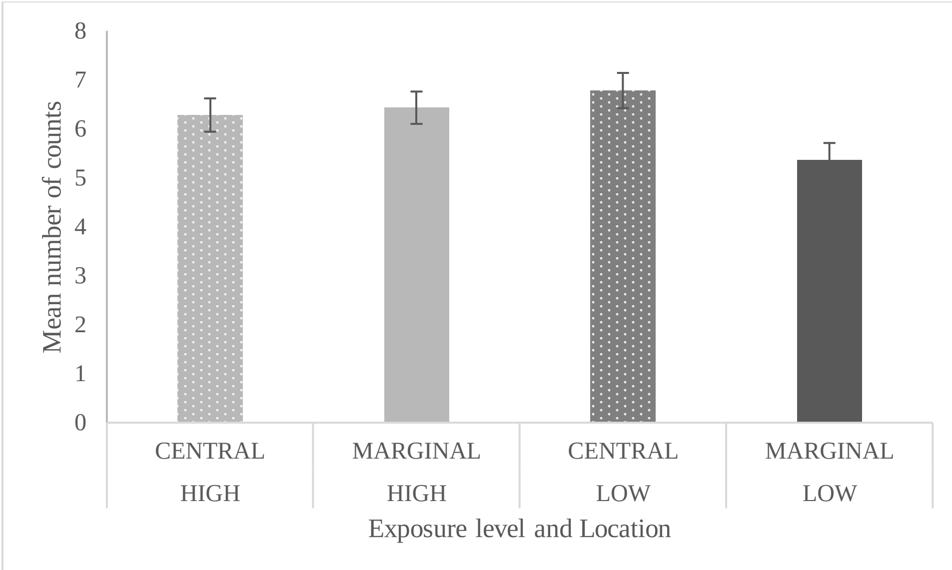

Figure 10 Means for count of fixations split by exposure and location

Bonferroni corrections were applied resulting in a new threshold criterion for significance of p < .025. Tests using exposure found no significant difference between the high and low exposure group centrally in the count of fixations $t(57) = -1.023$, $p = .311$; nor marginally $t(57) = -1.483$, $p = .143$. Within the high exposure group there was no significant difference between the central and marginal conditions in count of fixations $t(30) = -.290$, $p = .774$. However, in the low exposure group there was a significant difference between the central and marginal conditions in count of fixations $t(27) = -3.414$, $p = .002$. Results show in the low exposure group more counts were made centrally compared to marginally, see **Error! Reference source not found.**.

For fixation duration within the interest area there was a significant interaction between the location and exposure group $F(1,57) = 5.223$, $p < .05$, $\eta_p^2 = .084$. For both the high and low exposure groups central fixation duration within the interest area was shorter compared to marginal fixation duration within the interest area, see Figure 11 Mean of fixation duration within the interest area by exposure and location. Figure 11, appear to show a greater effect of location for the high exposure group compared to the low exposure group.

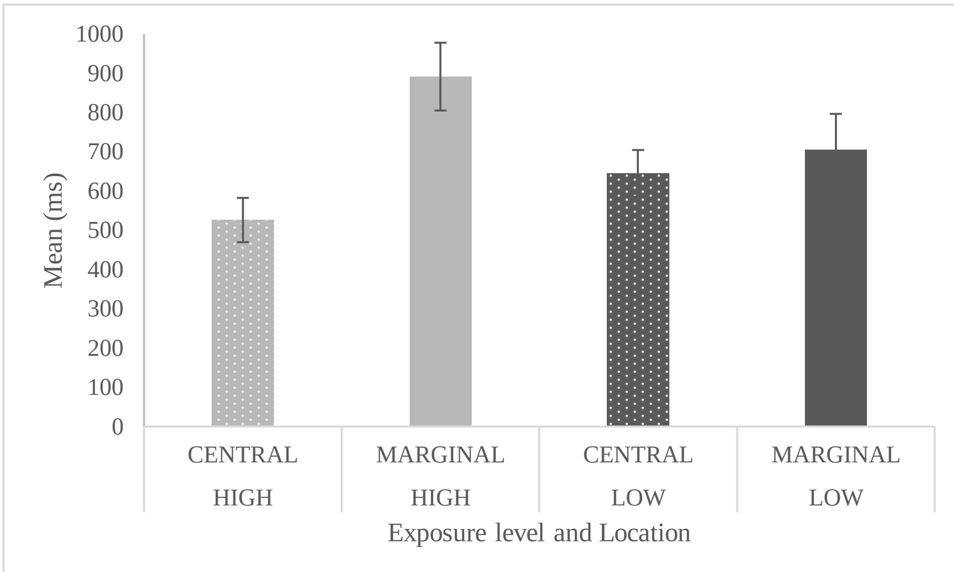

Figure 11 Mean of fixation duration within the interest area by exposure and location

Bonferroni corrections were applied resulting in a new threshold criterion for significance of $p < .0125$ and t-tests were conducted. There was no significant difference between the high and low exposure group centrally in fixation duration within the interest area $t(57) = -1.483$, $p = .143$; nor marginally t(57) = 2.200, $p = .032$. In the high exposure group there was a significant difference between the central and marginal conditions in the fixation duration within the interest area t(30)=-4.408, p=.001. Participants in the high exposure group spent a significantly shorter time looking centrally compared to marginally, see Figure 11. However in the low exposure group there was no difference of location $t(27) = -.777$, $p = .444$.

For time taken to first fixation, there was a significant interaction effect between the location and exposure group $F(1,57) = 8.438$, $p < .01$, $\eta_p^2 = .129$. For both the high and low exposure groups central first fixation duration was shorter compared to marginal first fixation duration, see Figure 12 Mean of first fixation duration by exposure and location.

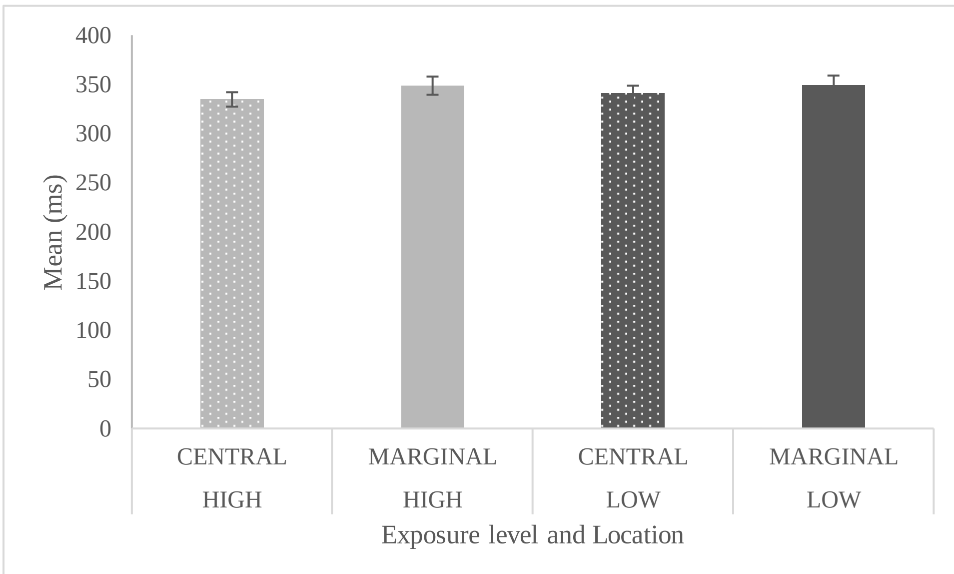

Figure 12 Mean of first fixation duration by exposure and location

Bonferroni corrections were applied, resulting in a new threshold criterion for significance of $p < .0125$. T-tests were conducted. In the high exposure group there was no significant difference in first fixation duration between marginal and central trials, $t(30) = -1.429$, $p = .163$. Additionally, in the low exposure group there was no significant difference in first fixation duration between marginal and central trials, $t(27) = -.906$, $p = .373$. Again, no significant difference between the high and low exposure group centrally in time taken to first fixation duration $t(57) = -1.293$. $p = .201$; nor marginally $t(57) = 2.088$. $p = .041$.

There were no significant three-way interactions between location of the change, the type of change and level of exposure to digital technology in all eye movement measures: fixation duration $F(1,57) = .113$, $p = .738$, $\eta_p^2 = .002$; time taken to first fixation $F(1,57) = 1.355$, $p = .249$, $\eta_p^2 = .023$; count of fixations $F(1,57) = 1.50$, $p = .226$, $\eta_p^2 = .06$; fixation duration within the interest area $F(1,5\ 7) = 2.444$, $p = .124$, $\eta_p^2 = .041$; total trial duration $F(1,57) = .21$, $p = .649$, $\eta_p^2 = .004$ and count of total trial fixations $F(1,57) = .200$, $p = .656$, $\eta_p^2 = .003$.

To summarise a main effect of type of change was found for both the time taken to first fixation and the number of counts of fixation. A main effect of location of change was found for: total trial duration, count of fixations, fixations within the interest area, time to first fixation in the interest area and count of fixation in the total trial. Overall, the length of fixations was longer centrally compared to marginally, this shows reaction time to spot central changes was longer. Additionally, more fixations were made in the interest area for the central condition compared to the marginal condition, however these fixations were in total for a shorter time period. This suggests more frequent, short fixations were made in the central condition. It took longer to get to the change in the central condition, but overall time is longer for the central condition a possible explanation is that participants may be looking in the interest area but have not noticed the change, therefore they spend longer looking. This could be explained by the fact that each trial starts with the participant fixating in the centre of the image. There were more counts of fixations in the central condition, suggesting that the participants expected the change to be more centrally. All eye movement measures were not significant three-way interactions between location of the change, the type of change and level of exposure to digital technology.

General Discussion

The aim of this chapter was to understand whether children's performance on a visual attention task was related to their levels of exposure to digital technology in the early years. Overall, results from both phases found no main effect of exposure to digital technology on children's performance on visual attention tasks.

In Phase 2, fixation duration within the interest area in the colour condition was significantly longer than in the absence/presence. This could be explained in the findings from studies using the flicker paradigm, which found objects of a similar colour may be less distinguishable as they can be combined into one memory structure (Rensink, 2002). This suggests that even when looking at the change, it took longer to process a colour change compared to an absence/presence change. This perhaps suggests that colour changes are harder to spot as the object (which has changed colour) is still there, resulting in the change being less obvious. Although in Phase 4, there was not a significant difference between the type of change in fixation duration in the interest area, there was for the time taken to first fixation and the count of fixations. The time taken to first fixation was longer in the absence/ presence condition compared to the colour condition even though fewer fixations were made in the absence/ presence condition compared to the colour condition. Overall, this suggests that when searching for a change initially it might take longer to spot the absence/presence change, but once spotted it is registered more quickly as fewer fixations are made for an absence/presence change and the overall fixation duration in the absence/presence condition is shorter.

In Phase 2, there were no significant effects of location of change, however, the same was not found in Phase 4. In Phase 4, a main effect of location of change was found for: total trial duration, count of fixations, fixations within the interest area, time to first fixation in the interest area and count of fixation in the total trial. Thus, the length of fixations was longer in the central condition compared to the marginal condition. Additionally, more fixations were made in the interest area for the central condition compared to the marginal condition, however these fixations were in total for a shorter time period meaning more frequent, short fixations were made in the central condition. It took longer to get to the change in the central condition, but overall time is longer for the central condition. As discussed earlier this may be explained by participants looking for longer in the interest area but not noticing the change therefore, they spend longer looking. This could be explained by the fact that each trial starts with the participant fixating in the centre of the image. Future research needs to be conducted in a manner that avoids this; a possible solution could be changing the initial fixating point for the different trials. There were more counts of fixations in the central condition, suggesting that the participants expected the change to be more centrally.

In both Phase 2 and Phase 4 there were no significant main effects of exposure for all eye movement measures obtained. This varies from previous research which found enhanced visual attention in video game players compared to non-video game players in a change detection tasks (K. Clark et al., 2011). However, the results of the present study may not show a significant effect like in Clark et al's., (2011) study because in the present study participants were aged between six to seven years old compared to 18 to 20 years old, thus there are a number of possible explanations of the present study's results differing. Due to this large discrepancy in age, the differences in levels of exposure are likely to be more significant in the older participants as they have had more time to be exposed to digital technology. Furthermore, the participants in Clark et al's., (2011) study were exposed specifically more to video games whereas the present study has a more general approach at creating exposure groups based on the use of a variety of digital technologies including: tablets, smartphones, computers, e-books, television and video games and as can be seen in Chapter 3: What are the effects of digital text exposure on young children?. Video games were not frequently used by young children in comparison to the other digital options, as reported by parent in Chapter 3: What are the effects of digital text exposure on young children?. Ergo, perhaps video games exposure specifically affects attention, but other digital technologies may relatively not have an effect on attention. Although, in support of the present study, results of a different study using a flanker task showed video game players did not perform significantly better non-video game players (Durlach et al., 2009). Additionally, unlike the present study Clark et al's., (2011) did not use an eye tracker, thus, an assumption which underlies these studies is that the mouse-press data is a valid interpretation of allocation of attention. Clark et al., (2011) state regardless, a difference is present in video game players and non-video game players and promote the use of video gaming due to the potential benefits of visual attention.

In both Phase 2 and 4 there were no significant interaction effects of type of change and location of change for all eye movement variables. However, in both Phase 2 and 4 there was a significant interaction effect for fixations within the interest area. For Phase 2, in the central condition for absence and presence changes fixation duration within the interest area was shorter that colour changes. However, there was no significant difference in the marginal condition between absence and presence changes fixation duration within the interest area or length of fixation in the interest area for colour changes. These results differed in Phase 4, where differences were not significant. In Phase 2, there was a significant interaction effect for fixation duration, which showed that in the central condition during absence/presence overall fixation time was longer compared to the colour change condition. Thus, suggesting that an absence/presence type of change is more difficult to identify and requires more attention.

In Phase 2 there were no significant interactions of location of change and exposure for all eye movement variables. However, in Phase 4 there were significant interactions of location of change and exposure for: count of fixations, fixations within the interest area and time taken to first fixation in the interest area. For the count of fixations in the high exposure group there was not a significant difference between location however, there were more fixations in the central condition compared to the marginal condition for the low exposure group. This shows that individuals with high exposure distribute their attention evenly across an image. For the fixation duration in the high exposure group there was a significant difference between the central and marginal conditions with central changes much shorter than marginal changes. However, this effect was not significant in the low exposure group.

Across both Phase 2 and 4 the only significant three-way interaction was found in Phase 2 for fixation duration within the interest area. For both the high and low exposure groups fixations in the interest area were longer for a colour change in the central condition compared to the marginal condition. However, for the absence/ presence change both high and low exposure group fixations in the interest area were longer for a colour change in the marginal condition compared to the central condition. Comparing the high and low exposure groups, shows that in the high exposure group it takes longer to confirm the change when the change is a colour change occurring centrally compared to the low exposure group. However, in marginal condition the opposite is true with the low exposure group it takes longer to confirm the change when the change is a colour change occurring marginally compared to the high exposure group. Comparing the high and low exposure groups again, shows that in the high exposure group it takes less time to confirm the change when the change is an absence/presence change occurring centrally compared to the low exposure group. However, in marginal condition the opposite is true again, with the low exposure group it takes less time to confirm the change when the change is a colour change occurring marginally compared to the high exposure group. These results differ from studies conducted by Green & Bavelier (2006a) that showed that video game players showed enhanced attentional resources compared with non-video game players, both peripherally and in centrally.

Overall, these studies found no effects of exposure to digital technology on children's performance on visual attention tasks. This may help alleviate parent's fears in regard to their children's digital technology use reported in Chapter 3. This is particularly reassuring given the recent dramatic increase in digital technology use through online home-schooling and socialising due to school closures because of COVID-19 (Williamson et al., 2020).

The present study is novel, as it is the first eye tracking study to measure change detection using a flicker paradigm and thus also the first to explore the differences in high and low exposure to digital technology using a change detection task. Using the eye tracker allowed for more variables to be collected and a more accurate measure of attention, e.g., compared to mouse-press data. Thus, providing more confidence in the notion that digital exposure in early years does not cause harm to children's visual attention spans. Another strength of the study is the use of natural stimuli which improves ecological validity. Additionally, the task presented is similar to a spot the difference task, which is a task familiar to children in this age range. Images used were taken from the Rising Stars Reading scheme which is a national reading scheme which at the time had not been rolled out into schools. These images therefore are something that a child would be familiar with. Additionally, the text at the bottom of the image resulted in an accurate representation of a page taken from a book or e-book. The task was presented in a video game format making it more fun for participant, however this required using a keyboard, this may provide some benefit to individuals who have more exposure to digital devices. Furthermore, although eye tracking is more useful that just reaction times data and provides more information than mouse-pressing, it has been suggested that attention precedes eye movements, thus perhaps future research could use neuroimaging during the administration of a change detection task.

Future research should be conducted with young children as data is limited and reliability needs to be accessed as Phase 2 and Phase 4 showed some differing results. It would also be interesting to explore change detection in a text format as that will allow for closer exploration on the effects of attention on reading. The next chapter focuses on exploring the differences between reading on different types of media.

Chapter 5: What are the impacts of reading across different media?

As discussed in Chapter 1, the visual attention span can predict variation in the ability to learning to read (Bosse & Valdois, 2009). On account of this the previous chapter explored children's performance on a visual attention task, on the whole, findings showing effects of exposure to digital technology on children's performance on visual attention tasks were limited. In wanting to expand and add to the knowledge of the effects on digital technology, the present Chapter deals with both the effects of device type and levels on digital exposure on reading related measures.

Over the past few decades, technology has rapidly advanced. Individuals are submerged in a world of technology; digital devices are used by most people every day. Computers and laptops are used for study and work, televisions and tablets for entertainment and mobile phones offer a range of services including the ability to communicate with friends and family across the world. With the advent of the World Wide Web, access to new information became instantaneous, leaving the fate of printing unclear. Many educational institutions have introduced digital assessments and learning environments. As discussed later in this chapter, this environment may not promote deep reading and comprehension. Now more than ever before an increased shift to digital and online learning has occurred with remote forms of learning promoted due to mass school closures as a result of the COVID-19 pandemic (Williamson et al., 2020). However, in the 21st century even though digital technology is omnipresent and crucial to many parts of life, print media continues to be used. This, alongside the inconclusive findings regarding the effects of digital technology on young children (lack of research on primary school aged children) discussed below, provides a strong rationale for the present study. Thus, the focus of this chapter is understanding how exposure to digital technology affects young children's reading related skills and the differences in reading across different types of media.

In today's world there is a continuing shift from reading print to reading on screen (Mangen, Walgermo & Bronnick, 2013). Children spend more time reading on computers and other digital technologies compared to reading print material, reinforcing the crucial role of technology in young people's literacy lives (Picton, 2014). There is an increase in device use including computer and laptops, tablets, e-books and smartphones. Children have access to these devices both at home and school. A UK survey of children aged eight to 16 years old found that 52.4% children preferred to read on screen rather than on paper, whilst a 30% preferred print to digital (Picton 2014). Additionally, this survey found that between 2010 and 2012 e-book reading increased from 25% to 46%, showing how children are moving away from print media to more digital text formats.

Some have wondered whether or not we should be concerned about the impact this shift to digital text formats has on the developing reader. Alexander (2012) questioned what is meant by being a competent reader in the 21st century and to what extent educators and researchers should be "disturbed" by future changes due to technology. Alexander (2012) argued that although devices and media may change, developing readers will still need the same resources and support. This can be supported by previous changes to our reading environment and society. It is suggested that reading is "multidimensional, developmental and goal-orientated" in nature rather than merely a set of bottom-up cognitive processes (Alexander, 2012, p. 259).

The shallowing hypothesis suggests exposure to digital texts would have a negative impact on reading development

One theory which predicts that exposure to digital technology will have a negative impact on reading development is the shallowing hypothesis (first introduce in Chapter 1). The shallowing hypothesis refers to the idea that digital texts are more shallowly processed as digital devices are used for quick interactions, for example reading or writing a text message (Annisette & Lafreniere, 2017). It suggests that the digital devices are leading to a decline in reflective thought and offer instant rewards which in turn encourage behaviours which avoid sustained attention which is needed for deep reading and comprehension. This shallow reading is associated with digital devices, therefore, may explain lower comprehension scores in comparisons of digital and print reading. However, Latini et al. (2020) state that there is essentially a lack of direct support for the shallow hypothesis, thus further research is necessary. Due to the increase in popularity of screen reading, several studies have been conducted comparing reading from print and digital devices.

In 1992, a literature review compared the differences between media regarding processes and outcomes of reading (Dillon, 1992). Prior to this study, research had focused on outcomes and aimed to identify a variable to explain differences in reading time. This study examined research to identify issues regarding reading and provide evidence for how single variable explanations do not provide satisfactory answers. It was concluded that digital reading is slower than print reading perhaps due to the awkwardness of digital reading, suggesting that complete uniformity across media is not achievable. However, as developments in technology continue, comparisons between devices are more accurate (print-based tasks can be transferred directly onto digital devices) and more positive attitudes towards digital technology as well as greater exposure suggest a future of equal reading time and performance.

A more recent review focused on the issue with equivalence between media by reviewing performance measures (Noyes & Garland 2008). Three types of tasks were identified including: non-standardised, open-ended tasks (e.g., writing about text), non-standardised, closed tasks (e.g., multiple-choice questions) and standardised task (e.g., a standardised test). It was found that not all studies took equivalence into account. Here the term equivalence refers to sameness in presentation across different media and formats. Equivalence is achieved through a variety of aspects, these can include, layout, font styles, size and colour. A lack of equivalence found in some studies could mean that studies may be confounded due to issues when transferring print text to digital text as the final task may not be the same. Overall, reaching equivalence in digital reading tasks and print reading tasks is difficult, but present studies are aware of the issue and strive for sameness across tasks.

Digital technology offers individualization and may increase print exposure

Alternatively, the individualization afforded by digital technology might actually be a positive attribute. Individualization allows children to create their own path in learning through selection of activities, content, immediate feedback and operational assistance (Tangirov, 2020).

Digital technology allows information to be accessed from multiple devices and one device can store a large amount of data including many books or other reading materials, thus giving digital devices the advantage of convenience over traditional print media. This is important as print exposure strongly correlates with reading time and reading attainment (Acheson et al., 2008; Martin-Chang et al., 2020; Mol & Bus, 2011; Moore & Gordon, 2015).

Therefore, if children are exposed to more print content via digital devices this could lead to benefits in reading.

Digital technology offers interactivity and different ways of reading which might impact on reading development

Certain features of digital learning and assessments might be particularly advantageous for literacy development, interactivity for example. The use of interactive features in digital stories were examined in a meta-analysis of 43 studies with 2147 participants aged between three to 10 years of age (Takacs et al., 2015). Interactive features of digital technology including the use of animated images, sound effects and music were found to be beneficial in young children's literacy development, including improved story compression and expressive vocabulary. However, other interactive functions such as dictionaries and games were found to be distracting. This shows the importance of content when trying to understand the effects of digital technology (Takacs et al., 2015). However, alongside recognition of these benefits of digital technology, there are also concerns about potential disadvantages to reading on digital devices compared to reading print.

Digital technology offers different ways of reading. A study using eye tracking to observe reading time and reading comprehension in 103 secondary school students with dyslexia suggests that differences in the amount of text that is displayed on a device might influence reading time and comprehension (Schneps, et al., 2013b). Print reading was compared to reading on a small e-reader displaying a few words per line. Reading time and comprehension improved during digital reading compared to print reading for specific groups of students. Individuals with phoneme decoding difficulties or sight word reading difficulties read digital texts more rapidly than print texts. Meanwhile, individuals with limited visual attention spans had improved comprehension when reading digitally compared to print reading (Schneps, et al., 2013b). However, this may be attributed to the short lines of text in the digital condition which tend to have a few words per line compared to the paper condition which had more words per line. Shorter line lengths have been found to facilitate reading in people with dyslexia (Krivec et al., 2020; Martelli et al., 2009; Schneps, et al., 2013a). Therefore, the use of short lines of text could explain the improved reading rather than the media itself.

We should not forget that reading is a goal directed task, and as a result a reader's intentions and motivations can influence the way that they read. Rose (2011) conducted a thematic analysis of interviews regarding undergraduate student's experiences of reading digital texts including e-books and pdfs. Conversely to popular opinion digital reading may not be a process of "skimming and rushing from one thing to another" (E. Rose 2011). Students are intentionally trying to adjust to digital reading by creating method to maintain focus and complete their reading. However, it was found that individuals interviewed had predetermined perceptions of technology. This cannot be avoided as impartiality is not associated with new technology as our experiences shape our opinions.

Deep reading – relationships between reading comprehension and reading time

There are fears that the new generation may be incapable of deep reading (Bauerlein, 2008). The term deep reading was coined in 1994 by Sven Birkerts in which he explains a form of reading we control and adapt to our needs, in which we can indulge and contemplatively enjoy a book. Deep reading is an important and active process in which thoughtful and considered reading is executed to develop comprehension through a range of processes that include "inferential and deductive reasoning, analogical skills, critical analysis, reflection and insight" (Wolf and Barzillai, 2009). This process is performed automatically within milliseconds for expert readers but requires time and practice for young children. Wolf and Barzillai (2009) claim that the time taken for deep reading is possibly threatened by the immediacy of digital technology and the information loading which encourage speed and discourages the deliberation associated with deep reading.

If children have a desire for speed and inability to endure a slow-paced environment and the ability to scan text allowing them to process information rapidly, they will prefer using digital devices (Rayner et al., 2016)(Carr, 2010; Tapscott, 2009). These devices may interfere with deep reading (Carr, 2010; Tapscott, 2009).

Is there compelling evidence that digital technology increases reading time and/or decreasing comprehension?

Clinton (2019) conducted a systematic literature review of thirty-three studies ranging from 2010 to 2018 with a total 2799 participants, comparing print reading and digital reading to consolidate research on reading time and reading performance. It was found that reading from digital devices has a negative effect on reading performance compared to reading print, however, this was only found for expository passages and not for narrative passages. This could be because expository passages are more difficult to read compared to narrative passages, which are more easily recalled and understood (Mar et al., 2021). Furthermore, other studies also found screen inferiority was found to be more prevalent in expository texts compared to narrative texts (Delgado et al., 2018; Delgado & Salmerón, 2021). The use of technical jargon and lack of timelines in expository texts may make it more difficult for the reader to understand. (Medina &

Pilonieta, 2006; Weaver III & Kintsch, 1991). Additionally, Clinton (2019) found that overall, there was no significant difference between reading time for digital reading compared to print reading.

Another study examined the effects of processing texts on 86 undergraduate students' comprehension, processing time and calibration in print and digitally (Trakhman, Alexander & Berkowitz, 2017). Calibration is the level of association between participants' predicted performance and their actual performance (Alexander, 2013). Three levels of comprehension were tested: the main concept of text, key points of text and other related information. Students' recall of key points and other related information was significantly better in the print condition compared to the digital condition; however, the main concept of text was not (Trakhman, Alexander & Berkowitz, 2017). This supports the shallow hypothesis as students gleaned the main idea but did not engage at a deeper level when digitally reading. Adding processing time as a mediator variable influenced the relation at all comprehension question levels between type of presentation and comprehension, with increased reading time resulting in reduced comprehension (Trakhman, Alexander & Berkowitz, 2017). With regard to calibration, undergraduate students read faster and predicted higher performance in comprehension for digital reading, however the converse was true for performance (Trakhman, Alexander & Berkowitz, 2017). This is concerning as students believe that they are reading better digitally although the findings suggested the opposite.

One of the few studies to collect data exploring media effects on attention in children took place in Germany. Two-thousand, eight-hundred and seven children from grade one to six read at word, sentence and text level then complete comprehension questions under a time constraint on paper or via computer (Lenhard et al., 2017). Results showed that on screen children worked faster however, this was at the expense of reading accuracy (Lenhard et al., 2017). Thus, it is of key interest to see if this finding is reliable for in English speaking children in the UK.

A literature review of 20 recent studies from 2000 – 2017 found no decisive agreement for whether digital reading or print reading is more effective for individuals learning English as a Foreign Language (Pardede, 2018). Results varied, in terms of comprehension several studies suggested that print reading is superior to digital reading, whilst some suggested the opposite to be true and some studies found no significant differences between the two media (Pardede, 2018). Pardede (2018) identified the factor that possibly attributes to the inconsistent results. Firstly, the wide range of designs used. There was variation in ages across studies, settings, variables and mastery of reading. Secondly, the types of digital devices differed. Due to the ever-evolving nature some technologies used in the studies are on the verge of obsoletion. Therefore, to achieve a more decisive result regarding the effectiveness of digital reading and print reading further studies need to be conducted with controlled variables and valid and reliable measures. In addition, these studies must use the latest digital technology that are used for reading.

Research on reading across media has focused on adults. Sun, Shieh & Huang (2013) analysed the difference in comprehension of participants aged 45 to 54 years old between print reading and digital reading in the form of hypertext on computer screens. Findings showed no significant difference between comprehension performances between the two media. There was a significant difference of gender and education level on print reading comprehension but no significant differences for digital reading. There was no significant main effect of age on both print and digital reading comprehension performance. However, it was found that print material is better for middle-aged readers' literal comprehension, whereas hypertext is better for their inferential comprehension. These results were based on data from adults, there is a lack of evidence regarding children's reading across different media.

A recent meta-analysis examined 38 studies from 2000 to 2017 with a total sample of 54 participants compared reading comprehension across digital and print reading studies from 2000-2017 (Delgado et al., 2018, 2018). Results showed a significant advantage for paper reading in comparison to digital reading. The analyses found three significant moderators: time-frame, text genre and publication year. Paper reading showed advantages in time-constrained conditions compared to self-paced reading conditions. The advantages of paper reading were also found for information passages but not for narrative passages. This study surprisingly found that the advantage of paper reading increased over the year. This is surprising as digital reading is becoming more and more common.

Interestingly research has also examined individuals' perceptions of reading using digital technology. In one study, university students perceived themselves to have reduced comprehension when using digital devices in comparison to when they read from printed texts (Kirby & Anwar, 2020). It was implied that this occurred, because participants believed that accessing previous topics was more difficult when using an e-book, as they had less opportunity to note their thinking. This resulted in the participants having increased their cognitive loads as more information was stored in the working memory when using an e-book. When using smaller e-book documents students did not perceive a reduced level of comprehension and this could be explained by the idea that having to retain less information as from the start they are faced with less content and thus, less information. Additionally, for a long time it has been known that annotation including underlining and highlighting, has been beneficial in both retaining information and successful comprehension (Fowler & Barker, 1974). Therefore, it is clear that the ability to annotate on digital devices, similarly to print would improve individuals' reading comprehension. Ergo, as devices continue to evolve it is important to take note of how they can facilitate good reading and good reading comprehension. The present study contained only short passages, thus there was no need for annotations. Additionally, the present study focused on sameness across media by limiting confounding variables, which may have arisen through annotation.

Purpose of reading effects behaviour

Studies do not always provide participants with a purpose. If participants are provided with a purpose this might influence their reading. Latini et al., (2019) examined the extent to which undergraduate students' behavioural engagement and textual integration could differ between reading identical print and digital passages in preparation for an exam compared to reading for pleasure. It was expected that printed passage reading would result in better engagement in comparison to digital passage reading, but this would be moderated by the effect reading purpose as, individuals preparing for an exam would show greater engagement irrespective of the medium (Latini et al., 2019). The effect of interaction of medium with reading purpose on behavioural engagement indicators of reading time and the length of writing post-reading were found Latini et al., (2019). Students took longer reading for an exam compared to reading for pleasure when using digital devices compared to printed passages Latini et al., (2019). This is the opposite of many findings which support the abovementioned shallowing hypothesis, which suggests reading time would be shorter on digital devices (Annisette & Lafreniere, 2017). This suggests that individuals reading behaviour is adaptable to the situation. This can be explained by the role of reading purpose, in which an individual's reading and reading comprehension is affected by their understating of purpose for reading the text (Britt et al., 2017; McCrudden & Schraw, 2007). Length of writing was longer after reading printed text for exams but not for pleasure and there was no difference after reading digital passages Latini et al., (2019). Longer lengths of writing suggest better recollection; thus, recall was better after paper reading but only for examination. This is supported by Trakhman, Alexander & Berkowitz (2017) who as mentioned earlier found students' recall of key points and other related information was significantly better after print reading compared to digital reading.

Device preferences influences reading behaviour

A study explored potential difference in undergraduate students' comprehension of digital reading and print reading (Singer and Alexander, 2016). Before and after the reading task students stated their medium preferences. Results showed a preference for digital reading and students predicted better comprehension for digital reading. Conversely, it was found that students' preferences and comprehension predictions were not consistent with their performance. There was no difference across the different types of media when students identified key ideas from the text, but other relevant information was better recalled when engaged in print reading.

Similarly, a study compared 134 undergraduate students' (mean age of 23 years old, 52.5% female) perception of and learning from digital and print reading with an aim to provide recommendations for students and professors regarding the best methods for reading coursework (Sage, Augustine, Shand, Bakner & Rayne, 2019). It was shown that students learned equally well and spent equal time reading from print, computers and tablets. Eighty-one percent of students reported a preference for print. However, three more studies showed students were more likely to use digital resources. This suggests that for university students, digital resources are commonplace, but print reading and digital reading are both executed equivalently. This emphasises the importance of understanding the effects of digital technology as it becomes more ubiquitous with life.

A meta-analysis reviewed 17 studies dating from 2000 to 2016 comparing reading time and comprehension across digital and print reading (Kong, Seo & Zhai, 2018). The robust variance estimation (RVE) based meta-analysis models were used. Four RVE meta-regressions models were used to study possible effects of some moderators for mean differences in reading time and comprehension digitally and print reading. There were no significant differences in reading time across digital and print reading. However, reading comprehension was better for print reading in comparison to digital reading. Moderators were not significant. Perhaps there is an advantage of print reading as students have had years of previous experience reading on paper, which has influenced their preference for print media. This shows the importance of conducting studies with young children who are growing in the digital age and have been surrounded by digital technology from a young age, as they may not have the same preferences as individuals from older generations. There is also a bigger demand in cognitive load when reading is digital as a device may be unfamiliar to the reader (Ackerman & Lauterman, 2012).

Familiarity with medium effects reading behaviour

Familiarity with the medium might mediate successful reading. Currently, most individuals are more familiar with reading print compared to reading digital texts (G. Chen et al., 2014). G. Chen et al., (2014) considered the effects of user familiarity when comparing print and digital reading in 90 undergraduate students from a university in Bejing China. Familiarity was measured using the Tablet Familiarity Questionnaire established by Zheng et al., (2015). After reading, participants were asked two types of comprehension questions: multiple choice (shallow) and summarisation (deep). Results showed that participants in the paper condition performed significantly better on shallow comprehension questions than those in the digital condition (G. Chen et al., 2014). Furthermore, individuals with high familiarity in the digital condition performed better than those with low familiarity in the digital condition on deep comprehension questions (G. Chen et al., 2014). This suggests that if students receive training on digital reading their familiarity would increase thus resulting in better comprehension.

Overall rationale

The paradigm of reading has become decreasingly print based and increasingly screen based (Mangen at al., 2013). There is limited evidence concerning whether digital devices facilitate cognitive gains, particularly for children. Therefore, it is important to determine whether digital presentation of text affects reading time, reading accuracy and comprehension is of paramount importance. The theoretical and education consequences for the continuing digitisation of reading and reading comprehension are complex. Thus, leaving many important research questions only partly answered: are children's reading times and reading accuracy affected by the presentation of text, whether it is presented digitally on computer or tablet compared to being printed on paper? How and to what extent might comprehension of texts differ when texts are displayed on a screen as compared to being printed on paper? These issues have become relevant as children are more frequently presented with various digital texts. The aim of the present chapter is to understand the extent of this shift effect on reading comprehension. In Experiment 3a, a novel task is developed to assess the effects of media type on reading time, comprehension and the number and type of errors that children make during reading. Experiment 3b further examines whether exposure to digital technology (measured by the questionnaire developed in Chapter 3) mediates any effects that digital technology has on reading.

Experiment 3a: What are the differences in printing compared to digital reading?

The present study explores the differences in reading related skills and behaviours, including reading time, reading comprehension and the number and nature of reading errors made whilst reading aloud, across three different types of media. This study focused on the differences across devices.

Hypotheses

The present study explores whether the type of media influences reading time, comprehension and the number and nature of errors. It was hypothesised that reading time will be significantly different between the paper, laptop and tablet conditions, with it being longest in the paper condition. There will be a significantly lower score in comprehension score for the laptop and tablet condition compared to the paper condition. There will be significantly more reading errors in laptop and tablet condition compared to the paper condition. Exploratory analyses of the type of errors will allow the consideration of whether the nature of errors differs on different media.

Methods

For this study data was collected in two phases (Phase 3 and Phase 4) as reported in Chapter 2. Methodology is fully explained in Chapter 2: Methodology and have been presented in a more condensed format below.

Participants

Twenty-seven children between the ages of six to 12 years old with a mean age of 9.51 years old and an SD of 1.57 years participated in the present study. 56% of participants were female. All participants spoke English and 15% of these participants spoke an additional language. See Chapter 2: Phase 3 Data Collection for further information about participants.

Materials

Stimuli were presented on three different types of media: paper, tablet and laptop. For these three media conditions, text was left-justified using the same font in the colour black to ensure the formatting remained equal across conditions. The number of letters on a line for the same stimuli across the different conditions remained equal. However, the visual size of the text varied for each device (laptop and tablet) due to differences in screen resolution. The laptop was larger than the tablet. With permission from the publisher stimuli were formed from passages of text from the Rising Stars Planet, a UK based reading scheme. In total 18 passages were presented to the participants. The level of difficulty of these passages were easy or hard. Nine passages were easy and these all contained three sentences with between 15 and 27 words in total and a mean Flesch-Kincaid rating of 100. Nine passages were difficult and these all contained six sentences with between 59 and 76 words in total and a mean Flesch-Kincaid rating of 82.3.

Design

A mixed design with two independent variables (type of media and level of difficulty) was conducted. Passages of text were presented on three different types of media: paper, tablet and laptop. Level of reading difficulty had two levels: easy and difficult, which are defined below. Dependent variables were reading time, reading accuracy (including the nature of errors) and reading comprehension scores. The between-subjects factor was the level of digital exposure: high or low.

Procedure

Parents/guardians completed the Digital Technology Use questionnaire and the Parental Perceptions of Digital Technology questionnaire.

Child participants were tested individually in a room with fluorescent lighting and some ambient light. To ensure the child was looking at the screen before the start of each trial, participants fixated on a small crosshair. Participants were instructed to read the passages aloud. "I'd like you to read some passages for me. Some of them are very short and some are longer. You will read them on three different things: paper, tablet and laptop. Please try to understand what you read and read the passages aloud. If you come to a hard word, try to sound it out. After you have read the passage, I will either flip over the paper or on the screen the passage will disappear. After each passage, I will ask you a question about what you have read. So please read carefully". Participants were not given time to re-read after completing the passage. Participants were given the opportunity to have a break after the 6 passages (3 easy and 3 hard) between the changes of devices and paper. If required, the participant could take a break in between any passage.

Participants read a total of 18 short passages of text out load from the different types of media whilst being timed and scored for errors. After reading each passage children were asked one comprehension question. Therefore, after reading all passages, reading comprehension was scored as out of 18. Reading comprehension questions were all designed to be literal interpretations rather than inferential thus did not draw on any background knowledge.

Results and discussion

All data was assessed to see if parametric assumptions were met. The majority of measures met parametric assumptions. However, Shapiro-Wilk’s test of normality suggested data was not normally distributed. For example, reading scores slightly skewed towards the top of the distribution. However, the robustness of ANOVAs allows the present analyses to be conducted (Schminder et al., 2010). A Greenhouse-Geisser correction was applied to results that violated Mauchly’s Test of Sphericity. One-way repeated measure ANOVAs were conducted on the independent variable type of media (paper, tablet, laptop) and the dependent variables were reading time and comprehension scores, followed by analyses of the number and types of errors. The types of errors included were refusal, reversal, mispronunciation, substitution, addition, and omission.

There was a significant difference in reading time across the different devices $F(2, 52) = 3.346$, $p = .040$, $\eta_p^2 = .116$. Overall, participants spent longest reading on paper with a mean of 22.55s (SD:1.72s) followed by tablet with a mean of 21.14 (SD:1.19s) and laptop with a mean of 20.29s (SD:1.28s). Post-hoc tests using Bonferroni corrections (resulting in a new criterion level of 0.05/3 = .0166), showed no significant differences between tablet and laptop conditions $t(26) = -1.483$, $p = .150$, or between tablet and paper conditions $t(26) = -1.180$, $p = .249$, but the difference between paper and laptop conditions was significant $t(26) = -2.64$, $p = .014$. Participants spent significantly longer reading from paper than from the laptop.

A repeated measure ANOVA showed that there was no difference in comprehension scores across the different devices $F(2, 52) = .559$, $p = .575$, $\eta_p^2 = .021$, see Table 25 Mean comprehension scores across different media.

Table 25 Mean comprehension scores across different media

Type of Media	Mean comprehension score	Standard deviation
Paper	5.22	.16
Tablet	5.22	.15
Laptop	5.41	.18

Analyses of error types showed no participant made refusal or reversal type errors, and therefore no further analyses were conducted on these error types. The most common type of error was substitution, followed by mispronunciation, omission and lastly addition. A repeated measures ANOVA showed that there was no significant difference in the number of errors made whilst reading across all three media, $F(2, 52) = .516$, $p = .600$, $\eta_p^2 = .019$. As can be seen from Table 26 Mean number of errors across different media, the mean number of errors on paper and laptop was 4.70 with standard deviations of 4.83 and 4.61 and the mean number of errors on the tablet was higher but not significantly at 5.44 (SD: 6.15). Looking at the error types separately four repeated measures ANOVAs were conducted. Results showed there was no significant difference in the number of for all types of errors made whilst reading across all three media, substitution: $F(2, 52) = .732$, $p = .486$, $\eta_p^2 =.027$, mispronunciation: $F(2, 52) = .194$, $p = .824$, $\eta_p^2 =.007$, omission: $F(2, 52) = .429$, $p = .653$, $\eta_p^2 =.016$ and addition $F(2, 52) = 1.170$, $p = .318$, $\eta_p^2 =.043$.

Table 26 Mean number of errors across different media

Type of error	**Device**	**Mean number of errors**	**Standard deviation**
Substitution	Paper	1.63	1.84
	Tablet	1.81	1.90
	Laptop	1.85	1.46
Mispronunciation	Paper	1.56	2.12
	Tablet	1.41	1.50
	Laptop	1.33	2.22
Omission	Paper	1.41	2.19
	Tablet	1.67	3.93
	Laptop	1.07	1.36
Addition	Paper	0.89	1.09
	Tablet	0.70	0.99
	Laptop	0.93	1.04
Total	Paper	4.70	4.83
	Tablet	5.44	6.15
	Laptop	4.70	4.61

To summarise, results showed that as expected participants spent longer reading the text on paper compared to reading on digital devices. Specifically, participants read fastest on the computer and slowest on paper. However, it is useful to note that this did not affect their reading comprehension score, nor did it affect the number or nature of errors they made. In total and between different types of errors participant did not differ depending on media type. These finding suggest that the increase in speed during digital device reading does not compromise accuracy nor does it compromise comprehension.

Experiment 3b: What are the differences in printing compared to digital reading when taking digital technology exposure into account?

This study differed from Experiment 3a as following task validation, the design was simplified. The laptop condition was removed. This was because of the lack of laptop use in children in the present study (as shown in the results of Chapter 3: What are the effects of digital text exposure on young children?), who were of a narrower age range of six to seven years old. Additionally, tablets are considered easier to use for younger children and are used more frequently than laptops (Geist, 2014). The present study explored the differences in reading related skills and behaviours, including reading time, reading comprehension and the number and nature of reading errors made whilst reading aloud, across paper and tablet condition. Unlike Experiment 3a, this study focused on the differences across devices as well as taking into account participants' prior experience with digital technology. Level of exposure to digital technology was added as an independent variable.

Hypotheses

The present study explores whether the type of media influences reading time, comprehension and the number and nature of errors. It was hypothesised that reading time will be significantly longer in the paper condition compared to the tablet condition. There will be no significant difference in comprehension score in the tablet condition compared to the paper condition. There will be no significant difference in reading accuracy in the tablet condition compared to the paper condition. There will be an interaction of media and exposure level for reading time. There will be an interaction of media and exposure level for comprehension score. There will be an interaction of media and exposure level for reading accuracy.

Methods

Participants

Fifty-three children between the ages of six to seven years old with a mean age of seven years old and an SD of six months participated in the present study (see Chapter 2: Phase 4 data collection for further details about these participants). 61% of participants were female. All participants spoke English and 8% of these participants spoke an additional language. Data from one participant was removed due to significant outliers.

Materials

Stimuli were presented on paper and on a tablet. Text was left-justified using the same font in the colour black to ensure the formatting remained equal across both conditions. The number of letters on a line for the same stimuli across the different conditions remained equal. With permission from the publisher stimuli were formed from passages of text from the Rising Stars Planet, a UK based reading scheme. These passages were the same 18 passages used in Experiment 3a.

Design

A mixed design with two independent variables (type of media and level of difficulty) was conducted. Stimuli were presented on paper and on a tablet. The two levels of difficulty were easy and difficult, which are defined below. Dependent variables were reading time, reading accuracy (and nature of errors) and reading comprehension.

Procedure

Parents/guardians completed the Digital Technology Use questionnaire and the Parental Perceptions of Digital Technology questionnaire.

Child participants were tested individually in a room with fluorescent lighting and some ambient light. To ensure the child was looking at the screen before the start of each trial, when reading from the tablet participants fixated on a small crosshair. Participants were instructed to read the passages aloud. "I'd like you to read some passages for me. Some of them are very short and some are longer. You will read them from paper and this tablet. Please try to understand what you read and read the passages aloud. If you come to a hard word, try to sound it out. After you have read the passage, I will either flip over the paper or on the screen the passage will disappear. After each passage, I will ask you a question about what you have read. So please read carefully". Participants were not given time to re-read after completing the passage. Participants were given the opportunity to have a break whilst changing their reading medium. If required, the participant could take a break in between any passage. Additionally, counterbalancing was used in the presenting media. The paper and tablet conditions were presented in an alternating order across participants (e.g., if the first participant read from the paper and then the tablet, the second participant read from the tablet then the paper and so on.

In Experiment 3b, the within-subjects independent variable of type of media was reduced to two levels: paper and tablet. The dependent variables were reading time, comprehension scores and reading accuracy which refers to the number of refusal errors, the number of errors reversal, the number of errors mispronunciation, the number of errors substitution, the number of errors addition, and the number of errors omission and the number of total errors. An additional independent variable was a between-subjects factor of digital exposure with two levels: high and low, based on results on the questionnaire in Chapter 3. This study involved reading a total of 16 short passages of text out loud from paper and from a tablet. As in Experiment 3a after each passage the participant answered a comprehension question (see Chapter 2: Experiment 3b for full description of methodology).

Results and discussion

Mixed ANOVAs were conducted with the within-subjects variable type of media (paper and tablet) and the between-subjects variable exposure group (high and low). The dependent variables were reading time, comprehension scores and the number of errors. Analyses of types of errors were also included. The types of errors analysed were refusal, reversal, mispronunciation, substitution, addition, and omission.

Table 27 Mean number of errors by type of error and type of device

Type of error	**Device**	**Mean number of errors**	**Standard deviation**
Substitution	Paper	5.70	0.78
	Tablet	4.63	0.58
Mispronunciation	Paper	10.92	1.13
	Tablet	13.44	1.18
Omission	Paper	2.62	0.36
	Tablet	2.50	0.28
Addition	Paper	0.73	0.12
	Tablet	0.96	0.16
Total	Paper	20.19	1.98
	Tablet	21.25	1.82

All data was assessed to see if parametric assumptions were met. As mentioned previously data from one participant was removed due to significant outliers. The majority of measures met parametric assumptions. However, Shapiro-Wilk's test of normality suggested data was not normally distributed. For example, reading scores slightly skewed towards the top of the distribution. However, the robustness of ANOVAs allows the present analyses to be conducted (Schminder et al., 2010). Levene's Test of Equality of Error Variances showed that the assumption of homogeneity of variance was met. A Greenhouse-Geisser correction was applied to results that violated Mauchly's Test of Sphericity. A mixed ANOVA revealed a significant interaction between media type and exposure for reading time was significant $F(1, 50) = 4.490$, $p = .039$, $\eta_p^2 =.082$. The main effect of reading time between media was not significant, $F(1, 50) = 1.639$, $p = .206$, $\eta_p^2 =.0032$. Paper reading time was lower, but not significantly with a mean of 43.16s (SD: 5.07s) compared to tablet reading time with a mean of 46.28s (SD: 4.96s). The interaction was significant Figure 13 Reading time by level of exposure and media type with error bars, shows participants in the low exposure group tending to read faster than those in the high exposure group. The main effects of exposure group on reading times, showed no significant differences in reading time between the high exposure and low exposure group, $F(1,50) = 1.478$, $p =.230$, $\eta_p^2 =.029$. Interestingly, in the high exposure group tablet reading time was longer than paper reading time, but not significantly. The mean for the high exposure group was 48.81 seconds (SD: 5.35 seconds), compared to the quicker time for the low exposure group which had a mean of 40.62 seconds (SD: 4.70 seconds).

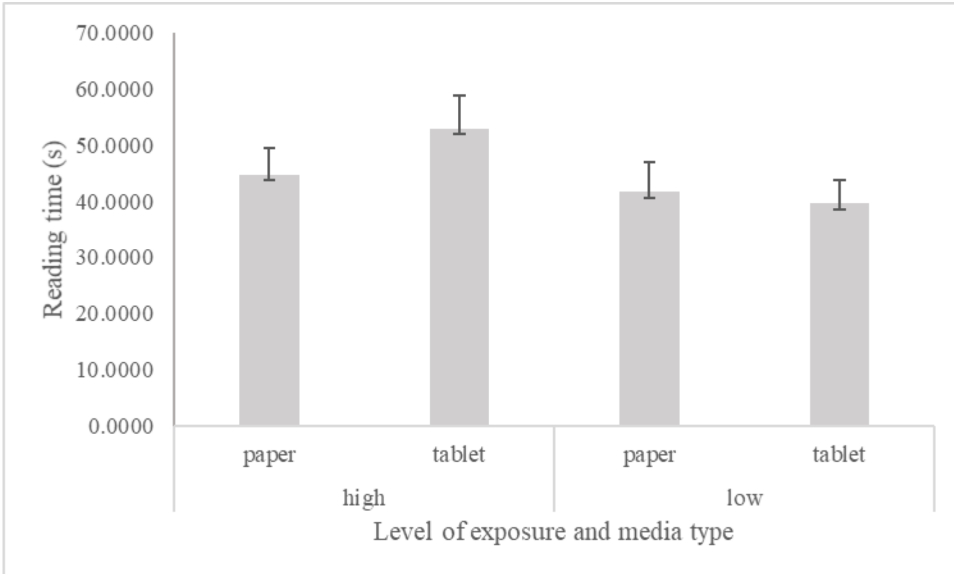

Figure 13 Reading time by level of exposure and media type with error bars

A repeated measure ANOVA showed that there was no significant interaction between the type of device and exposure for comprehension scores, $F(1, 50) = 2.034$, $p = .160$, $\eta_p^2 = .039$. There was no main effect of device type for comprehension scores $F(1, 50) = 2.034$, $p = .160$, $\eta_p^2 = .039$. For paper the mean comprehension score was 6.15 (SD: 0.24) and similarly the mean comprehension score on the tablet was 6.44 (SD: 0.26). Although not significantly different, it appears from Figure 14 Comprehension score by level of exposure and media type with error bars, that the low exposure group had higher comprehension scores. The main effect of exposure group on reading comprehension scores, showed no significant differences in reading comprehension scores between the high exposure and low exposure group, $F(1, 50) = 1.1.183$, $p = .282$, $\eta_p^2 = .023$. The high exposure group had a mean reading comprehension score of 6.13 (SD: 0.238). Similarly, the low exposure group had a mean reading comprehension score of 6.46 (SD: 0.273).

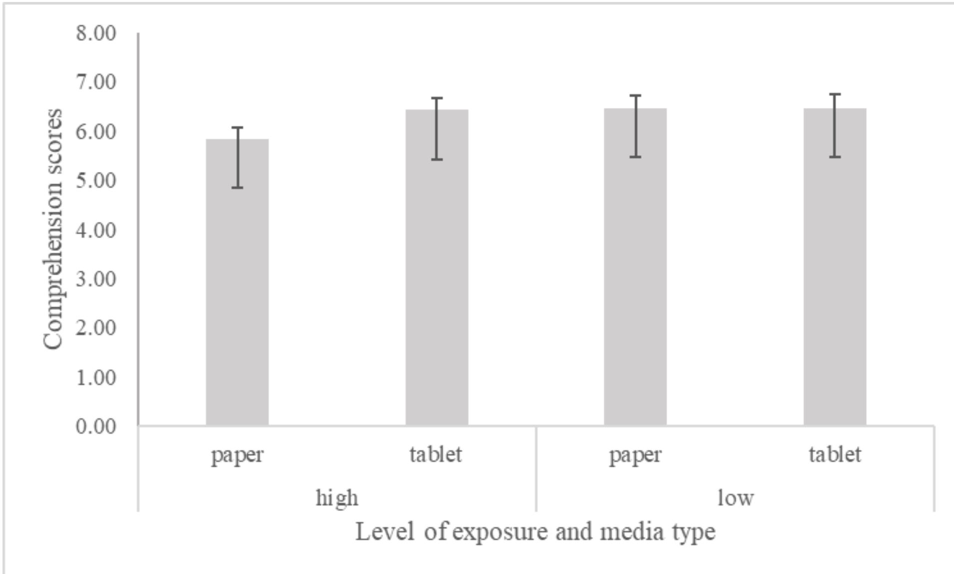

Figure 14 Comprehension score by level of exposure and media type with error bars

Analyses of error types showed no participant made refusal or reversal type errors and so these error types were not analysed further. Across all devices, mispronunciation was the most common type of error followed respectively by substitution, omission and addition. A repeated measures ANOVA showed that there was no significant interaction between device type and exposure level for the number or errors made, $F(1, 50) = 0.513$, $p = .477$, $\eta_p^2 =.010$. There was no main effect of device type for the number or errors made, $F(1, 51) = 0.417$, $p = .521$, $\eta_p^2 =.008$. As can be seen from Table 27 Mean number of errors by type of error and type of device, the mean number of errors on paper was 20.19 (SD: 2.64) compared to the not significantly different mean for tablet which was 21.25 (SD: 2.57). Interestingly, although not significant it appears from Figure 15 Mean number of errors by level of exposure and media type fewer errors were made on paper compared to the tablet and few errors were made by the high exposure group. Furthermore, the main effect of exposure group on the total number or reading errors was analysed. Analysis showed no significant differences in the total number or reading errors between the high exposure and low exposure group, $F(1,50) = 1.948$, $p = .169$, $\eta_p^2 = .037$. The mean number or reading errors made by the high exposure group was 19.46 (SD: 2.49). The mean number or reading errors made by the low exposure group was 23.04 (SD: 2.65). It is interesting to note that fewer reading errors were made when passages were read slowly. Thus, the high exposure group took longer to read and made fewer reading errors compared to the low exposure group, but as discussed above these findings were not significant.

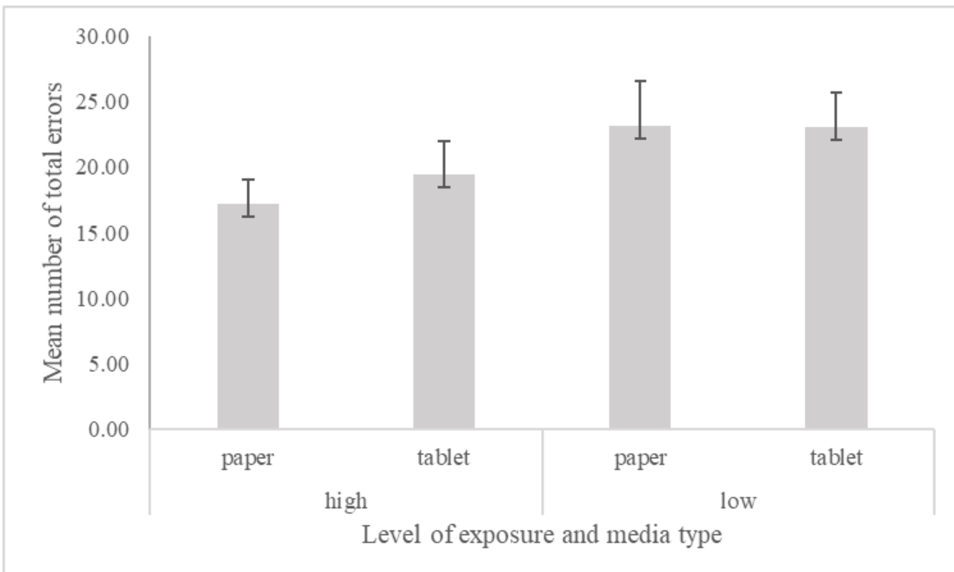

Figure 15 Mean number of errors by level of exposure and media type

Looking at the error types separately four repeated measures ANOVAs were conducted. Results showed there was no main effect on substitution errors across device type, $F(1, 50) = 2.068$, $p = .157$, $\eta_p^2 = .040$. Analysis showed no significant differences in the number substitution errors between the high exposure and low exposure group, $F(1,50) = 1.604$, $p = .211$, $\eta_p^2 = .031$.There was no interaction across device type and exposure group on substitution errors, $F(1, 50) = 0.302$, $p = .585$, $\eta_p^2 = .006$. Results showed there was a main effect of mispronunciation errors across device type, $F(1, 50) = 5.975$, $p = .018$, $\eta_p^2 = .107$. Fewer mispronunciation errors were made on paper compared to on the tablet with mean of 10.92 (SD: 8.16) and 13.44 (SD: 8.50), respectively. There was no interaction across device type and exposure group on mispronunciation errors, $F(1, 50) = 0.530$, $p = .470$, $\eta_p^2 = .010$. Analysis showed no significant differences in the number mispronunciation errors between the high exposure and low exposure group, $F(1,50) = 2.413$ $p = .127$, $\eta_p^2 = .046$. Results showed there was no main effect on omission errors across device type, $F(1, 50) = .093$, $p = .762$, $\eta_p^2 = .002$. There was no interaction across device type and exposure group on omission errors, $F(1, 50) = 0.093$, $p = .481$, $\eta_p^2 = .010$. Analysis showed no significant differences in the number omission errors between the high exposure and low exposure group, $F(1,50) = 0.226$ $p = .637$, $\eta_p^2 = .005$. Results showed there was no main effect on addition errors across device type, $F(1, 50) = 1.800$, $p = .186$, $\eta_p^2 = .035$. There was no interaction across device type and exposure group on addition errors, $F(1, 50) = 0.200$, $p = .657$, $\eta_p^2 = .004$. Analysis showed no significant differences in the number mispronunciation errors between the high exposure and low exposure group, $F(1,50) = 0.000$, $p = 1.000$, $\eta_p^2 = .000$. See **Error! Reference source not found.** for mean number of types of errors across devices.

To summarise, there were no significant interactions between the type of device and level of exposure for any dependent variables, except for a significant interaction between media type and exposure for reading time was significant however, not in comprehension or error types. There was no significant difference in reading time between paper and tablet reading. Additionally, there was no difference in reading comprehension score between the devices. Generally, there was no difference for the number of errors made including substitution, mispronunciation, omission, addition and total number or errors made. However, there was a significant difference in the number of mispronunciation errors made across media, with fewer mispronunciation errors made during paper reading compared to tablet reading. This effect was not mediated by exposure.

General discussion

Performance measures reading time, the number or errors and the types of errors were selected as dependent variables for the present study, because reading time and ease of word identification are thought to be the most important aspects of skilled reading (Share, 2008). Reading comprehension was used as an dependent variable as it is an important skill developed from childhood which allow an individual the ability to function effectively in today's society (McNamara & Magliano, 2009).

Results from Phase 3 showed to some extent supported the hypothesis (H1) as a repeated measure ANOVA found a significant difference between devices. Reading time was longest for paper, followed by tablet and the computer. This supports previous findings that showed difference in reading times across different media. However, on further analysis there was no significant difference between tablet and laptop conditions, tablet and paper conditions and paper and laptop. Across the three media no significant differences were found for reading comprehension. Thus, the hypothesis (H2) was not supported. Additionally, there were no differences in the total number or errors and the individual types of errors across the different media. Thus, the hypothesis (H3) was not supported. These results differed from other studies which found effects of media on reading time and reading comprehension (Lenhard et al., 2017). The present study only used narrative texts and supports findings from Clinton (2019) and Delgado et al., (2018) who found no effects of media on reading performance on narrative text.

A second study was conducted in Phase 4 to have a larger sample and a narrower age gap. The use of a narrower age gap is important to reduce potential individual difference cause by age. For example, throughout primary school vocabulary, word decoding ability and reading comprehension all significantly improve, thus the reading ability of a six year old substantially varies from an 11 year old (Verhoeven et al., 2011). Additionally, the computer condition was dropped as results from Chapter 3 and other studies show that children between the ages of six to seven years old are more likely to use tablets compared to computer. Thus, this is a more appropriate comparison. Furthermore, between each media type in Phase 3 no significant differences were found thus, the present study added a new variable which was level of exposure. This was to see if high and low levels of exposure effected reading performance across device. As in Phase 3 these results differed from other studies which found effects of media on reading time and reading comprehension (Lenhard et al., 2017). As in Phase 3, the present study only used narrative texts and supports findings from Clinton (2019) and Delgado et al., (2018) who found no effects of media on reading performance on narrative text.

In Phase 4, the hypothesis (H1) was not supported as there was no significant difference in reading time across media. Hypotheses (H2 and H3) were supported as there were no significant differences in reading comprehension nor reading accuracy measure across print and tablet media. Except for mispronunciation errors which occurred significantly more on the tablet compared to the paper condition. Hypotheses (H4, H5 and H6) were not supported as there were no interactions between media type and exposure level for reading time, reading comprehension score nor reading accuracy measures.

Strengths and Limitations

A strength of the present study was the sameness across all devices. Text was present on each device equally, with the same passages being presented on each media at the same size, font size, colour and words per line. This was to control confounding variables and ensure equivalence across device, which Noyes & Garland (2008) previously stressed the importance of. The only difference was the use of a light grey background for digital presentation to avoid screen glare and minimize eye strain (Breadmore & Carroll, 2018). Another strength of the study was the use of a real National reading scheme called the Rising Stars Reading Scheme as this allowed Key Stage appropriate content that could be matched across readability scales, line and word length (Rising Stars REF). This ensured ecological validity as, the reading task was similar to what children partake in at school. Additionally, during the time of testing the reading scheme had not been released therefore, there was no chance that participants had read the text prior to participation.

A limitation is the use of only narrative test as previous meta-analyses found effects of media more on expository texts compared to narrative texts (Clinton, 2019; Delgado et al., 2018). Therefore, future research should look at the effects of media type on reading performance of expository text in young children.

Due to the lack of significant effects of reading across devices future research should compare paper reading to computer reading as this was near significance is Phase 2 and although children do not frequently use computer, as they get older computer use will increase.

Chapter 6: What are the effects of digital technology on standardized measures of vocabulary, word reading and attention?

Having explored the effects of digital technology on young children's attention and reading in previous chapters through "novel tasks". The present chapter used standardised measures to explore the effects of digital media on vocabulary, word reading and three types of attention: selective attention, sustained attention and everyday attention. This was done to ensure measures of vocabulary, word reading and attention were valid and reliable. Furthermore, using standardised measures, allowed for scores to be compared to the normative population scores.

The acquisition of reading skills is important as it enables the development and provides the foundations of successful learning (Stanovich, 2000). This in turn is vital for engagement in everyday life through interaction with one's environment and the people in it, which provides the opportunity for a successful education and career prospects (Çakıroğlu, 2018). The present study explores the effects of digital media on vocabulary, word reading and attention – component skills for learning to read.

Vocabulary

Sufficient reading comprehension cannot occur without vocabulary, which provides the understanding of individual words (Nation & Snowling, 1998; Wagner & Meros, 2010). Vocabulary has been found to strongly correlate with the development of reading comprehension (J. B. Carroll, 1993; de Jong & van der Leij, 2002; McKeown et al., 1983; Wagner et al., 1997). Therefore, it seems important to consider whether and how digital technology may impact on vocabulary learning.

Knowing that vocabulary affects reading comprehension and reading comprehension can affect successful education, it is of utmost importance to investigate the effects that digital technology use has on children's vocabulary knowledge (Takacs et al., 2015). To this end, a large number of studies have explored the effects of using digital technology directly to support vocabulary learning and, in turn, reading comprehension. A meta-analysis of 43 studies with a total of 2147 participants published between 1980 and 2014 reviewed the effects of traditional print stories and digitally enhanced stories on young children's reading development (Takacs et al., 2015). Results show a small but significant positive effect of digital technology reading on expressive vocabulary and reading comprehension (Takacs et al., 2015). However, there was no effect on receptive vocabulary measures (Takacs et al., 2015). The digitally enhanced story features, including animated images, sound effects and music were found to have a positive effect (Takacs et al., 2015). However, certain features including games, dictionaries and hotspots caused distraction and appeared to reduce/limit vocabulary learning rather than enhance it (Takacs et al., 2015). Overall, these findings suggest that digital technology can have a positive effect on reading performance through the development of expressive vocabulary, especially if distracting features are avoided. Support for digital technology use comes from Shamir & Shlafer (2011), who conducted a study on the effectiveness of e-books used on reading related skills. One-hundred and thirty-six children aged between five and seven years old (60 of whom were typically developing and 75 with learning disabilities) were randomly assigned to the e-book condition or a control group (Shamir & Shlafer, 2011). Results showed significant positive effects of e-book use on phonological awareness and the concept of print. This was found for both the typically developing children and the children with learning disabilities, in the e-book condition. These results provide evidence to support the use of e-book interventions.

Smeets & Bus, (2012) conducted a study to examine the effect of word reading through e-book reading alone compared to reading an e-book with vocabulary instructions embedded. Use of multiple-choice vocabulary questions increased both receptive and expressive vocabulary. Additionally, a second study found that when using e-books, multiple choice vocabulary questions were found to be more effective in increasing the learning of novel words compared to a hotspot feature, which enabled participants to click a section of the page and receive a definition (Smeets & Bus, 2012). This suggests that not only are there differences between print and digital reading (as found in previously discussed studies) but within digital reading various digital features may affect the relationship between vocabulary and reading performance. It is important for future research to piece apart and examine the effects of these features of digital technology on reading related skills including vocabulary knowledge.

In addition to research exploring the effects of e-books on vocabulary, the effectiveness of other types of digital media have also been explored. Aghlara & Tamjid (2011) explored the effects of a digital computer game on vocabulary in English language acquisition. Forty, six to seven year old females who have no prior English knowledge, were divided into two groups of 20 participants. One of which were part of the control condition who was taught English traditionally and the other who were part of the computer condition who were taught English via a computer game. Over six and a half weeks they took part in three 90-minute-long sessions per week. Results showed that vocabulary improved significantly in the computer condition. Aghlara & Tamjid (2011) explain these findings as a result of better motivation due to the computer games being more enjoyable compared to traditional learning which reduced stress associated with learning and in turn increased children's vocabulary. However, motivation levels of participants were not measured, therefore these explanations are conjecture. Despite this, these findings suggests that a digital intervention can have a positive impact on learning vocabulary.

An external feature of digital technology that has been considered is the screen size of a digital device. Kim & Kim (2012) examined 135 Korean middle school children learning English as an additional language, who were presented stimuli across three different screen sizes: large, medium and small. Results found an effect of screen size with large screen devices resulting in improvement in English vocabulary compared to small screen in both post-test and retention test scores (Kim & Kim, 2012). An explanation of this could be that individuals pay more attention to information on larger screens regardless of the content (Reeves et al., 1999). Again, this suggests features of digital devices can affect vocabulary learning. This is important to note for research and practical purposes, including educational apps aimed at young children's literacy learning.

The inconsistency in findings regarding the effects of digital technology on vocabulary and reading comprehension prompted Furenes et al., (2021) to conduct a meta-analysis of 39 studies with a total of 1812 participants published from 2002 to 2019. Both the effect of media and subsequent moderators through digital enhancements including digital dictionaries and story-related enhancements were reviewed (Furenes et al., 2021). When the text in print and digital media is presented equivalently, vocabulary scores are better during the paper condition compared to the digital condition (Furenes et al., 2021). Even when minor digital enhancements (specifically voiceovers and highlighted text) were added digital stories, paper surpassed digital (Furenes et al., 2021). However, these screen inferiority effects can be reduced or removed by different additional digital enhancement and the presence of adult mediation (Furenes et al., 2021). This occurs when digital enhancements specifically focus on the content of a story for example providing background information, resulting in improved reading comprehension on digital devices (Furenes et al., 2021). Unlike Delgado et al., (2018) for vocabulary, screen inferiority was not evident for expository texts compared to narrative text (Furenes et al., 2021). However, as suggested by Takacs et al., (2015) a digital dictionary use had a harmful effect on reading comprehension, due to a lack of focus on the story content (Furenes et al., 2021). This suggests that the way in which technology is used can facilitate vocabulary learning.

The majority of research discussed in this chapter up until now would suggest that, overall, digital technology is beneficial in improving vocabulary learning. However, while many have considered the effectiveness of digital technology within the context of intervention, others have considered the potential impact of exposure to digital technology in the longer term. Pfost et al., (2013) highlight the potential negatives of digital technology exposure. Data from a longitudinal study by Bildungsprozesse, Kompetenzentwicklung und Formation von Selektionsentscheidungen im Vor-/Schulalter (BiKS research group) explored, to examine the effects of extracurricular reading activities in reading development through measures of vocabulary and reading comprehension (Pfost et al., 2013). Results from the 1226 children in grades five and seven in Germany from 2006 until 2010 substantiated the importance of print reading for positive development of both vocabulary and reading comprehension, even when reading achievement was accounted for. Thus, improvements in vocabulary and reading comprehension continued to grow in grade seven through book reading, regardless of whether or not vocabulary and reading comprehension was good in grade five. Contrastingly, digital technology related activities including email usage, web forum use and online chatting related negatively to vocabulary and reading comprehension. This suggests that exposure to digital technology can potentially have harmful effect on reading ability.

Word reading

There are many precursor skills to successful reading, having covered vocabulary above this section focused on word reading as a precursor to reading ability.

In addition to measuring vocabulary, Mangen et al., (2013) measured word reading and reading comprehension. Participants were 72 Norwegian children aged between 16 and 17 years old (43% female) (Mangen et al., 2013). Interestingly, a word-chain test was used which consisted of four semantically unrelated words (Mangen et al., 2013). Four words are combined into a word can and participants were told to divide the letters into their constituent words. There was no difference in word reading accuracy between the paper reading condition and the digital reading condition. Nor was there a difference between vocabulary scores between the two conditions (Mangen et al., 2013). However, when controlling for variance in their model, word reading and vocabulary were found to be predictors of reading comprehension (Mangen et al., 2013). Reading medium was significant, resulting in participants who read digital text compared to paper text to have lower comprehension scores (Mangen et al., 2013). Furthermore, participants who read digital text had lower comprehension scores compared to those reading paper text (Mangen et al., 2013). Mangen et al., (2013) drew attention to the idea that text cannot simply be transferred from paper to a digital format without consequences e.g., scrolling inhibits the use of spatiotemporal markers thus hindering reading performance. Research has shown the importance of having a good spatial mental representation of the layout and formatting, physically of text, in supporting good reading comprehension (Baccino & Pynte, 1994; Cataldo & Oakhill, 2000; Piolat et al., 1997). However, this cannot necessarily be achieved when using digital device which require scrolling, as the text moves up and down the page, subsequently not allowing a specific spatial mental representation. Overall, Mangen et al., (2013) suggests use of digital technology to have no effect on word reading, but to have a negative effect on reading comprehension.

Similarly, the effect of reading medium on word reading and reading comprehension was examined (Halamish & Elbaz, 2020). Thirty-eight children from a primary school in Israel (mean age: 10.95 years old, 22 females) completed a single word reading test and a reading comprehension task (Halamish & Elbaz, 2020). There was no difference between the paper and digital condition for both reading time and reading comprehension, thus there was no effect of medium on reading skills.

Attention

As discussed in Chapter 4, there are concerns regarding the effects of digital technology on young children's attention. One concern is the promotion of multitasking through digital technology use, which has been found to have negative effects on educational performance (Aagaard, 2015b). This is due to dividing of attention which results in attentional demands exceeding the available capacity thus, resulting in reduced performance of a task (Gopher, 1993).

There have been concerns about the effects off high amounts of screen time on sustained attention – for example, infants and children may be distracted from other activities and forms of play when the television is on in the background (Courage, 2017). With 56% of mothers reporting having the television on in the background throughout the day (Masur & Flynn, 2008), this suggests that many infants are exposed to digital technology in a way that could affect their sustained attention. This is important to explore and understand, particularly as sustained attention (which refers to the ability to keep ones attention for an extended period of time), plays an important role in academic performance through the ability to concentrate over long periods of time and understand and combine a lot of information (Betts et al., 2006; Catroppa et al., 1999).

Very recently, the first study to specifically examine the effects of type of reading medium on readers attention was conducted on 140 undergraduate students from Spain with a mean age of 20.46 years (Delgado & Salmerón, 2021). Results showed that reading via screen results in inattentive reading, thus attention is not sustained (Delgado & Salmerón, 2021). In attentive reading occurred especially, when task demands increased in terms of attention required to perform efficiently (Delgado & Salmerón, 2021). These findings support concerns discussed in Chapter 4 that suggests digital technology under certain circumstances reduces reading performance (Wolf, 2018).

Looking at the effects of medium on sustained attention among 40 adolescents (aged between 15 to 18 years old) (Stern & Shalev, 2013). Twenty participants had ADHD and 20 did not have ADHD (Stern & Shalev, 2013). Results showed as sustained attention decreased, reading comprehension scores decreased (Stern & Shalev, 2013). Between the paper and computer condition there was no overall difference in comprehension scores (Stern & Shalev, 2013). Between the standard text and spaced text conditions, there was no difference in comprehension scores (Stern & Shalev, 2013). However, it is interesting to note that the interaction between levels of sustained attention, type of media and the spacing of text was significant (Stern & Shalev, 2013). Individuals with good levels of sustained attention, performed best in the computer screen condition with standard spacing of text (Stern & Shalev, 2013). However, individuals with poor levels of sustained attention performed best in the computer screen condition with text having extra spacing (Stern & Shalev, 2013).

Although many studies find digital technology to have a negative impact on individuals' sustained attention, effects on selective attention differ (Matern et al., 2020). Eighty university students between the ages of 18 to 25 years old took part in a study in which they were grouped as either a regular video game player or a non-video game player and completed a stroop task (Matern et al., 2020). Video game players' responses on the stroop task were significantly faster than nonvideo gameplayers' (Matern et al., 2020). This shows that video game players exhibited better attentional skills.

A longitudinal study, assessed visual attention using a whole report and a partial report task, with children aged four years old who were reassessed at seven years (Prieler, 2018). No relationship was found between visual attention measures and children's exposure to digital technology.

The present study

The present study explored the impact of digital technology exposure on vocabulary, word reading and attention through the use of standardised measures. Over time, the use of standardised measures in education has increased (Holdsworth, 2016). An assessment is the procedure used to gather, record and interpret individuals' responses to a task (Lambert & Lines, 2013). Norm referenced standardised tests have demonstrable reliability and validity and enable us to consider whether the present samples are representative of the general population. A standardised measure is an assessment which has been externally created to score the evaluation of learning in a uniformly administered manner (Wang et al., 2006). Within the field of education, the impact of standardised measures has been considerable in regards to development of knowledge and policy changes (Holdsworth, 2016).

It is hypothesised that vocabulary scores will be higher in the low exposure group compared to the high exposure group. Word reading scores will be higher in the low exposure group compared to the high exposure group. Selective attention scores will be lower in the low exposure group compared to the high exposure group. Sustained attention scores will be higher in the low exposure group compared to the high exposure group.

Methods

Participants were 60 school children aged from six to seven years old with a mean age of six years and 11 months old and a standard deviation of 3 months. 62% of participants were female. The participants took part in the experiment during Phase 4 data collection (see Chapter 2: Phase 4 data collection: The relationship between digital exposure and reading print versus digital for further information about participant demographics). They were assessed on three standardised measures: the British Picture Vocabulary Scale III (BPVS III) (Dunn, et al., 1997), the Diagnostic Test of Word Reading Processes (DTWRP) (Stainthorp, 2012) and the Test of Everyday Attention for children (TEA-Ch 2) (Manly et al., 2016). Standardised measures were administered as per advised by their respective manuals. The BPVS III a receptive vocabulary measure, in which the experimenter says a word and the participant points to one of four images presented to them that they think correspond to the meaning of the word. The words increased in difficulty as the task continued. The DTWRP is a measure of cognitive process in written word recognition and word reading. The DTWRP has three sections which test non-word reading, exception word reading and regular word reading. It was individually administered in accordance with the standardised instructions with no time limit. Participants are presented with a list of words which they are instructed to read out loud. Participants started at the first word and continued to the end unless five consecutive reading errors were made. For each correctly read word participants were given one point, resulting in a score out of 30 for each section. TEA-Ch 2 is an assessment of attention, which included paper and computerised tasks that measure selective, sustained and everyday attention. See Chapter 4: Study 4: Standardised background measures for more information about task administration of these measures.

Results

The high exposure group had a lower BPVS III vocabulary score with a mean of 93.69 (SD: 11.34) compared to the low exposure group which has a mean of 99.82 (SD: 8.02), an independent t-test confirmed a significant difference between the high and low exposure groups in receptive standardised vocabulary scores $t(58) = -2.387$, $p = .020$. Children in the high exposure group had significantly lower vocabulary scores compared to the lower exposure group, as shown in Figure 16 Standardised vocabulary score by exposure level.

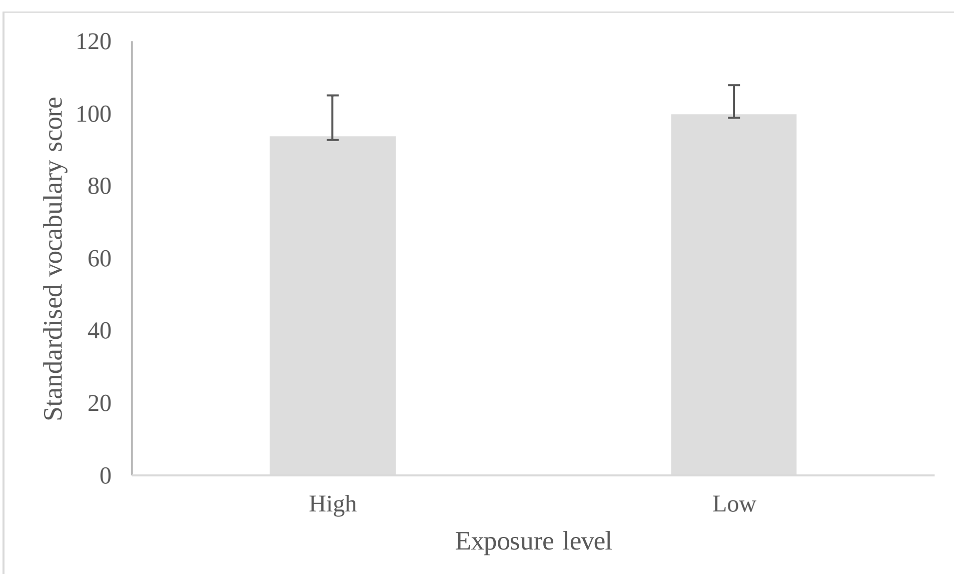

Figure 16 Standardised vocabulary score by exposure level

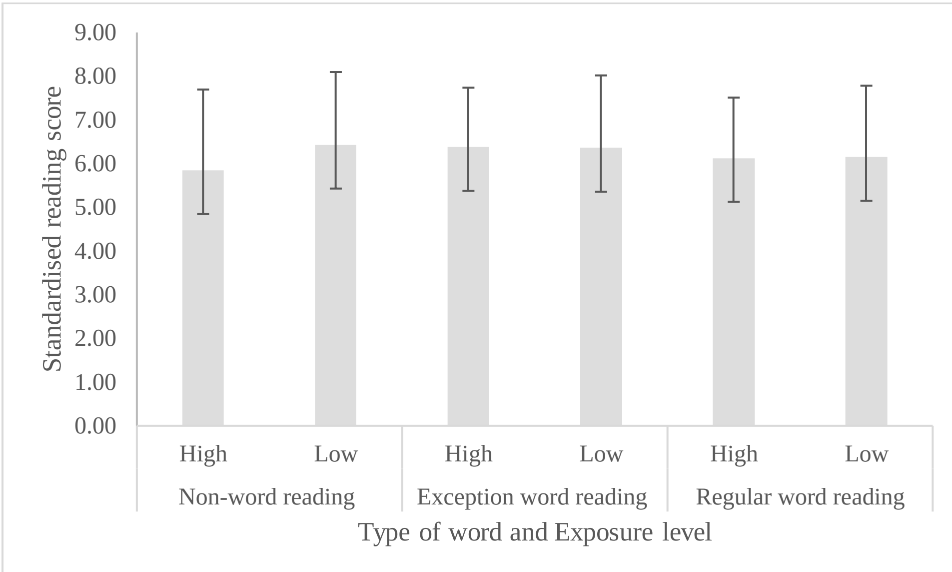

Figure 17 Standardised reading score by type of word reading and exposure level

In high and low exposure groups' means were similar across all DTWRP word reading measures, see Figure 17 Standardised reading score by type of word reading and exposure level. For non-word reading the high exposure group had a mean stanine score of 5.84 (SD: 1.85) compared to the low exposure group which had a mean stanine score of 6.43 (SD: 1.67). For exception word reading the high exposure group had a mean stanine score of 6.38 (SD: 1.36) compared to the low exposure group which had a mean stanine score of 6.36 (SD: 1.66). For regular word reading the high exposure group had a mean stanine score of 6.13 (SD: 1.39) compared to the low exposure group which had a mean stanine score of 6.15 (SD: 1.63). However, independent t-tests showed no significant differences between the high and low exposure groups for all standardised reading scores: non-word reading $t(58) = -1.279$, $p = .206$, exception word reading $t(58) = .46$, $p = .964$ and regular word reading $t(57) = -.059$, $p = .953$. All word reading stanine scores fall within the average range for this population.

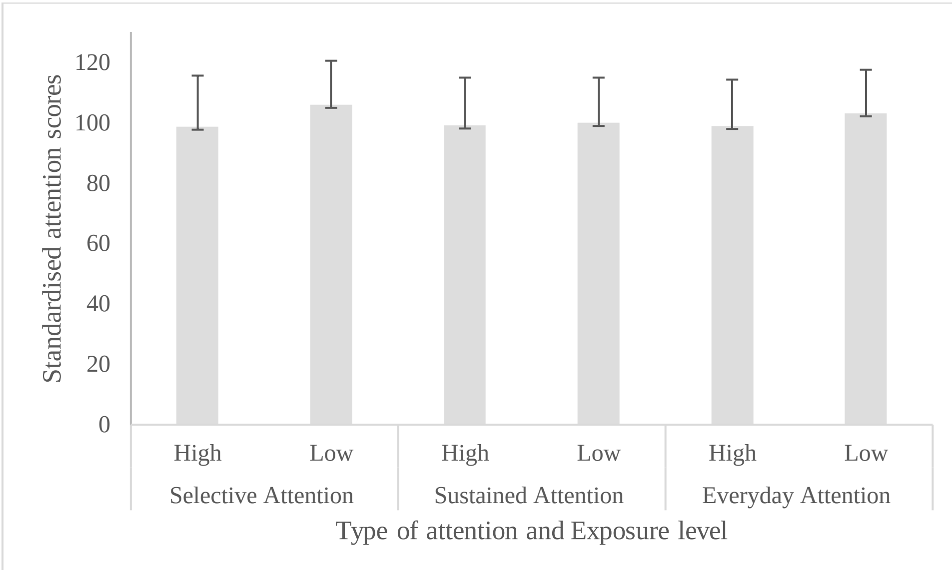

Figure 18 Standardised attention score by type of attention and exposure level

In high and low exposure groups' means were similar across all TEA-Ch 2 attention measures see Figure 18 Standardised attention score by type of attention and exposure level. For selective attention, the high exposure group had a mean of 98.65 (SD: 16.91) compared to the low exposure group which had a mean of 105.89 (SD: 14.58). For sustained attention, the high exposure group had a mean of 99.03 (SD: 15.85) compared to the low exposure group which had a mean of 99.88 (SD: 15.00). For everyday attention, the high exposure group had a mean of 98.90 (SD: 15.32) compared to the low exposure group which had a mean of 103.08 (SD: 14.42). However, independent t-tests showed no significant differences between the high and low exposure groups on any of the TEA-Ch2 measures of attention: selective attention $t(56) = -1.734$, $p = .088$, sustained attention $t(53) = -.204$, $p = .839$ and everyday attention $t(53) = -1.039$, $p = .304$.

Discussion

Standardised measures of vocabulary, word reading and attention were collected to explore difference between high and low exposure groups. It appears that exposure influences vocabulary. No difference was found between the high and low exposure groups for word reading or attention.

Children in the high exposure group had significantly lower vocabulary scores compared to the low exposure group. Although there is a significant difference between groups, it is important to note that the vocabulary standard scores for the high exposure group are still within the normal range within the relevant population. This study did not compare the direct effect of media, but instead the effect of exposure to digital media, the initial finding with the smaller group, supports the finding from Takacs et al., 2015, that medium does not affect receptive vocabulary. Nonetheless, the results are in line with Pfost et al. (2013) who found high levels of exposure to certain digital activities related negatively to vocabulary. However, these findings contrast with the predictions from studies using digital technology as an intervention to improve vocabulary, which instead found a small but significant positive effect of exposure to digital text on expressive vocabulary, as well as reading comprehension (Takacs et al., 2015). Together these findings show that the nature of the experiment can affect results, as when experiments just compare either high or low exposure group, or compare digital reading or print reading, results show a negative effect of technology. However, when an experiment that purposely used technology as an intervention, it was found to have positive effects on vocabulary. Thus, future research should take into account the content of their participants digital technology use, along with the context of their participants' digital technology use and the context of the experiment.

For word reading, there were no significant differences between the high and low exposure groups for non-word reading, exception word reading or regular word reading. This finding is similar to Halamish & Elbaz (2020) who found no difference in word reading ability between paper and digital conditions. The present study extends this by exploring the impact of longer term exposure. Additionally, the present study seperated out different types of word but, nonetheless, found no effects of digital technology exposure.

For all measures of attention: selective attention, sustained attention and everday attention, there was no significant differences in scores between the high and low exposure groups. These finding are interesting as they differ from what was expected. For example, previous research indicated that high video game exposure in adults was associated with better and quicker selective attention (Matern et al., 2020). However, the present results showed no difference between high and low digital exposure levels in children. This may be explained by the results from the questionnaire in Chapter 2, as although children in the high exposure group used video games more frequently than those in the low exposure group, this was not the sole reason for their grouping. Indeed, video game exposure in the high exposure group was low compared to tablet use and tablet viewing. This may explain why the present results differ from prior findings and might play a part in finding no differences between the groups.

Similarly, in the present study sustained attention was not significantly different between the high and low exposure groups. This finding also differs from prior research that suggest digital technology facilitates inattention (Delgado & Salmerón, 2021).

A strength of the present study is the use of standardised measures, as these tests have been shown to be valid and reliable and allow us to consider how representative the present sample are to the general population. For example, although there were significant differences in the vocabulary scores of children in the high and low exposure groups, both groups' scores fell in the normal range.

Overall, the present study found no negative effects of high exposure to digital technology on cognitive skills in this case word reading and attention. Apart, from a potential small negative effect on vocabulary. This effect on vocabulary deserves further investigation through the use of a longitudinal study. A longitudinal measurement would allow consideration of causation. From the current results, it is not known whether high exposure to digital technology exposure leads to a lower vocabulary or if a low vocabulary in some way results in individuals having higher exposure to digital technology. There is also the possibility of some third factor - such as socio-economic status, which may be responsible for the association. More detailed measures of vocabulary, including expressive measures across a wider range of children would be an interesting idea for future research. On the whole, these findings ease concerns of the detrimental effects of digital technology use on young children.

Chapter 7: General Discussion

This thesis aimed to examine the effects of young children's exposure to digital technology on reading, through visual attention and other more established predictors of reading. For this, a novel survey was conducted to understand children's use prior to starting formal school and their parents' use of digital technology in relation to print media. Additionally, information was gathered regarding parental attitudes, fears and concerns regarding their children's technology use to provide a fuller picture of their children's home environments. From this initial survey, a shorter questionnaire was developed to categorise participants into either the high exposure or low exposure groups depending on their level of exposure to digital technology. These groups were used to answer the research questions.

Research Question 1: What is the extent of digital technology use and digital text exposure in early years?

To answer this central research question, a questionnaire was developed (see Chapter 3: What are the effects of digital text exposure on young children?). This questionnaire explored both young children's and their parents' digital technology use and digital text exposure. It also examined parental attitudes to, and perceptions of, digital technology.

Research Question 2: Is there a difference in attentional ability in children with high and low levels of digital exposure?

To answer this question, a selective visual attention task was developed and deployed using an eye tracker to observe children's eye movements in both the high and low exposure group (see Chapter 2: Methodology: Study design and procedures: Study 2: Change Detection

Task for full methodology). In addition, the TEA-Ch 2, a standardised measure of attention was used to compare the high and low exposure groups.

Research Question 3: Is there a difference in reading and reading related skills in children with high and low levels of digital exposure?

To answer this question, a reading task was developed in which high and low exposure groups read passages on either paper or on a digital device. Reading time, the number and types of errors and reading comprehension scores were recorded. In addition, single-word reading was accessed between high and low exposure groups using the DTWRP which consists of three types of word reading: non-word reading, exception word reading and regular words.

This thesis found notwithstanding parents' concerns, there appears to be a lack of evidence indicating negative effects of digital technology exposure in terms of reading and attention. These findings from Chapters 3, 4, 5 and 6 will be revisited in relation to previous research, followed by a discussion of strengths and limitations. Implications and directions for future research will be considered throughout this chapter.

Summary of studies and findings

This section will be presented in three parts to provide a summary of the studies and subsequent findings. The first part considers children and their parents' use of digital technology and the parents' attitudes toward digital technology. The second part focuses on the effects of digital technology exposure on attention. The third part focuses on the effects of digital technology exposure on reading and reading related skills.

Children's and their parent's exposure to digital technology

The first study of this thesis was conducted to assess the landscape and magnitude of pre-school children's access and use of digital technology and the influences of parents' own digital technology use and their perceptions of and attitudes towards their children's digital technology use.

The transition from print media to digital technology has grown exponentially in recent times (Iivari et al., 2020; Williamson et al., 2020). Digital technology is a part of everyday life and children continue to be exposed to digital technology from a young age. Even prior to COVID-19, schools in the UK and elsewhere increased the use of computers and tablets to support education in various school curricula including literacy (Burnett, 2016; L. Green et al., 2020). The ubiquitous nature of digital technology in young children's lives provided the rationale for this thesis. The questionnaire developed in Chapter 3, provided a multitude of information from parents of young children. In the face of widespread digital technology use as mentioned above and in Chapter 1, parents reported that their children were first exposed to print media before using any forms of digital technology. The most popular forms of technology used were passive, with television remaining the most popular device used, in line with previous findings (Genc, 2014; Lauricella et al., 2015). It is, therefore, no surprise that the most popular activity involved watching a programme as this activity tends to occur using television or tablets, again supporting previous findings (Genc, 2014; Lauricella et al., 2015). Overall, the present study found parents' perceptions of digital technology were neutral. Parents recognised the potential educational benefits of digital technology; they stated that television and computer use had positive effects on children's mathematics skills and communication abilities, specifically speaking skills. Parents also believed that television viewing has a positive effect on their children's creativity. However, parents were concerned with the negative effects of digital technology, in particular the effects of gaming and smartphone use on their children's level of physical activity. Additionally, parents reported, education-related negative perceptions of digital technology in terms of digital devices poorly affecting their children's attention. These concerns give further rationale for examining the effects of digital technology use on attention, which were explored in Chapters 4 and 6.

Pre-school children's home learning environment (HLE) has been found to be a significant predictor of later measures of HLE in secondary school children, which in turn affects children's social and cognitive development including literacy attainment (Bradley, 1994; J. M. Carroll et al., 2019; Toth et al., 2020). With regards to pre-school children's HLE, the present study found that shared story-reading and television viewing to still be key components of home life. Toth et al., (2020) did not measure tablet and smartphone use in their longitudinal study, stating just a decade earlier that tablets and smartphones were not commonly used with younger age groups. However, the present study found these devices are now typically a part of a child's HLE. As mentioned in Chapter 3: What are the effects of digital text exposure on young children?, parents seemed concerned with digital technology having an effect on their children's physical activity levels. However, this appeared not to be an issue of major concern as the most popular activities that families reported to engage in are outdoor activities. This finding suggests that, in this age group, concerns of children living more inactive lives are not supported (Edwards et al., 2016).

With regard to literacy behaviours, parents tended not to read on their own, but did read with their children. Thus, shared book reading is still a part of young children's HLE. This finding is promising, as shared book reading has been found to have positive effects on children's development especially in reading comprehension and later academic success (Hoyne & Egan, 2019). However, instead of reading for pleasure by themselves, parents tended to use their smartphones more frequently, this may have a negative effect as children may be aware of their parent's preference for digital technology over print media and may model this behaviour. This modelling of parents' print reading behaviour has been shown in previous research, which additionally found daughters were more influenced by their mothers and sons by their fathers (Wollscheid, 2014). Wollscheid (2014) focused on print reading, but it would be of interest for future research to look at whether or not children model their parents' digital device use. If this is the case, perhaps future digital reading intervention studies could incorporate parents modelling reading on digital devices, including laptops, tablets and e-books.

As parents reported to use digital devices frequently themselves, their familiarity with such devices may play a part in their perceptions of digital technology, which were generally that digital technology use is not a major concern. Screen time was only limited by 58% of parents. However, a larger proportion of parents (72%) reported limiting their children's access to certain online content. This finding suggests parents are aware of the potential threats associated with online technology and choose to monitor and restrict content rather than remove the device completely.

The content analysis of survey responses revealed parents' biggest concerns to be harmful effects on attention and potential addiction to digital technology. This finding was consistent with other findings in parents with older children, where 37% were concerned with digital technology use negatively impacting attention and becoming addictive. Addiction to digital technology, in particular online gaming, has been a concern elsewhere too, to the extent that a condition called "Internet Gaming Disorder" was added to the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (Besser et al., 2019).

On the other hand, parents also described the positive effects of technology. For example, in support of previous research findings, some parents believed that digital technology can be used for fun, entertainment and promotes creative play (Marsh et al., 2018; Sullivan, 2017).

The overall finding was that children's exposure to digital technology can be explained by parents' encouragement, and this is logical. However, parents' attitudes and the extent of their rules and restrictions to children's access to digital technology did not impact their children's level of exposure to digital technology.

The COVID-19 pandemic resulted in a sudden and extensive increase in children's exposure to digital technology (Iivari et al., 2020; Williamson et al., 2020). With schools closing their doors, children and teachers have had to adapt from a traditional classroom to remote learning, this has been implemented through a variety of online tools including education websites and video call apps (Iivari et al., 2020; Williamson et al., 2020). This will have had major effects on children's level of exposure to digital technology, therefore future research should re-examine children's digital technology use, their parent's use and their parent's attitudes, concerns and rules and regulations. The present study was conducted before the pandemic, and so could be considered as a baseline reference point to consider what has changed as a result of the pandemic. The essential shift in digital technology use may have impacted a variety of factors. Through parents' and teachers' reliance on digital technology to support children's education, parents may have been introduced to new educational features of digital technology. Has this subsequently influenced change longer term within the HLE? Will newly formed digital use behaviours continue to exist? Additionally, during COVID-19 did parents encourage digital technology use outside of education purposes? With home-schooling and parents possibly working from home, parents may be more aware of possibilities, that allow them to take advantage of digital devices which can keep young children busy whilst parents work or support siblings through home-schooling and homework. Even prior to the effects of COVID-19, there have been concerns about digital technology being used as a "digital babysitter" (Steinkuehler, 2016). Thus, research on this topic is required to possibly dispel, reinforce or enhance these concerns.

Children's digital exposure and its impact on attention

Other studies in this thesis were conducted to examine the effects of young children's digital exposure on attention, specifically on selective attention.

In the present study, the TEA-Ch 2 was used to obtain standardised measures of attention, specifically: selective attention, sustained attention and everyday attention. These measures were obtained through a variety of visual and auditory tasks (see Chapter 2 for a full breakdown of methods). Results showed that there were no significant differences between the high and low exposure groups for all measures of attention (see Chapter 6: What are the effects of digital technology on standardized measures of vocabulary, word reading and attention?). Interestingly, these findings were different to those of previous research. Specifically, selective attention has been shown to be better in groups with high exposure to digital technology, however, this high exposure to digital technology was based on participants use of video games (Matern et al., 2020). Individuals with high levels of video game exposure have been found to have better and quicker selective attention compared to those with low levels of video game exposure (Matern et al., 2020). These findings may not be born out in the present study because, although there were differences in video gaming use between the high and low exposure groups, generally both groups had low exposure to video games in comparison to television viewing and tablet use. Thus, the present sample has had limited experience with video gaming and have perhaps not had enough exposure for their selective attention skills to have been influenced by this type of digital technology.

Previous research has suggested that an increase in digital technology use has led to increases in non-linear reading and a decline in sustained attention abilities (Birkerts, 2006; Liu, 2005). However, the present study found no differences in sustained attention between children in the high and low exposure groups. An explanation for the lack of difference may be the age of participants. Experience with digital technology can encourage non-linear reading which causes a decline in sustained attention. This lack of sustained attention can typically occur when using computers, especially for online activities where hyperlinks are commonly used to "jump" sections of text (Liu, 2005). As reported in Chapter 2 the children in the Phase 2 data were aged between six and seven years old, in comparison to the majority of studies that collect data from adult participants. Additionally, as reported in Chapter 3 they have limited experience in computer use in comparison to other digital devices, including television viewing and tablet use. This lack of exposure to computers and in turn hyper-link and other forms of hyper-reading may explain the lack of difference found between the high and low exposure groups.

In addition to finding no effects on selective attention between exposure groups based on their TEA-Ch2 score, data collected in Phase 2 and 4, from an eye tracking change detection task, also showed no effect on selective attention between exposure groups (see Chapter 4: Understanding the Impact of Early Exposure to Digital Technology on Children's Visual Attention).

In both Phase 2 and Phase 4 samples, there were no significant main effects of exposure for any eye movement measures obtained. Thus, suggesting that there is no difference in children's selective visual attention ability based on their level of exposure to digital technology. Previous findings have been mixed. For example, some have found that visual attention is better in video game players compared to non-video game players during change detection tasks ((K. Clark et al., 2011) cf. (Durlach et al., 2009)). However, the results of the present study are not unquestionably comparable to those studies because of differences in the nature of the samples and the nature and amount of digital exposure. In the present study, participants were aged between six to seven years old compared to 18 to 20 years olds in Clark et al's., (2011). Thus, the difference in age could mean a difference in levels of exposure. Older participants have likely had more time to be exposed to digital technology. Furthermore, the participants in Clark et al's., (2011) were exposed specifically more to video games whereas the present study took a more general approach at creating exposure groups based on the use of a variety of digital technologies including tablets, smartphones, computers, e-books, television and video games as can be seen in Chapter 3, video games were not frequently used by young children in comparison to the other digital options. Thus, the contrast between these studies might suggest that it is video games exposure specifically that affects attention, but other uses of digital technologies may relatively not influence attention. Additionally, unlike the present study Clark et al's., (2011) did not use an eye tracker, thus, there is an assumption which underlies these studies, which is that the mouse-press data is an interpretation of allocation of attention. It is, therefore, possible that the differences found were due to the measure of reaction speed of mouse-pressing rather than a measure of reaction speed of allocating attention. Clark et al., (2011) state regardless, a difference exists in video game players and non-video game players and promote the use of video gaming due to the potential benefits of visual attention. Thus, evidence regarding children’s digital technology exposure and its effects on attention is still inconclusive and further research is necessary. Data from the present thesis has added to knowledge, by, to the experimenter’s knowledge being the first to use eye tracking on a change detection task with young children. The eye movement data allowed for higher validity than requiring a response that uses the same technology that would have introduced a confound, as participants with high exposure are more familiar with a button press response mode. This was avoided by studying eye movement measures and thus the present study has greater validity.

In Phase 2 there was no significant interaction between the location of change and level of exposure for any eye movement variables. However, in Phase 4 there were interactions between the location of change and level of exposure for: count of fixations, fixations within the interest area and time taken to the first fixation in the interest area. For the count of fixations, in the high exposure group, there was not a significant difference between locations. In contrast, there were more fixations in the central condition compared to the marginal condition for the low exposure group. This shows that individuals with high exposure distribute their attention evenly across an image. For the fixation duration in the high exposure group, there was a significant difference between the central and marginal conditions with central changes much shorter than marginal changes. This means that children with high exposure to digital technology tend to spend longer when looking peripherally. However, this effect was not significant in the low exposure group.

Across both Phase 2 and 4 the only significant three-way interaction between the location of change, type of change and level of exposure was found in Phase 2 for fixation duration within the interest area. Effects were small but significant suggesting high and low exposure groups have differing methods when dealing with a change detection task, suggesting that there are differences in their attentional processes. For both high and low exposure groups, fixations in the interest area were longer for a colour change in the central condition compared to the marginal condition. However, for absence/ presence change both high and low exposure group fixations in the interest area were longer for an absence/ presence in the marginal condition compared to the central condition. Comparing the high and low exposure groups shows that in the high exposure group it takes longer to confirm the change when the change is a colour change occurring centrally compared to the low exposure group. However, in the marginal condition the opposite is true with the low exposure group it takes longer to confirm the change when the change is a colour change occurring marginally compared to the high exposure group. Comparing the high and low exposure groups again shows that in the high exposure group it takes less time to confirm the change when the change is an absence/presence change occurring centrally compared to the low exposure group. However, in the marginal condition the opposite is true again with the low exposure group it takes less time to confirm the change when the change is a colour change occurring marginally compared to the high exposure group. These findings are unexpected as, results differ from previous studies conducted by Green & Bavelier (2006a) that showed video game players demonstrated enhanced attentional resources compared with non-video game players, in both peripheral and central vision. However, for the reasons already argued above, this study is not directly comparable to studies of adult video game players.

Overall, it was found that exposure to digital technology in the early years appeared to have only a small effect on children's performance on visual attention tasks. This finding may help alleviate parents' fears regarding their children's digital technology use reported in Chapter

3. This is particularly reassuring given the recent dramatic increase in digital technology use through online homeschooling and socialising due to school closures because of COVID-19 (Williamson et al., 2020). It would be of interest for future research to break down the analysis of young children’s digital technology further. Future research should try to unpick whether specific types of digital exposure influence attention while others do not. This could be done by creating participant groups based on levels of exposure to different digital devices and a control group with low exposure to digital technology. Furthermore, separately the degree of children’s digital exposure needs to be examined to understand at what point exposure becomes an issue.

Children’s digital exposure and its impact on reading

Some of the studies in this thesis also examined the effects of young children’s digital exposure on reading related skills, including vocabulary, word reading, reading time, the number and types of reading errors and reading comprehension. It was found that children in the high exposure group had significantly lower vocabulary scores on the BPVS III compared to the lower exposure group. This result is in line with Pfost et al., 2013 who found high levels of exposure to certain digital activities were related negatively to vocabulary. These findings can be explained by the type of activities participants engage in whilst using digital technology. In Pfost et al.'s, (2013) study, participants frequently used digital technology to check their emails and browse online forums, the content and quality of texts presented during these activities will vary compared to frequently used print media, such as novels, newspapers and magazines. For example, email content tends to be more conversational and uses abbreviations (Dürscheid, 2006; Stenschke, 2006). Perhaps the repeated exposure to this type of content stifles vocabulary growth. However, when considering the content of short messaging system (SMS) text messages via mobile phones, abbreviations often referred to as "textisms" are common and these appear to have a positive impact on some literacy measures including spelling (Powell & Dixon, 2011). This finding is supported by Wood et al. (2011) who conducted an intervention study in which 114, nine to 10 year old children were randomly assigned to the intervention group which gave them access to a mobile phone only for text messaging, on weekends, over a 10 week period and a control group. It was found that text messaging has no adverse effects on the development of children's literacy skills. However, a study of secondary school children and undergraduate students found textism use to be negatively correlated with spelling, reading and nonword reading. These findings suggest frequent text messaging may be a factor in poor literacy skills. Thus, it is important to continue research regarding mobile device use.

Although directly comparable to the present study, the notion of content and quality of content affecting vocabulary is reasonable. This is because as shown in Chapter 3: What are the effects of digital text exposure on young children?, participants with high exposure to digital technology tended to engage in passive activities, including watching programmes via a television or a tablet. It has been shown that television viewing is not as effective as child-parent interaction in developing young children's vocabulary (Krcmar et al., 2007). This provides a potential explanation, for the results of the present study. Perhaps due to the high exposure groups increased viewing of television and video programmes on tablets, they spend less time interacting with their parent and therefore have lower vocabulary levels. Furthermore, research has shown that parental scaffolding is a key predictor of children's vocabulary (Blankson et al., 2015). Thus, if digital technology is being used as a digital "baby-sitter" as suggested by Livingstone et al. (2015), this would reduce children's interaction with their parent and in turn limiting their chances of experiencing parental scaffolding, thus resulting in lower vocabularies compared to children with more engaged parents. However, in this thesis, there was no evidence that children's digital exposure affected their word reading abilities either positively or negatively. There were no differences between the means scores of non-word reading, exception word reading or regular word reading between the high and low exposure group.

In addition to these findings, there were no effects found on word reading between exposure groups based on the participants DTWRP scores from data collected in Phases 3 and 4. Halamish & Elbaz (2020) compared the effect of reading medium on word reading and reading comprehension for which no difference in reading time and reading accuracy between paper and digital reading conditions was found (Halamish & Elbaz, 2020). Similarly, the study presented in Chapter 6: What are the effects of digital technology on standardized measures of vocabulary, word reading and attention? found no difference for the paper and tablet reading conditions for reading time, reading comprehension and number of reading errors. In the present study, a new variable which was the level of digital exposure was added to see if high and low levels of exposure affected reading performance across media. Results showed no difference between the low and high exposure groups. This differed from other studies which found effects of media on reading time and reading comprehension (Lenhard et al., 2017). The present study only used narrative texts and supports findings from Clinton (2019) and Delgado et al., (2018), who found no effects of media on reading performance on narrative text. However, when a computer condition was included, and reading was compared across paper, tablet and laptop conditions a significant difference was found in reading time. Reading time was longest for paper, followed by tablet and then laptop. This supports previous findings that showed a difference in reading times across different media. This finding supports the idea of the shallowing hypothesis.

However, it is only a small effect and since it is not born out in reading comprehension, it is most likely not of the utmost concern for parents and teachers.

However, on further analysis, there was no significant difference between tablet and laptop conditions and tablet and paper conditions. There was a small significant difference between the paper and laptop conditions. Overall, there were no significant differences between the paper, tablet and laptop conditions for reading comprehension. Additionally, there were no differences in the total number of errors and the individual types of errors across the different media. Again, these results differed from other studies which found effects of media on reading time and reading comprehension (Lenhard et al., 2017). Due to the difference in findings for reading time in both experiments, it would be of interest for future studies to examine young children's reading across different media using a larger sample size. In one of the present studies perhaps the fact that the age range of the sample was quite broad had an effect on the outcome of results. Effects of digital technology exposure may emerge once they are over a sustained period of time, as suggested earlier for the impact on attention. Thus, it would be of interest for future research to explore the effects of digital technology exposure over a larger age range.

Strengths and limitations

This thesis successfully built upon previous knowledge regarding digital technology use and its impact on attention and reading. Prior to this, there was a lack of research specifically looking at children's digital technology use prior to starting school. Research is a never-ending process and as more knowledge is obtained, more questions are uncovered. Research continuously builds upon prior knowledge and upon completing the present series of studies it is clear to see considerations for future research and follow-up studies and this section examines the strengths and limitations of this project in order to do so.

A key strength of the research reported here is the focus on collecting data from both young children and their parents. The explorative nature of the questionnaire used provided a wealth of information. However, a more stratified sampling approach would have allowed a larger sample of parents and insights based on parents and children from different backgrounds and contexts. The sample obtained was modest in size, but the data benefit from the inclusion of a measure of socially desirable response bias, and it was found that parents’ answers were not correlated with that tendency, which validates the responses that were received from them. Therefore, this is a successful tool that can be used in future to measure levels of exposure to digital technology in larger-scale studies that are recommended for future research. Even so, the survey design relied solely on parental self-report, future research should further explore the extent to which parental attitudes are related to direct observation of device use. Furthermore, given the impact of the recent COVID-19 pandemic, and the centrality of technology-mediated communication and education for children that has formed part of the response, there is a need to re-examine parental attitudes and concerns. This necessary shift in children’s technology use is likely to have also impacted parental attitudes and practices. Its impact on oral language skills and interpersonal communication within specific subgroups is likely to be of significance and needs particular attention, especially given the tension between increased home working and childcare needs in the homes of young children during the pandemic. Parents of school age children are likely to have relied on technology to support their child’s education more than ever before (Williamson et al., 2020). Having collected the data for this project prior to COVID-19, it would be of interest to compare it with data collected during and after the pandemic to explore changes in digital technology use and changes in attitudes.

A strength of the present thesis is the use of a novel design, which was the first to explore differences between young children, with high and low exposure to digital technology.

A novel experimental design was also employed to address the question of the impact of exposure to technology on attention, using eye tracking to measure attention in a change detection task using a flicker paradigm. The use of an eye tracker allowed for more dependent variables to be collected and therefore a more accurate measure of attention, e.g., compared to mouse-press data.

Another strength of the study is the use of natural stimuli, which improves ecological validity. Images used were taken from the Rising Stars Reading scheme which is a national reading scheme available in print and digital formats, which at the time had not been rolled out into schools. These images therefore are in the style of materials that a child would be used to using while learning to read, without having prior experience with the particular stimuli. Additionally, the text at the bottom of the image resulted in an accurate representation of a page taken from a book or e-book. Additionally, the text used in the reading on different devices study (Chapter 6: What are the effects of digital technology on standardized measures of vocabulary, word reading and attention?) was also taken from the Rising Stars Reading Scheme (Rising Stars REF). This ensured Key Stage appropriate content, which was then matched across readability scales, line and word length. This ensured ecological validity as the reading task was similar to what children partake in at school when learning to read. Additionally, during the time of testing the reading scheme had not been released therefore, there was no chance that participants had read the text prior to participation.

The task was similar to a spot the difference task which children tend to be familiar with. The task was presented in a video game format making it more fun for the participant, however, this required using a keyboard, which may provide some benefit to individuals who have had more exposure to digital devices. It is important to note that the keyboard response only affected total duration which is equivalent to reaction time and did not affect other eye movement measures such as, fixation duration. Furthermore, although eye tracking can be considered more useful as it provides richer data than just reaction times data and provides more information than mouse-pressing, it has been suggested that attention precedes eye movements. In consequence, perhaps future research could use neuroimaging during the administration of a change detection task measuring attention for high and low digital exposure groups. This would allow for attention to be measured including the time between attention and eye movement allowing for more even more accurate measure of attention.

For the reading on different devices task in Chapter 6: What are the effects of digital technology on standardized measures of vocabulary, word reading and attention? a key strength was the equivalence of stimuli across all devices. Text was presented on each device equally, with the same passages being presented on each media at the same size, font size, colour and words per line. This was to control confounding variables and ensure equivalence across the devices, which Noyes & Garland (2008) previously stressed the importance of. As mentioned in Chapter 6, the only difference was the use of a light grey background for digital presentation to avoid screen glare and minimize eye strain (Breadmore & Carroll, 2018). Future research should also compare paper reading to laptop/ computer reading as this was just significant is Phase 2 and although children do not frequently use computers, as they get older computer use will increase. Thus, it would be beneficial for future research to explore whether there are age related effects in attention based on exposure to digital technology. This could be further explored using a longitudinal study, which measures children's levels of exposure across the years and measures outcome variables of both attention and reading.

A limitation is the use of only narrative text as previous meta-analyses found effects of media more on expository texts compared to narrative texts (Clinton, 2019; Delgado et al., 2018). Therefore, future research should look at the effects of media type on the reading performance of expository texts in young children.

Future research should continue to explore the effects of digital technology use and digital text exposure attention and other predictors of reading, along with reading and reading comprehension. The link between attention and reading is important and future research should aim to draw together this link. It would also be interesting to explore change detection in a text format as that will allow for closer exploration of the effects of attention on reading. This could be done by studying eye movement during reading, with changes in the text instead of images.

Conclusion

The first aim of this thesis was to establish children's and their parents' digital technology use as well as parental attitudes towards digital technology through a questionnaire. Additionally, this questionnaire was developed to group children into high and low exposure groups based on their digital technology use. The main aim of the present thesis, however, was to gain a better understanding of the relationships between digital technology exposure, attention and reading including predictors of reading, reading time and reading comprehension. Overall, there appeared to be a lack of difference between children in the high and low exposure groups. For measures of selective and sustained attention obtained via the TEA-Ch2 results showed that there were no significant differences between the high and low exposure groups. All eye movement measures for the change detection task showed no significant differences between the high and low exposure groups. Thus, suggesting that there is no difference in children's selective visual attention ability based on their level of exposure to digital technology. No effect of children's level of digital exposure was found on their word reading abilities. There were no differences between the means scores of non-word reading, exception word reading or regular word reading between the high and low exposure group. On the other hand, vocabulary scores, which are a predictor of reading ability and are an essential skill in their own right, were found to be lower in the high exposure group compared to the lower exposure group. As mentioned above this finding may be a result of the type and the quality of content consumed by and/or the activities children in the high exposure group participated in compared to the children in the low exposure group. Furthering this point, it could be a result of behaviours around these activities. For example, in shared print reading with a parent has been found to encourage conversations about the characters, the story and the text which helps improve vocabulary, print awareness, language development and comprehension (Reich et al., 2016). However, the use of digital technology in the form of e-books and tablets have been found to be less effective and at some points distracting (Reich et al., 2016). Although there was a difference in vocabulary scores between the high and low exposure groups, this was not found across other reading related variables, including reading time and reading comprehension (measured in Chapter 5: What are the impacts of reading across different media) nor word reading measure in (Chapter 6: What are the effects of digital technology on standardized measures of vocabulary, word reading and attention?). However, it is important not to ignore this finding as vocabulary is an important component of successful reading as shown by the Simple View of Reading model (Hoover & Gough, 1990).

Perhaps, the influence of digital technology use is not an issue at the moment but could be cause for concern downstream as children grow older and require a broader vocabulary. Therefore, it is important for future research to explore the impact of digital technology exposure across a varied age range of children.

The ubiquitous nature of digital technology has a continued effect on children's home literacy environments and their classroom environments. This shift has resulted in children being more exposed to digital text, thus impacting the skills necessary for successful reading acquisition and reading comprehension. Digital technology offers great benefits however there is the potential of harm. When examining reading, a key benefit of digital technology is the interactive and engaging nature of certain devices. However, a negative aspect is the distracting and the possible facilitation of shallow reading and hyper-reading. Thus, for children to read successfully on digital devices perhaps they must acquire meta-cognitive skills for example attention, to navigate digital texts. Research on these skills is limited. More research is required to fully understand children's reading acquisition and reading development to facilitate the best support for children's literacy development, which is known to affect all aspects of life. The majority of reading research has focused on phonological awareness, letter knowledge and vocabulary and this research is mostly conducted using print reading. This has resulted in valuable models of reading that have in turn have been used to form guidance and educational policies. However, most of these do not take into account the impact of digital text.

Overall, findings from this thesis appear to show little cause for concern as there is an absence of differences between individuals with high or low exposure to digital technology in numerous measures of reading and attention. The findings from the present study ought to help alleviate parents' fears regarding their children's digital technology use, in a digitally oriented world. Given the recent extraordinary increase in digital technology use through both online homeschooling and socialising due to school closures because of COVID-19 (Williamson et al., 2020), it is reassuring that the present study did not find sizeable variations in children's reading or reading related skills dependent on the children's levels of exposure to digital technology. It is therefore, as found in the questionnaire in Chapter 3: What are the effects of digital text exposure on young children?, seemingly appropriate that parents prefer to monitor or restrict their children access to digital technology rather than removing the digital device.

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Appendices

Appendix 1: Online Questionnaire

Please fill out the following questions about your child.

1) Child's Age

- ○ 4 (1)
- ○ 5 (2)
- ○ 6 (3)
- ○ 7 (4)
- ○ 8 (5)

2) Child's Gender

- ○ Male (1)
- ○ Female (2)
- ○ Other (3)

3) Does your child have any special educational needs or disabilities?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Does your child have any special educational needs or disabilities? = Yes

4) Please give details.

____

____

____

____

____

5) Does your child have any siblings?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Does your child have any siblings? = Yes

6) How many siblings does your child have?

- ○ 1 (1)
- ○ 2 (2)
- ○ 3 (3)
- ○ 4 (4)
- ○ 5 (5)
- ○ 6 (6)
- ○ 7 (7)
- ○ 8 (8)
- ○ 9 (9)
- ○ 10+ (10)

7) In what order of birth is your child among their siblings?

- ○ 1st (1)
- ○ 2nd (2)
- ○ 3rd (3)
- ○ 4th (4)
- ○ 5th (5)
- ○ 6th (6)
- ○ 7th (7)
- ○ 8th (8)
- ○ 9th (9)
- ○ 10th onwards (10)

8) Please fill out the following questions about yourself.

9) What is your relationship to the child?

1. ____

10) Your Age

2. ____

11) Your Gender

- ○ Male (1)
- ○ Female (2)
- ○ Other (3)

12) What is the highest degree or level of school you have completed? (If you're currently enrolled in school, please indicate the highest degree you have *received.*)

- Secondary Education (GCSE/O-Levels) (1)
- Post-Secondary Education (College, A-Levels, NVQ3 or below, or similar) (2)
- Vocational Qualification (Diploma, Certificate, BTEC, NVQ 4 and above, or similar) (3)
- Undergraduate Degree (BA, BSc etc.) (4)
- Post-graduate Degree (MA, MSc etc.) (5)
- Doctorate (PhD, EdD) (6)
- Other (please specify) (7) ____________________

13) Occupation

____

14) How old was your child when;

	Under 1 (1)	1 (2)	2 (3)	3 (4)	4 (5)	5 (6)	6 (7)	7 (8)	Never (9)
You started reading books to them (1)									
They first looked at/read books themselves (2)									
They first used a digital device {excluding TV?} (3)									

15) Which of the following devices has your child used and where?

	At home (1)	At playgroup/ nursery/ school (2)	At family's or friends' house (3)	Out and about (e.g. in the car/ at shops / café) (4)	Child hasn't used this item so far (5)
Smartphone (with a touchscreen) (1)	☐	☐	☐	☐	☐
E-reader (Kobo, Kindle) (2)	☐	☐	☐	☐	☐
Tablet (iPad) (3)	☐	☐	☐	☐	☐
Computer/Laptop (4)	☐	☐	☐	☐	☐
Gaming console (Wii, PS, Xbox) (5)	☐	☐	☐	☐	☐
Television (6)	☐	☐	☐	☐	☐

16) Which of these does your child use the most?

- ○ Smartphone (1)
- ○ E-reader (2)
- ○ Tablet (3)
- ○ Computer/Laptop (4)
- ○ Gaming console (5)
- ○ Printed books (6)
- ○ Television (7)
- ○ None of the above (8)

17) What is your child's favourite app?

____

18) What is your child's favourite activity on the computer/laptop?

____

19) What is your child's favourite game on a console?

____

20) What is your child's favourite television programme?

____

21) In the 6 months before reception, how often did your child spend 5 minutes or more using the following things?

	More than once a day (1)	Once a day (2)	3-4 times a week (3)	Once a week (4)	Less than once a week (5)	Never (6)
Smartphone (1)	○	○	○	○	○	○
E-reader (2)	○	○	○	○	○	○
Tablet (3)	○	○	○	○	○	○
Computer/Laptop (4)	○	○	○	○	○	○
Gaming console (5)	○	○	○	○	○	○
Printed books (6)	○	○	○	○	○	○
Television (7)	○	○	○	○	○	○

22) When reading with your child in the 6 months before starting Reception did you tend to read more print books or more e-books?

○ Only print books (1)

○ Mainly print books (2)

○ Print and e-books equally (3)

○ Mainly e-books (4)

○ Only e-books (5)

23) How often did your child use digital devices for the following activities in the 6 months before starting Reception?

	More than once a day (1)	Once a day (2)	3-4 times a week (3)	Once a week (4)	Less than once a week (5)	Never (6)
Playing games for fun (1)	○	○	○	○	○	○
Playing educational games (letter or number) (2)	○	○	○	○	○	○
Watching video/programmes (3)	○	○	○	○	○	○
Watching/Listening to music (4)	○	○	○	○	○	○
Communication with other (Skype, Facetime) (5)	○	○	○	○	○	○
Using children gaming websites (Miniclip) (6)	○	○	○	○	○	○
Using educational children's websites (BBC bitesize) (7)	○	○	○	○	○	○
Reading e-books (8)	○	○	○	○	○	○
Finding things out (9)	○	○	○	○	○	○

24) Which do you think your child would pay attention to for the longest?

○ Print book (1)

○ E-book (2)

25) What are the **benefits** of your child using a digital device (if any)?

____

____

____

____

____

26) What are the **downsides** of your child using a digital device (if any)?

____

____

____

____

____

27) Do you limit the amount of time your child spends on digital devices?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Do you limit the amount of time your child spends on digital devices? = Yes

28) Please specify how you limit the amount of time your child spends on digital devices?

____

____

____

____

____

29) Is your child aware of how often you use digital devices?

- Yes (1)
- No (2)

30) How often do you personally (P) use these things in front of your child and how often together with (W) your child?

	More than once a day		Once a day		3-4 times a week		Once a week		Less than once a week		Never	
	P (1)	W (2)	P (1)	W (2)	P (1)	W (2)	P (1)	W (2)	P (1)	W (2)	P (1)	W (2)
Smartphone (1)												
E-reader (2)												
Tablet (3)												
Computer/Laptop (4)												
Gaming console (5)												
Printed books (6)												
Television (7)												

31) Which of the following does your child have in his/her bedroom?

- ☐ Television (1)
- ☐ Computer/ Laptop (2)
- ☐ DVD player (3)
- ☐ Gaming console (4)
- ☐ Music player (5)
- ☐ E-books (6)
- ☐ Printed books (7)
- ☐ Tablet (8)

32) How many TV sets do you have in your home?

▼ 0 (1) ... 7+ (9)

33) When someone is at home in your household, how often is the TV on, even if no one is actually watching it?

- ○ Always (1)
- ○ Most of the time (2)
- ○ Some of the time (3)
- ○ Hardly ever (4)
- ○ Never (5)

34) When it comes to family time, how much does your family enjoy doing the following activities together?

	A lot (1)	Sometimes (2)	Occasionally (3)	Never (4)	None at all (5)
Watching TV/movies together (1)	○	○	○	○	○
Reading together (2)	○	○	○	○	○
Outdoor activities together (playing in the garden/ going to the park) (3)	○	○	○	○	○
Playing gaming consoles together (4)	○	○	○	○	○
Playing or attending sports events together (5)	○	○	○	○	○
Participating in clubs or other groups together (6)	○	○	○	○	○
Singing songs or making music together (7)	○	○	○	○	○
Doing things on a computer, tablet, or smart phone together (8)	○	○	○	○	○

35) How do you usually find TV shows, movies, video games, apps or websites for your child to use?

- ○ Child finds them (1)
- ○ Recommendations for friends (2)
- ○ Newspaper/ magazine reviews (3)
- ○ I watch/play content first (4)
- ○ Website reviews (5)
- ○ Reputation of company/ brand (6)

36) For children who are your child's age, do you think **television** mainly has a positive or negative effect on their...?

	Very positive (1)	Somewhat positive (2)	Neither positive nor negative (3)	Somewhat negative (4)	Very negative (5)
Reading skills (1)	○	○	○	○	○
Speaking skills (2)	○	○	○	○	○
Math skills (3)	○	○	○	○	○
Social skills (4)	○	○	○	○	○
Physical activity (5)	○	○	○	○	○
Attention span (6)	○	○	○	○	○
Creativity (7)	○	○	○	○	○
Behaviour (8)	○	○	○	○	○
Sleep (9)	○	○	○	○	○

37) For children who are your child's age, do you think **computers/laptops** mainly have a positive or negative effect on their...?

	Very positive (1)	Somewhat positive (2)	Neither positive nor negative (3)	Somewhat negative (4)	Very negative (5)
Reading skills (1)	○	○	○	○	○
Speaking skills (2)	○	○	○	○	○
Math skills (3)	○	○	○	○	○
Social skills (4)	○	○	○	○	○
Physical activity (5)	○	○	○	○	○
Attention span (6)	○	○	○	○	○
Creativity (7)	○	○	○	○	○
Behaviour (8)	○	○	○	○	○
Sleep (9)	○	○	○	○	○

38) For children who are your child's age, do you think **gaming consoles** mainly have a positive or negative effect on their...?

	Very positive (1)	Somewhat positive (2)	Neither positive nor negative (3)	Somewhat negative (4)	Very negative (5)
Reading skills (1)	○	○	○	○	○
Speaking skills (2)	○	○	○	○	○
Math skills (3)	○	○	○	○	○
Social skills (4)	○	○	○	○	○
Physical activity (5)	○	○	○	○	○
Attention span (6)	○	○	○	○	○
Creativity (7)	○	○	○	○	○
Behaviour (8)	○	○	○	○	○
Sleep (9)	○	○	○	○	○

39) For children who are your child's age, do you think smartphones/tablets mainly have a positive or negative effect on their...?

	Very positive (1)	Somewhat positive (2)	Neither positive nor negative (3)	Somewhat negative (4)	Very negative (5)
Reading skills (1)	○	○	○	○	○
Speaking skills (2)	○	○	○	○	○
Math skills (3)	○	○	○	○	○
Social skills (4)	○	○	○	○	○
Physical activity (5)	○	○	○	○	○
Attention span (6)	○	○	○	○	○
Creativity (7)	○	○	○	○	○
Behaviour (8)	○	○	○	○	○
Sleep (9)	○	○	○	○	○

40) Please leave any further comments you wish to add.

____

____

____

____

____

41) To what extent do the following statements apply to you?

	Always me (1)	Usually me (2)	Sometimes me (3)	Rarely me (4)	Never me (5)
I set limits on the amount of time my child spends on digital devices. (1)	○	○	○	○	○
I set limits on when digital devices can be used. (2)	○	○	○	○	○
I set limits on the types of content my child can assess. (3)	○	○	○	○	○
I do not have rules for screen time. (4)	○	○	○	○	○
I use passwords on my digital devices. (5)	○	○	○	○	○
I remove devices if possible (video games, tablet, and power cords). (6)	○	○	○	○	○
I set limits using parental features on digital devices. (7)	○	○	○	○	○
I use digital devices with my child. (8)	○	○	○	○	○

I encourage my child to use digital devices. (9)	○	○	○	○	○
I routinely monitor my child's use of the Internet and other digital media. (10)	○	○	○	○	○
I encourage my child to use the Internet and other digital media to learn about things he or she is interested in. (11)	○	○	○	○	○
I use media as a way to connect with my child. (12)	○	○	○	○	○
My partner and I usually agree when it comes to making decisions about my child's media. (13)	○	○	○	○	○

3.

42) To what extent do you agree with the following statements?

	Strongly agree (1)	Agree (2)	Neither agree nor disagree (3)	Disagree (4)	Strongly disagree (5)
Digital devices are more interactive than books. (1)	○	○	○	○	○
Digital devices make people lazy. (2)	○	○	○	○	○
My child will be exposed to illicit material if they use these devices. (3)	○	○	○	○	○
My child would be better off without digital devices in schools. (4)	○	○	○	○	○
Digital devices are hard to use. (5)	○	○	○	○	○
It's difficult to set control and rule for my child regarding digital devices. (6)	○	○	○	○	○
My child knows more about digital devices than me. (7)	○	○	○	○	○

I am confident in my ability at using digital devices. (8)	○	○	○	○	○
I would be concerned if my child did not know how to use digital devices by the time they left primary school. (9)	○	○	○	○	○
I think the right apps have huge educational potential. (10)	○	○	○	○	○
I find new technology intimidating. (11)	○	○	○	○	○
I believe need to be technology literate. (12)	○	○	○	○	○
My child is more likely use digital print (e.g. ebooks) than printed books. (13)	○	○	○	○	○
My child is more likely use printed books than digital print (e.g. ebooks). (14)	○	○	○	○	○

Television helps my child's language development. (15)	○	○	○	○	○
Smartphones and tablet devices make parenting easier. (16)	○	○	○	○	○
My child needs to be skilled with computers and new tablet devices to be successful in life. (17)	○	○	○	○	○
I am concerned that my child may become addicted to new mobile media like smartphones or tablet. (18)	○	○	○	○	○
Negotiating media use causes conflicts in our home. (19)	○	○	○	○	○
Children should not use digital technology when eating. (20)	○	○	○	○	○

I am concerned that my child's peers may be able to use computers and tablet better than him/her. (21)	○	○	○	○	○
I worry about my child's exposure to media when he/she is at someone else's home and not with me. (22)	○	○	○	○	○
Smartphones and tablets have lots of fun things to keep children entertained. (23)	○	○	○	○	○
Smartphones and tablets have lots of educational content that teaches important lessons. (24)	○	○	○	○	○
Children always have their heads buried in their devices and it's harder to get their attention. (25)	○	○	○	○	○

Children don't learn social skills because they spend so much time smartphones and tablets. (26)	○	○	○	○	○
Children get addicted to smartphones and tablets. (27)	○	○	○	○	○
It is beneficial to use digital technology whilst children are eating. (28)	○	○	○	○	○

43) Read each item and decide whether it is TRUE or FALSE for you. Please try to work rapidly.

	TRUE (1)	FALSE (2)
Before voting I thoroughly investigate the qualifications of all the candidates. (1)	○	○
I never hesitate to go out of my way to help someone in trouble. (2)	○	○
It is sometimes hard for me to go on with my work if I am not encouraged. (3)	○	○
I have never intensely disliked anyone. (4)	○	○
On occasions I have had doubts about my ability to succeed in life. (5)	○	○
I sometimes feel resentful when I don't get my way. (6)	○	○
I am always careful about my manner of dress. (7)	○	○
My table manners at home are as good as when I eat out in a restaurant. (8)	○	○
If I could get into a movie without paying and be sure I was not seen, I would probably do it. (9)	○	○
On a few occasions, I have given up something because I thought too little of my ability. (10)	○	○
I like to gossip at times. (11)	○	○
There have been times when I felt like rebelling against people in authority even though I knew they were right. (12)	○	○
No matter who I'm talking to, I'm always a good listener. (13)	○	○

I can remember "playing sick" to get out of something. (14)	○	○
There have been occasions when I have taken advantage of someone. (15)	○	○
I'm always willing to admit it when I make a mistake. (16)	○	○
I always try to practice what I preach. (17)	○	○
I don't find it particularly difficult to get along with loudmouthed, obnoxious people. (18)	○	○
I sometimes try to get even rather than forgive and forget. (19)	○	○
When I don't know something I don't mind at all admitting it. (20)	○	○
I am always courteous, even to people who are disagreeable. (21)	○	○
At times I have really insisted on having things my own way. (22)	○	○
There have been occasions when I felt like smashing things. (23)	○	○
I would never think of letting someone else be punished for my wrong-doings. (24)	○	○
I never resent being asked to return a favour. (25)	○	○
I have never been irked when people expressed ideas very different from my own. (26)	○	○
I never make a long trip without checking the safety of my car. (27)	○	○

There have been times when I was quite jealous of the good fortune of others. (28)	○	○
I have almost never felt the urge to tell someone off. (29)	○	○
I am sometimes irritated by people who ask favours of me. (30)	○	○
I have never felt that I was punished without cause. (31)	○	○
I sometimes think when people have a misfortune they only got what they deserved. (32)	○	○
I have never deliberately said something that hurt someone's feelings. (33)	○	○

Appendix 2: Paper-based Questionnaire

Digital Technology Questionnaire

Please tick all that apply:

1) How old was your child when;

	Under 1	1-2	2-3	3-4	4-5	5-6	6-7	Never
You started reading books to them								
They first looked at/read books themselves								
They first used a digital device {excluding TV?}								

2) Which of the following devices has your child used and where?

	At home	At playgroup/ nursery/ school	At family's or friends' house	Out and about (e.g. in the car/ at shops / café)	Child hasn't used this item so far
Smartphone (with a touchscreen)					
E-reader (Kobo, Kindle)					
Tablet (iPad)					
Computer/Laptop					
Gaming console (Wii, PS, Xbox)					
Television					

3) Which of these does your child uses the most?

Smartphone	
E-reader	
Tablet	
Computer/Laptop	
Gaming console	
Printed books	
Television	
None of the above	

4) In the 6 months before reception, how often did your child spend 5 minutes or more using the following things?

	More than once a day	**Once a day**	**3-4 times a week**	**Once a week**	**Less than once a week**	**Never**
Smartphone						
E-reader						
Tablet						
Computer/Laptop						
Gaming console						
Printed books						
Television						

5) When reading with your child in the 6 months before starting Reception did you tend to read more print books or more e-books?

Only print books	**Mainly print books**	**Print and e-books equally**	**Mainly e-books**	**Only e-books**

6) How often did your child use digital devices for the following activities in the 6 months before starting Reception?

	More than once a day	**Once a day**	**3-4 times a week**	**Once a week**	**Less than once a week**	**Never**
Playing games for fun						
Playing educational games (letter or number)						
Watching video/programmes						
Watching/Listening to music						
Communication with others (Skype, Facetime)						
Using children's gaming websites (Miniclip)						
Using educational children's websites (BBC bitesize)						
Reading e-books						

Finding things out						

7) Which do you think your child would pay attention to for the longest?

Print book	**E-book**

8) Do you limit the amount of time your child spends on digital devices?

Yes	**No**

9) When it comes to family time, how much does your family enjoy doing the following activities together?

	A lot	**Sometimes**	**Occasionally**	**Never**
Watching TV/movies together				
Reading together				
Outdoor activities together (playing in the garden/ going to the park)				
Indoor activities together (board games/ drawing (not TV etc.))				
Playing gaming consoles together				
Playing or attending sports events together				
Participating in clubs or other groups together				
Singing songs or making music together				
Cooking and eating meals together				
Doing things on a computer, tablet, or smart phone together				

10) To what extent do the following statements apply to you?

	Always me	**Usually me**	**Sometimes me**	**Rarely me**	**Never me**
I set limits on the amount of time my child spends on digital devices.					
I set limits on when digital devices can be used.					
I set limits on the types of content my child can access.					
I do not have rules for screen time.					
I use passwords on my digital devices.					
I remove devices if possible (video games, tablet, and power cords).					
I set limits using parental features on digital devices.					
I use digital devices with my child.					
I encourage my child to use digital devices.					
I routinely monitor my child's use of the Internet and other digital media.					
I encourage my child to use the Internet and other digital media to learn about things he or she is interested in.					
I use media as a way to connect with my child.					
My partner and I usually agree when it comes to making decisions about my child's media.					

11) To what extent do you agree with the following statements?

	Strongly agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**
Digital devices make people lazy.					
My child will be exposed to illicit material if they use these devices.					
My child would be better off without digital devices in schools.					
Digital devices are hard to use.					
It's difficult to set controls and rules for my child regarding digital devices.					
My child knows more about digital devices than me.					
I find new technology intimidating.					
My child is more likely use digital print (e.g. e-books) than printed books.					
My child is more likely use printed books than digital print (e.g. e-books).					
Television helps my child's language development.					
Smartphones and tablet devices make parenting easier.					
My child needs to be skilled with computers and new tablet devices to be successful in life.					
I am concerned that my child may become addicted to new mobile media like smartphones or tablet.					
Negotiating media use causes conflicts in our home.					
I am concerned that my child's peers may be able to use computers and tablet better than him/her.					
I worry about my child's exposure to media when he/she is at someone else's home and not with me.					
Children always have their heads buried in their devices and it's harder to get their attention.					
It is beneficial to use digital technology whilst children are eating.					

Demographic Questionnaire

Please fill out the following questions about your child:

1. Child's date of birth: ____ /____ /______
2. Child's gender: Male / Female *(circle correct response)*
3. Handedness: Left / Right / Other
4. Does your child have any special educational needs or disabilities? Yes* / No
   *If yes, please give details:

   ____

5. Does your child have normal vision? Yes / No / Corrected with glasses or lenses
6. Does your child speak any languages other than English?
   Yes*/ No

*If no, go to 7. If yes,

a. What languages do they speak?

   ____

b. What language did they learn first?

   ____

7. Does your child have a history of epilepsy or seizures Yes / No

Please fill out the following questions about yourself:

1) What is your relationship to the child? _____________________________________
2) Your date of birth: ____ /____ /______
3) Your gender: Male / Female /Other
4) What is the highest degree or level of school you have completed? (If you're currently enrolled in school, please indicate the highest degree you have *received.*)
   - ☐ Secondary Education (GCSE/O-Levels)
   - ☐ Post-Secondary Education (College, A-Levels, NVQ3 or below, or similar)
   - ☐ Vocational Qualification (Diploma, Certificate, BTEC, NVQ 4 and above, or similar)
   - ☐ Undergraduate Degree (BA, BSc etc.)
   - ☐ Post-graduate Degree (MA, MSc etc.)
   - ☐ Doctorate (PhD, EdD)
   - ☐ Other (please specify) ____
5) Occupation: ____________________________________

Appendix 3: Passages for reading on different media task

Passage	Difficulty Level	Used in Phase 4
Asha put on a wig. Tess got a red wig. They had a lot of fun with the wigs.	Easy	No
Finn was sitting in the classroom. A bright green bug landed on his book! Finn put the bug in a pot.	Easy	Yes
Grandad took Tess and Finn fishing. Tess and Finn held their fishing rods still. Then Tess felt a tug on her fishing rod.	Easy	Yes
Mum has lost Tom. He is not in the sandwich shop. Tom has lost Mum.	Easy	Yes
Tess and Finn went to work with Mum. They went to look at the wombats. They went to look at the zebras.	Easy	Yes
Jess has an egg but no nest! Jetta has a nest. Jem has a nest.	Easy	Yes
Rav went to visit the theme park. Asha, Tess and Finn went too. Rav went down fast.	Easy	Yes
Frog swims across the big rock pond. Fox jumps onto a twig raft. Frog hopped on the six wet pads.	Easy	Yes
Mum got Finn and Tess a pet! Finn and Tess went to visit Rav. They went to visit Asha.	Easy	Yes
Light Year 2 were going on a school trip to a space station. The children jostled in their seats to look out of the shuttle. "Max is pressing his nose against the window and I can't see!" said Zachary. "I'm keeping watch for aliens," said Max. "The shuttle docked at the space station. One by one, the children floated through the hatch into a gleaming room.	Hard	Yes
Rav and his friends were trying a new ride at Planet Zoom. "It's called the Solar System Spinner!" Rav said, laughing. They climbed into a pod that looked like Earth. The pod began to spin around the sun at the centre of the ride. "I'm dizzy already" cried Tess, closing her eyes. Stars whizzed around their heads as the ride spun away.	Hard	Yes
Asha's dad was sorting out the rubbish. "Please could you help me with the recycling?" he asked Asha and Tess. "These boxes and bottles need to go in the bins downstairs." Asha and Tess shivered it in the icy wind outside. "Look at the poor birds!" cried Tess. "Now it's winter, there isn't much food for them to eat."	Hard	No
Crystal Class were practising their play for the school production. It was about an explorer who planned to steal a magical gem from an evil queen! The teacher, Mrs Swan, came into the room smiling. "This is Mrs Knight. She's a real explorer. She's going to teach us about the pyramids in Egypt before the play tonight!" The class learned all about pyramids, mummies and cats! Billy, Lee and Jasmine looked through a box of artefacts.	Hard	Yes
Today, I am excited because I'm visiting the opticians with my dad. An optician is someone who decides if your eyes have good or bad vision. At school, I recently found that letters looked a bit blurry. I may need to wear glasses to help with reading and writing. It's busy in the opticians. There are racks of glasses on the walls.	Hard	Yes
Mr Gale's class had been practising for their assembly all week. They were going to play lots of different instruments for their parents. Finn had	Hard	Yes

a triangle, Tess has maracas and Rav had a bongo drum. Asha was going to play her recorder. The day before assembly, Mr Gale asked Rav and Tess to put the instruments in the hall. "Then they'll be ready for tomorrow!" he said.		
Once upon a time, there lived a gentle giant called Gina, who loved to knit. Each night, she would fetch her rucksack and huge needles, and start to knit. Click, click, click went the needles, as she knitted large jumpers and colourful socks. One day, Gina decided to trudge down to a little village to sell her knitting. But the villagers just chuckled. "Why would we want these?" they laughed.	Hard	Yes
One snowy day, Tess, Finn and their friends were helping at the wildlife park. They were digging snow away from the footpath when a fresh flurry of snowflakes swirled around. A blizzard lifted the friends off their feet and they closed their eyes. When they landed, they were gazing at a glistening white landscape. "We're in the Arctic!" cried Finn, pointing at the Arctic fox. They followed the little white animal across the snow.	Hard	Yes
The Mer-king banged his gong and the children jumped into the water. Joy felt her legs turn into a tail. She could breathe underwater and search the seabed. She saw lots of oysters, but they were all firmly closed. Then, Joy found the biggest pearl she had ever seen! Joy was about to swim up when she heard a shout.	Hard	No