The Influence of Touchscreens on Young Children's Problem Solving, Divergent Thinking, and Novelty Seeking

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Abstract

Preschooler’s use of touchscreen devices has been strongly debated in recent years, with differing opinions on whether they are beneficial or detrimental to children’s cognitive skills. Previous research explored television-watching and its impact on creative thinking, but few studies have examined the influence of touchscreens and apps. The aim of this thesis was to explore how touchscreen use influenced different facets of creative thinking in young children. Children’s creative thinking was assessed using measures of problem solving, divergent thinking, and novelty seeking. Caregiver reports were used to measure children’s engagement in different activities, including touchscreen and app use. In the first study, caregivers completed the Early Creativity Survey to measure naturalistic problem solving and novelty seeking behaviours in 12- to 47-month-olds through an online survey. Key findings included positive correlations between problem solving and novelty seeking and using learning apps and creative apps. The second study used the Unusual Box Test to measure divergent thinking and the Great Ape Tool Test Battery to measure problem solving directly in 24- to 47-month-olds. Divergent thinking was not significantly related to any activities. However, problem solving was again positively related to using learning apps. In the final study, using a problem-solving app had a positive effect on subsequent performance in the Great Ape Tool Test Battery in 36- to 47-month-olds compared to an exploration app or not using an app at all. In sum, the findings from this thesis suggest touchscreens may generally have a positive influence in children’s creative thinking. It has consistently demonstrated that learning apps, and specifically problem-solving apps, may support preschooler problem solving. This enhances our understanding of how touchscreens and apps can be beneficial in young children’s lives.

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When times were at their darkest, the song that helped me find my way back:

“I Was Born For This” – Austin Wintory

(*Journey* Soundtrack)

Dedication

To my dad, Martin, who passed away in 2004.

After I found out that I’d been awarded funding for the PhD, my grandma told me of a time when I was a child and came running through her house shouting "Dad says I can be anything I want, even a doctor!". I'm sure younger me probably had a medical doctor in mind since I wouldn’t have had a clue about PhDs, but I didn’t quite end up going in that direction! Nevertheless, I think the resounding message is that he would have supported me to pursue whatever I decided to put my mind to, instilling a sense of determination and drive to be the best that I can.

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CHAPTER ONE:

Literature Review

1. Introduction

Media use has become an integral part of our everyday lives and it has also transcended into children's lives. Watching television has been a popular activity for children for decades (Pecora, 2007). However, more recent reports have shown children's access and use of touchscreen devices, such as tablet computers and smartphones, has increased significantly in the past few years (Ofcom, 2017; 2019a; Rideout & Robb, 2020). Indeed, the number of apps targeting preschoolers represent a large proportion of available activities in online stores (Hirsh-Pasek et al., 2015). Given the popularity of touchscreens, it has attracted the attention of researchers, policymakers, and the public (Orben, 2020; Weale, 2016). It is a contentious issue and opinion is divided on whether these devices are beneficial or detrimental for young children. Despite the attention and policy in response to increased use, there is little understanding about how touchscreens can influence young children's development. This likely feeds into public concerns about children using touchscreens and thus continues the cycle into policymaking (Orben, 2020). Therefore, understanding children's touchscreen use is of great importance across different areas.

The aim of this thesis was to explore how touchscreens might relate to different aspects of creative thinking. The decision to focus on creative thinking was partly because it has been an area of interest in previous media research (Singer & Singer, 1990; Calvert, 2015). Creativity is seen as an important asset in everyday life and particularly desirable for young children to cultivate across different settings (Sternberg & Lubart, 1996; Department for Education, 2017). Therefore, it is crucial to understand the factors that can facilitate or hinder it. Additionally, factors relating to creative thinking, such as exploration and problem solving, have been highlighted by policymakers as an area of concern in relation to media use (Yogman et al., 2018). Thus, it was pertinent to expand on previous research and establish conclusions about how touchscreen use may help or hinder creative thinking. Three studies were conducted to explore the potential influence of touchscreens. Specifically, problem solving, divergent thinking, and novelty seeking were used as markers of creative thinking and these concepts are discussed in more detail in the literature review. To measure touchscreen use, caregivers were asked about their children's touchscreen use at home. Children's touchscreen use can include a variety of activities, including using apps to engage with educational material, drawing or playing games, or watching video content through streaming services (Hirsh-Pasek et al., 2015; Ofcom, 2019a; Rideout, 2017). Consequently, caregivers were asked to report on their children's engagement with different types of apps, including learning apps and creative apps. They were also asked to report on other activities, including non-media-based activities, to compare media-based relationships with creative thinking and pursuits such as reading and creative activities.

The key questions this thesis attempted to answer centred around whether touchscreens and apps were positively or negatively related to preschooler creative thinking. Other activities that did not involve any form of media, for example reading or engaging in creative activities, were also examined. The decision to explore the potential influence of touchscreens was made because touchscreen use has accelerated rapidly amongst young children and relatively few studies have addressed this topic so far. It was of interest to explore how it might have an influence in preschoolers as it is a key period of development before they enter more structured environments such as schools. Other factors were considered alongside touchscreens, including other media-based activities, for example, watching child-directed video content. This would enable a snapshot into how touchscreens relate to other activities as well as providing insight into their influence on creative thinking.

To begin, the following literature review seeks to explore the key concepts noted in this thesis. Firstly, children's media use is explored, including the prevalence of touchscreen use, policy on children's media use and key theories that have shaped these guidelines, with reference to television and touchscreen research. Secondly, creative thinking is addressed, including how it is defined, how it is measured across different age groups, and a brief examination of creative thinking in childhood. Finally, the two areas of media use and creativity are combined to explore theories about how media use affects children's creativity and to discuss key studies that have explored this in more detail.

1.1 Young children's media use

1.1.1 Prevalence

While touchscreen technology has existed for some time, it is believed that the release of the iPhone in 2007 and the iPad in 2010 contributed to a surge in the popularity of touchscreen devices, even amongst children (Hirsh-Pasek et al., 2015). In 2013, the Common Sense Media report from the United States showed that 40% of 0- to 8-year-olds had access to a tablet computer compared to 8% in 2011, which had increased to 78% by 2017 (Rideout, 2013; 2017). In preschoolers, it was also reported that 2- to 4-year-olds used mobile devices for an average of 58 minutes (Rideout, 2017). The 2020 Common Sense Media report showed further increases amongst preschoolers, with 40% of children under the age of 2 and 93% of 2- to 4-year-olds having used mobile media, including touchscreens (Rideout & Robb, 2020). Furthermore, the report demonstrated that on average, children under the age of 2 years spent 7 minutes a day using mobile devices. Amongst 2- to 4-year-olds, this increased to 59 minutes. Ownership is also an important indicator of touchscreen access and the report showed 46% of 2- to 4-year-olds own their own tablet or smartphone. Though there is limited data on how much time children are spending using touchscreens, increases in touchscreen access are reflected in the United Kingdom. For example, in 2013, 28% of 3- to 4-year-olds had access to a touchscreen at home (Ofcom, 2013). The most recent Ofcom figures showed a significant increase in access, where 63% of 3- to 4-year-olds used tablets in the home and 24% owned their own device (Ofcom, 2019b). The data from these nationally representative surveys show clear evidence that young children's touchscreen use has risen dramatically.

Additional academic research also supports these conclusions, where most children have used a touchscreen (Huber et al., 2018; Kabali et al., 2015), demonstrating a striking ubiquity of touchscreen use. It is also important to note that it is not mere exposure to touchscreens; young children can purposefully engage with these devices. Cristia & Seidl (2015) found a positive relationship between the frequency of touchscreen use and parent-reported gestures while using touchscreens. Additionally, movements such as pressing, dragging, pinching, and spreading on touchscreens increased with age. In contrast, reports of banging on the touchscreen decreased with age. This demonstrates that children used more precise, purposeful movements as they got older. This could also reflect positive associations between fine motor control and touchscreen use, a finding observed by Bedford et al., (2016) in 6- to 36-month-olds. Cristia and Seidl (2015) also found that as children got older, they preferred using videos and puzzle apps. These two findings could be connected in that as children get older, the way they interact with touchscreens becomes more advanced and purposeful, both in terms of their physical gestures and the content they enjoy engaging with.

It is clear from both academic research and reports on children's media use that young children's access to touchscreens and use of these devices has increased over recent years. Additionally, this increases with age, as does their ability to engage with these devices in a purposeful manner. It is therefore important to understand how these devices might influence their development and learning. However, there is limited research about how touchscreens could influence development. As with many issues, public and professional concern tends be addressed using policy from leading governing bodies. Thus, policy is an important aspect of media research, which is discussed further in the next section.

1.1.2. Policy

The prevalence of touchscreens has led to concern about the kind of impact they have on young children's development. While the type of media may be relatively new, concern about children's media use is not a novel phenomenon. Orben (2020) observes that there is a consistent cycle where a new technology becomes popular in children's lives, which is promptly followed by concern about the potential effects. Consequently, policymakers react to the concern by providing guidelines on children's engagement with media and highlighting potential considerations on how and when it should be used.

One organisation that has been extremely influential in policy about children's media use is the American Academy of Pediatrics (AAP). Over recent years, the AAP have published various iterations of guidance on children's media use (AAP Committee on Public Education, 1999; AAP Council on Communications and Media, 2011; 2016). Starting in 1999, they suggested television could have a negative impact on children through the time children spend using media, potentially harmful content, and potential negative health effects. In earlier policy, the AAP also suggested their infamous "2x2" rule, where children under the age of two years should not access any form of screen-based media at all (AAP Committee on Public Education, 2001). Additionally, they suggested that children over the age of two years should limit media use to one to two hours a day. These guidelines were driven by the assumption that the first two years of life are developmentally critical and activities involving direct interaction are more valuable for healthy brain, cognitive, and emotional development. The insinuation therefore was that televisions were not beneficial for children's development and their use should be minimised or regulated as much as possible. The AAP also suggested parents closely monitor children's media use by ensuring the content was educational and encouraging engagement in other pursuits, such as reading and creative activities (AAP, 1999). The AAP re-released the guidelines in 2011 and again emphasised their "2x2" suggestion. However, it was clear that despite the guidelines, caregivers reported that young children were using media regularly (Barr, Danziger et al., 2010; Rideout, 2013). Additionally, McClure et al., (2015) found 85% of parents of 6- to 24-month-olds reported their child had used video chat software, and owing to the positive perception towards its use, saw it is an exception to the guidelines. Additionally, a limitation of the 2011 guidelines was the lack of reference to new technology like touchscreens. Christakis (2014) argued the guidelines could be modified to better reflect technological advancements and exponential increase of touchscreens over recent years. The critical idea Christakis (2014) endorsed was that not all digital technology is equal, and touchscreens could provide features such as reactivity, interactivity, and promote joint attention, aligning them more closely to traditional toys, such as blocks and reading books, than to television. Additionally, touchscreens could offer various play opportunities across different settings and may therefore have a positive role in children's learning and play (Huber et al., 2018).

The 2016 AAP guidelines presented more flexible recommendations, including the removal of the "2x2" rule and addressing touchscreen use (AAP, 2016). The guidelines and accompanying technical report highlighted several areas of concern, including health and developmental risks, the transfer deficit hypothesis, and a lack of truly educational apps for children to use (Chassiakos et al., 2016). However, they also acknowledge the transition from what could be perceived as more passive media, such as television, into more interactive media, such as touchscreens, that blur the boundaries between passive and engaging activities. The main recommendations include no screens for children under the age of 18 months (except for video chatting) and introducing 18- to 24-month-old children to high-quality programming with co-viewing. For children aged between 2 and 5 years, the AAP suggested a maximum of one-hour, high-quality screen time per day. They also emphasise using consistent limits on media use and ensuring it does not disrupt sleep, physical activity, and other behaviours considered important for healthy development. Consequently, though the AAP still adopt a cautionary approach to children's media use, they have also recognised the different opportunities offered by devices such as touchscreens.

While there have been attempts at providing guidance on children's media use in the United Kingdom (UK), they have been limited and arguably not fit for purpose (see Public Health England, 2013). Given that reports published at a similar time showed how younger children used media (Ofcom, 2013; Rideout 2013), the lack of sufficient guidance left a potential gap for UK-based policy on children's media use. A key development in this regard was the introduction of the "Digital 5-a-day" campaign (Children's Commissioner for England, 2017). This provided a simple framework which could be used by children and their families to ensure a balanced and positive approach to using media and the internet. Specifically, it suggested five ways to use the internet constructively; being social, being mindful of use, giving to others, being active and being creative. The campaign also emphasised the importance of engaging in these activities offline, and suggested children could use the internet to facilitate this, for example, learning a new skill from YouTube tutorials or researching sports clubs in the local area. Thus, by not necessarily endorsing restrictions on media use, but instead emphasising balance, moderation, and using the internet in positive ways, the Digital-5-a-day campaign signalled a relatively positive approach to children's media use. However, a gap remained for evidence-based guidance equivalent to the AAP's efforts.

In 2019, the Royal College of Paediatrics and Child Health (RCPCH) introduced formal guidelines for children's media use that could apply to children of any age (Royal College of Paediatrics and Child Health, 2019). Unlike the AAP, the RCPCH do not specify time or age limits for media use. Instead, they suggest that caregivers review whether media use is interfering with key lifestyle factors, such as family time, children's sleeping, and snacking. If they think these lifestyle factors are affected and require addressing, the RCPCH suggest various approaches, including creating and adhering to a media management plan. The lack of age- or time-related thresholds for media use stemmed from an accompanying umbrella review suggesting the evidence was too weak to warrant setting specific limits (Stiglic & Viner, 2019). Additionally, research has found no difference in wellbeing between families who follow the "2x2" rule and those who do not, challenging the necessity of arbitrary time-based guidelines (Przybylski & Weinstein, 2019). Interestingly, the RCPCH also recommend avoiding being judgemental or monitoring media use excessively, highlighting a more holistic and less restrictive perspective compared to the AAP. In contrast, the AAP's approach is cautionary and preventative, where the absence of any evidence indicating positive effects of media use on young children's development is sufficient to consider limiting the activity (Strasburger, 1989). However, the RCPCH also state the evidence base for a direct and negative effect of media use is currently weak and suggest harm can be overstated. Specifically, they state a key issue in the literature is most studies examined television use, with a smaller percentage investigating touchscreens. This is notable as the supporting evidence for the AAP guidelines is limited by its reliance on television-watching studies (Huber et al., 2018). Resultantly, the RCPCH suggests more and higher-quality research is required, particularly with newer media devices like touchscreens, to determine the potential impact on children's development and wellbeing, a sentiment echoed by other researchers (Galpin & Taylor, 2018).

1.1.3 Key elements of children's media use

Several notable elements of children's media use have formed the basis of concerns and subsequent policy. Of note, the displacement hypothesis and transfer deficit hypothesis have been key theories underlying assumptions in policy. Additionally, the content and context of media use has been integral in discussions about media and later policy changes. In the next section, they will each be considered, referring to relevant research where applicable.

Displacement. The displacement hypothesis is a highly influential theory in media research and has been a concern from as early as the 1950s (Maccoby, 1951). It proposes media use supplants other activities, a suggestion directly referenced across different policy documentation (AAP, 1999; 2001; 2016). In developmental psychology, this could be a child watching a television programme instead of engaging in activities considered more beneficial for development, such as play, social interactions, or physical activity. It is this lack of engagement with a beneficial activity that is hypothesised to have negative consequences. Therefore, the insinuation is that media use may have a deleterious effect on children's development because it prevents them from engaging in activities thought to be of more value.

The displacement hypothesis has received marginal amounts of support. The umbrella review conducted by Stiglic and Viner (2019) in support of the RCPCH guidelines suggested there could be some evidence of media use displacing physical activity, though it was relatively weak. Vandewater et al., (2006) observed watching television was negatively associated with interactions with parents and siblings, as well as creative activities. Thus, there is some evidence that theoretically supports the displacement hypothesis. However, despite its popularity, its assumptions are limited. Mutz et al., (1993) provide a thorough consideration of the displacement hypothesis and suggest three key limitations: equivalence, rigidity, and perceived importance of activities. Firstly, they highlight that displacement assumes equivalence, for example, if an hour is spent using media, an hour is lost from a different activity. Equally, an hour less of media use would result in an additional hour gained in a different activity, thus assuming a symmetrical relationship. However, their own findings showed displacement can be asymmetric, where decreased television time was not associated with increased engagement in other activities. Displacement also assumes activities are rigid and finite, where time spent engaging in one activity cannot be spent doing another. However, Mutz and colleagues highlight this assumption cannot account for all differences. For instance, Schmitt et al., (2003) demonstrated that other activities took place while the television was on, suggesting activities can occur simultaneously. Finally, Mutz et al., (1993) discuss the issue of perceived importance of activities. The insinuation of policy citing displacement concerns is that media use is not a beneficial use of children's time and is therefore unimportant compared to other activities (AAP, 2016). However, the advent of educational media content and interactive touchscreen apps may afford children new opportunities to engage in beneficial activities.

Given the ubiquity of media, there may be disadvantages to not engaging with it. An alternative theory to displacement that accounts for this is the Digital Goldilock's Hypothesis (Przybylski & Weinstein, 2017). Based on the fairy-tale where Goldilocks samples porridge that is "too hot", "too cold" and "just right", this theory proposes different amounts of media use could have different effects, specifically that moderate media use may be most beneficial. It stipulates that "overuse" may be a disadvantage and displace other activities and "underuse" may deprive individuals of important information and skills. Thus, media use at moderate levels could be the most balanced option. The data presented in Przybylski and Weinstein (2017) support this notion and showed wellbeing was highest with moderate media use. Additionally, earlier research may support the Goldilocks Hypothesis, where Schmidt et al., (2009) suggested a lack of negative relationships between 3-year-olds' language and media use may be because participants were not exposed to a detrimental amount of media.

In summary, while the displacement hypothesis is theoretically logical in its most basic form, the notion that media use automatically detracts from other activities is too simplistic. The hypothesis makes numerous assumptions that are not necessarily reflected in research observations. Additionally, relying on correlational data limits the ability to make causal conclusions, a critical weakness of displacement theories (Mutz et al., 1993; Vandewater et al., 2006). There is evidence to suggest the relationship between time spent engaging in media and other activities thought to be beneficial for development is asymmetrical. It is also important to consider that in a society where media is abundant, media use may assist with the development of key skills, particularly when considering the diversity of content available.

Content. As briefly noted, a significant rebuttal of the displacement hypothesis could be that media can offer educational opportunities, for example, through television programmes and apps, and therefore has value. A key limitation of previous media research is failing to take different types of media content into account (Christakis, 2004; Courage & Howe, 2010; Schmidt et al., 2009). Kirkorian et al., (2008) highlighted that educational media, such as curriculum-based programmes that aim to teach specific social and academic skills (for instance; language, shapes or numbers), can offer different learning opportunities that children can potentially benefit from. This is further bolstered by the inclusion of "high-quality" content as an acceptable media activity in policy (AAP, 2016). However, it is not a clear-cut concept as media companies can claim that their product is beneficial, for example by improving cognitive outcomes, though there is little empirical evidence to support such claims (Garrison & Christakis, 2005). Therefore, research exploring the potential impact of different content is extremely valuable in enhancing our understanding of how media can affect development.

A key distinction in media content is whether it is child-directed or adult-directed. Child-directed content typically contains features that are appealing to children, for example, colourful characters and accessible and comprehensible delivery of information, particularly in educational content (Anderson, Bryant, et al., 2000; Anderson, Huston, et al., 2001). Adult-directed content on the other hand contains themes that are of interest to adults and faster pacing. Barr, Lauricella, et al., (2010) found high exposure to adult-directed content was associated with poorer cognitive outcomes, including vocabulary, executive function, and school readiness. However, they also observed neutral findings, where child-directed content was neither positively nor negatively associated with cognitive outcomes at 4 years, highlighting the differential impact of content. While there has been some, albeit highly disputed, evidence to suggest child-directed content is not always beneficial (for example, in language; Ferguson & Donnellan, 2014; Zimmerman et al., 2007), other child-directed programmes have been investigated in relation to children's cognitive outcomes. One highly influential and popular educational television programme is *Sesame Street*. Reaching popularity in the 1970s, *Sesame Street* is a programme aimed at preschoolers. It addresses educational concepts, such as the alphabet and mathematics, as well as more sensitive topics such as bereavement, with production being informed by child development theories and research (American Journal of Play, 2019). Its popularity resulted in it being frequently evaluated on whether it achieves the desired learning outcomes. For example, a longitudinal study conducted by Rice et al., (1990) found a positive relationship between watching *Sesame Street* and vocabulary development in 3- to 5-year-olds, though the benefits decreased in 5- to 7-year-olds. In another longitudinal study, Wright et al., (2001) found watching informative programmes such as *Sesame Street* and *Mister Rogers Neighborhood* was positively associated with a range of cognitive skills, including number skills, vocabulary and school readiness, the latter of which was strongest at ages 2 and 3. These studies suggest watching educational child-directed programmes can be beneficial for children's cognition. This could be because information is presented in a comprehensible and engaging format, allowing children to successfully engage with and learn from the programmes (Courage & Howe, 2010; Kirkorian et al., 2008; Wright et al., 2001).

To summarise, content is essential to consider in children's media use research. Different content has been shown to have different influences, particularly regarding how educational content can be beneficial for children's outcomes. Had content not been considered, useful findings such as this would have been missed. Therefore, it is important to look at media use in depth and examine not only the quantity of children's media use, but the content they are engaging with.

Transfer deficit. The transfer deficit has been highlighted as a cause for concern in relation to children's media use (AAP, 2016). This theory suggests young children are not as adept at learning information from 2D sources, such as televisions and touchscreens, and transferring it to equivalent real-world scenarios (Hipp et al., 2017). Additionally, research examining the transfer deficit has suggested children learn better from live social models compared to media demonstrations. It is this lack of ability to learn from screens that has led to policymakers advising against young children using media, or at the very least, having an adult present to provide support when using devices (Chassiakos et al., 2016). Anderson and Pempek (2005) provided a formative discussion of the transfer deficit (or as it was known at the time, the video deficit effect). They outline four areas in which children generally display poorer performance if delivered through video: imitation, object retrieval, language learning, and emotional responses. Several explanations have been offered for the seeming deficit in information transfer between media and other platforms. Hipp et al., (2017) highlight three main areas that may influence children's ability to transfer information between modalities: perceptual factors, such as scale and sensory feedback; social factors, such as contingent interactions, and cognitive constraints, like memory. It is the combination of these factors that may affect children's ability to successfully learn from media.

Context. The 2016 AAP guidelines highlight difficulties with transfer as a reason to limit very young children's media use (AAP, 2016). However, there are certain features which facilitate young children's ability to learn and transfer information between different contexts, for example, scaffolding, interactivity and contingency, and ensuring cognitive load is not too great for the child (Barr, 2013; Hipp et al., 2017; Lovato & Waxman, 2016; Zack & Barr, 2016). One important contextual factor could be co-use, where social interaction during media use can mitigate potentially negative effects of television watching and play an important role in helping children learn from educational content (Mendelsohn et al., 2010; Strouse et al., 2013). Similarly, transfer research investigating children's ability to learn from touchscreens has found young children generally learn better from live interactions compared to watching videos or viewing ghost demonstrations (Moser et al., 2015; Zack et al., 2009; Zimmermann et al., 2017). However, some evidence suggests older children can learn information from touchscreens equally well as face-to-face instruction, provided the relevant information was clear from the outset (Kwok et al., 2016). Additionally, interactional quality has been found to facilitate learning and transfer between different modalities in 15- to 16-month-old children (Zack & Barr, 2016).

Some research has addressed features that can be embedded in touchscreens that could enhance learning. For example, contingency, where interactions are reciprocal, relevant, and appropriate in content, is thought to facilitate learning from media (Roseberry et al., 2014; Strouse et al., 2013). This is important to consider as there may be instances where a social partner is not available to support media use. However, due to their inherently interactive and reactive design, contingency can be embedded directly into a touchscreen activity. Kirkorian et al., (2016) investigated touchscreen interactivity and whether 2-year-olds' word learning through video was influenced by contingent touchscreen experiences. Children watched an individual label several objects and were instructed to either touch the labelled object (specific contingency), to touch anywhere on the screen (general contingency), or they were not given instructions and simply watched the video (no contingency). To test word learning, the experimenter brought out the objects and asked children to select objects according to the labels given in the video. They found younger children (23.5 to 27.5 months) performed significantly better if they were in the specific-contingency condition compared to the non-contingent and general-contingency conditions. Additionally, older children (32 to 36 months) were able to learn words, regardless of condition, with the highest significance levels observed in the contingent conditions. In a separate study, Choi and Kirkorian (2016) used a similar paradigm in an object retrieval task and found younger children performed better in the specific-contingency condition compared to other conditions. These studies have important implications as they showed children can learn from videos and touchscreens without the assistance of a social partner. Additionally, their learning may be enhanced depending on the level of contingency. Specifically, younger children may benefit more from highly contingent instructions compared to older children, who are capable of learning from less contingent experiences.

1.1.4 Summary of young children's media use

To summarise, touchscreen use has increased exponentially among young children over recent years, vastly outpacing research seeking to examine how it affects development. Consequently, little is known about the influence of touchscreens and while there has been some progress, many assumptions made by policymakers rely on knowledge learned from television research. This area has been formative and although there have been observations of negative influences, television watching can be positively related to some outcomes, particularly with child-directed or educational content, highlighting the importance of completing fine-grained analysis of media use. However, the rise of touchscreens means that this research is somewhat outdated. This is particularly true considering that television is largely a non-interactive activity. Conversely, touchscreens are inherently interactive and may offer an entirely different experience to television. Indeed, recent paradigms have shown that factors such as scaffolding and contingency can help children learn from touchscreens. However, there is still much to learn regarding the more general effect touchscreens could have on cognitive skills. One such skill is creative thinking, which is explored in the next section.

1.2 Creativity

Creativity is defined as the ability to produce novel and appropriate ideas (Hennessey & Amabile, 2010). This can manifest in different ways, such as the production of solutions to problems or creating products in response to a need. It is a highly regarded ability, thought to have great societal and economic value, for example, identifying problems and working towards solutions to improve society, productivity and quality of life, or utilising problem solving skills in science, as well as being able to express oneself as part of a culture (Guilford, 1950; Moran, 2010). It is also seen as valuable for individuals when they need to generate ideas and solutions to problems encountered in everyday life (Sternberg & Lubart, 1996). The value of creativity in childhood is also well-recognised, with groups such as the Organisation for Economic Co-operation and Development highlighting it as a skill that allows children to flourish in modern society (OECD, 2015). Additionally, skills associated with creative thinking, such as generating ideas and problem solving, have been promoted in education, including in the early years (Department for Education, 2017), suggesting it has been identified as an important area for development.

Creativity research is a diverse field and has been conceptualised and examined from various perspectives. A well-known theory is the Four Ps of creativity. Rhodes (1961) observed four main clusters of creativity definitions; *person*, which focused on individual characteristics such as personality and attitudes; *process*, which referred to cognitive abilities like thinking and perception; *press* of the environment, where environmental influences such as culture and past experiences are considered, and finally, *product*, where creative ideas become tangible and can manifest in different ways, such as stories, pieces of art and scientific inventions. Rhodes (1961) suggested these strands can overlap with one another, highlighting the complex and multifaceted nature of creativity. Another popular approach has involved big-c and little-c creativity, where there is a distinction between everyday instances of creativity (little-c) and eminent creative output by renowned individuals (big-c) (Kaufman & Beghetto, 2009). Kaufman and Beghetto (2009) also suggested expanding on this with the addition of mini-c, which acknowledges creative potential and the development of creative ideas, and pro-c, which considers creativity in expert and professional contexts. Thus, there a broad range of definitions and perspectives from which creativity can be examined.

In psychological research, creativity can be viewed through different perspectives, including biological, organisational, and cultural approaches (Runco, 2004). The research presented in this thesis takes the cognitive approach, where it is assumed intellectual processes underlie creativity (Hennessey & Amabile, 2010). It is important to note that this is not to say creativity is equivalent to intelligence; while they are moderately related, they are viewed and measured as distinct processes (Wallach & Kogan, 1965). The cognitive approach to creativity can be traced back to the 1950s, where interest in creativity was magnified following Guilford's 1950 Presidential Address at the American Psychological Association (Plucker, 2001). Guilford (1950) viewed creativity as an asset in society but also highlighted it as an under-researched area. He therefore advocated empirical exploration and emphasised the need to understand how to identify and facilitate creativity. Guilford (1956) proposed there were three main processes that broadly represented intellect; cognition factors (used to identify problems and other constructs), production factors (used to generate a response to the problem or construct) and evaluation factors (used to ascertain whether the response is appropriate). Of note are production factors, where Guilford outlines the concepts of divergent thinking and convergent thinking. Guilford defines divergent thinking as a process that can go in various directions, rather than down a singular line of thought (Guilford, 1956). In contrast, Guilford saw convergent thinking as a controlled process directed towards arriving at one conclusion or solution. Guilford viewed these two abilities as distinct entities serving different purposes. However, he also acknowledged that there were instances, such as in problem-solving tasks, where both processes would be used. It is important to note the definition for divergent thinking has evolved over time and is presently viewed as the ability to generate multiple ideas or solutions to a problem (Hennessey & Amabile, 2010). The definition of convergent thinking is largely similar to Guilford's original suggestion and denotes a way of thinking that is characterised by logical and evaluative thought (Cropley 2006; Guilford, 1959). Additionally, both divergent and convergent thinking are still viewed as separate processes, but complementary and reciprocal, where both are necessary for true creativity to be achieved (Cropley, 2006).

Divergent thinking and convergent thinking, as manifested through problem solving, are the focus of this thesis. Over the next section, they will be discussed in greater detail, including how they are measured across different age groups, as well as a brief exploration of factors thought to be related to performance in the described tasks.

1.2.1 Divergent thinking

Divergent thinking centres around the notion of being able to generate multiple solutions or ideas in response to a prompt. It is a useful skill and viewed as an indicator of creative potential, where being able to formulate several potential ideas could lead to greater chances of successful creativity (Runco & Acar, 2012). Guilford identified several factors central to divergent thinking which have translated to indices for divergent thinking measures in contemporary research: fluency, originality, flexibility, and elaboration (Guilford, 1956; 1959). Fluency is defined as the number of unique responses generated in a divergent thinking task. Originality is defined as the 'unusualness' of responses, for example, if a participant gives a response that no other participant gives, it would be considered a statistically infrequent response and classified as highly original. Divergent thinking can also be measured using the indices of flexibility and elaboration. Flexibility indicates the number of different categories of relevant responses, for example, if asked to think of as many round things as possible, high flexibility scores would be awarded if a participant gave responses that could be organised into multiple distinct categories. For instance, if a participant said "basketball, orange, plate", these responses could be organised into three separate categories: sports equipment, fruit, and kitchen items. However, if a participant said "basketball, football, baseball", these responses would be classified into the single category of sports equipment and therefore score lower on flexibility. Finally, elaboration measures the extent to which an idea manifests or how much detail is added to a response. This could be the number of different details added to a painting (Guilford, 1966) or lexical diversity in a story (Kandemirci, 2018). For elaboration, a more detailed response would be awarded a higher score, whereas more simplistic responses result in lower scores. Overall, the indices are intended to capture different aspects of divergent thinking by taking the quantity and quality of ideas into account. The next section describes popular standardised measures of divergent thinking that can incorporate these indices into their scoring schemes.

Measuring divergent thinking

Divergent thinking can be measured with various tasks in different domains such as verbal, figural, and physical tasks. Most tasks have been presented as test batteries, such as the Torrance Tests for Creative Thinking (TTCT; Torrance, 1974, as cited in Kim, 2006) and the Wallach-Kogan test battery (Wallach & Kogan, 1965). Test batteries can include different task domains, for example, the TTCT contains both verbal and figural tasks. Ideally, several tasks, if not an entire battery, would be administered to participants. However, it is not uncommon for researchers to use single divergent thinking tasks, though this can be a limitation as the results may lose generalisability (Runco et al., 2016). Divergent thinking tests can be used with most age groups, but some test features may disadvantage younger participants. Indeed, Wallach and Kogan (1965) specifically outlined a procedure which removed time constraints and encouraged a game-like atmosphere to make their tasks more accessible for children as young as three years. The next section describes divergent thinking tasks in different domains, and how they vary in their suitability for different age groups.

Verbal. One of the most popular verbal measures is the Unusual Uses Task, where participants are asked to generate alternative uses for everyday items (Guilford, 1966; Guilford, 1967, as cited in Hoicka et al., 2018). A common item used in research is a brick and can elicit answers such as building a wall, a paperweight, or a projectile. Other items have included a paperclip or a newspaper. The responses can be coded for fluency, originality, and flexibility, though the indices used may depend on the researcher and the study aims. Another example of a verbal task is the Consequences task or the Just Suppose task, where participants are given a hypothetical scenario which they must generate possible consequences for. For example, they could be asked to describe what the consequences would be if sleep were no longer necessary (Silvia et al., 2008). Here, the index of elaboration could also be used to measure divergent thinking as participants could generate detailed ideas in response to these open-ended and abstract questions, such as exploring the different ways that not needing sleep could potentially have on the economy. The described tasks offer an opportunity to explore ideas in response to abstract and unusual questions. However, these types of questions may be too advanced for younger participants. Given that there is a large gap in understanding how divergent thinking and creativity generally develops, it is important to have accessible tasks for younger age groups. Therefore, Wallach and Kogan (1965) offer a selection of verbal tasks that could be considered as more suitable for young children. For example, the Instances task requires participants to generate ideas for things that fit into certain categories, such as things that are round or that move on wheels. Additionally, the Wallach-Kogan test battery includes the Pattern Meaning and Line Meanings tasks. Participants are asked to generate interpretations of what a set of abstract images might represent. These verbal tasks include visual prompts, which enables participants to refer to the image, rather than relying solely on abstract thought.

Verbal divergent thinking measures have several advantages, including time efficiency, the ability to be administered to large groups simultaneously under exam conditions, and relatively easy scoring using the aforementioned indices. However, there are disadvantages including the reliance on verbal proficiency and representational understanding (Bijvoet van den Berg & Hoicka, 2014). Thus, the tasks may be considered unsuitable for very young children or populations with language difficulties, as it could be assumed that greater verbal proficiency or mastery over language could lead to greater articulation and therefore, higher scores. It is therefore important to consider other divergent thinking domains.

Figural. An alternative method of measuring divergent thinking is to use figural tasks, where participants draw their responses to prompts. Figural tasks are used as part of the Torrance Test of Creative Thinking (Torrance, 1974, as cited in Kim, 2006). For instance, in the Picture Construction task, participants are given a sheet of paper and told to draw something where a given shape, such as a jellybean, is integral to the picture. Another popular task is the Circles task, where participants are given a series of identical circles and asked to draw something that incorporates the circles. They could opt to draw something for each individual circle, such as an apple and an orange, or they could draw something that integrates multiple circles, like a bicycle. This task can be coded for fluency, where the number of unique drawings using at least one circle are counted, and originality, where higher scores are given for more unique drawings (see Piotrowski & Meester, 2018). Additionally, participants can be rated on the originality of their drawing titles, introducing a verbal element to the task (Roskos-Ewoldson et al., 2008).

Overall, figural tasks are useful for tapping into another divergent thinking domain that might not be captured in verbal tasks. This is important to consider as distinctions have been observed between verbal and figural abilities (Baer, 2011). However, even though these tasks could be considered as accessible to most children and adults, there is still a limitation as fine motor skills may be important to success in figural tasks. Since children's drawing skills develop over time (Matthews, 2003), it is possible that young children, such as infants and toddlers, possess neither the motor skills nor representational understanding needed to adequately participate in figural divergent thinking tasks (Urban, 1991). Thus, physical tasks may be an appropriate option for assessing divergent thinking in younger participants.

Physical. The development of physical divergent thinking measures allows children as young as three years to demonstrate this skill as there is less reliance on verbal and fine motor ability. A key example of a physical divergent thinking measure is the Thinking Creatively in Action and Movement (TCAM) battery (Torrance, 1981, as cited in Bijvoet-van den Berg & Hoicka, 2014). Participants are asked how many ways they can move across a room, if they can move like an animal or a tree, what other ways they could put a paper cup in a waste bin, and other uses for a paper cup (similar to the Unusual Uses Task). Indices such as fluency and originality could still be applied to these tasks and thus allow divergent thinking to be measured in a different domain. Using batteries such as the TCAM can offer a richer perspective on divergent thinking as an ability that can manifest in different domains. However, it does rely on instructions, meaning an element of verbal and representational understanding is still required and may therefore be inappropriate for very young participants, such as infants and toddlers. Thus, little is known about the emergence of divergent thinking, as much focus has been on older children and adolescents (Runco, 2004; Urban, 1991). This has left infants, toddlers and young preschoolers largely unaccounted for, as they do not possess the verbal or motor skills required to engage with the tasks.

In response to these issues, Bijvoet-van den Berg and Hoicka (2014) presented and validated a divergent thinking task for toddlers, the Unusual Box Test. In this task, participants are presented with a colourful wooden box that has different features attached to it, including blocks and rings. Participants are video-recorded interacting with the box and a series of five other objects. Participant interactions with the box are coded according to the action completed (for example, hitting, pushing, or jumping) and the specific location on the box where the action takes place (for example, the blocks, the stairs, or the rings). It is also noted if actions take place away from the box or if participants use the whole box to complete an action. The main method of scoring involves the fluency index, where the total number of unique actions are summed, providing a divergent thinking score. Originality can also be used as an index for the

Unusual Box Test, where the statistical infrequency of an action is considered. However, it is important to note that originality was observed as collinear with fluency in this task (Bijvoet-van den Berg & Hoicka, 2014), so may not necessarily add further value to the understanding of divergent thinking in populations using this measure. The Unusual Box Test is an innovative approach to measuring divergent thinking in the early years and can be used with children as young as one year (Hoicka et al., 2016). This presents opportunities to examine how divergent thinking emerges and develops across the lifespan, enriching the understanding of processes underlying creative thinking.

Factors relating to divergent thinking

Age. One factor relating to divergent thinking is age, where there has been interest in how it changes over time. In adulthood, McCrae et al., (1987) found divergent thinking increased until middle age, where subsequent declines in ability were observed. Research has also examined how divergent thinking changes across childhood and adolescence. A seminal example of is Torrance (1968), where the notion of a "fourth-grade slump" in divergent thinking was proposed. The findings showed around 50% of the sample experienced a decline in their divergent thinking scores in fourth grade, or at 9- to 10- years. However, this has been debated. Said-Metwaly et al., (2020) noted inconsistencies in whether the fourth-grade slump is observed in research and conducted a meta-analysis to establish whether it is a reliable finding. They observed a general upward trend of scores, where divergent thinking seemed to increase with age. However, they note this was interspersed with irregularities in scores observed through childhood and adolescence. They did not find evidence of the fourth-grade slump but reported some support for a decline in divergent thinking scores for seventh-grade children (or 12- to 13-year-olds). Said-Metwaly and colleagues (2020) suggest these findings could be for several reasons, including school transitions. This could be supported by research such as Besançon and Lubart (2008), who observed different pedagogical approaches in schools were differentially associated with divergent thinking, indicating a potential environmental influence. Additionally, Said-Metwaly et al., (2020) suggested puberty and associated changes in brain development could affect high-level cognitive functions like divergent thinking. The authors suggested biological and environmental influences could combine and produce changes in thinking, where other cognitive skills, such as reasoning, peak where divergent thinking falls.

In addition to introducing a new measure for toddlers, Bijvoet van den Berg and Hoicka (2014) also examined age-related differences in divergent thinking. They found fluency and originality increased with age in 2- and 3-year-olds. Interestingly, they observed that the lower range of scores stayed relatively stable across age compared to the higher end, which increased with age. They suggested this could be because children can perform a series of basic actions, but as they get older, more actions are added to their repertoire. This could result in more potential actions that can be performed and may also increase the likelihood of more unique actions. Thus, research has demonstrated that divergent thinking is a skill that fluctuates across the lifespan. It could be inferred that while there is some variation, it generally follows an upward trajectory from early childhood until middle age, where declines start to be observed. However, there are other mechanisms besides age that could underlie these changes, including environmental factors.

Social influences. One potential environmental influence is social learning. Hoicka et al., (2016) investigated the relationship between parent and infant divergent thinking. Parents completed the two figural tasks (Incomplete Pictures task and Circles task), while their one-year-old completed the Unusual Box Test. They found divergent thinking in one-year-olds was positively related to parental divergent thinking. One suggestion for the positive relationship was that it could be due to social learning, where if children see their parents exploring the world and acting in a divergent manner, they may imitate their behaviour and explore objects in a divergent way as well. Conversely, if parents do not explore their environment as much, their children may exhibit fewer exploratory behaviours. Relatedly, Hoicka et al., (2018) found that after observing an experimenter model high levels of divergent thinking using the Unusual Box Test, 2-year-olds produced more actions compared to participants who observed low levels of divergent thinking. Collaboration could also be a factor in children's divergent thinking performance. Kandemirci (2018) explored how collaboration could influence children's creativity using a mixture of storytelling measures and divergent thinking measures in 5-to-7-year-olds. They found collaboration led to higher fluency scores (or in this case, longer stories or more drawings) compared to individual performance, but it did not seem to support originality or elaboration. Kandemirci (2018) suggested this could be because of the interests and knowledge of both participants synthesising, resulting in the production of more ideas but not necessarily more detailed or unique ideas.

Play. Russ et al., (1999) examined pretend and imaginative play and divergent thinking with children in 1st and 2nd grade (or 6- to 8-year-olds), who were followed up in 6th and 7th

grade (11 to 13 years). Overall, they found higher quality pretend play was associated with higher fluency scores later. Additionally, imagination was positively associated with both fluency and flexibility. The positive relationship between pretend play and divergent thinking has been supported by more recent work, with Fehr and Russ (2016) demonstrating that pretend play was related to higher divergent thinking scores in 4- to 6-year-olds. Specifically, fluency and originality scores were positively associated with elaboration and organisation in pretend play. Additionally, higher originality scores were associated with pretend play overall, whereas interactions that did not contain any pretend play were negatively associated with originality. This suggests that imaginative thinking and high-quality pretend play may be beneficial for divergent thinking. This could be because children who are better at creating fantasy play scenarios are better able to produce ideas that are also varied in nature, resulting in higher levels of divergent thinking later in childhood.

To summarise, different factors are associated with divergent thinking. Factors that allow participants to learn and incorporate ideas or lead to further exploration and experimentation are beneficial for some aspects of divergent thinking, such as the production of ideas. However, it is important to note that these studies address divergent thinking alone, which is only one component of creative thinking. This is an important consideration, as the popularity of divergent thinking tests has led to some confusion over what they represent (Baer, 1993). Piffer (2012) noted that it is not uncommon for research exploring divergent thinking to label their papers as "creativity", despite only using measures of divergent thinking. Indeed, the popular battery of Torrance Tests of Creative Thinking is labelled as "measures of creative thinking", but only contains divergent thinking measures. As previously discussed, Guilford suggested both divergent thinking and convergent thinking were important processes in creativity (Guilford, 1956). Thus, to focus on a single process and attribute that as "creativity" is problematic. Therefore, the next section discusses convergent thinking in more detail.

1.2.2 Convergent thinking

Divergent thinking has been a popular focus of creative thinking research. However, convergent thinking was also highlighted as an important process in creativity (Guilford, 1956). Convergent thinking is defined as the ability to produce a single solution using logical and analytic thought, particularly in response to clear questions or problems (Cropley, 2006; Guilford, 1956). In contrast to divergent thinking, where the goal is to produce many ideas, the aim of convergent thinking is to arrive at a single idea most appropriate to the task at hand.

Cropley (2006) provided a comprehensive overview of the benefits of convergent thinking and how it interacts with divergent thinking to facilitate creativity. Cropley views convergent thinking as a rational and effortful process that refines and benefits ideas generated through divergent thinking. Operating on the "novel and useful" definition of creativity, Cropley suggested that although divergent thinking allows the production of novel ideas, if left unchecked, it can result in ideas that are neither effective nor useful. He highlights how knowledge can help provide a starting point for creative ideas, allow judgements to be made on the creative merits of an idea and allow the progression or modification of ideas to improve their effectiveness. However, he also highlighted that knowledge can be a disadvantage if based on misunderstanding, misinformation, or if it is just lacking. Additionally, high levels of knowledge could also restrict the ability to produce new and effective ideas. Therefore, a key point from Cropley (2006) is that both divergent thinking and convergent thinking are necessary for creativity but are not individually sufficient for producing effective novelty. Additionally, they are both important processes that underlie creative thinking, particularly in problem solving, as suggested by Guilford (1956). Indeed, Keen (2011) suggests four main processes involved in problem solving: finding the problem, devising and implementing a solution, monitoring its effectiveness, and correcting if necessary. This broadly reflects creative thinking theories, where generating and evaluating ideas results in novel and appropriate solutions. Thus, convergent thinking and problem solving could be seen as similar processes.

Innovation

An important concept that has been linked to convergent thinking and creative thinking generally is innovation. Fundamentally, this describes a process where individuals produce a novel behaviour in response to a problem. This could manifest as a completely new behaviour produced independently, or as a learned behaviour that has been modified to help solve a new problem, or perhaps address an existing problem in a new way (Carr et al., 2016). This definition mirrors aspects of convergent thinking, particularly in producing and evaluating solutions to problems and modifying the behaviour if necessary. Indeed, it could be argued that innovation is a product of creative thinking, however, it is interesting to note that divergent thinking ability is not significantly related to innovation (Beck et al., 2016). Innovation research often manifests through tool use tasks, which are discussed in more detail in the next section. As tool use is not a uniquely human behaviour, innovation can be examined across species, for example comparing innovation in humans against other great apes or corvids (Beck, 2017). If similar behaviours are observed across different species, it could be inferred there are some fundamental biological mechanisms underlying behaviour. Additionally, it can also indicate whether some behaviours are unique to humans, such as using more sophisticated tool use techniques (Hanus et al., 2011; Liebal & Huan, 2012). Thus, innovation is an important behaviour to consider alongside convergent thinking and creative thinking more generally as the underlying processes could be very similar.

The next section discusses popular measures of convergent thinking, as well as measures used to observe similar processes in young children, including innovation studies. Then, there is a brief discussion of factors thought to be associated with convergent thinking.

Measuring convergent thinking

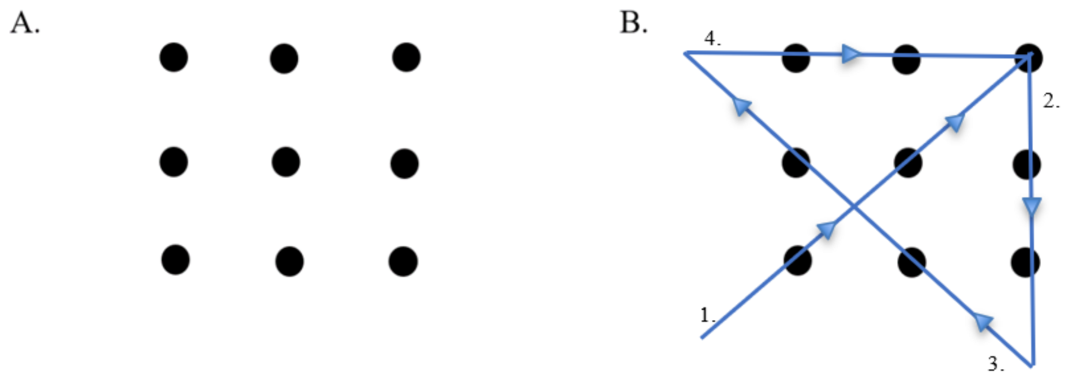
Convergent thinking measures tend to require participants to produce a single solution in response to a given problem. Thus, problem-solving tasks are commonly used in research and can manifest through various domains, including verbal, spatial, mathematical, and physical tasks (Dow & Mayer, 2004). Compared to divergent thinking which can be measured with several indices, one could argue that measuring convergent thinking is somewhat simpler, where success depends on the return of the correct solution and how quickly it is achieved.

A seminal measure for convergent thinking is the Remote Associations Test (Mednick, 1962). Participants are asked to identify a word that correctly links three otherwise unrelated words, for example, “COTTAGE”, “MOUSE” and “BLUE” would be linked by the word “CHEESE”. The underlying idea is that each of the stimulus words have associations with other words and participants must discard irrelevant associations which do not connect all three words to reach the correct answer. For example, “COTTAGE” could be linked with “PIE”, but this would not connect with the other words and should therefore be removed. The Remote Associations Task captures the processes used in convergent thinking, such as making judgements and decisions on the merits of individual ideas and refining them where necessary. It is therefore a well-known measure for convergent thinking and can be used with adults and older children (Howe et al., 2011).

Insight problems are also used to measure convergent thinking. Participants are given a question or problem to solve, however, a key feature of an insight problem is that it primes participants to a familiar but inappropriate solution (Dow & Mayer, 2004). To solve the problem, participants must overcome the prime and generate a novel solution that leads to the correct answer. Therefore, participants must be able to adopt different perspectives to reach the solution. In layman’s terms, this could be viewed as ‘thinking outside of the box’. Insight problems can be verbal, spatial, or mathematical (Dow & Mayer, 2004). The Nine-Dot Problem is an example of a spatial insight problem (Maier, 1930), where participants must connect nine dots using four straight lines, without lifting the pencil off the page (Figure 1). The prime is that the nine dots are displayed in a 3 by 3 formation, thus giving the impression of a square. Consequently, participants often try to solve the problem within the confines of the perceived square. However, the solution involves using the space beyond the dots, thus overcoming the typical pattern of working within a perceived space.

Figure 1.

The Nine-Dot Problem. A) The Nine-Dot Problem as presented to the participant. B) The solution to the Nine-Dot Problem, which requires the participant to use the space outside of the dots to successfully solve the problem.



Convergent thinking in children. Like divergent thinking, it could be argued that some convergent thinking measures may rely on processes that younger children are not yet able to engage in. Therefore, one solution to this issue is to use tool-use paradigms as a method of exploring convergent thinking and problem solving in younger participants. Keen (2011) noted that tool-use can be observed from an early age, for example, when infants are learning to self-feed and correct their grip on a spoon to feed themselves more efficiently. Relatedly, Willats (1999) observed 8-month-olds adjusted their behaviour to pull a cloth over a distance to retrieve a toy, demonstrating infants can engage in means-end behaviours using tools. From there, older children can examine tool characteristics and opt for the most appropriate method to achieve their goal. This can progress into tool modification and tool innovation, where tools are altered or created to achieve a goal. Therefore, tool-use paradigms are a useful way of measuring different levels of children's problem-solving abilities.

Tool-use tasks usually involve a problem scenario, where a participant is given a goal to achieve. The task can be accompanied by a tool that could be used to help achieve the goal or participants may have to make their own tools. Additionally, distractor tools could be used to measure children's ability to evaluate potential approaches (see Holyoak et al., 1984). Adults can also complete tool-use tasks, allowing the trajectory of tool-use and problem solving to be observed across development (Beck et al., 2011). Reindl et al., (2016) devised an effective measure of spontaneous tool use for toddlers. Following observations of tool innovation in great apes (for example, using sticks to fish termites out of mounds), Reindl and colleagues devised a series of tasks based on these behaviours. Participants aged between 2.5 and 3 years were asked to solve a problem, for example, retrieving small stars placed into a box with a narrow opening (to emulate termite fishing). They were given a tool to help them solve the problem but were not directly instructed to use it, instead being left to realise it would be helpful independently. They found that children as young as 2.5 years were able to spontaneously use tools to solve problems and demonstrated that tool-use tasks can be used with toddlers, enabling further exploration of early convergent thinking in young children.

Tool-use tasks can also be integrated into analogical problem-solving paradigms. Here, children are shown a scenario where a character uses a tool to solve a problem (see Chen & Siegler, 2013 or Holyoak et al., 1984 as examples). Participants are then given a comparable problem-solving scenario which they are asked to solve. To correctly solve the problem, they must apply their previously learned knowledge to the new task. In essence, the demonstration should prime participants to select the appropriate tool for the problem, even though the problem-solving scenarios are different. However, this is subject to how well children can transfer information generally, which could be influenced by factors such as age and memory, and thus may not be as appropriate for very young children (Barr, 2010).

In summary, convergent thinking tasks have a similar end-goal; for participants to produce a single solution in response to a problem. However, problems can vary greatly, for example, verbal associations (RAT), adopting alternative perspectives in insight problems, applying analogies and tool-use tasks. Problem-solving tasks such as these have been used across different ages to examine the development of convergent thinking and the factors that might affect these processes. The next section discusses some of these studies in more detail.

Factors influencing convergent thinking

Compared to divergent thinking, convergent thinking has not been explored in detail, thus there is a limited understanding of how it is influenced. However, some research has addressed potential factors that could relate to convergent thinking.

Age. Holyoak et al., (1984) explored children's analogical problem-solving abilities with participants aged from 4-years to 11-years across a range of experiments. They found older children were proficient in analogical problem solving but 4- to 6-year-olds had more difficulty. However, their performance was better if the solutions were clear and the tools needed to solve the problem were perceptually and functionally similar to the original problem scenario. Furthermore, they found superfluous information and greater distance between the example goal and the goal of the presented problem made tasks substantially more difficult for younger children. These findings suggest analogical problem solving improves with age. This could be due to older children being able to draw parallels between two different scenarios and apply the learned information more easily without being distracted. However, it is important to note that the experimenter provided hints if children became stuck. Thus, the level of spontaneous convergent thinking and role of scaffolding could be debated. Beck et al., (2011) offers excellent insight into how tool innovation develops over time. Using a sample of 3- to 11-year-olds, plus an additional group of adults, Beck and colleagues asked participants to retrieve a bucket containing a reward from a bottle. Participants were provided with pipe cleaners, which could be fashioned into a hook to assist with the task. They found tool innovation increased with age. Less than 10% of 3- to 4- and 4- to 5-year-olds were able to make a hook. This increased with age, with 8 years being the key point where most participants made tools to retrieve the reward. This demonstrates tool innovation is a skill that develops with age. The authors suggest that being able to identify the helpful properties of a tool might be a sophisticated ability that feeds into tool innovation and subsequent problem solving.

Cognitive bias. Another factor thought to affect convergent thinking is functional fixedness. This is a cognitive bias where individuals find it difficult to think of ways to use objects that differ from their conventional uses. Additionally, demonstrating a function with an object could mean it is less likely to be used for a different purpose in subsequent interactions (Duncker, 1945). Defeyter and German (2003) explored functional fixedness in 5- to 7-year-olds using a tool-use task. They found 6- and 7-year-olds were less likely to select the target object after seeing the demonstration of its typical use compared to if there was no demonstration. Interestingly, 5-year-olds were unaffected by demonstrations, suggesting they were less susceptible to functional fixedness compared to older children. The authors posit this may be because the younger participants may conceptualise objects differently and see them as a means to achieve a goal. In contrast, older children may see objects in terms of their typical use, reflecting Cropley (2006)'s suggestion that knowledge can sometimes be detrimental in problem solving. Thus, functional fixedness can be a barrier to problem solving for older children, but not for younger children. However, prior exposure to a tool might be beneficial for subsequent tool innovation. For example, Whalley et al., (2017) found that while spontaneous tool use was still challenging for 4- to 7-year-olds, it was improved by interaction with the tool before the test phase. Whalley and colleagues suggest that once children are aware of the solution, they are more likely to be able to successfully innovate a tool and solve the problem. This could suggest that relevant information about a tool or an opportunity to practice can facilitate children's tool innovation to solve problems. This also links to the idea of analogical problem solving where children can learn information from one scenario and apply it to another.

Social learning. Convergent thinking could be affected by social learning as it is a key way for children to gain information (Want & Harris, 2002). Similar to the notion of functional fixedness, it is possible that learned behaviours can affect an individual's ability to generate new ideas to solve problems. For example, Carr et al., (2015) investigated the likelihood of innovation or imitation in 4- to 9-year-olds. They found younger children faithfully imitated adult behaviour with a novel puzzle box, even if the efficacy of the demonstrated actions were low, resulting in lower levels of innovation. However, they also observed that a small proportion of the sample did innovate, and this increased with age, particularly if the demonstration involved a method of low efficacy. Carr and colleagues suggest that in this instance, children prioritised social information, even if the demonstrated behaviour was maladaptive. Indeed, Bonawitz et al., (2011) showed preschoolers were less likely to explore a novel object if an experimenter demonstrated a specific action and informed participants this was how the object worked, which could subsequently affect innovation with novel objects. Thus, social learning could have a detrimental impact on innovation, to the point where inefficient methods might be used in preference to exploration and experimenting with new ideas independently. However, it is also important to note that an individual's learning preference may play a fundamental role in their ability to innovate. Flynn et al., (2016) observed an overall preference for social learning when presented with a novel puzzle box, which led to more efficient problem solving, but less innovation. Interestingly they noted participants over the age of 5 years were equally as efficient if they chose to complete the task independently compared to those who chose to have a demonstration. This suggests children as young as 5 years can make strategic decisions about how to approach a novel task, perhaps indicating this is a key period where individuals are able to identify the information they need to solve problems and act accordingly.

1.2.3 Divergent thinking and convergent thinking

Some developmental studies have combined convergent thinking and divergent thinking. However, this focus has been relatively sparse. As previously mentioned, innovation is important to consider alongside creative thinking and it has been suggested that it could be connected to divergent thinking (Carr et al., 2016). Beck et al., (2016) used a hook innovation task to investigate whether divergent thinking and executive function predicted innovation in 5- to 7-year-olds. Contrary to their hypotheses, divergent thinking and executive function did not predict performance in the hook-innovation task. They suggested that alternative individual characteristics, such as personality traits, may better predict innovation. Another interpretation is that perhaps divergent thinking, executive function, and innovation are separate processes that are not strongly related. Therefore, Beck et al., (2016) supports the notion that divergent thinking and convergent thinking processes are separate constructs.

Other research has found that divergent and convergent activities may facilitate the respective process. For example, Pepler and Ross (1981) found 3- to 4-year-olds who engaged in convergent play employed more strategies in a convergent thinking task. However, they persisted for longer with reasonable but inappropriate strategies. In comparison, participants who engaged in divergent play adopted more flexible approaches and were quicker to switch from ineffective strategies. The authors concluded that both convergent and divergent play can have differential effects on task performance, where convergent play may lead to strategic approaches to problems and divergent play may lead to more flexibility. In a separate study, Lloyd and Howe (2003) found divergent thinking in 4- to 5-year-olds was positively related with active solitary play, such as engaging in pretense alone, which could indicate an association between imagination and divergent thinking. Convergent thinking scores were related to using close-ended objects and using objects in intended and conventional ways. Similar to Pepler and Ross (1981), it is possible that different types of play enhance the respective divergent and convergent thinking skills. Alternatively, children who are better divergent or convergent thinkers play in ways that reflect their skills more. These findings suggest play can have a differential influence on children’s convergent and divergent thinking, again highlighting the two processes as separate entities (Cropley, 2006).

1.2.4 Novelty seeking, curiosity and exploration

An interesting area to consider alongside creative thinking is why an individual might engage in divergent and convergent thinking processes. Three closely related concepts that could explain this motivation are novelty seeking, curiosity, and exploration. Previous research has found that certain personality traits are related to divergent thinking (Batey & Furnham, 2006). These traits can be characterised by a willingness to seek out novelty and engage in new experiences and could be interpreted as novelty seeking and curiosity. Curiosity is generally defined as the motivation to seek out and obtain new knowledge (Carr et al., 2016; Loewenstein, 1994; Litman; 2005). This could apply within a task context or even in relation to hypothetical events (FitzGibbon et al., 2019). Two motivations for curiosity have been suggested; Loewenstein (1994) suggested curiosity is driven by an individual's lack of knowledge and curiosity represents attempts to rectify this deficit. This is acknowledged in epistemic curiosity theories and known as D-type curiosity (Litman, 2008). However, in addition to D-type curiosity, Litman (2008) suggested curiosity can be driven by the joy of discovering new information and making intellectual gains, or I-Type curiosity. In a similar vein, novelty seeking is defined as the propensity to seek out new information and experiences. This relates to the concept of neophilia, where an individual is novelty-oriented and unafraid to engage in interactions with new objects, which could lead to exploration (Carr et al., 2016). Exploration involves engagement and experimentation, which can manifest as exploration of thoughts, beliefs, or physical exploration of the environment (Bonawitz, 2009; Bonawitz et al., 2011). Indeed, physical exploration is a fundamental behaviour that very young children, including infants, use to learn more about the properties of their environment (Bourgeois et al., 2005). This has been applied in research where young children's physical exploration of a novel object is used as an indicator of divergent thinking (Bijvoet van den Berg & Hoicka, 2014).

These three concepts could be seen as similar processes that underlie creative thinking and behaviour. For example, if an individual is highly curious, they may seek out novel experiences which could subsequently lead to exploration of new concepts and ideas. Indeed, Loewenstein (1994) noted it is reasonable to expect positive associations between curiosity and creativity and it has been highlighted as an area of potential interest (Hardy et al., 2017; Piotrowski et al., 2014). Additionally, Batey and Furnham (2006) suggested if an individual engages in more diverse experiences, they may have a wider pool of ideas from which to draw on, which could be beneficial in divergent thinking and convergent thinking scenarios. Furthermore, Carr et al., (2016) proposed a model which emphasised curiosity, novelty seeking, and exploration as potentially important contributors to innovation. They suggest curiosity and novelty seeking can facilitate exposure to behavioural possibilities through exploration, which consequently enhances causal understanding and insight. This facilitates divergent thinking and if a valuable idea is generated, after assessment from convergent thinking, it can be implemented, and a new behaviour innovated. Therefore, curiosity, novelty-seeking and exploration could serve as foundations for creative thinking.

It is important to consider these behaviours as they may lead to interactions where creative thinking is either required or can be facilitated. For example, Bonawitz et al., (2011) found children's exploration was limited after watching an experimenter demonstrate actions. Had this demonstration not occurred, participants may have explored the novel object further and discovered more actions that could be completed with the item. Additionally, demonstrating high levels of exploration led to increased divergent thinking in toddlers (Hoicka et al., 2018). Therefore, exploration, particularly if demonstrated through social learning, could impact on curiosity by way of either dampening it (Bonawitz et al., 2011) or facilitating it (Hoicka et al., 2018). Additionally, Hardy et al., (2017) found that I-Type curiosity was positively associated with creative performance in adults, specifically in terms of solution quality and originality. This is further supported by evidence from comparative research, where higher levels of curiosity in orangutans led to better performance in problem-solving tasks (Damerius et al., 2017). This suggests having a higher desire to seek out knowledge to enhance intellectual understanding may be beneficial for creative thinking overall.

1.2.5 Summary of creativity research

To conclude, the cognitive perspective on creativity has enjoyed sustained interest across the years, particularly in adult samples and research involving divergent thinking. However, both convergent and divergent thinking are crucial to consider, though the processes alone are not sufficient to fully explain creativity. To examine one of the two processes without the other and claiming it is completely representational of creativity would be incorrect (Piffer, 2012). Therefore, examining the two processes together offers a more holistic overview of creative thinking and related factors, such as innovation. Divergent thinking allows the generation of potential ideas that could apply to the presented question; convergent thinking allows the exploration, assessment, and selection of the most appropriate solution (Cropley, 2006). Together, the processes fulfil the generally accepted definition of creativity. Thus, it is important to examine both divergent and convergent thinking to fully understand creativity from a cognitive perspective. It is also important to try and understand the concepts that potentially underlie these behaviours, such as curiosity, novelty seeking, and exploration. The understanding of how divergent and convergent thinking emerge and develop has been limited, yet the introduction of developmentally-appropriate measures has led to progress in this area (Bijvoet-van den Berg & Hoicka, 2014; Keen, 2011; Reindl et al., 2016). There is still much to learn about creative thinking in preschoolers, particularly in how play and interaction with different materials influences creativity and problem solving (Keen, 2011). A potentially critical influence could be media use in the home. Research discussed in this review so far has shown creative thinking can be influenced by factors such as social learning (Bonawitz et al., 2011; Flynn et al., 2016; Hoicka et al., 2018) and play (Fehr & Russ, 2016; Pepler & Ross, 1981; Russ et al., 1999). Today, there are many different opportunities for play, including the use of media, such as televisions and touchscreens (Marsh et al., 2016). Additionally, touchscreens can provide opportunities for social learning, whether that is through co-use with an adult or from in-app directions (Christakis, 2014; Zimmermann et al., 2017) which can facilitate children’s learning from media (Kirkorian et al., 2016; Strouse et al., 2013). Therefore, it is feasible that touchscreens could influence children’s creative thinking.

There are numerous touchscreen applications and devices aimed at children which claim to facilitate cognitive development, including creativity and problem-solving skills (Carrell Moore, 2017). There are also concerns from policymakers that technology could be detrimental to children’s creative thinking skills and exploration. Additionally, because technology has the potential to provide so much content, it may influence children’s desire to seek out new experiences and thus affect their subsequent creative thinking. However, the research base to support the claims of app developers and policymakers is limited. This, coupled with the fact that creative thinking is seen as a valuable psychological asset and that media use among young children has accelerated rapidly while academic research has lagged, makes it an important area for investigation. The intersection of young children’s creative thinking and media use is discussed in more detail in the next section of this literature review.

1.3 Creativity and media use

Media use and creativity are both considered important aspects of young children’s lives. Media use is an area that has created much debate about whether it is beneficial or detrimental to young children’s development, yet there have been increasing amounts of access and use of touchscreens in the home (Ofcom, 2017; 2019a; Rideout & Robb, 2020). Creativity is seen as a valuable skill at an individual and societal level and something that should be cultivated in children’s lives (OECD, 2015; Department for Education, 2017). Despite their respective importance in children's lives, little is known about how these two areas intersect and whether media facilitates or impedes creative thinking, particularly in relation to touchscreens. Thus, the popularity of media use, combined with the uncertainty about its effects, may create dissonance about whether to allow young children to use touchscreens and if so, what apps they could use. This is an important consideration as touchscreens have been recognised by some organisations as a vehicle for developing skills such as literacy and language (Department for Education, 2020). As discussed in the last section, it is feasible that they could benefit creative thinking, making this an essential area for investigation. The following section explores how media use might influence creative thinking. Firstly, different perspectives and policy guidance about media use and creativity are highlighted. Secondly, several key theories about how media use is thought to affect creativity are discussed. Finally, research investigating how creative thinking is associated with different types of media use, such as television-watching, video games, and touchscreen use, is discussed.

1.3.1 Perspectives and policy

Earlier perspectives on children's media use and creative thinking have suggested television has a negative effect on creativity (Singer & Singer, 1990). One explanation is that it disrupts the quiet environment thought to be needed for creativity, therefore limiting the opportunities to engage in creative thought (Calvert, 2015). In contrast, other perspectives suggest a potentially positive role of media in creativity. A report published by the LEGO Foundation suggests parents value children's creativity and play highly, but also recognise that media could offer these opportunities as well (LEGO Foundation, 2018). Additionally, the "Digital-5-a-day" campaign suggested being creative with media, such as playing Minecraft, creating video content, or learning to code, as one way of engaging with media in a healthy and positive way (Children's Commissioner for England, 2017). This echoes previous perspectives that have suggested the influence of media may depend on the type of activities and content being consumed (Courage & Howe, 2010). This aligns with recent research suggesting touchscreens could facilitate creativity by blurring the boundaries between digital and non-digital play (Huber et al., 2018; LEGO Foundation, 2018; Marsh et al., 2018).

The debate on whether media use affects creativity has transcended into policy. The American Academy of Pediatrics (AAP) have consistently stated that media use can be detrimental to children's development (AAP, 2016), which is also extended to creative thinking. Again, adopting a cautionary approach and alluding to the displacement hypothesis, the AAP suggest media use supplants other beneficial activities for development, including creative thinking (Yogman et al., 2018). Additionally, Healey et al., (2019) suggest traditional toys are more desirable as they can promote interactions between caregivers and children, encourage exploration and problem solving, and be progressive in parallel with children's abilities. However, Yogman et al., (2018) and Healey et al., (2019) are limited by a lack evidence to support their claims, particularly in relation to touchscreens. Indeed, many of the relevant studies are based on television research, which could be considered as outdated when considering the affordances of newer media such as touchscreens. Additionally, there has been suggestion that touchscreens could closely resemble real-world play, for example, through interactivity, the promotion of joint attention, and tailorability, particularly in comparison to more passive forms of media such as television (Christakis, 2014). Indeed, it has been suggested that engaging with media is a legitimate form of play (Marsh et al., 2016) and, given the evidence that suggests play is positively associated with divergent thinking (Fehr & Russ, 2016; Russ et al., 1999), it is therefore possible that it could be beneficial for creative thinking.

1.3.2 Theory

Broadly speaking, two main hypotheses about how media use affects creative thinking have been suggested; the reduction hypotheses and the stimulation hypothesis (Valkenburg & van der Voort, 1994). The reduction hypotheses suggest media use is detrimental to imaginative and creative thinking. Conversely, the stimulation hypothesis suggests media use could facilitate creative thinking. These two wide-ranging theories are explored further, discussing the finer-grained hypotheses that constitute the main schools of thought.

Reduction hypotheses

The reduction hypotheses consist of five separate theories that suggest how media use could negatively impact creative thinking; the displacement hypothesis (as discussed on page 7), the visualisation hypothesis, the arousal hypothesis, the passivity hypothesis, and the rapid pacing hypothesis. Valkenburg and van der Voort (1994) provided a comprehensive overview of these theories, which are described in more detail below.

Displacement. Arguably the most widespread belief about how media use affects creativity and cognition more generally is the notion of displacement. As previously discussed earlier in the chapter, displacement suggests media use detracts from time spent engaging in activities that would otherwise be beneficial. It has been a popular theory and has informed policy on children's media use, despite limited supporting evidence and theoretical flaws (AAP, 2016; Mutz et al., 1993). With creativity, it is suggested that engaging in media use means that children are spending less time in other activities that could be beneficial for creative thinking, such as creative pursuits like painting or reading. The displacement hypothesis has received some support (Harrison & Williams, 1986; Vandewater et al., 2006). However, the findings from these studies, which are discussed in more detail later in this section, are not as straightforward as they would appear at face value. Additionally, the displacement hypothesis in relation to creative thinking experiences the same limitations as its relation to other aspects of development, such as the notion of a zero-sum and reciprocal relationship between activities and correlational designs (Vandewater et al., 2006).

Visualisation. The visualisation hypothesis suggests media activities are inherently visual and present ready-made images as part of its content. It is proposed that because individuals do not need to build their own mental images, imaginative and creative thought is impeded. This hypothesis has received some support, where research has observed children produced fewer novel ideas after being presented with information through television compared to other systems, such as radio (Calvert & Valkenburg, 2013; Valkenburg & Beentjes, 1997; Valkenburg & van der Voort, 1994). However, it is important to note that a lack of differences between different media presentations have also been observed (Runco & Pezdek, 1984; Valkenburg & Beentjes, 1997). Thus, while the visualisation hypothesis receives some support, it is not always consistent and the specific mechanisms that do underlie differences in creative thinking are relatively unknown (Calvert & Valkenburg, 2013).

Arousal. The arousal hypothesis stipulates that action-based or violent content could facilitate physical arousal and impulsive behaviours, disrupting the focus needed for creative thinking. It has been suggested that quiet environments are optimal for creative thinking as it allows individuals to reflect and focus on imagining or creating ideas (Calvert, 2015). Therefore, if that quiet, focused space is disturbed, creativity could be negatively affected. However, it is important to note that the arousal hypothesis has not been directly tested in research (Calvert & Valkenburg, 2013). Instead, inferences are made based on indirect assumptions about how media use could affect other aspects of cognition and behaviour, such as arousal. Thus, the merit of the arousal hypothesis is questionable.

Passivity. The passivity hypothesis suggests that because watching television is a low-effort and passive activity, this leads to a passive way of thinking. The lack of mental effort therefore leads to detrimental effects on creativity. Given that creativity tests can be cognitively demanding, it is theoretically possible that adopting a passive way of thinking may be a disadvantage. However, the passivity hypothesis has received little in the way of empirical support and is again a theory-driven hypothesis inferred from indirect and untested assumptions, such as the idea that television-watching is low-effort and this generalises to other activities (Calvert, 2015; Calvert &Valkenburg, 2013).

Rapid pacing hypothesis. This theory suggests that the pacing of television content could affect creative thinking. Specifically, it suggests that production features, such as switching between scenes and fast-paced action, leave little time for reflection on the presented information. As a reflective style of thinking is thought to be beneficial for creativity, it is assumed that television prevents reflection and impairs creative thinking (Singer & Singer, 1990; Calvert & Valkenburg, 2013). The rapid pacing hypothesis is another theory that has received no empirical support (Calvert, 2015). However, indirect support could be inferred from studies that examine the impact of educational programming targeted at young children. For example, Anderson, Huston et al., (2001) found positive associations between watching *Mister Roger's Neighborhood* and later divergent thinking. It had been noted that educational programming contained pauses and slower-paced content, which could allow children to reflect and practice creative thinking skills. However, it is important to note that this could also be due to the content itself, which would contribute to the stimulation hypothesis, rather than the rapid pacing hypothesis.

Stimulation hypothesis

The stimulation hypothesis suggests that media can provide content that children can use in subsequent creative activities or play and consequently indicates that media could be beneficial for creativity (Calvert, 2015). The mechanisms thought to underlie this positive effect include production features, such as pacing and parasocial interactions, and modelling behaviours. As previously discussed, developmentally appropriate production features, such as slower pacing and pauses, may allow children to respond to any questions posed to them via the programme and thus develop cognitive skills (Anderson, Bryant et al., 2000). In terms of modelling, it has been suggested that content can present characters from which children can imitate behaviours (Calvert & Valkenburg, 2013). If the character is demonstrating an imaginative, creative, or problem-solving behaviour, children can learn this behaviour and apply it in other contexts. This is a feasible explanation as previous research has shown modelling high levels of exploration can increase toddler's subsequent exploration (Hoicka et al., 2018). Thus, it is theoretically possible that children watching television characters can learn and apply creative behaviour from media as well.

The stimulation hypothesis has received support from research in varying degrees. Educational content, such as *Sesame Street*, has been positively associated with children's outcomes (Rice et al., 1990). With creative thinking specifically, there have been several studies demonstrating positive outcomes after engaging with educational programming, such as *Mister Rogers Neighborhood* (Anderson, Huston et al., 2001) and *Blue's Clues* (Anderson, Bryant et al., 2000). Additionally, research examining analogical problem solving after watching videos has found that having clearly defined goals in a video allowed 2.5-year-old children to learn and apply problem solving information to real-world contexts (Chen & Siegler, 2013). Thus, there is evidence to suggest television and specifically, educational content can be beneficial for different aspects of creative thinking.

The key theories that have outlined potential ways in which media use can affect creativity have been discussed extensively (Calvert & Valkenburg, 2013; Valkenburg & van der Voort, 1994). It has been theorised that media use has a reductive effect on creativity (Singer & Singer, 1990). While theories such as displacement and visualisation have received some empirical support, others have not been directly investigated so the merit of these theories is questionable. There are also substantial limitations owing to the fundamental assumptions of the theories or a lack of nuance within the research. Specifically, it has repeatedly been highlighted that content is vital to consider when assessing the impact of media use on creativity and the presented theories are no exception (Vandewater et al., 2006). Indeed, support for the stimulation hypothesis centres around media proving appropriate and helpful content. It is important to note the presented hypotheses concern television use and research exploring these hypotheses in relation to touchscreens has been minimal (Calvert, 2015). Theoretically, these hypotheses could also apply to touchscreen use. However, the levels of interactivity present in these devices mean it is plausible that different effects would be observed. The following section considers research that has examined the influence of media use on different aspects of creative thinking, firstly with television, then with touchscreens.

1.3.3 Television and creative thinking

Concerns about the impact of media use on creativity have been driven by television use as it has been viewed as a passive activity that does not provide the optimal conditions for creative thinking (Singer & Singer, 1990). Several studies have investigated how television affects children's creativity. The following section discusses television research that has explored how it impacts on divergent thinking, followed by problem solving.

Divergent thinking

In addition to providing an overview of theories about how media use could affect creativity, Valkenburg & van der Voort (1994) also reviewed research that examined media's influence on creativity. They collated studies that used different methodological approaches including quasi-experimental studies (such as Harrison & Williams, 1986; discussed in more detail below), correlational studies, and experimental studies. Overall, there were mixed findings; correlational studies reported either no significant relationships or negative relationships between television use and creative thinking outcomes. Additionally, studies comparing different media types generally found impeded creative thinking performance after information was presented on a television compared to verbal delivery methods, such as the radio. Overall, Valkenburg and van der Voort (1994) reported that the balance tipped in favour of television having a negative effect on creativity. They suggested that although media can offer enriching content, and thus provide some support for the stimulation hypothesis, the negative effects outweigh the benefits. However, the authors also highlight that a key weakness of the research was that there was little causal evidence. Indeed, many studies correlated total time spent viewing television with task performance, rather than examining finer-grained details such as educational content or manipulating programme features to directly test reduction hypotheses.

In a pivotal, and potentially once-in-a-generation study, Harrison and Williams (1986) used longitudinal methods to examine the effect of introducing television on school-age children in a community who had previously not had access to television. Three North American communities were compared; one community received no television in Phase 1 at the start of the study (Notel), the second community received one television channel (Unitel) and the final community received multiple television channels (Multitel). Notel eventually gained access to television and the communities were revisited two years later in Phase 2 to investigate whether the introduction of television in Notel had any effects on divergent thinking. The key finding was that scores from the Unusual Uses task were significantly higher in Notel compared to Unitel and Multitel in Phase 1. However, their scores decreased significantly between Phase 1 and Phase 2, with older children seeing a significant decline, resulting in no significant differences between the communities. At face value, the findings could show television negatively affected divergent thinking. However, it is important to note there were no negative correlations observed between television watching and divergent thinking, leading the authors to suggest television may have had an indirect effect. One possible explanation could involve displacement, as activities such as book-reading were more strongly correlated with divergent thinking. Therefore, it is possible time spent watching television led to reduced time spent engaged in other activities, which then impacted on divergent thinking. The authors suggested this could be viewed as support for the displacement hypothesis, but also point out there were no significant negative relationships between television-watching and other activities. Without these relationships, a simple displacement explanation is unlikely to be sufficient in accounting for the negative effect. Despite this, Harrison and Williams (1986) conclude television played an inhibitive role in divergent thinking, but the mechanisms underlying the effect were unclear.

The previous studies have generally indicated that television-watching has a negative impact on divergent thinking. However, other studies offer alternative perspectives. Runco and Pezdek (1984) used an adapted version of Torrance's "Just Suppose" task and found no significant differences between children who saw a story on television compared to those who heard a story through radio across all divergent thinking indices. The authors therefore suggest that the short-term exposure to media did not affect subsequent divergent thinking, refuting the visualisation hypothesis. There is also research that has revealed positive associations between media and divergent thinking. Jackson et al., (2012) found significant positive relationships between playing video games and divergent thinking in 12-year-olds, regardless of the type of video game played. Jackson and colleagues suggested video games could satisfy creative needs and so children engage in this activity more. Alternatively, video games could promote creativity because of the rich, stimulating visual content, alluding to the stimulation hypothesis. Indeed, the authors also suggested video games may offer opportunities to develop skills such as problem-solving, persistence, and how to evaluate and potentially re-adjust generated ideas, promoting the idea that some forms of media may be beneficial for creative thinking.

Research has also examined how television content relates to divergent thinking. As part of a comprehensive portfolio of research, Anderson et al., (2001) initially found that total time spent watching television was a negative predictor of divergent thinking in adolescence. However, on further examination, they found that watching informative content at preschool age, such as *Mister Rogers Neighborhood*, was a positive predictor of later divergent thinking, suggesting educational child-directed content can be beneficial. In a separate study, Subbotsky et al., (2010) examined how magical television content affected divergent thinking in 4- and 6-year-olds. Participants completed one pre-test divergent thinking task, then watched either a 15-minute clip from Harry Potter that contained magical content (for example, magic wands being used to perform spells or animals talking) or a clip from the same film that did not contain any magical content. The findings showed no significant differences between pre-test divergent thinking scores. Participants who watched the magical content scored significantly higher on post-test divergent thinking tasks, which was also replicated in a second experiment with 6- and 8-year-olds. The authors suggested the magical content may have facilitated divergent thinking by promoting magical thinking, which they propose allows children to see the world from different perspectives and generate new ideas. These studies demonstrate television content can support children's divergent thinking and may therefore support the stimulation hypothesis.

Problem solving

The rapid pacing hypothesis has been tested in relation to problem solving recently. Rose et al., (2021) investigated whether pacing in a child-directed television programme affected goal-directed problem solving in 3- to 4-year-olds. Participants watched either a fast-paced or slow-paced episode of Postman Pat during a first visit to their home by the experimenter, and the other episode during a second visit. They found no significant difference between problem-solving performance after watching the fast-paced programme compared to the slow-paced program. However, the authors note a trend towards more correct solutions in the problem-solving task after watching the fast-paced programme. Rose and colleagues suggest this could be due to priming, where faster programme pacing led to faster attentional shifts. They proposed this allowed children to switch their attention between blocks faster, thus helping them quickly identify the correct solution and solve more problems in the allotted time. It is also possible that the brief scaffolding that took place prior to the participants completing the task may have aided their performance. The authors conclude that faster paced programmes are not necessarily detrimental to problem solving and may have potential benefits, counteracting the rapid pacing hypothesis.

Educational content has also been examined in relation to children's problem solving. Anderson et al., (2000) examined how *Blue's Clues* affected 3- and 5-year-olds across a series of studies. *Blue's Clues* was a popular television programme targeted at preschoolers and aimed to teach thinking skills using techniques such as audience participation, educational problem-solving games, and positive reinforcement. In a longitudinal study, they found *Blue's Clues* viewers performed better in problem solving tasks. Additionally, caregiver ratings of problem solving for these children also increased over time. The authors concluded that *Blue's Clues* helped young children develop problem solving skills and the benefits were long-lasting and cumulative.

To examine how specific video features affect problem solving, Chen and Siegler (2013) conducted a study examining toddlers' ability to transfer information learned from a video to an analogous problem-solving task. Two- and 2.5-year-olds were assigned to a goal-directed condition or an isolated-action condition. In the goal-directed condition, participants watched a short video of a person dressed in a panda costume attempting to reach an apple, failing, then choosing the most effective tool to reach it (in this case, a cane). In the isolated-action condition, the reaching action was shown without context, removing footage showing the panda's intention and goal achievement. After watching the videos, participants were asked to try and reach a desirable object and had a selection of tools to choose from, with the target tool bearing similar resemblance to the cane seen in the video. The findings showed poorer performance in the isolated-action condition for both age groups. However, older children in the goal-directed condition were more likely to touch the target tool first and complete the task. The results show developmental differences in toddler's ability to transfer problem-solving information from a video into real-world context. Additionally, they demonstrate goal intention and goal achievement may be important in helping toddlers identify and transfer information from video to analogous real-world contexts.

In summary, while initial research might have indicated that television had a negative impact on creative thinking, specifically in terms of divergent thinking, studies have also shown positive associations. This highlights the importance of considering media use in detail, for example, taking specific content into account or examining video features that could support problem solving. However, the presented evidence is limited by its focus on television use and lack of progression to interactive media, like touchscreens (Calvert & Valkenburg, 2013). Media research has found content and features such as contingency to be beneficial for children's cognitive skills. Given the inherently interactive nature of touchscreens, and the potential opportunities for varied content, contingency, and social learning, it is reasonable to suggest they could affect and potentially even enhance creative thinking skills. The next section explores research that has investigated touchscreens and their potential influence on creative thinking, starting with qualitative research and progressing into psychological research.

1.3.4 Touchscreens and creative thinking

It has been suggested that touchscreens and their associated apps could facilitate creativity. Carrell Moore (2017) offered a perspective that suggested open-ended apps, such as drawing or painting apps, could foster children's creativity. They highlighted how different apps, such as drawing, scene creation and digital manipulation apps can encourage children to explore different ideas and experiment in a digital space. Indeed, they also equate activities like drawing apps to traditional pursuits, such as colouring books, showing that fundamentally, apps can offer similar opportunities to real-world activities. Carrell Moore (2017) suggested that carefully chosen apps can present different learning opportunities for children and potentially foster creativity, particularly if children are supported by caregivers or teachers. Thus, some apps have the potential to promote creative behaviours and creative thinking.

Qualitative research

Research examining children's touchscreen use from qualitative perspectives has provided interesting insight into how touchscreens and apps might influence children's creativity. The qualitative findings from Kucirkova et al., (2014) suggested 4- to 5-year-old children used more exploratory talk and engaged in more collaborative problem solving when using story-telling apps and drawing apps compared to construction apps (such as jigsaw apps). They suggested these open-ended apps encouraged situations where children used exploratory questions, built on their peers' suggestions and sought approval when collaborating. Conversely, close-ended apps did not offer opportunities for extended dialogue or critical evaluation. Kucirkova and colleagues also emphasised that apps could support learning and provide an engaging and educational experience, particularly if there is incremental difficulty and scaffolding built into the app that still allows for exploration. Therefore, the authors suggest open-ended apps could be used to facilitate collaboration and creativity**.** Sylla et al., (2014) also explored storytelling with the assistance of touchscreens. They observed that children used both traditional methods of expression, such as drawing, and touchscreens (e.g., taking pictures) together to create a hybrid storybook. This led the authors to suggest that well-designed technology could potentially create environments in which children can be challenged but still encourage their imagination and exploration. Similarly, Arnott et al., (2016) suggested touchscreens offer a medium that young children can express their creativity in. Thus, touchscreens could present an opportunity for young children to explore ideas and consequently develop creative thinking skills.

In a seminal study, Marsh et al., (2018) used a combination of caregiver surveys and ethnographic observational methods to ascertain how touchscreen and app use could influence creativity. The observations taken from a small sample of case studies suggested tablets and apps could promote creativity. For example, children were observed incorporating tablets in non-digital play, thanks in part to their portability. This was a key feature of touchscreens highlighted by Christakis (2014) and this may indicate that the portability of touchscreen devices can facilitate creativity in non-digital settings. Additionally, children were observed engaging in related real-world activities after playing with apps, for example, cooking after using a cooking app. This could suggest that boundaries between digital and non-digital creative play were blurred and perhaps reciprocal, echoing findings from Sylla et al., (2014). However, Marsh et al., (2018) made an important point regarding app design and suggested clear aims, opportunities for parental scaffolding, and repetition of instructions are needed for touchscreens to be beneficial for young children. Taken together, qualitative research shows that touchscreens could offer children opportunities to experiment with new ideas and combine them with other mediums, such as drawing or engaging in pretend play. It is therefore possible that touchscreens could promote creative thinking. The next section discusses research that has examined divergent thinking and problem solving in relation to touchscreen use.

Divergent thinking

There has been some exploration of how touchscreens might influence divergent thinking, though the research is relatively sparse. Piotrowski and Meester (2018) tested whether 8- to 10-year-olds' use of moderately discrepant creative apps (open-ended apps targeted at their age group) could support divergent thinking compared to highly discrepant apps (targeted at preschoolers). They suggested that because children prefer activities that match their ability level, they engage with them more and therefore learn from them. They predicted using moderately discrepant apps would lead to higher divergent thinking scores. However, no significant differences were observed, which the authors suggested could be because touchscreens are suited to near-transfer gains rather than generalised gains. That is, because the commercially available apps were not closely matched to the divergent thinking task (in this case, the Circles figural task), participants did not benefit from them.

In another study, Kandemirci (2018) investigated how storytelling in 5- to 7-year-olds might be affected by touchscreens compared to using a 3D version of the same task using a within-participants design. Participants were asked to roll a set of pictorial dice and create a story from the pictures shown on the cubes. The task was presented with 3D cubes or via a touchscreen app. There was also a control condition where children did not use any tool and were instead asked to tell a free-form story. There were no significant differences between the cubes and app in how creative the subsequent stories were. However, the stories produced in the control condition were rated as significantly more creative compared to the cube and app conditions. Kandemirci (2018) suggests this could be because the participants in the control condition were able to choose their own topics and therefore had no constraints. However, participants in the cubes and app condition had to create a story based on the images that appeared after they rolled the cubes and may have therefore been restricted by the images. The findings suggest storytelling may not benefit from additional tools generally, but it is also important to note that stories produced in the app condition were no less creative than the cube condition. This suggests the app did not impact on storytelling or hinder divergent thinking any more than a 3D version of the task.

Problem solving

Several pieces of research have focused specifically on problem solving and how this might be affected by touchscreen use. Donahue et al., (2013) examined adult performance in a problem-solving task that was presented across different interfaces; either on a touchscreen, via a computer and mouse set-up, or a tangible 3D version of the task. They found that participants took longest to complete trials in the tangible condition compared to the other conditions. However, participants in both the tangible and touchscreen conditions did not need to submit as many attempts compared to the mouse condition. Overall, they observed that participants in the touchscreen condition were as fast as participants using the mouse and nearly as efficient as participants in the tangible condition, suggesting that the touchscreen condition offered the optimal balance between speed and efficiency. This suggests that touchscreens may be a good medium in which problem-solving skills could be developed.

Other studies have explored the effect of touchscreens on problem solving in children and specifically whether they experience a transfer deficit. Huber et al., (2016) investigated how practicing the Tower of Hanoi on a touchscreen affected later performance on a 3D version of the task compared to practicing on the 3D version in 4- to 6-year-olds. Participants were presented with a 3D version of the Tower of Hanoi to complete in the first trial. Then, they either continued using the 3D version for the rest of the session or they received the touchscreen version for two trials and the 3D version for the last trial, testing whether transfer affected performance. They found participant performance improved, regardless of practice modality, where both groups reduced the number of moves needed to complete the task and the time they took for each move. The authors concluded that children were able to transfer their learning from the touchscreen to the 3D modality, and learning problem-solving strategies is not impeded by touchscreens. Tarasuik et al., (2017) sought to replicate Huber et al., (2016) and expand their findings by including 3-year-olds. They repeated Huber et al., (2016)'s materials and procedure, where children had four attempts to complete the Tower of Hanoi, with the final trial being a 3D version of the task after practicing with either the touchscreen or 3D apparatus. The findings showed 3-year-olds did not improve across trials regardless of modality, which the authors suggested could be due to the task being too complex for this age. However, they found that children aged 4 years and over improved from Trial 1 to Trial 4, regardless of practice modality, converging with the findings from Huber et al., (2016). Overall, Tarasuik et al., (2017) serves as a direct replication of the findings observed by Huber et al., (2016) and bolsters the suggestion that children can learn and transfer problem solving strategies from touchscreens.

The studies investigating problem solving and touchscreen use suggest that touchscreens may not have a negative impact on problem solving. Indeed, following research from Chen and Siegler (2013), it appears that children can learn problem solving from touchscreens and apply the information to real-world tasks. This could be due to the desired goals states being clear or the interactive and contingent nature of the devices (Chen & Siegler, 2013; Huber et al., 2016; Tarasuik et al., 2017). As touchscreens inherently require individuals to touch the device to perform an action, it automatically involves them in the process, rather than a passive viewer. Thus, the combination of clear goals and interactivity may allow children to learn problem solving skills from touchscreens.

1.3.5 Summary of creativity and media use research

Taken together, the studies that have examined media use and creativity produce a relatively mixed perspective. There were early suggestions that media use would be detrimental for creativity. However, the evidence for the theories have been limited and perhaps more hypothetical in nature (Calvert & Valkenburg, 2013; Valkenburg & van der Voort, 1994). However, television-watching research can often lack nuance by not taking the type of content into account and therefore miss key observations. In expanding the view of research to address important aspects of media use, such as content and context, it becomes clear that media use may not be as detrimental to creativity as previously thought. For example, some television content can facilitate divergent thinking and young children have been observed learning and implementing problem solving strategies after watching videos. There is also consistent emphasis that goals and instructions should be clear so that children benefit from use. Furthermore, in progressing to touchscreen research, it appears that touchscreens do not necessarily impact on divergent thinking, but the lack of negative effects suggest that touchscreens may not necessarily be detrimental to the generation of new ideas. For problem solving, evidence has shown that children can learn problem solving strategies from touchscreens and apply them to real-world tasks, which could be due to their interactivity. Taken together, the findings suggest touchscreens could have a positive influence on children's creative thinking and this could apply to preschooler touchscreen and app use.

1.4 Thesis Aims

The overall aim of the presented thesis is to explore the extent to which touchscreens may influence creative thinking and behaviour in young children. The research discussed in the literature review demonstrates that media use can have differential relationships and effects on children's development. This can differ based on content, such as educational television programmes, and by the type of media being used, for example, whether it is television- or touchscreen-based. Indeed, some research has demonstrated that touchscreens may be capable of facilitating young children's learning and development through features such as interactivity and contingency. In relation to children's creative thinking, this literature review has demonstrated that different factors can affect children's divergent thinking and problem solving, such as social learning and play. Additionally, it has presented evidence to suggest that media use can have benefits for different aspects of children's creative thinking. As touchscreens are increasingly viewed as a type of play in children's lives and can offer elements of social learning, like interactivity, contingency, and being a potential vehicle for co-use, it is reasonable to suggest that touchscreens may influence young children's creative thinking. Some studies have explored this with older children but there is limited psychological research exploring this proposal in younger age groups. Therefore, this thesis addresses how touchscreen use, including different apps, may influence creative thinking in preschoolers.

The thesis is comprised of three studies which seek to explore how touchscreen use and other activities might relate to different aspects of creative thinking and behaviour, including problem solving, divergent thinking, and novelty seeking. Across the studies, various measurements and designs are used to explore different questions. In each case, the findings from the previous studies inform the approach of the next study.

The first study, discussed in Chapter Two, explores how reported touchscreen use and other activities relate to reported problem solving and novelty seeking in 12- to 47-month-olds. Caregivers completed an online survey asking about their children's activities during the previous day. These responses were correlated with scores from problem solving and novelty seeking scales from the Early Creativity Survey (Hoicka et al., in prep), which asked caregivers about their children's propensity to display these behaviours. This study also included a longitudinal element where caregivers had the opportunity to repeat the survey six months later.

The second study, in Chapter Three, similarly examines the relationship between touchscreen use and different activities but progresses from the first study by using behavioural measures of creative thinking in 24- to 47-month-olds. Participants completed the Unusual Box Test (Bijvoet-van den Berg & Hoicka, 2014) and tasks from the Great Ape Tool Test Battery (Reindl et al., 2016) to measure divergent thinking and problem solving, respectively. Caregivers completed a survey asking about their children's activities, the responses of which were correlated with the creative thinking scores.

Finally, the third study, discussed in Chapter Four, examines how using apps could affect problem solving in 36- to 47-month-olds. Participants either used a problem-solving app that emphasised logical and trial-and-error approaches to problems or an exploration app where they were free to discover different features of scenes. After using the app, participants completed a series of tasks from the Great Ape Tool Test Battery to explore whether using a problem-solving app would facilitate subsequent problem solving. Additionally, a baseline condition, comprised of age- and condition-matched participants from Chapter Three, was used to compare whether app use was better or worse for problem solving compared to not using an app at all.

CHAPTER TWO:

Exploring the relationships between touchscreen use and reported problem solving and novelty seeking in 12- to 47-month-olds

In this chapter, the main aim of the study was to establish whether touchscreen use and associated activities were related to reported problem-solving and novelty seeking behaviour in 12- to 47-month-olds. Caregivers completed an online survey asking about their children's time spent engaged in media-based and non-media-based activities and their propensity to exhibit behaviours relating to problem solving and novelty seeking. Approximately one third of the sample also completed the survey six months later, allowing for longitudinal analyses. The key findings involving touchscreens and apps included higher problem-solving scores being associated with more time spent using learning apps and creative apps. Novelty seeking was also positively related to learning and creative apps. Most of these relationships were not observed longitudinally, however, it was revealed that gaming apps were positively correlated with problem-solving scores six months later. Additional significant relationships were observed with other activities, including independent reading, and watching different types of video content and other media-based activities. The findings were discussed in relation to media content and how the specific features of different activities could influence children's problem solving and novelty seeking.

2.1 Introduction

Touchscreens have become increasingly prevalent in young children's everyday lives, with reports showing that 3- to 4-year-olds' use of tablets at home in the UK increased from 28% in 2013 to 58% in 2018 (Ofcom, 2013; 2018). For even younger children, data from the United States has shown 40% of 0- to 2-year-olds have used touchscreen devices (Rideout & Robb, 2020). Ownership of touchscreen devices has also increased where 24% of 3- to 4-year-olds in 2019 owned a tablet compared to 3% in 2013 (Ofcom, 2013; 2019b). The rapid uptake in these devices led to policymakers, such as the American Academy of Pediatrics (AAP), creating guidance to help caregivers decide whether they should allow their children to use media, and if so, how best to do this (AAP Council on Communications and Media, 2016). The AAP guidelines have been highly influential, though they take a cautionary approach in children's media use. Indeed, a recurring theme is that media use may detract from activities considered to be beneficial for young children's development, consequently having a detrimental impact on their wellbeing and cognitive skills, otherwise known as the displacement hypothesis (Chassiakos et al., 2016). For creative thinking, it is assumed media use diminishes children's opportunities for play and creativity, leading to suggestions that children should avoid media and digital play in favour of other activities perceived to foster creative thinking (Healey et al., 2019; Valkenburg & van der Voort, 1994; Vandewater et al., 2006). Creativity and the cognitive skills associated with it are highly valued across society and seen as a particularly important asset for children (Keen, 2011; Moran, 2010). Thus, the stance adopted by policymakers may be understandable to an extent. Additionally, the issue of media use affecting creativity has been a longstanding theoretical point of contention, with early suggestions of media use such as television having a negative impact on children's imagination and desire to seek out new experiences (Singer & Singer, 1990; Valkenburg & van der Voort, 1994). However, evidence supporting these claims is relatively limited (Calvert & Valkenburg, 2013), which is a critical issue that pervades theories and policies implying media use has a detrimental impact on development (Stiglic & Viner, 2019). When considering new forms of media use, such as touchscreen devices, the evidence is limited even further. However, there is suggestion from qualitative and education research that touchscreens and their associated apps may foster children's creativity (Marsh et al., 2018). Therefore, this study sought to establish whether touchscreen use was associated with problem solving and novelty seeking in 12- to 47-month-olds.

Previous research has examined children's creativity and television use. There has been suggestion that media use is not conducive to facilitating creativity (Valkenburg & van der Voort, 1994). Valkenburg and Beentjes (1997) found 8.5- to 10-year-olds produced more novel ideas after listening to a radio story compared to watching a television story. However, this was not replicated in 6.5- to 8-year-olds, where no significant differences were observed. Other research has also reported a lack of differences. For instance, Runco and Pezdek (1984), found no difference in divergent thinking after 8- to 9-year-olds and 11- to 12-year-olds were presented with a story through radio or television. These studies demonstrate that while there are theoretical concerns about how television may negatively affect creative thinking, the actual influence is relatively unclear and could be considered as somewhat inconsistent. Other studies have found television may have a positive influence. Subbotsky et al., (2010) found 4- to 6-year-olds who watched magical television content performed better on divergent thinking tasks compared to children who watched non-magical content. More recently, Rose et al., (2021) reported a trend that showed 3- and 4-year-olds solved more puzzles correctly in a problem-solving task after watching a fast-paced television programme compared to a slow-paced programme. The authors suggested the fast-paced content may have primed faster attentional shifts, allowing children to quickly switch their attention between task materials and solutions, leading to more puzzles being correctly completed in the allotted time. While a non-significant finding, it suggests fast-paced television may not hinder problem solving and there could be potential benefits. Thus, media content and its presentation may influence subsequent creative thinking.

Research has also examined the longer-term impact of media use on creative thinking. A seminal study conducted by Harrison and Williams (1986) measured children's divergent thinking in a North American community that did not yet have access to television and then compared divergent thinking performance two years after television had been introduced. A key finding from this study was that divergent thinking among 14- to 15-year-olds was significantly lower after the introduction of television. The authors suggested this may be due to an indirect effect of children watching television more than engaging in activities beneficial for divergent thinking. However, a key limitation of this study was that the type of content was not considered. In a separate longitudinal study, Anderson et al., (2001) found watching child-directed educational television content at preschool age, specifically *Mister Roger's Neighborhood*, was a significant positive predictor of divergent thinking in adolescence. This study suggests that educational content may have some long-term benefits for divergent thinking. It also highlights the importance of studying content, alongside other contextual aspects such as co-use, when investigating how media use could influence cognition (Courage & Howe, 2010). Overall, previous research suggests the long-term effect of television on creative thinking is complex and may depend on the type of content consumed. Additionally, short-term effects may also be influenced by content and programming features, such as pacing. However, touchscreens offer opportunities for active media engagement beyond television and, due to their popularity, it is of great interest to explore how they may influence young children's creative thinking, including potential long-term relationships.

Education research has explored the role of touchscreens in children's creativity. Sylla et al., (2014) found school-age children were able to use both an iPad and traditional media, like drawings, to create a storybook that involved digital and non-digital elements, demonstrating that children were able to express their creativity using digital media. A seminal paper in this area is Marsh et al., (2018) who investigated how touchscreen apps may influence creativity in children up to the age of 5 years. By combining a large-scale survey with a small number of detailed case studies, they found apps could lead to a range of play and creativity. For example, playing with a character-based app could lead to later pretend play involving the same characters away from the app. Alternatively, children could create digital content such as photos, music, or scenes in construction-based apps. Additionally, they suggest the degree to which an app facilitates creativity may depend on specific features that make an app age appropriate. For instance, repetition and more forgiving user interfaces, such as the use of larger on-screen buttons that account for children's less precise fine motor control. Overall, this suggests that with careful selection, touchscreens could foster creativity by providing environments that encourage experimentation and exploration (Carrell Moore, 2017; Sylla et al., 2014). However, key limitations of this research include small-scale ethnographic study methods, which while valuable, restrict generalisability. Additionally, creativity was measured by examining what children produced during or after touchscreen use, for example, storybooks or pretend play scenarios. It does not necessarily indicate how the cognitive mechanisms underlying these behaviours are influenced by touchscreens. This is an important consideration because traits such as novelty seeking and curiosity are thought to contribute to exploration and subsequent creative thinking (Carr et al., 2016; Loewenstein, 1994). If individuals enjoy and seek out novelty, they can explore new ideas and enhance their understanding of how things work, which could benefit their divergent thinking, problem solving and innovation (Carr et al., 2016). If media use affects the likelihood of children seeking out and exploring new experiences, this could impact on skills such as divergent thinking and problem solving. Therefore, it is important to understand how media use might influence behaviours foundational for creative thinking, such as novelty seeking.

While laboratory studies involving touchscreens have remained relatively scarce, some studies have used online research methods and revealed interesting insights into children's touchscreen use. A key study that used an online survey to explore touchscreens was Bedford et al., (2016). They asked caregivers of 6- to 36-month-olds to report on their children's touchscreen use, motor ability and language development. They found a significant, albeit weak, positive correlation between fine motor control and the age at which children started to perform more purposeful movements on touchscreens. They suggested touchscreens may have a positive influence on fine motor skills, but also highlighted that children with greater fine motor control may use touchscreens earlier. In another online study, Cristia and Seidl (2015) investigated touchscreen use in 5- to 40-month-olds. They found 58% of children aged between 0 and 24 months had used a touchscreen. Additionally, more purposeful gestures associated with touchscreen use, such as pressing and dragging on-screen objects, increased with age. It is possible these findings may reflect Bedford et al., (2016)'s suggestion, where fine motor skills could be associated with children's propensity to meaningfully engage with touchscreens. Additionally, it could be inferred that with this increase in purposeful gestures, children become more adept and conscious touchscreen users. In summary, online surveys have been successfully used to explore fundamental touchscreen behaviour in young children. Online surveys present several advantages including convenience and allowing larger and potentially more diverse samples to be contacted (Evans & Mathur, 2005). Thus, online surveys are a useful tool to establish early findings about children's touchscreen use and the potential influence they may have on young children's cognitive development. Consequently, the present study uses an online survey to begin exploring relationships between young children's touchscreen use and problem solving and novelty seeking.

To summarise, previous research is limited by a lack of progression from television-watching to other activities such as touchscreen use. Consequently, current knowledge is outdated. It is possible that touchscreens do not provide opportunities to develop creative thinking and therefore have a negative influence, reflecting some previous theories and research (Harrison & Williams, 1986; Valkenburg & van der Voort, 1994). Alternatively, touchscreens may have a positive relationship with creative thinking due to the choice of potential app content and activities that could promote exploration and subsequent creative thinking (Anderson et al., 2001; Carrell Moore, 2017). For instance, Marsh et al., (2018) suggested touchscreens could facilitate creativity by making boundaries between digital and non-digital play less rigid, allowing the continuation of creative play between different mediums. Additionally, their inherent interactivity may create an engaging and stimulating experience, thus enhancing the likelihood of children seeking out, using, and benefitting from touchscreens (Christakis, 2014). The contrasting perspectives on whether media affects creative thinking, combined with the lack of research on touchscreens, means it is essential to establish whether touchscreens influence young children's creative thinking. The current study aimed to explore the relationships between caregiver reports of 12- to 47-month-olds' problem solving and novelty seeking behaviours with touchscreen activities using an online survey. The decision to use children's reported problem solving and novelty seeking behaviours was based on theoretical and practical considerations. Theoretically, novelty seeking is seen as foundational to other aspects of creativity, like divergent thinking, and likely to be related to creativity generally (Carr et al., 2016; Loewenstein, 1994). Problem solving is also seen as an important aspect of the creative process and a particularly important and observable behaviour in young children (Cropley, 2006; Keen, 2011). Thus, measuring these behaviours naturalistically using caregiver report may give insight into mechanisms underlying creative thinking and offer preliminary insight into how media use might relate to this. Practically, the scales used to measure children's novelty seeking and problem solving were of sound validity and reliability and therefore suitable for addressing the research questions (Hoicka et al., in prep). In addition to touchscreen use and app use, other media-based and non-media-based activities were also examined to ascertain whether problem solving and novelty seeking held stronger relationships with these pursuits. It also sought to explore whether there were longitudinal relationships to determine whether some activities may have a longer-term influence over children's problem solving and novelty seeking. Finally, the study provides a brief examination of whether touchscreen use and other media-based activities might displace non-media-activities as suggested by previous research (Valkenburg & van der Voort, 1994; Vandewater et al., 2006).

2.2 Method

2.2.1 Participants

A power analysis showed 191 children were needed to observe a two-tailed small-to-medium correlation (r = .2, α = 0.05, power = .8; Faul et al., 2007). To account for attrition at Time 2, the aim was to recruit three times as many participants as this number, or approximately 600 participants in total. As the survey contained 17 questions about home activities, 212 participants were needed to observe a small effect size in regression analyses with 17 predictors (f^2 = 0.1, α = 0.05, power =.8; Faul et al., 2007). In total, 597 caregivers of 12- to 47-month-old children completed the survey. Four participants were excluded after reporting cognitive or physical disabilities. A further 29 participants were excluded for partial completion of the problem solving and novelty seeking scales at Time 1 (where over half of the questions were missing or "Not Applicable" responses) and an additional 3 participants were excluded for partial completion of the novelty seeking scale at Time 2 (see Missing Values section for more information on this criteria). Thus, at Time 1, the sample taken forward to analyses consisted of 564 participants. Of this sample, 172 participants repeated the survey and were included in Time 2 analyses. The survey was administered between December 2016 and June 2019 using Baby Loves Science, a website where caregivers of 12- to 47-month-old children can fill in surveys to learn more about their child's development. Caregivers who were signed up to Baby Loves Science were emailed to invite them to complete the survey at Time 1. It was also advertised through social media, including paid Facebook advertisements through the Baby Loves Science page. Additionally, volunteers from the Sheffield Cognitive Development research volunteer list were invited to take part in the study via email. For Time 2, caregivers who had completed the survey at Time 1 were emailed again six months later and offered the opportunity to repeat the survey. The survey itself included several other measures of children's behaviour that were not examined in relation to the present research questions, such as social cognition and humour. The survey took approximately 25 minutes to complete in its entirety. The present study focused on the responses caregivers gave to the technology use survey and the problem solving and novelty seeking scales. The descriptive statistics for the sample included in the analyses are described below.

At Time 1, the average age of children was 857.81 days (SD = 295.88) or 28 months 6 days (*SD* = 9 months 22 days), with ages ranging from 12 months to 47 months 24 days. The sample at Time 1 consisted of 281 females and 280 males, and 3 children whose gender was not specified. In terms of ethnicity, information was not disclosed for 153 children (27.1% of the sample). Most children were White (*n* = 378; 67% of sample), followed by children of Mixed ethnicity (*n* = 15; 2.7%), "Other" (*n* = 9; 1.6%), Asian (*n* = 3; 0.5%), Black (*n* = 2; 0.4%) and Arab (*n* = 1, 0.2%). Of those who were of "Other" ethnicity, one respondent elaborated further and described "Pacific Islander" ethnicity. Responses were recorded from 18 different countries. Most respondents were from the United Kingdom (*n* = 463; 82.1%) followed by the United States (*n* = 61; 10.8%), Canada (*n* = 10; 1.8%) and Australia (*n* = 9; 1.6%). Two respondents were from France (0.4%) and the remaining respondents who disclosed country information were from 13 other countries (Antigua and Barbuda, Bangladesh, China, Germany, Hong Kong, India, Ireland, Jamaica, Netherlands, New Zealand, Portugal, Sweden, and Trinidad and Tobago). Six respondents did not disclose country information. Where reported, most caregivers had completed up to a postgraduate level of education (*n* = 163; 28.9%), followed by undergraduate education (*n* = 161; 28.5%), GCSE/ A-Level/ High School equivalent qualifications (*n* = 58; 10.3%) and Community college education (*n* = 21; 3.7%). Education information was not disclosed for 28.6% of the sample (*n* = 161).

At Time 2, the average age of children was 1030.63 days (*SD* = 297.09 days) or 33 months 26 days (*SD* = 9 months 23 days). The sample consisted of 87 female children and 85 male children. Most children were White (*n* = 120, 69.8% of the sample), followed by "Other" ethnicity (*n* = 5, 2.9%) and of Mixed ethnicity (*n* = 4, 2.4%). No further information as provided for those who responded with "Other" ethnicity. Ethnicity information for 44 children (25.6%) was not disclosed. Most respondents who repeated the survey were from the UK (*n* = 127, 73.8%), followed by the USA (*n* = 32, 18.6%). Five respondents were from Canada (2.9%) and three respondents were from Australia (1.7%). Other countries included Bangladesh, China, France, and Portugal. One respondent chose not to disclose country information. Most caregivers had postgraduate education qualifications (*n* = 61, 35.5%), followed by undergraduate qualifications (*n* = 43, 25%), GCSE/ A-Level/ High School equivalent qualifications (*n* = 17, 9.9%) and Community college education (*n* = 9, 5.2%). Caregiver education information was missing for 24.4% of the sample (*n* = 42).

Caregivers gave consent to participate in the study when registering with the Baby Loves Science website. No monetary compensation was offered directly to respondents at Time 1. During the first wave of testing in 2017, a charitable donation of £2 was made on respondents' behalf to UNICEF for each repeated survey. During the second wave in 2019, caregivers received a £5 (or currency equivalent) Amazon voucher for repeating the survey.

2.2.2 Materials

Design

Two dependent variables were examined in this study: problem solving and novelty seeking. These variables are thought to be associated with creativity (Carr et al., 2016; Cropley, 2006; Hardy et al., 2017) and were measured using the Early Problem-Solving Scale and Early Novelty Seeking Scale from the Early Creativity Survey (Hoicka et al., in prep). The independent variables were how much time children spent engaged in different activities at home, including media-based activities such as touchscreen use, app use, and watching video content. Additionally, time spent engaged in non-digital activities, such as reading and creative activities, were considered. These variables were measured using an activities survey created by the research team, which was partially based on questions used in previous surveys (e.g., Marsh et al., 2015, which preceded the publication of Marsh et al., 2018). The surveys measuring the independent and dependent variables are described in more detail below.

Activities Survey

This survey aimed to measure children's engagement in different activities at home, including touchscreen and app use (see Appendix A for full survey). It consisted of three questions asking about children's access to devices, including smartphones and tablet computers. For example, caregivers were asked whether their children had access to a tablet computer at home, if they owned their own device, if they had access to one elsewhere (for example, a grandparent's house) or if they did not have access to this device at all. It also asked about the amount of time children had spent engaging in different activities on the previous day in minutes. The decision to ask about activities from the previous day reflects prior research that used similar phrasing to measure children's media use to potentially elicit more accurate responses (Huber et al., 2018; Rideout, 2016; 2017). It is important to note that while global time estimates are common in children's media research, they are limited by a reliance on caregivers' ability to accurately remember and report patterns of use in a relatively short period of time (Rideout, 2016; Vandewater & Lee, 2009). However, it was felt that the advantages, such as efficiency and gaining potentially more detailed information by asking for specific responses, outweighed the limitations in the context of the current study.

Caregivers were asked about general touchscreen use, watching child-directed video content and non-child-directed video content, which were further separated by independent use and use with an adult. Different types of video content were asked about because previous research has found outcomes can vary based on content, for example, educational child-directed content has been positively associated with language and divergent thinking (Anderson et al., 2001; Rice et al., 1990). Conversely, adult-directed content has been negatively associated with outcomes such as executive function (Barr, Lauricella et al., 2010). Caregivers were asked about independent and joint engagement in different activities as the most recent guidelines from the American Academy of Pediatrics (AAP) suggested media use should be supervised by caregivers (AAP, 2016). Additionally, research has suggested interaction during media use can be beneficial for cognitive outcomes, such as story comprehension and language (Mendelsohn et al., 2010; Strouse et al., 2013). They were also asked about other activities including time spent using learning apps, gaming apps, creative apps, video call software (such as Skype) and using multiple screens simultaneously (for example, watching television while also using a tablet). This allowed touchscreen content to be examined in more detail, as well as taking other media-based behaviours that have been of interest in previous research into account (Rideout, 2017). For example, Roseberry et al., (2014) found toddlers were able to learn from interactions that took place through video call software, therefore making it an important consideration. Finally, caregivers were also asked about the amount of time their child spent engaging in non-digital activities (reading, playing with toys, and creative activities, also separated into independent and shared activities with an adult). These activities were measured to explore whether there were any indications of displacement, where media use supplants other activities (Valkenburg & van der Voort, 1994; Vandewater et al., 2006). Additionally, it was of interest to explore whether creative thinking was associated with non-media-based activities that could be perceived as beneficial (Healey et al., 2019; Yogman et al., 2018).

Early Problem Solving and Early Novelty Seeking Scales

This survey consisted of 21 questions, with 10 questions for the Early Problem-Solving Scale and 11 questions for the Early Novelty Seeking Scale (see Appendix B for all questions). The Early Problem-Solving Scale asked caregivers to rate how much they agreed with statements designed to assess children's problem-solving tendencies, for instance, "My child looks at the mechanisms of how things work, e.g., how wheels are connected to toy cars" and "My child needs help completing simple puzzles". For the Early Novelty Seeking Scale, caregivers rated their agreement to statements designed to assess how much their child enjoys novelty, such as "My child likes watching new television shows more than familiar shows" and "My child likes to look at new books more than familiar books". For both scales, caregivers rated the extent of their agreement on a four-point scale; Strongly Agree, Agree, Disagree or Strongly Disagree. The scale responses corresponded to a value between one to four (for example, Strongly Agree = 1; Strongly Disagree = 4). Reverse scoring was also used for some items, which are highlighted in Appendix B. Caregivers could also choose "Not Applicable" or skip the question if they felt the statement was not relevant to their child, for example, if they do not watch television.

2.2.3 Coding

The overall problem solving and novelty seeking scores were calculated by averaging caregiver responses across the respective scales. Higher scores indicated increased engagement in behaviours related to problem solving and novelty seeking.

2.2.4 Missing values

To address missing values because of caregivers choosing "Not Applicable" or skipping questions, the author consulted with the survey designer to discuss the handling of non-responses. They indicated the survey was designed to be flexible and allow caregivers to choose "Not Applicable" or skip the question if they felt it was not relevant to them and still be included in the analysis. It was therefore decided that instead of using Complete Case Analysis or using multiple imputation to fill in missing values, a threshold would be required to establish an 'acceptable' number of cases with missing values (Pichette et al., 2015). This would allow distinctions between cases to be included in the analyses and those who would be excluded. After discussion, it was decided that cases where over 50% of responses were missing values (six out of ten items for the problem-solving scale and six out of eleven items for the novelty seeking scale) would be removed from the final dataset in preparation for analyses. A Missing Values Analysis was conducted to accurately identify cases where the agreed 50% threshold was exceeded (de Leeuw & Hox, 2008). Twenty-nine respondents were identified and excluded from the subsequent analyses for Time 1 (n = 13 for both scales, plus an additional n = 7 for problem solving, n = 9 for novelty seeking). Additionally, three further respondents were removed for not reaching the 50% threshold for the novelty seeking scale at Time 2. Thus, the final sample size for Time 1 was 564 and the final sample size for Time 2 was 172. In the remaining sample, 74% of respondents had completed all ten items in the problem-solving scale and 57% of respondents completed the eleven items in the novelty seeking scale. Some cases contained missing values, where the majority had one or two missing values (22% for problem solving and 35% for novelty seeking). Then, there was a relatively small proportion of respondents who had more than three missing values (4% for problem solving, 8% for novelty seeking). However, to assess the potential reliability for the scales had all respondents completed them fully, multiple imputation was used to substitute missing values and then Cronbach's alpha was calculated, the results of which are reported below.

Scale reliability. Multiple imputation was used to substitute missing values. As scale reliability uses listwise deletion of cases, multiple imputation was used with the aim of maximising the number of cases that would contribute to Cronbach's alpha (Béland et al., 2016; Rubin, 1976). Reliability for the problem-solving scale was acceptable (original α = .672; pooled α = .679) and the reliability for the novelty seeking scale was also acceptable (original α; .748; pooled α = .661) (Lance et al., 2006; Taber, 2018).

2.3 Results

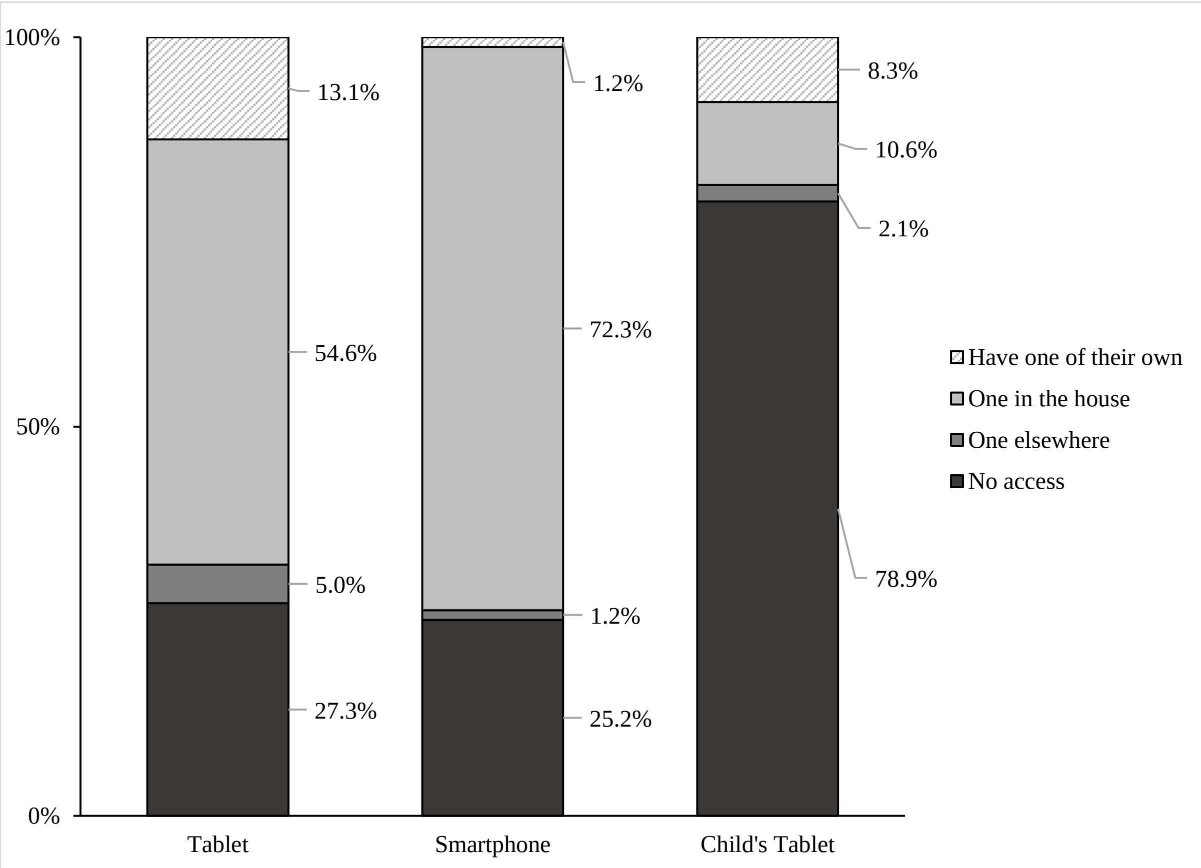
Firstly, results from Time 1 analyses are presented, which examined the relationships and predictive value of home activities on problem solving and novelty seeking. Secondly, the results of Time 2 analyses are presented, with the primary aim of examining whether home activities at Time 1 related to problem solving and novelty seeking at Time 2. Next, analyses exploring potential directionality in observed correlations (by examining relationships between activities at Time 2 and problem solving and novelty seeking at Time 1) are reported. Finally, correlations between media-based and non-media-based activities at Time 1 are reported to briefly consider the displacement hypothesis.

2.3.1 Relationships between activities, problem solving and novelty seeking at Time 1

Creative thinking and device access. At Time 1, the average score for reported problem solving was 2.82 (*SD* = .41, CIs = 2.10, 3.50). The average score for reported novelty seeking was 2.15 (*SD* = .33, CIs = 1.64, 2.73). Figure 2 illustrates the proportion of device access across the sample. Of the 564 respondents, over half the children had access to a tablet in the house and over a quarter did not have access to a tablet at all. For smartphones, most children were able to access one in the house compared to a quarter of the sample who did not have access to a smartphone at all. Most children did not have access to a children's tablet, though a relatively small proportion were able to access one in the house and 8.3% had their own device.

Figure 2.

Percentage of children's access to different touchscreen devices at Time 1 (n = 564).



Activities. Table 1 displays the average time spent engaging in different activities at Time 1. The reported standard deviations, skewness, and kurtosis represent clear non-normal distributions regarding time spent engaging in different activities at home (Field, 2013; Tabachnick & Fidell, 2014). Therefore, bootstrapping was applied to the subsequent analyses to account for the non-normality of the data (Wright et al., 2011).

Table 1.

Descriptive statistics for reported time spent in minutes engaging in different activities during the previous day at home at Time 1.

Activity	M	Med	SD	Range	S	K
Touchscreen use (independent)	10.24	0	27.95	0 - 360	6.04	55.57
Touchscreen use (with an adult)	10.24	0	21.22	0 - 240	4.77	35.62
Learning apps	6.35	0	14.68	0 - 200	5.92	60.75
Gaming apps	1.59	0	6.49	0 - 60	5.68	39.29
Creative apps	2.10	0	6.38	0 - 60	4.21	22.32
Child-directed video content (independent)	21.38	0	37.14	0 - 360	3.55	19.59
Child-directed video content (with an adult)	35.18	30	46.17	0 - 600	4.52	42.89
Non-child-directed video content (independent)	1.97	0	10.69	0 - 120	7.56	67.02
Non-child-directed video content (with an adult)	8.37	0	21.46	0 - 180	3.60	15.88
Video call use	3.46	0	8.50	0 - 60	3.21	11.41
Multiple screen use	2.67	0	11.70	0 - 120	6.70	53.26
Reading (independent)	11.14	8	15.04	0 - 120	3.11	15.88
Reading (with an adult)	24.59	20	23.06	0 - 360	5.95	78.89
Playing with non-digital toys (independent)	76.45	60	69.33	0 - 480	2.13	6.34
Playing with non-digital toys (with an adult)	74.55	60	75.06	0 - 600	2.41	8.70
Creative activities (independent)	12.67	5	22.70	0 - 300	5.64	53.80
Creative activities (with an adult)	21.28	15	27.70	0 - 300	3.37	21.73

Note. M = Mean, Med = Median, SD = Standard Deviation, S = Skewness, K = Kurtosis.

Time 1 Correlations

Age. There was a significant positive relationship between child age in days and problem solving at Time 1 (r (562) = .456, p < .001). Both age and problem solving were also positively related to several home activities, including time spent using learning apps, gaming apps and creative apps, as well as engaging in creative activities both independently and with an adult (*p*s all <.001; see Appendix C for full table). Consequently, it was decided that bootstrapped partial correlations controlling for child age should be used to investigate further relationships between home activities and problem solving. In contrast to problem solving, age was not significantly related to novelty seeking at Time 1 (r (562) = .006, p = .882). Therefore, it was decided that partial correlations controlling for age would not be necessary to analyse the relationships between novelty seeking and home activities. Table 2 displays all bootstrapped correlations and, where appropriate, bootstrapped partial correlations between home activities and problem solving and novelty seeking at Time 1.

Problem solving. Of note, Table 2 shows that when age is controlled for, there were significant positive correlations between problem solving and touchscreen use with an adult, time spent using learning apps, creative apps, and independent reading. No significant negative correlations were observed.

Novelty seeking. Significant positive relationships were observed between novelty seeking and time spent using touchscreens independently, learning apps, and creative apps. It was also positively correlated with watching non-child-directed video content independently and using multiple screens simultaneously. No significant negative relationships were observed.

Table 2.

Bootstrapped Pearson's correlations between problem solving, novelty seeking and activities at Time 1. Confidence intervals based on 1000 bootstrap samples.

	Problem Solving				Novelty Seeking			
Activity	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Touchscreen use (independent)	.076 (.008)	.070 (.844)	-.005 (-.067)	.168 (.098)	.083*	.050	-.011	.172
Touchscreen use (with an adult)	.101* (.088*)	.017 (.036)	.045 (.024)	.167 (.149)	.045	.286	-.037	.137
Learning apps	.171** (.127**)	.000 (.003)	.105 (.049)	.230 (.196)	.105*	.013	.004	.229
Gaming apps	.071 (.008)	.093 (.841)	.001 (-.060)	.151 (.078)	.076	.073	-.064	.196
Creative apps	.164** (.113**)	.000 (.007)	.095 (.035)	.225 (.186)	.128**	.002	.021	.227
Child-directed video content (independent)	.081 (-.049)	.054 (.248)	.004 (-.116)	.158 (.034)	.029	.496	-.059	.113
Child-directed video content (with an adult)	-.026 (-.046)	.531 (.275)	-.138 (-.158)	.063 (.045)	-.019	.645	-.139	.101
Non-child-directed video content (independent)	.037 (.026)	.381 (.541)	-.047 (-.027)	.110 (.076)	.142**	.001	.062	.208
Non-child-directed video content (with an adult)	-.061 (-.043)	.147 (.310)	-.142 (-.126)	.015 (.038)	.050	.234	-.039	.137

Note. Values in parentheses are from bootstrapped partial correlations controlling for age.; CI (L) = lower 95% confidence interval; CI (U) = upper 95% confidence interval. * $p < .05$. ** $p < .01$.

	Problem Solving				Novelty Seeking			
Activity	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Video call use	-.067 (-.006)	.113 (.892)	-.165 (-.099)	.028 (.092)	.010	.813	-.074	.093
Multi-screen use	.069 (.031)	.102 (.468)	-.004 (-.033)	.141 (.093)	.133**	.002	.026	.222
Reading (independent)	.108** (.130**)	.010 (.002)	.023 (.041)	.194 (.216)	.016	.696	-.093	.126
Reading (with an adult)	.025 (.017)	.551 (.679)	-.040 (-.056)	.120 (.105)	.009	.823	-.063	.082
Non-digital toys (independent)	.080 (.046)	.058 (.272)	-.001 (-.042)	.159 (.136)	-.042	.320	-.141	.059
Non-digital toys (with an adult)	.010 (.078)	.807 (.066)	-.083 (.001)	.099 (.156)	.008	.857	-.079	.089
Creative activities (independent)	.137** (.078)	.001 (.065)	.077 (.017)	.210 (.142)	.064	.129	.001	.137
Creative activities (with an adult)	.122** (.079)	.004 (.060)	.058 (.001)	.187 (.151)	-.029	.497	-.107	.049

Note. Values in parentheses are from bootstrapped partial correlations controlling for age.; CI (L) = lower 95% confidence interval; CI (U) = upper 95% confidence interval. * $p < .05$. ** $p < .01$.

Time 1 Regressions

To investigate which variables best predicted problem solving and novelty seeking, bootstrapped hierarchical regression analyses were used. Data was checked for heteroscedasticity, but no evidence was found for it. Thus, hierarchical regression with simple bootstrapping was used. Table 3 shows a summary of regression analyses for problem solving and Table 4 shows a summary of analyses for novelty seeking.

Problem solving. Age was entered into the model at Step 1 and home activities were entered at Step 2 in order relationship strength observed in partial correlations, where the strongest relationships were entered first. Table 3 summarises the overall findings from this model. At Step 1, the overall model was significant and explained 20.8% of the variance in problem solving (F (1, 562) = 147.151, p < .001). Age was a significant positive predictor of problem solving at both Step 1 and Step 2. The overall model at Step 2 was significant and explained 26.2% of the variance (F = (18, 545) = 10.731, p < .001). The addition of survey variables represented an increase of 5.4% variance explained, which was a significant contribution to the model (F (17, 545) = 2.352, p = .002). At Step 2, independent reading and learning apps were significant positive predictors of problem solving. Negative predictors were also observed, where watching child-directed video content with an adult and independent touchscreen use were significant negative predictors of problem solving.

Novelty seeking. As age was not a significant correlate of novelty seeking, it was not used in the regression model. Instead, home activities were entered into the model in order of relationship strength observed in the bootstrapped correlations. At Step 1, the model was significant and explained 5.2% of variance in novelty seeking, (F (17, 546) = 1.753, p = .031). As shown in Table 4, the only significant predictor observed in the model was watching non-child-directed content individually, which was a positive predictor of novelty seeking.

Table 3.

Bootstrapped hierarchical regression analysis of predictors of problem solving with 95% confidence intervals reported. Confidence intervals and standard errors based on 1000 bootstrap samples.

Step	Predictor	*B*	*95% CI (L)*	*95% CI (U)*	*SE B*	*β*	*p*
Step 1	(Constant)	2.274	2.178	2.364	.048		.001
	Child age	.001	.001	.001	.000	.456**	.001
Step 2	(Constant)	2.219	2.095	2.332	.059		.001
	Child age	.001	.001	.001	.000	.463**	.001
	Reading (independent)	.003	.001	.006	.001	.105*	.018
	Learning app	.002	.000	.005	.001	.087*	.037
	Creative app	.006	.000	.012	.003	.088	.060
	Touchscreen (with an adult)	.001	.000	.003	.001	.059	.076
	Creative activities (with an adult)	.001	-.001	.002	.001	.042	.322
	Creative activities (independent)	.000	-.001	.002	.001	.024	.526
	Toys (with an adult)	.000	.000	.001	.000	.071	.065
	Child-directed video content (independent)	-.001	-.002	.000	.001	-.078	.104
	Toys (independent)	.000	.000	.001	.000	.026	.538
	Child-directed video content (with an adult)	-.001	-.002	.000	.000	-.093*	.034
	Non-child-directed video content (with an adult)	-.001	-.002	.001	.001	-.032	.377
	Multi-screen use	.001	-.002	.004	.001	.029	.451
	Non-child-directed video content (independent)	.001	-.002	.004	.002	.028	.469
	Reading (with an adult)	-.001	-.002	.001	.001	-.038	.249
	Touchscreen (independent)	-.001	-.003	.000	.001	-.080*	.042
	Gaming app	-.002	-.006	.003	.002	-.030	.402
	Video call software	-.001	-.005	.003	.002	-.019	.674
DV	PS	R^2 = .208** for Step 1; ΔR^2 = .054** for Step 2					

Note. PS = problem solving; DV = dependent variable. 95% CI (L) = lower 95% confidence interval; 95% CI (U) = upper 95% confidence interval. * $p < .05$, ** $p < .01$.

Table 4.

Bootstrapped hierarchical regression analysis of predictors of novelty seeking with 95% confidence intervals reported. Confidence intervals and standard errors based on 1000 bootstrap samples.

Step	Predictor	*B*	*95% CI (L)*	*95% CI (U)*	*SE B*	*β*	*p*
Step 1	(Constant)	2.139	2.079	2.206	.033		.001
	Non-child-directed video content (independent)	.003	.000	.006	.001	.098*	.013
	Multi-screen use	.002	-.002	.005	.002	.062	.286
	Creative app	.005	-.002	.011	.003	.093	.114
	Learning app	.002	-.001	.006	.002	.069	.339
	Touchscreen (independent)	.000	-.002	.001	.001	-.018	.794
	Gaming app	.000	-.007	.008	.004	.007	.936
	Creative activities (independent)	.001	-.001	.002	.001	.064	.183
	Non-child-directed video content (with an adult)	.001	-.001	.002	.001	.043	.387
	Touchscreen (with an adult)	.000	-.002	.001	.001	-.015	.727
	Toys (independent)	.000	-.001	.000	.000	-.078	.172
	Child-directed video content (independent)	.000	-.001	.001	.000	-.013	.793
	Creative activities (with an adult)	-.001	-.002	.000	.001	-.051	.277
	Child-directed video content (with an adult)	.000	-.001	.000	.000	-.047	.372
	Reading (independent)	.000	-.003	.003	.001	-.015	.811
	Video call software	.000	-.003	.004	.002	.007	.892
	Reading (with an adult)	.000	-.001	.002	.001	.019	.627
	Toys (with an adult)	.000	.000	.001	.000	.066	.168
DV	NS	R^2 = .052* for Step 1.					

Note. NS = novelty seeking; DV = dependent variable. 95% CI (L) = lower 95% confidence interval; 95% CI (U) = upper 95% confidence interval. * p < .05, ** p < .01.

2.3.2 Relationships between activities, problem solving and novelty seeking at Time 2

Data was analysed for 172 participants who completed the survey at Time 1 and Time 2. Firstly, the descriptive statistics for the creative thinking measures and device access are reported below. Table 5 shows the average time spent engaging in different activities at Time 1. Secondly, bootstrapped correlations and appropriate partial correlations are described and summarised in Table 6. Thirdly, bootstrapped hierarchical regression analyses were used to investigate whether home activities at Time 1 predicted reported problem solving and novelty seeking at Time 2, the findings of which are displayed in Tables 7 and 8. Finally, bootstrapped correlational analyses were run between Time 1 problem solving and novelty seeking and Time 2 activities, summarised in Table 9. The assumption behind these analyses were that if significant relationships were observed, this could indicate an influence of children's earlier problem solving and novelty seeking behaviours on their engagement in activities later.

Descriptive statistics. The average age of the sample at Time 1 was 850.24 days (*SD* = 296.97 days) or 27 months 28 days (*SD* = 9 months 23 days). At Time 2, the average age of the sample was 1030.63 days (*SD* = 297.09 days) or 33 months 26 days (*SD* = 9 months 23 days). The average problem-solving score at Time 1 was 2.85 (*SD* = .44, CIs = 2.10, 3.56). At Time 2, this was 3.01 (*SD* = .43, CIs = 2.30, 3.70). The average novelty seeking score at Time 1 was 2.13 (*SD* = .31, CIs = 1.66, 2.65) and 2.18 (*SD* = .36, CIs = 1.68, 2.91) at Time 2.

Device access. Figure 3 shows device access at both time points. At Time 1, most of the sample had access to a tablet at home, and just under a quarter of the sample did not have access to a tablet at all. At Time 2, the percentage of those with access to a device elsewhere and those who did not have access remained the same. There was a decrease in the proportion of children who had access to a tablet at home, which was mirrored by an identical percentage point increase in children who owned their own tablet, which may suggest children were moving towards owning devices rather than sharing them. For smartphones, at Time 1, most children were able to access a smartphone in the home, while a quarter did not have access to this device and these figures were similar at Time 2. For children's tablets, most of the sample did not have access to this device at Time 1 and this was consistent at Time 2. However, a noticeably larger proportion of children owned a device at Time 2.

Figure 3.

Percentage of children's access to different touchscreen devices at Time 1 and Time 2 (n = 172).

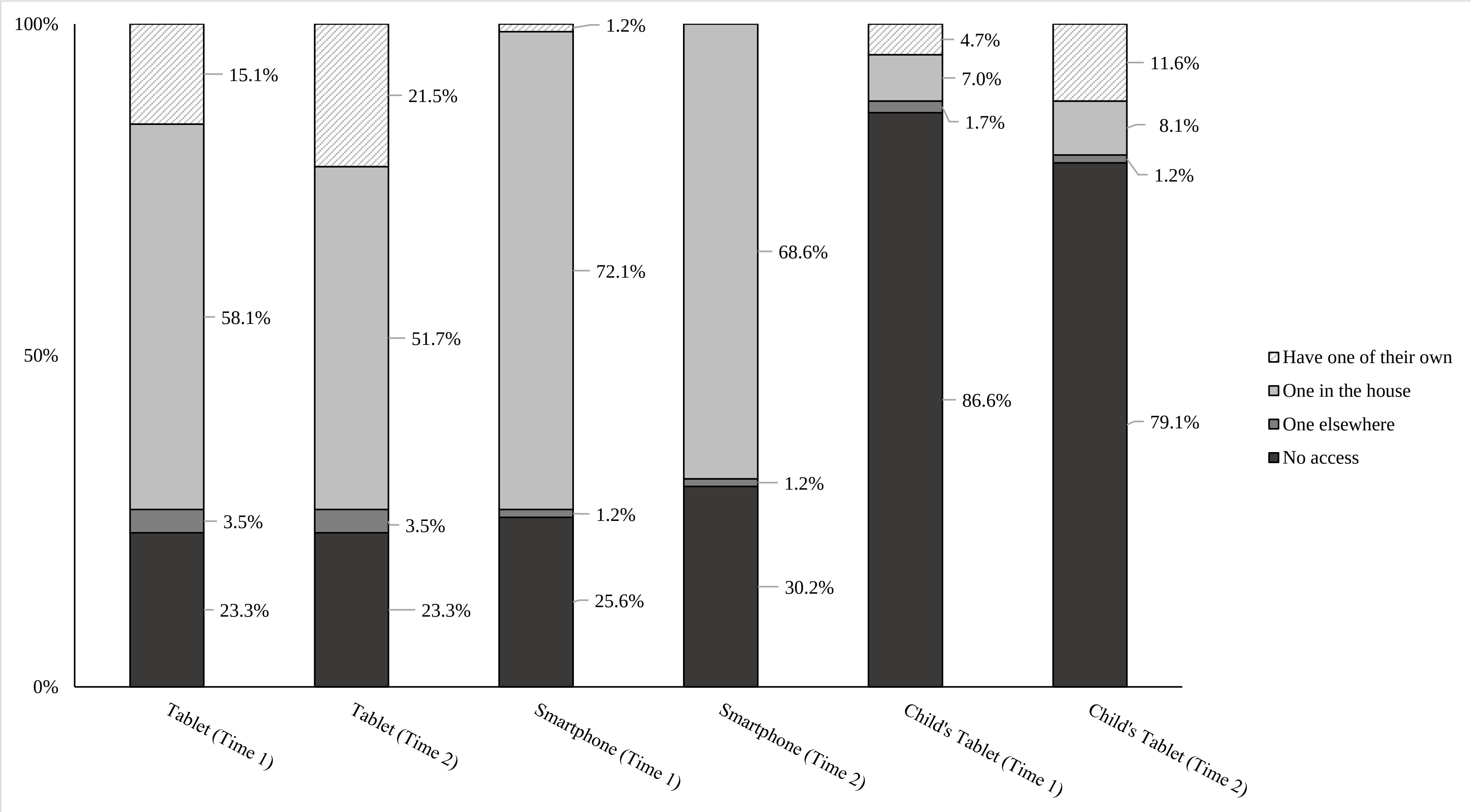


Table 5.

Descriptive statistics for reported minutes spent engaging in different activities during the previous day at home at Time 1 and Time 2.

Activity	Time 1						Time 2					
	M	Med	SD	Range	S	K	M	Med	SD	Range	S	K
Touchscreen use (independent)	8.59	0	24.30	0 - 240	6.08	50.26	11.60	0	22.57	0 - 120	2.60	7.41
Touchscreen use (with an adult)	9.93	0	20.37	0 - 180	4.45	29.50	12.56	0	29.86	0 - 300	6.56	55.47
Learning apps	6.58	0	18.23	0 - 200	7.44	74.48	8.04	0	18.22	0 - 180	5.83	48.28
Gaming apps	1.13	0	6.05	0 - 60	7.14	58.82	2.15	0	8.40	0 - 60	5.14	29.08
Creative apps	1.67	0	6.62	0 - 60	6.03	43.15	1.58	0	5.09	0 - 30	4.02	17.50
Child-directed video content (independent)	18.19	0	29.66	0 - 180	2.81	10.48	20.76	10	30.60	0 - 240	3.01	15.38
Child-directed video content (with an adult)	37.89	30	59.42	0 - 600	5.77	48.95	26.37	20	29.54	0 - 180	1.67	4.17
Non-child-directed video content (independent)	1.63	0	8.44	0 - 60	5.73	33.64	1.05	0	5.86	0 - 60	7.61	66.54
Non-child-directed video content (with an adult)	8.39	0	20.99	0 - 120	2.94	8.92	6.20	0	15.66	0 - 90	2.90	8.48
Video call use	3.40	0	8.10	0 - 60	3.42	15.63	3.21	0	7.97	0 - 60	3.77	18.41
Multiple screen use	1.98	0	9.30	0 - 90	6.90	55.91	1.89	0	10.49	0 - 120	9.00	95.77
Reading (independent)	11.69	10	15.94	0 - 120	3.16	15.41	12.45	7.5	17.53	0 - 120	2.89	11.80
Reading (with an adult)	25.57	20	19.20	0 - 90	1.07	1.23	23.87	20	18.92	0 - 120	1.40	3.80
Playing with non-digital toys (independent)	80.99	60	67.90	0 - 400	2.13	6.58	79.37	60	63.84	0 - 360	1.73	4.09
Playing with non-digital toys (with an adult)	79.06	60	81.59	0 - 480	2.10	5.61	69.46	60	66.69	0 - 400	1.78	4.07
Creative activities (independent)	12.69	5	20.54	0 - 120	3.05	11.91	14.27	5	22.09	0 - 180	3.59	20.49
Creative activities (with an adult)	19.31	15	23.83	0 - 180	2.71	12.34	20.56	15	30.56	0 - 240	3.61	19.42

Note. M = Mean, Med = Median, SD = Standard Deviation, S = Skewness, K = Kurtosis.

Time 2 Correlations

Age. Child age at Time 2 was significantly correlated with problem solving at Time 2 (r (170) = .353, p < .001; see Appendix D for full correlation tables). Additionally, problem solving at Time 1 was significantly correlated with problem solving at Time 2 (r (170) = .695, p < .001). Consequently, bootstrapped partial correlations controlling for age and problem solving at Time 1 were used to investigate the relationship between problem solving at Time 2 and home activities at Time 1. Child age was not significantly related to novelty seeking at Time 2. However, novelty seeking at Time 1 was positively related to novelty seeking at Time 2 (r (170) =.590, p <.001). Thus, novelty seeking at Time 1 was used as a control variable in subsequent bootstrapped partial correlations. Table 6 summarises the results from bootstrapped correlational analyses and bootstrapped partial correlations between home activities at Time 1 and problem solving and novelty seeking at Time 2. Key findings to note are described below.

Problem solving. The only significant positive correlation observed after controlling for age and problem solving at Time 1 was between problem solving at Time 2 and time spent using gaming apps at Time 1. In addition to this, there was a significant negative relationship between watching non-child-directed video content with an adult at Time 1 and problem solving at Time 2.

Novelty seeking. No significant relationships between home activities at Time 1 and novelty seeking at Time 2 were observed (*p*s all > .05). Table 6 summarises the findings from these analyses.

Table 6.

Bootstrapped Pearson's correlations and bootstrapped partial correlations between activities at Time 1 and problem solving and novelty seeking at Time 2. Confidence intervals based on 1000 bootstrap samples.

	Problem Solving (T2)				Novelty Seeking (T2)			
Activity (T1)	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Touchscreen use (independent)	.123 (.042)	.109 (.588)	-.043 (-.105)	.235 (.173)	.041 (.019)	.593 (.804)	-.090 (-.077)	.241 (.163)
Touchscreen use (with an adult)	.077 (.007)	.315 (.925)	-.035 (-.150)	.203 (.173)	.089 (.090)	.245 (.244)	-.077 (-.086)	.213 (.228)
Learning Apps	.197** (.043)	.010 (.577)	.069 (-.095)	.303 (.146)	-.001 (-.011)	.990 (.881)	-.136 (-.109)	.236 (.161)
Gaming Apps	.191* (.194*)	.012 (.011)	.002 (.040)	.311 (.309)	.133 (.057)	.083 (.457)	-.047 (-.082)	.282 (.166)
Creative Apps	.221** (.145)	.004 (.059)	.050 (.004)	.330 (.247)	.099 (.003)	.195 (.964)	-.100 (-.123)	.264 (.115)
Child-directed video content (independent)	.175* (.062)	.022 (.423)	.064 (-.052)	.278 (.160)	.064 (.051)	.403 (.511)	-.057 (-.095)	.195 (.210)
Child-directed video content (with an adult)	.008 (.033)	.915 (.674)	-.346 (-.229)	.241 (.227)	.001 (-.036)	.991 (.636)	-.324 (-.265)	.233 (.128)
Non-child-directed video content (independent)	-.133 (-.145)	.082 (.058)	-.242 (-.281b)	.009 (-.004b)	.017 (.013)	.829 (.864)	-.096 (-.127)	.164 (.201)
Non-child-directed video content (with an adult)	-.220** (-.214**)	.004 (.005)	-.368 (-.374)	-.066 (-.038)	-.066 (-.079)	.390 (.306)	-.206 (-.203)	.079 (.039)

Note. Values in parentheses are from bootstrapped partial correlations. Partial correlations for problem solving control for problem solving at Time 1 and age. Partial correlations for novelty seeking control for novelty seeking at Time 1. 95% CI (L) = lower 95% confidence interval; 95% CI (U) = upper 95% confidence interval. * $p < .05$. ** $p < .01$.

Activity (T1)	Problem Solving (T2)				Novelty Seeking (T2)			
	r	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Video call use	.111 (.026)	.147 (.736)	.005 (-.105)	.206 (.142)	.135 (.139)	.078 (.069)	.017 (.020)	.267 (.261)
Multi-screen use	.072 (.060)	.351 (.439)	-.084 (-.098)	.231 (.179)	.144 (.003)	.060 (.969)	-.044 (-.117)	.285 (.140)
Reading (independent)	.210** (.140)	.006 (.069)	.044 (.011)	.342 (.250)	.023 (-.001)	.760 (.994)	-.166 (-.140)	.215 (.146)
Reading (with an adult)	.154* (.130)	.043 (.092)	.000 (-.023)	.296 (.275)	.079 (.031)	.300 (.689)	-.122 (-.136)	.253 (.196)
Non-digital toys (independent)	-.100 (-.043)	.191 (.575)	-.328 (-.261)	.118 (.206)	-.073 (-.080)	.340 (.301)	-.248 (-.237)	.099 (.085)
Non-digital toys (with an adult)	.118 (.079)	.124 (.303)	-.018 (-.046)	.249 (.204)	.012 (.036)	.880 (.642)	-.131 (-.111)	.161 (.182)
Creative activities (independent)	.030 (-.086)	.697 (.265)	-.120 (-.242)	.177 (.068)	.034 (.006)	.655 (.943)	-.131 (-.132)	.193 (.151)
Creative activities (with an adult)	.162* (.087)	.034 (.257)	.024 (-.059)	.330 (.233)	-.063 (-.015)	.415 (.844)	-.218 (-.171)	.113 (.166)

Note. Values in parentheses are from bootstrapped partial correlations. Partial correlations for problem solving control for problem solving at Time 1 and age. Partial correlations for novelty seeking control for novelty seeking at Time 1. 95% CI (L) = lower 95% confidence interval; 95% CI (U) = upper 95% confidence interval.
* $p < .05$. ** $p < .01$.

Time 2 Regressions

Bootstrapped hierarchical regression analyses were used to assess whether time spent engaging in different activities at Time 1 predicted later problem solving and novelty seeking. No evidence for heteroscedasticity was observed so simple bootstrapping was used to analyse the data. Table 7 summarises the bootstrapped regression model for problem solving at Time 2 and Table 8 summarises the model for novelty seeking at Time 2.

Problem solving. As age and problem solving at Time 1 were found to be significant correlates of problem solving at Time 2, they were entered into the model at Step 1. Home activities were entered into the model at Step 2, in order of relationship strength observed in partial correlations (see Table 6). Table 7 summarises the results for this model. At Step 1, the model was significant and explained 48.4% of the variance in problem solving at Time 2 (F (2, 169) = 79.251, $p < .001$). Problem solving at Time 1 was a significant positive predictor at Step 1 and was the only significant predictor at this stage. At Step 2, the overall model was significant (F (19, 152) = 9.753, $p < .001$). However, there was only a 6.5% increase in variance explained, which was not a significant contribution to the model (F (17, 152) = 1.297, p = .201). Problem solving at Time 1 remained a significant positive predictor at Step 2 and was the only significant predictor of problem solving at Time 2.

Novelty seeking. Age was not a significant correlate of novelty seeking at Time 2, therefore only novelty seeking at Time 1 was entered into the model at Step 1. At Step 2, home activities were entered into the model in order of relationship strength observed in bootstrapped partial correlations (see Table 6). The overall model at Step 1 was significant (F (1, 170) = 90.837, $p < .001$) and explained 34.8% of the variance in novelty seeking at Time 2. In terms of predictors, novelty seeking at Time 1 was a significant positive predictor of novelty seeking at Time 2. The model at Step 2 was significant (F (17, 153) = 5.591, $p < .001$) and there was an increase of 4.9% of variance explained, but this was not a significant contribution (F (17, 153) = .724, p = .775). Novelty seeking at Time 1 remained a significant positive predictor and using video call software at Time 1 was also a significant positive predictor of novelty seeking at Time 2. No significant negative predictors of novelty seeking were observed in the model.

Table 7.

Bootstrapped hierarchical regression analysis of predictors of problem solving at Time 2 with 95% confidence intervals reported. Confidence intervals and standard errors based on 1000 bootstrap samples unless otherwise noted.

Step	Predictor	*B*	*95% CI (L)*	*95% CI (U)*	*SE B*	*β*	*p*
Step 1	(Constant)	1.054	.722[b]	1.392[b]	.169[b]		.001[b]
	PS (T1)	.671	.524[b]	.817[b]	.074[b]	.681**	.001[b]
	Child age (T2)	.000	.000[b]	.000[b]	.000[b]	.029	.676[b]
Step 2	(Constant)	1.141	.799[c]	1.423[c]	.159[c]		.001[c]
	PS (T1)	.628	.496[c]	.753[c]	.068[c]	.637**	.001[c]
	Child age (T2)	.000	.000[c]	.000[c]	.000[c]	.020	.764[c]
	Non-child-directed video content (with an adult) (T1)	-.003	-.006[c]	.000[c]	.002[c]	-.125	.092[c]
	Gaming app (T1)	.010	-.007[c]	.022[c]	.007[c]	.137	.078[c]
	Creative app (T1)	.005	-.009[c]	.019[c]	.007[c]	.070	.442[c]
	Non-child-directed video content (independent) (T1)	-.001	-.006[c]	.006[c]	.004[c]	-.029	.601[c]
	Reading (independent) (T1)	.003	-.001[c]	.007[c]	.002[c]	.101	.186[c]
	Reading (with an adult) (T1)	.001	-.002[c]	.004[c]	.001[c]	.043	.431[c]
	Creative (with an adult) (T1)	.000	-.002[c]	.003[c]	.001[c]	.023	.714[c]
	Creative (independent) (T1)	-.001	-.004[c]	.001[c]	.001[c]	-.061	.264[c]
	Toys (with an adult) (T1)	.000	.000[c]	.001[c]	.000[c]	.047	.379[c]
	Child-directed video content (independent) (T1)	.001	-.001[c]	.002[c]	.001[c]	.045	.468[c]
	Multi-screen use (T1)	-.002	-.018[c]	.004[c]	.006[c]	-.037	.581[c]
	Learning app (T1)	-.002	-.008[c]	.003[c]	.003[c]	-.088	.375[c]
	Toys (independent) (T1)	.000	-.001[c]	.001[c]	.000[c]	.022	.787[c]
	Touchscreen (independent) (T1)	.000	-.003[c]	.005[c]	.002[c]	.012	.891[c]
	Child-directed video content (with an adult) (T1)	-.001	-.002[c]	.002[c]	.001[c]	-.106	.322[c]
	Video call software (T1)	.002	-.005[c]	.008[c]	.003[c]	.034	.510[c]
	Touchscreen (with an adult) (T1)	.000	-.004[c]	.003[c]	.002[c]	.015	.843[c]
DV	PS (T2)	R^2 = .484** for Step 1; ΔR^2 = .065 for Step 2					

Note. PS = problem solving; T1 = Time 1; T2 = Time 2; DV = dependent variable. 95% CI (L) = lower 95% confidence interval; 95% CI (U) = upper 95% confidence interval. * $p < .05$, ** $p < .01$. [b] = Based on 818 samples. [c] = Based on 816 samples.

Table 8.

Bootstrapped hierarchical regression analysis of predictors of novelty seeking at Time 2 with 95% confidence intervals reported. Confidence intervals and standard errors based on 1000 bootstrap samples.

Step	Predictor	*B*	*95% CI (L)*	*95% CI (U)*	*SE B*	*β*	*p*
Step 1	(Constant)	.751	.374	1.114	.181		.001
	NS (T1)	.669	.509	.832	.082	.590**	.001
Step 2	(Constant)	.758	.415	1.200	.200		.001
	NS (T1)	.657	.462	.820	.090	.580**	.001
	Video call software (T1)	.007	.002	.012	.003	.152**	.005
	Touchscreen (with an adult) (T1)	.002	-.002	.004	.001	.095	.173
	Toys (independent) (T1)	.000	-.001	.001	.000	-.076	.298
	Non-child-directed video content (with an adult) (T1)	-.001	-.004	.001	.001	-.087	.183
	Gaming app (T1)	.007	-.012	.018	.007	.113	.235
	Child-directed video content (independent) (T1)	.001	-.001	.003	.001	.059	.504
	Toys (with an adult) (T1)	.000	.000	.001	.000	.059	.355
	Child-directed video content (with an adult) (T1)	.000	-.002	.001	.001	-.057	.615
	Reading (with an adult) (T1)	.000	-.003	.004	.001	.020	.795
	Touchscreen (independent) (T1)	.001	-.003	.005	.002	.059	.611
	Creative (with an adult) (T1)	-.001	-.003	.001	.001	-.068	.383
	Non-child-directed video content (independent) (T1)	.002	-.005	.013	.004	.046	.609
	Learning app (T1)	-.001	-.006	.004	.003	-.063	.603
	Creative (independent) (T1)	.001	-.003	.003	.002	.044	.594
	Creative app (T1)	-.001	-.013	.014	.007	-.027	.812
	Multi-screen use (T1)	-.004	-.012	.007	.004	-.092	.217
	Reading (independent) (T1)	.000	-.004	.005	.002	.007	.949
DV	NS (T2)	R^2 = .348** for Step 1; ΔR^2 = .049 for Step 2					

Note. NS = novelty seeking; T1 = Time 1; T2 = Time 2; DV = dependent variable. 95% CI (L) = lower 95% confidence interval; 95% CI (U) = upper 95% confidence interval. * $p < .05$, ** $p < .01$.

2.3.3 Correlations between Time 2 activities, problem solving and novelty seeking

To ascertain some potential directionality amongst the observed correlations, it was decided that additional bootstrapped correlations would be conducted. For these analyses, problem solving and novelty seeking at Time 1 were correlated with home activities at Time 2. It was hoped the results of these analyses may indicate whether children who had higher levels of problem solving or novelty seeking engaged in certain activities more six months later. Key findings are described below, and Table 9 summarises the results of bootstrapped correlations and partial correlations for both problem solving and novelty seeking.

Problem solving. As age and problem solving at Time 1 were significantly correlated (r (170) = .474, $p < .001$), age was controlled for along with the activity at Time 1. The results showed that there were no significant relationships between problem solving at Time 1 and activities at Time 2 (*p*s all > .05).

Novelty seeking. Age was not significantly correlated with novelty seeking at Time 1 so was not controlled for in the subsequent correlations (r (170) = .012, p = .880). Instead, home activities at Time 1 were controlled for in the partial correlations. The results revealed that the only significant relationship with novelty seeking was time spent engaging with creative activities with an adult, which was a positive association (r' (169) = .156, p = .042).

Table 9.

Bootstrapped Pearson's correlations and bootstrapped partial correlations between activities at Time 2 and problem solving and novelty seeking at Time 1 with 95% confidence intervals reported. Confidence intervals based on 1000 bootstrap samples.

	Problem Solving (T1)				Novelty Seeking (T1)			
Activity (T2)	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Touchscreen use (independent)	.012 (-.119)	.873 (.123)	-.119 (-.234)	.152 (.019)	-.022 (-.040)	.776 (.605)	-.166 (-.238)	.126 (.114)
Touchscreen use (with an adult)	.010 (-.055)	.893 (.475)	-.228 (-.276)	.129 (.050)	-.024 (-.039)	.751 (.614)	-.107 (-.165)	.058 (.059)
Learning Apps	.044 (-.009)	.564 (.903)	-.063 (-.157)	.145 (.093)	-.010 (-.011)	.899 (.887)	-.123 (-.126)	.128 (.136)
Gaming Apps	.057 (.002)	.457 (.977)	-.066 (-.107)	.157 (.141)	-.036 (-.102)	.638 (.185)	-.170 (-.202)	.064 (.035)
Creative Apps	.085 (-.007)	.268 (.926)	-.019 (-.102)	.174 (.084)	-.014 (-.054)	.856 (.487)	-.144 (-.172)	.129 (.090)
Child-directed video content (independent)	-.052 (-.122)	.502 (.113)	-.180 (-.258)	.061 (.011)	.002 (-.018)	.974 (.812)	-.198 (-.203)	.168 (.165)
Child-directed video content (with an adult)	.020 (.074)	.794 (.338)	-.145 (-.079)	.167 (.246)	-.073 (-.099)	.341 (.196)	-.229 (-.254)	.080 (.098)
Non-child-directed video content (independent)	.001 (-.012)	.990 (.874)	-.076 (-.092)	.165 (.143)	.020 (.019)	.796 (.804)	-.080 (-.082)	.162 (.163)
Non-child-directed video content (with an adult)	-.044 (-.062)	.564 (.422)	-.170 (-.195)	.073 (.082)	.025 (.027)	.741 (.728)	-.095 (-.095)	.150 (.160)

Note. Values in parentheses are from bootstrapped partial correlations. For problem solving, age at Time 2 and the respective activity at Time 1 were controlled for. For novelty seeking, only the respective activity at Time 1 was controlled for. T1 = Time 1; T2 = Time 2; 95% CI (L) = 95% confidence interval (lower); 95% CI (U) = 95% confidence interval (upper). * $p < .05$. ** $p < .01$.

	Problem Solving (T1)				Novelty Seeking (T1)			
Activity (T2)	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Video call software	.053 (-.099)	.493 (.198)	-.051 (-.200)	.154 (.032)	-.006 (-.044)	.935 (.565)	-.127 (-.157)	.106 (.076)
Multi-screen use	-.147 (-.136)	.055 (.076)	-.255 (-.246)	.016 (.043)	-.093 (-.105)	.224 (.171)	-.197 (-.203)	.068 (.056)
Reading (independent)	.111 (-.024)	.149 (.756)	-.036 (-.166)	.242 (.112)	-.007 (-.026)	.925 (.739)	-.163 (-.159)	.164 (.141)
Reading (with an adult)	.059 (.052)	.442 (.499)	-.079 (-.083)	.207 (.193)	.005 (-.024)	.943 (.754)	-.144 (-.171)	.167 (.142)
Non-digital toys (independent)	.089 (.083)	.247 (.280)	-.057 (-.065)	.242 (.229)	-.024 (-.021)	.756 (.787)	-.262 (-.260)	.206 (.215)
Non-digital toys (with an adult)	.077 (.076)	.312 (.327)	-.097 (-.085)	.232 (.206)	.015 (.027)	.842 (.729)	-.147 (-.135)	.171 (.184)
Creative activities (independent)	.101 (-.032)	.189 (.681)	-.001 (-.137)	.219 (.089)	.079 (.071)	.303 (.357)	-.076 (-.087)	.212 (.205)
Creative activities (with an adult)	.056 (.039)	.467 (.610)	-.090 (-.119)	.164 (.147)	.131 (.156*)	.088 (.042)	-.025 (-.001)	.273 (.304)

Note. Values in parentheses are from bootstrapped partial correlations. For problem solving, age at Time 2 and the respective activity at Time 1 were controlled for. For novelty seeking, only the respective activity at Time 1 was controlled for. T1 = Time 1; T2 = Time 2; 95% CI (L) = 95% confidence interval (lower); 95% CI (U) = 95% confidence interval (upper). * $p < .05$. ** $p < .01$.

2.3.4 Displacement

One concern that has been repeatedly raised in children's media use is displacement, where media is thought to take time away from activities that may be beneficial for development. In the present study, it is possible to examine the displacement hypothesis to an extent. Using the larger Time 1 sample, bootstrapped partial correlations controlling for child age were run between media-based activities and non-media-based activities. The findings from those analyses are presented in Table 10 and Table 11.

There were no significant negative relationships observed between media-based activities and independent non-media-based activities (Table 10). Several significant positive relationships were observed, for example, time spent reading independently was positively related to time spent using learning apps, creative apps and watching child-directed video content with an adult. Additionally, engaging in creative activities independently was positively related to touchscreen use and using creative apps. Finally, playing with toys independently was positively associated with watching both child-directed and non-child-directed video content independently. It is important to note that the strongest relationship was between learning apps and reading independently.

Table 11 shows the relationships between media use and engaging in non-media-based activities with adults. There are observations of significant negative relationships. Independent touchscreen use, learning apps, gaming apps, and watching non-child-directed video content were negatively associated with playing with toys with an adult. Independent touchscreen use was also negatively associated with reading with an adult. Additionally, a small negative relationship between creative activities and watching non-child-directed video content independently was observed. Some significant positive relationships were also found, where reading was positively related to engaging in video calls and watching child-directed video content with an adult. The latter was also positively related to playing with toys with an adult. Finally, engaging in video calls was positively associated with engaging in creative activities with an adult. The strongest relationship noted in this table was the positive relationship between co-watching child-directed video content and reading with an adult.

Table 10.

Bootstrapped partial correlations controlling for age between media-based activities and independent non-media-based activities at Time 1 with 95% confidence intervals reported. Confidence intervals based on 1000 bootstrapped samples.

	Reading (independent)				Non-digital toys (independent)				Creative activities (independent)			
Activity	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Touchscreen use (independent)	.091*	.031	-.069	.314	.032	.450	-.044	.102	.114**	.007	.026	.223
Touchscreen use (with an adult)	.071	.091	-.015	.185	.024	.565	-.059	.117	.124**	.003	.029	.246
Learning Apps	.271**	.000	.042	.484	.030	.473	-.049	.103	.073	.085	-.014	.182
Gaming Apps	.042	.318	-.083	.227	.036	.395	-.027	.095	.000	.997	-.085	.100
Creative Apps	.189**	.000	.003	.381	.005	.905	-.056	.065	.118**	.005	.031	.238
Child-directed video content (independent)	.158**	.000	-.023	.359	.239**	.000	.143	.337	.029	.494	-.039	.122
Child-directed video content (with an adult)	.167**	.000	-.003	.348	.019	.644	-.080	.154	.042	.317	-.040	.139
Non-child-directed video content (independent)	-.031	.464	-.090	.041	.106*	.012	-.002	.225	.195**	.000	.037	.393
Non-child-directed video content (with an adult)	.026	.532	-.050	.115	.064	.127	-.049	.179	.035	.404	-.067	.182
Video call software use	.075	.074	-.009	.170	-.011	.792	-.080	.061	.001	.980	-.055	.075
Multi-screen use	.104*	.014	-.031	.273	.052	.217	-.011	.125	.073	.082	.000	.180

Note. 95% CI (L) = 95% confidence interval (lower); 95% CI (U) = 95% confidence interval (upper). * $p < .05$. ** $p < .01$.

Table 11.

Bootstrapped partial correlations controlling for child age between media-based activities and joint non-media activities at Time 1 with 95% confidence intervals reported. Confidence intervals based on 1000 bootstrapped samples.

	Reading (with an adult)				Non-digital toys (with an adult)				Creative activities (with an adult)			
Activity	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Touchscreen use (independent)	-.092*	.029	-.161	-.031	-.108**	.010	-.154	-.066	-.070	.097	-.138	-.009
Touchscreen use (with an adult)	.015	.722	-.053	.093	.055	.193	-.049	.179	-.009	.839	-.075	.082
Learning Apps	-.009	.836	-.080	.068	-.100*	.018	-.144	-.042	-.030	.480	-.086	.043
Gaming Apps	-.009	.837	-.099	.096	-.083*	.050	-.130	-.038	-.036	.400	-.114	.033
Creative Apps	.022	.606	-.069	.138	-.074	.080	-.128	-.019	.041	.330	-.028	.118
Child-directed video content (independent)	-.027	.527	-.115	.054	-.007	.864	-.122	.108	-.080	.057	-.181	.032
Child-directed video content (with an adult)	.150**	.000	.015	.251	.135**	.001	.057	.229	.059	.166	-.018	.133
Non-child-directed video content (independent)	-.072	.090	-.139	-.015	-.127**	.003	-.167	-.090	-.090*	.034	-.130	-.046
Non-child-directed video content (with an adult)	-.026	.545	-.088	.043	-.094*	.025	-.154	-.025	-.024	.574	-.099	.063
Video call software use	.141**	.001	.008	.248	.056	.188	-.055	.165	.127**	.003	.046	.226
Multi-screen use	-.022	.607	-.090	.069	-.054	.202	-.107	.018	-.071	.092	-.127	-.011

Note. 95% CI (L) = 95% confidence interval (lower); 95% CI (U) = 95% confidence interval (upper). * $p < .05$. ** $p < .01$.

2.4 Discussion

2.4.1 Overview

This study sought to explore the possible relationships between reported problem solving and novelty seeking behaviour in 12- to 47-month-olds and activities such as using touchscreens and apps. The results of the current study show an array of findings. Data from the overall sample at Time 1 showed that, after controlling for age, there were significant positive relationships between reported problem solving and time spent using touchscreens with an adult, learning apps, creative apps, and independent reading. Overall, learning apps and independent reading were the best predictors of problem solving, along with age. Although no significant negative relationships were observed, watching child-directed video content with an adult and independent touchscreen use were found to be significant negative predictors of problem solving when including all variables in one analysis. For novelty seeking, there were significant positive relationships with time spent using touchscreens independently, learning apps, and creative apps. Additionally, there were significant positive relationships between novelty seeking and watching non-child-directed video content independently and multi-screen use. No significant negative relationships were observed for novelty seeking. In regression analyses, watching non-child-directed video content independently was the only significant predictor of novelty seeking. This study also sought to explore whether reported activities were related to later problem solving and novelty seeking. The results for the longitudinal data demonstrated that time spent using gaming apps positively correlated with problem solving six months later. Additionally, watching non-child-directed video content with an adult negatively correlated with later problem solving. However, these variables did not predict problem solving at Time 2. No significant relationships were observed between novelty seeking at Time 2 and activities at Time 1. Nevertheless, time spent using video call software at Time 1 was a significant positive predictor of novelty seeking at Time 2 after accounting for novelty seeking at Time 1.

In an attempt to ascertain some potential directionality in the findings, correlational analyses were conducted between problem solving and novelty seeking at Time 1 and activities at Time 2. The assumption motivating this decision was that the correlational nature of the research, particularly at Time 1, does not allow directional theories about the potential mechanisms underlying significant relationships to be made. For example, if there is a significant positive relationship between problem solving and creative apps at Time 1, the nature of the analyses means it is not possible to establish causality. However, if there is an additional significant positive relationship between problem solving at Time 1 and creative app use at Time 2, it may serve as a potential indication that children who are better problem solvers engage in this activity more. Thus, it may provide some information about whether it is the ability or the activity potentially driving significant relationships observed in other analyses. However, the findings from these analyses showed no significant relationships between problem solving at Time 1 and any activities at Time 2. With regards to novelty seeking, only one significant relationship was observed, where time spent engaging in creative activities with an adult at Time 2 was positively associated with novelty seeking at Time 1. The next section will firstly discuss the findings observed with touchscreen and app use, then other media use. Secondly, findings about reading are discussed, then turning to findings concerning other non-media-based activities. Finally, observations relating to displacement are discussed.

2.4.2 Touchscreens

Firstly, bootstrapped correlations controlling for children's age showed touchscreen use with an adult was positively related to problem solving. This could be due to scaffolding throughout this activity, which has previously been found to help children engage with media in a meaningful way and enable them to take advantage of the potential benefits of touchscreens (Hirsh-Pasek et al., 2015; Zack & Barr, 2016). Interestingly, while it was not observed as a significant relationship in correlation analyses, independent touchscreen use was a negative predictor of problem solving. This may lend support to the idea that touchscreen use in general is an activity that would benefit from having an adult to support device use. For example, an adult could help children navigate the touchscreen, assist them if they get stuck and encourage using apps that may be perceived as having more educational value. Thus, children are better able to benefit from touchscreen use if there is an adult present who can help guide their use appropriately. In an interesting contrast, correlation analysis showed novelty seeking was positively related to independent touchscreen use. A potential explanation of this finding links to the idea of epistemic curiosity. Novelty seeking is thought to be linked with epistemic curiosity, or the desire to obtain new knowledge (Piotrowski et al., 2014). One type of epistemic curiosity is I-type, which is thought to be driven by interest and the joy of learning new information (Litman, 2008). It could be argued that touchscreen and app use may encourage I-type epistemic curiosity and consequently, novelty seeking behaviours. Conversely, it is possible that children who engage in novelty seeking behaviours more may use touchscreens more as they may satisfy the desire for new experiences. It could be argued that the tailorability of touchscreens and choice of potential experiences available through apps (Christakis, 2014) may make them an ideal vehicle for the facilitation or satisfaction of novelty seeking behaviours. However, this relationship may also indicate a potentially double-edged influence of independent touchscreen use with problem solving. Where young children who enjoy new experiences may engage with touchscreens more often, there may be a potentially detrimental influence on problem solving because they do not have an adult guiding their use. Alternatively, it is possible that the lack of shared use means children have the freedom to explore the device, for example, switching between apps and the different activities available. However, it is important to note that these findings were not consistent across correlation and regression analyses. This may suggest the specific relationships are not as robust when viewed alongside other variables, perhaps due to overlapping variance or statistical noise. Therefore, a degree of caution when interpreting the findings is required. This issue is discussed in more detail in the limitations section of the Discussion.

There were interesting findings at Time 1 regarding app use. In the current study, results from correlation analyses showed learning apps were significantly and positively related to both problem solving and novelty seeking at Time 1. Additionally, engaging with learning apps was the best media-based predictor of problem solving. As these findings related to touchscreen content, it could be argued that they align with previous research. Anderson, Huston et al., (2001) found educational television content was positively associated with divergent thinking and Anderson, Bryant et al., (2000) found preschooler problem solving was enhanced by the children's television programme *Blue's Clues*. A potential explanation for problem solving relating to learning apps may be that they provide opportunities that allow children to practise their problem-solving skills. For example, the educational content of learning apps may present activities that require children to identify problems, generate solutions and attempt to implement those solutions correctly. This means children have a dedicated space that can meaningfully encourage their problem-solving behaviour and skills, which could be attractive to them, leading to higher levels of engagement (Hirsh-Pasek et al., 2015). Similar for novelty seeking, learning apps may offer an opportunity to facilitate this through features of the app. One example of this could be progression, where new levels and new challenges might be encountered, thus facilitating novelty seeking by keeping the content novel and interesting. The use of creative apps was also positively related to problem solving and novelty seeking at Time 1. Creative apps may be beneficial for problem solving and novelty seeking for a similar reason. For problem solving, generating ideas is seen as a valuable step in the process (Cropley, 2006; Keen, 2011) and creative apps may facilitate this by providing a space in which to create and experiment with different ideas. Similarly, the more open-ended nature of creative apps may stimulate novelty seeking by allowing children to freely explore and experiment within the app (Carrell Moore, 2017; Marsh et al., 2018). However, it should be acknowledged that these significant relationships did not extend to regression analyses and using creative apps was not a significant predictor of children's problem solving or novelty seeking. Indeed, no touchscreen activities were found to be significant predictors of novelty seeking. This may have been because of variable variance, where entering the activities into the regression may have meant variance overlapped, consequently reducing the amount of variance explained by the variable and the overall contribution it has to the model. Overall, it is possible that learning and creative apps may be beneficial for creative thinking because the content may promote similar ways of thinking and offer opportunities to practice these skills. It is also possible that children who are better problem solvers or enjoy novelty seeking may use these apps more frequently because they find them enjoyable and satisfy their desire to engage in problem solving or novelty seeking behaviour. Generally, the findings from Time 1 could indicate specific content may be beneficial for different types of creative thinking and demonstrate the importance of taking content into account when examining the influence of media use. However, it is important to note to that the inconsistency of findings between correlation and regression analyses may suggest the strength of the associations may not be particularly robust and must therefore be interpreted cautiously.

For Time 2 findings, a significant positive relationship was observed between time spent using gaming apps at Time 1 and problem solving at Time 2. Previous research has indicated that gaming may be beneficial for problem solving (Granic et al., 2014). Granic and colleagues note that problem solving is central to many gaming experiences and the types of problem-solving scenarios can vary in difficulty, for example, getting from A to B or engaging in situations that involve analytical and memory skills. Thus, gaming apps could offer a similar experience, where children are required to generate and use different strategies to progress further in the apps. The fact that time spent using gaming apps six months earlier was associated with higher problem-solving scores at Time 2 could suggest that the strategies adopted, and thus the skills developed, had a longer-term influence compared to other apps. In relation to longitudinal findings concerning touchscreens and apps, it is interesting to note that significant relationships observed at Time 1 were not observed at Time 2, for example, a positive longitudinal relationship with learning apps. A potential reason for this could be that the mechanisms underlying the relationships are more acute in the short-term. For example, if learning apps do lead to more problem-solving behaviours, it is possible that this effect is strongest in the most immediate interval after taking part in the activity. Overall, the findings from Time 1 suggest touchscreens and apps, specifically learning and creative apps, may be beneficial for problem solving and novelty seeking. However, the lack of significant associations observed between these measures at Time 1 and activities at Time 2 may indicate that the relationship is temporary and does not have long-term effects. However, the correlational nature of the findings limits the ability to make causal assumptions. Additionally, the lack of consistency across regression analyses may also limit the strength of the conclusions. For these reasons, it would be beneficial for future research to attempt to replicate the study and explore whether the findings hold.

2.4.3 Other media use

While some findings indicate positive relationships between touchscreens, apps, and problem solving, it is important to note that there were also negative findings. An interesting finding from Time 1 was that watching child-directed video content with an adult was a significant negative predictor of problem solving, though this was not observed as a significant correlation. This finding was somewhat unexpected, given that policy and research advocates developmentally appropriate content and co-viewing (AAP, 2016; Coyne et al., 2017; Strouse et al., 2013). Additionally, preschooler-aimed content has been found to facilitate problem solving (Anderson, Bryant et al., 2000). A possible explanation for this relationship could be that the presence of an adult may potentially have a detrimental influence on children's problem solving. For example, it is possible adults vocalise less while the video is on (Courage et al., 2010) or the interactions they do provide are not of optimal quality to help children learn from the content (Zack & Barr, 2016). This could affect children's ability to learn information and thus impact on problem solving. However, given that the evidence is largely in favour of co-viewing, this seems relatively unlikely. An alternative explanation is that children may spend more time co-viewing with an adult because, given their lower reported problem-solving behaviour, adults may perceive that they would benefit from a partner who can guide their understanding of the content. Once adults feel their child has developed enough skills to be able to benefit from watching content independently, they may spend less time co-using media (Nikken & Schols, 2015). This could also explain why the same relationship was not observed at Time 2, as their skills may have advanced to the point where caregiver assistance is not needed as often.

Longitudinally, a significant negative relationship between time spent watching non-child-directed video content with an adult at Time 1 and problem solving at Time 2 was observed. The explanation for this may be two-fold. Firstly, as children are not the main target audience, the content is unlikely to be comprehensible. Thus, children may not pay attention to the content, consequently minimising meaningful engagement, and their ability to learn new skills (Barr, Lauricella et al., 2010). Secondly, if the content is aimed at adults and children are co-viewing with an adult, it is possible that adults may not scaffold the content to make it understandable for the child because they are already engaged with content targeted for them (Courage et al., 2010). Thus, children are not able to engage with the content and benefit from any potential learning opportunities. Alternatively, it is possible that children who engaged in more problem-solving behaviours later did not watch this content with an adult as often at an earlier period compared to children who engaged in fewer problem-solving behaviours. Overall, these findings regarding co-viewing video content may indicate that this may not necessarily be an optimal media activity in relation to problem solving. This could be due to suboptimal interactions between children and adults during viewing, or in the case of non-child-directed video content, may be due to the potentially incomprehensible content of the video itself. Another potential explanation is that children who exhibit fewer problem-solving behaviours may engage in co-viewing more often because the adults feel they need additional support to benefit from the content and therefore engage in joint viewing of video content. However, it is important to note that watching non-child-directed video content with an adult was not observed as a significant predictor of problem solving at Time 2. This could potentially suggest the contribution of this activity to problem solving when examined in relation to other variables was relatively weak.

Relating to novelty seeking, there was a significant positive relationship between novelty seeking at Time 1 and watching non-child-directed video content independently. This was also the only significant predictor of novelty seeking at Time 1. Previous research has indicated that non-child-directed video content has negative associations with young children's cognition (Barr, Lauricella et al., 2010), making this a surprising finding. The potential reasons for the relationship are unclear. However, a possible explanation is that although the content may not necessarily be ideal for children (for example, as a lack of child-appropriate features, such as comprehensible subject matter, repetition or slower pacing), it is still attractive to them. The data from the current study shows that children watch non-child-directed video content less than child-directed (Table 1). Thus, if the opportunity to engage with something that is otherwise a relatively rare occurrence arises, children may be more likely to do so, particularly if they enjoy seeking out new experiences. Alternatively, it is possible that non-child-directed video content may contain events or subject matter that more targeted content does not, thus showing information that could be considered outside of their typical schema. Being exposed to novel information in this way may prompt them to look for other new opportunities or experiences that are not typically available to them, thus facilitating novelty seeking. Overall, it would be interesting to examine how features of this content might interact with young children's novelty seeking to understand the mechanisms underlying this relationship.

Correlational analyses revealed novelty seeking at Time 1 was significantly related with time spent using multiple screens simultaneously. This relationship could be explained through the understanding of what novelty seeking behaviour entails. Epistemic curiosity, as previously mentioned, is where behaviour is driven by the desire to learn new information (Litman, 2008). This suggestion may also apply to the relationship with multi-screen use, where having various sources of content may stimulate the desire to engage in varied activities. For example, one possible scenario is that a child might be using a tablet while the television is switched on. The tablet may provide one activity such as a drawing app, while the television may provide another, for example, showing their favourite television programme. Thus, the desire for learning new information and stimulation is achieved, and children's novelty seeking and motivation to engage in multi-screen use is facilitated. Likewise, it is possible that children who exhibit more novelty seeking tendencies engage more in multi-screen use because it fulfils their need for diverse experiences. While it has been observed as a positive relationship in the current study, it is not clear what the potential impact of this might be. Courage et al., (2015) reviewed children's multitasking and its potential consequences, including media multitasking. They highlight a series of previous studies that have suggested infant and toddler distractibility means that background television can lead to diminished attention and superficial engagement with later play. However, they also suggest that while there are potential negative consequences, they could be mitigated by factors such as developmentally appropriate content and scaffolding from an adult or peer. Additionally, they propose children born into today's technology-rich world may also develop strategies that allow them to resist distraction and focus on the task at hand. To say whether the observed relationship between novelty seeking behaviour and multi-screen use is detrimental to cognition is not within the scope of the current study. Additionally, as multi-screen use was not found to be a significant predictor of novelty seeking in regression analyses, the relationship could be considered as relatively weak when assessed alongside other variables. However, given the media-rich environment young children find themselves in, this would be an important avenue for future research to explore.

Despite not observing any significant correlations between novelty seeking and activities at Time 1, using video call software was a significant positive predictor of novelty seeking in the regression analyses. This may be due to video calls providing a form of social interaction in which new or interesting information might be learned. For example, Roseberry et al., (2014) demonstrated that if interactions through video calls were socially contingent, that is, a two-way interaction where responses are relevant to the child, 24- to 30-month-olds successfully learned novel verbs. This might suggest that video calls that fulfil these conditions may be an opportunity to learn new information and may facilitate novelty seeking in young children. However, the lack of significant correlations followed by an observation of video calls being a significant positive predictor of novelty seeking could also be due to the analysis. That is, when entering all the variables into the regression model, it is possible that interconnecting relationships between the different survey variables produced slightly different findings to the correlations. Therefore, this significant predictor may be a result of statistical noise, as opposed to representing a meaningful relationship.

2.4.4 Reading

Spending more time engaged in independent reading was associated with higher problem-solving scores and was also the strongest predictor of problem solving at Time 1. Reading is seen as a generally positive activity for children and adults alike (Billington, 2015; Poitras et al., 2017) and adult research has suggested that reading and associated skills, such as comprehension, are positively associated with creative thinking (Mourgues et al., 2014; Ritchie et al., 2013). Ritchie et al., (2013) suggested this may be due to facilitation, where greater fluency in written language may allow greater creative thinking by diversifying mental representations available during activities that require creative thought. That is, by engaging more with reading and enhancing comprehension skills, there are more potential avenues that can be explored and used to help formulate and apply ideas. Additionally, it has been suggested that reading and creative thinking may share important biological or cognitive processes that underlie positive relationships between the two (Mourgues et al., 2014; Ritchie et al., 2013). For children, Pape (2004) suggested that problem solving could be examined through the lens of reading comprehension. Specifically, Pape (2004) argues that reading is an active process and requires strategic behaviours, such as decoding, re-reading and summarising. Additionally, they argued readers are guided by existing expectations, knowledge, and their ability to filter out irrelevant information. This could be mirrored in problem solving, where problem solvers need to identify the problem (similar to decoding), focus on relevant information, attempt to solve the problem by relying on previous experience or knowledge and potentially re-evaluating their approach (similar to re-reading). Thus, there may be features of reading that are mirrored in problem solving processes. Finally, Gosen et al., (2015) showed that reading can facilitate problem solving in preschoolers by providing a space to explore problems and potential solutions. For example, a character may encounter a problem and the story consists of them attempting to overcome the barrier. While reading, children can explore the problem, generate their own potential solutions and in sum, practice the skills necessary for successful problem solving without necessarily being in an active problem-solving space. In relation to the current study, children who read independently may have developed the aforementioned skills and consequently be better problem solvers. It is equally possible that better problem solvers spend more time reading independently; if there are processes that underlie both behaviours, there may be a mutual benefit when engaging in problem solving or reading. However, this explanation may only have limited validity given that much of the sample in the present study are unlikely to be proficient readers at this age. It is possible that other variables that were not examined in this study may underlie this relationship. For example, one potential factor could involve the home environment. It is possible that caregivers may provide environments where encouragement and resources for reading are accessible, leading to higher levels of engagement. This may also reflect an environment where the development of children's problem solving is actively encouraged, potentially leading to a significant relationship between the two. Thus, it may be beneficial for future research to expand on the variables included in the study to further understand how children's environments can influence both reading and problem-solving abilities, as well as media use.

2.4.5 Other activities

Many of the findings discussed have been significant. However, it is also important to acknowledge the non-significant findings, particularly concerning non-media-based activities. In arguments against children's media use, it has often been suggested that children should spend their time engaging in activities that benefit them. Indeed, Healey et al., (2019) suggested there was no evidence to indicate that the possible benefits of media engagement match other activities, such as being active, creative, and hands-on with traditional toys. However, the findings from this study indicate firstly, that some media use does not necessarily have a detrimental impact on creative thinking and some activities, such as learning apps, may have a positive influence. Secondly, it also suggests that non-media-based activities (aside from independent reading) are not necessarily facilitative in this respect either. This is particularly notable since such value is placed on non-digital activities (AAP, 2011; 2016). Yet in the current study, there was limited evidence to indicate that desirable non-digital activities were "better" for problem solving or novelty seeking. Finally, it contrasts with Healey and colleagues (2019) suggestion that media use does not match non-media-based activities. The implication of their statement is that media activities are not better than other hands-on activities and children should therefore engage with activities known to be beneficial. However, the non-significant findings from this study suggest that neither forms of activity are particularly detrimental or beneficial and thus, could be considered as "matching". This is important to consider in relation to the displacement hypothesis, where a central assumption involves media use supplanting beneficial activities.

2.4.6 Displacement

An interesting pattern of findings emerged when examining how time spent using media related to engagement in other activities. Media use was not negatively related to any independent non-media-based activities, like reading, creative activities or playing with toys. Indeed, several positive relationships were observed, including independent reading being associated with more time spent using learning apps and creative apps, watching child-directed video content and independent touchscreen use. Additionally, playing with non-digital toys independently was positively associated with watching child-directed and non-child-directed independently. Finally, time spent engaging in independent creative activities was positively associated with touchscreen use, creative apps and watching non-child-directed video content independently. However, more significant negative relationships were observed when examining activities with an adult. For example, playing with non-digital toys with an adult was negatively associated with independent touchscreen use, learning and gaming apps, and watching non-child-directed video content. Additionally, independent touchscreen use was negatively associated with reading with an adult. Finally, watching non-child-directed video content independently was negatively associated with creative activities with an adult.

The positive findings between relationships may indicate that media use could facilitate engagement in media-based activities. This is a particularly interesting idea when considering the relationship between independent creative activities and engaging with creative apps. It is possible that engaging in the respective activity may facilitate the other. For example, using a painting app may lead children to want to physically paint, or vice versa. If this was the case, it may serve as support for previous suggestions that apps can facilitate the transfer of play between the digital and physical world, blurring the boundaries between the two (Marsh et al., 2018). The negative findings between joint activities and some media activities are interesting to consider. A simple explanation using the displacement hypothesis might suggest that media activities are negatively impacting on the amount of time children spend engaging with their parents in different activities, particularly for playing with toys. However, the pattern of negative relationships appearing with joint activities is noteworthy and may point towards some alternative explanations. It has been previously suggested that negative relationships between media and non-media-based activities might be because some non-media-based activities, such as creative activities, take time to set up and put away (Vandewater et al., 2006). Media behaviours, such as learning apps and child-directed video content may take less time to set up and may therefore be preferable to activities that require setting up or supervision, resulting in more time spent engaged with media. Additionally, some caregivers have previously reported that lack of time can be a barrier to playing with their children (LEGO Foundation, 2018). Coupled with findings that indicate some caregivers let their children use media while they complete errands (Rideout & Robb, 2020), it is feasible to suggest children may use media more often to compensate for this, particularly if it is perceived as potentially beneficial, such as learning and creative apps or child-directed video content. The lack of significant findings is also noteworthy. Most of the findings between media and non-digital activities were non-significant, which could indicate that these media activities simply do not have facilitative or inhibitive effects on non-media activities. It may also serve as an indicator that children's time spent engaged in different activities is not symmetrical, where time spent engaged in one activity is equivalent to taking time away from another. Indeed, Mutz et al., (1993) observed in their own data that less media use was not associated with increased time engaged in other activities. Therefore, the relationship is more likely to be asymmetrical and indicate that activities are largely independent from each other.

The array of relationships (and indeed, lack of relationships) between activities makes for a complex web of observations, where some findings seem to refute the displacement hypothesis, and others, particularly concerning joint activities, could indicate some limited support for it. However, it is important to note that the displacement hypothesis suggests that media use supplants other beneficial activities and consequently has negative effects on children's learning and cognition. Thus, one would expect several conditions to be fulfilled:

1. Significant negative observations between creative thinking and media use, to demonstrate that media use may not be beneficial for creative thinking.
2. Significant positive observations between creative thinking and non-media-based activities, to show these activities may be beneficial for these skills.
3. Significant negative observations between media-based and non-media-based activities, to demonstrate non-media activities may be supplanted by media.

Yet, aside from the aforementioned negative findings, which can be explained in terms separate to the displacement hypothesis, there appears to be little evidence from this study to support the suggestion that media use supplants beneficial activities. This is important as the popularity of the displacement hypothesis means that it is regularly inferred and cited as a reason for children to avoid media (AAP, 2016; Yogman et al., 2018). However, if there is limited evidence for media use being detrimental to both non-media activities and cognitive skills, it seems redundant to instigate this assumption, particularly since this study has shown positive relationships between media activities and reported problem solving and novelty seeking. Therefore, omitting media activities such as learning apps may deprive children of an additional opportunity to practice these skills or an activity that they enjoy. It is also important to note that the current study relies on correlational data, as do other studies exploring displacement and this has been noted as a limitation of the displacement hypothesis (Mutz et al., 1993; Vandewater et al., 2006). As it is not possible to ascertain whether it is media-based activities affecting non-media-based activities, or a lack of non-media-based activities leading to higher engagement in media, it is difficult to make conclusive statements about how media may or may not affect other activities. However, it is reasonable to suggest that in the present study, most non-media-based activities are unaffected by media and in some cases, there may be indication of facilitation between different activities. Furthermore, the negative associations between some joint activities and media activities are interesting and it may be of interest to pursue questions about how different activities interact and influence creative thinking further. If this were to be completed, it would be recommended that researchers use more detailed methods, such as 24-hour diaries (Vandewater et al., 2006; Vandewater & Lee, 2009), to ensure a more complete picture of how children spend their time.

2.4.7 Summary

Overall, significant positive relationships were observed regarding media use, including between reported problem-solving behaviour and learning apps and creative apps. Additionally, independent reading was positively related to problem solving and was the strongest predictor of problem solving overall. However, these relationships were not observed longitudinally. Novelty seeking was positively related to several variables including learning and creative apps, independent touchscreen use, and multi-screen use. It was also positively related to watching non-child-directed video content independently, which was the only significant predictor of novelty seeking. This suggests that media use generally may not have a detrimental influence on young children's reported problem solving and novelty seeking behaviours. Interestingly, the only negative observations were noted in regression analyses, where watching child-directed video content with an adult and independent touchscreen use were significant negative predictors of problem solving. While the potential mechanisms underlying these relationships are unclear, it is important to note that the context of the activities may be factors in these observations. With regards to the significant findings, it is critical to consider that some findings were not consistent across correlation and regression analyses. This may suggest that relationships are somewhat tenuous and should be viewed with a degree of caution until they can be confirmed as robust with future research. Furthermore, there were many non-significant findings. In an area where children's media use can be maligned, the notion that media use may not have any influence, positive or negative, is a critical point to consider. Non-significant findings, on one hand, may indicate that problem solving and novelty seeking do not have any bearing on children's engagement with these activities. On the other hand, it could indicate that these activities are neutral in terms of problem solving and novelty seeking, where it is neither facilitative nor a hinderance. This may support guidance such as the Royal College of Paediatrics and Child Health (RCPCH) policy, where they do not specify any restrictions except to observe when children's media use becomes problematic and interferes with lifestyle factors, such as sleeping and eating (RCPCH, 2019). This is in stark contrast to more restrictive and preventative policies, where organisations advise against activities like media use because there is limited evidence for specific benefits (AAP, 2016). As long as the activities do not cause harm, they could be permissible and a supplementary option in children's play repertoire.

2.4.8 Limitations

The current study presents preliminary insight into how touchscreen use and other activities may relate to aspects of creative thinking. The large sample size, as well as the longitudinal element of the study, allowed insight into how activities may have a longer-term influence on aspects of creativity. However, it is important to acknowledge that despite the reasonable sample size, statistical power may not have been reached for the longitudinal analyses. Additionally, the sole use of an online survey may raise some limitations. Relying on caregiver report may introduce some bias, though caregivers are thought to be reasonably accurate at reporting children's behaviour and cognitive abilities (Waschbusch et al., 2000). Furthermore, the use of an online survey also allowed a wider and potentially more diverse sample of responses to be collected, potentially improving the generalisability of the research compared to a laboratory-based study. Additionally, previous research has also favoured using specific questions about media use in the previous day (Huber et al., 2018; Rideout, 2016; 2017) and while it does have limitations in terms of retrospective questioning, the specificity allows an interesting snapshot of time spent engaged in different activities (Rideout, 2016). A further consideration of the survey is how well the problem solving and novelty seeking scales represent creative thinking skills. Given that they are commonly measured using behavioural methods (Bijvoet-van den Berg & Hoicka, 2014; Reindl et al., 2016), it is possible the scales represent personality traits or behavioural tendencies, rather than actual creative thinking abilities. However, the alpha values from Cronbach reliability analyses were acceptable and could be considered as reasonable measures of children's naturalistic problem solving and novelty seeking behaviour.

While the study presented some interesting significant findings, it is important to acknowledge potential limitations regarding the observations themselves. As has been noted throughout the Discussion, there were inconsistencies in relationships between variables across correlational and regression analyses. One might expect that if the associations were robust, significance would be observed across the analyses. However, there were instances where significant relationships with variables did not translate into significant predictors of the respective dependent variable, and vice versa. This could be due to variance explained by each variable overlapping, thus reducing the overall contribution of that specific variable to the model and how well it predicts problem solving or novelty seeking. This is important to consider as the lack of consistency across analyses may suggest the relationships are relatively weak and may be susceptible to the influence of other variables, both within the analyses and possible extraneous factors that were not accounted for in the study. Indeed, while significant, the overall variance explained in the novelty seeking regression model and the change in variance explained in the problem-solving regression model was low. This may suggest that the overall contribution of the activity variables may not have a large bearing on children's naturalistic problem solving and novelty seeking behaviours when examined together, as opposed to examining specific relationships. Indeed, it is possible that other variables not accounted for in the study may be stronger predictors of children's behaviour or perhaps have a moderating influence on the relationships. Thus, it is important to acknowledge the potential weakness of the findings and be mindful of this when interpreting them. Given that this study was exploratory, and the findings are preliminary, it would be beneficial for future research to attempt to replicate the study and assess whether the findings are consistent and robust.

It is important to note there are other variables not accounted for in the study that may potentially have an influence on the observed findings. For example, caregivers will likely have a large impact on children's media use. Their own media use and attitudes towards it have been found to predict the amount of time children spend using devices, where more caregiver use and more positive attitudes are associated with higher use in children (Lauricella et al., 2015). Additionally, Rideout and Robb (2020) found lower-income families were more likely to perceive screen media as providing educational benefits compared to higher-income families, and lower-income families also reported higher levels of media use. Thus, caregivers could potentially have a large influence over children's media use generally. Another variable to consider that is linked with caregiver attitudes is the home environment. Previous research has highlighted high-quality home learning environments as being important for children's development (Kluczniok et al, 2013). Depending on caregiver values, this may feed into their children's environment more generally, as caregivers attempt to match environments to their values (Livingstone et al., 2015). Thus, if caregivers view media use favourably, the home environment may permit more media use with greater ease. In comparison, if media use is not viewed favourably, there may be limited access and use in favour of other non-media-based activities. It is also possible that caregivers who value the development of children's creativity, which can include media use (LEGO Foundation, 2020), will provide an enriching environment that also facilitates different aspects of creative thinking, such as problem solving. Thus, the home environment may have an impact on both children's media use and their creative thinking. Finally, another interesting variable to consider could be the amount of time children spend in more formal childcare settings, such as nurseries. This could be important as the survey used in the study asks specifically about media use and other activities at home. It is possible children may have differential activity levels and media use depending on how much time they actually spend at home. For example, those who spend most of their time in nursery may not have the opportunity to use media as much as those who spend more time at home. Thus, while the findings presented in the study are of interest, there are some limitations in how far these findings can apply, given the potential influence of third variables that were not accounted for.

It would therefore be of interest for future research to include other variables, such as caregiver use and attitudes towards media, to better assess their potential contribution to children's media use. This would also be beneficial in allowing better understanding of how these variables may have potential moderating influences on relationships between children's media use and their problem solving and novelty seeking behaviours.

Another factor to consider is socioeconomic status. The aforementioned third variables can also differ as a function of socioeconomic status (Livingstone et al., 2015; Nikken & Opree, 2018). For example, in relation to the home environment, a report from the UK's Department for Education suggested families from lower socioeconomic backgrounds may experience barriers, such as capability, financial and time-related constraints and motivation (Department for Education, 2018). While these barriers were highlighted in relation to language development, these ideas may also apply in the context of the current study. For example, caregivers with higher socioeconomic status may be in a better position to provide guidance on media use as they can acquire newer devices and learn the requisite skills, leading to more consistent application of knowledge and scaffolding experiences with their children (Nikken & Schols, 2015). Outside of media use, it is possible that in providing high-quality home learning environments, caregivers from higher socioeconomic backgrounds also provide a generally enriching environment which may benefit different aspects of cognition and behaviour, including children's problem solving and novelty seeking. This is important to consider in relation to the present sample, where 57.4% of caregivers reported undergraduate or postgraduate education at Time 1 (60.5% at Time 2) and around a quarter of caregiver education not being disclosed. Thus, there was a relatively high proportion of well-educated caregivers. This particular profile of participants may have implications in terms of the findings and generalisability of the research. Previous research has noted that children's media use is associated with caregiver socioeconomic status. For example, Rideout and Robb (2020) observed children from families with lower income and lower education levels used media more than those from higher-income or higher-education backgrounds. Additionally, Ribner & McHarg (2021) found media use was higher in children of caregivers who perceived themselves as being of lower social status. Given the low median values and negatively skewed data presented in the current study (see Tables 1 and 5), this could suggest relatively small amounts of media use, which may reflect the socioeconomic profile of the sample. This is important to acknowledge because the findings from the study may not necessarily apply to families from lower socioeconomic status. Additionally, socioeconomic status may play a role in extraneous variables that also have a bearing on children's media use. This may therefore illustrate a complex interplay of factors involved in children's media use and potentially, relationships with problem solving and novelty seeking. It would be of great interest for future research to examine these factors in greater detail and assess the influence on media use and whether they have a moderating effect on the relationships observed in the present study. It would also be fruitful for future research to attempt to recruit diverse samples, both in terms of socioeconomic status and other variables such as ethnicity, to enable detailed analysis of the potential contribution of these factors. Additionally, it would enhance our understanding of commonalities and differences between various groups of people, providing greater representation of the population and a richer perspective on children's media use and creative thinking traits (Jordan & Prendella, 2019; Nielsen et al., 2017).

2.4.9 Conclusions

To conclude, the current study provided evidence that contributes to the understanding of how touchscreens may influence naturalistic problem solving and novelty seeking in 12- to 47-month-olds using an online survey. As an exploratory study, it reveals that, generally, media use may not be detrimental nor beneficial for children's problem solving and novelty seeking, given the amount of null findings and inconsistency between correlation and regression analyses. Additionally, there was limited evidence to suggest a longitudinal influence of media. However, the positive association and significant prediction between engaging with learning apps and children's problem solving may suggest a potentially beneficial influence. A key progression from this study would be to explore whether there are relationships between touchscreen use and behavioural measures of creative thinking. Previous research concerned with media use and creative thinking have used behavioural methods, such as divergent thinking measures and problem-solving tasks (Anderson, Huston et al., 2001; Chen & Siegler, 2013; Harrison & Williams, 1986). Since there are behavioural measures suitable for preschool children (Bijvoet van den Berg & Hoicka, 2014; Reindl et al., 2016), it would be fruitful to explore whether the observed relationships exist with direct measures of creative thinking. A second way of progressing the research would be to examine specific causal mechanisms that underlie the observed relationships in more detail. That is, it would be informative to explore the features of different activities, like apps and reading, to discover the direction of effect and identify features that facilitate or impede creative thinking. The next chapter of thesis address the first suggestion and explores how behavioural measures of creative thinking might relate to different activities.

CHAPTER THREE:

The relationships between 24- to 47-month-olds' touchscreen use, divergent thinking, and problem solving

Progressing from the previous chapter, the main aim of this study was to use behavioural creative thinking measures and assess whether the previously observed relationships would be consistent with more controlled measures in a laboratory setting. Children aged between 24 and 47 months completed two creative thinking tasks; the Unusual Box Test to assess divergent thinking and the Great Ape Tool Test Battery to measure problem solving. Caregivers completed a survey asking about their children's engagement in media-based and non-media-based activities. No significant relationships were observed between divergent thinking and any of the measured activities. However, higher problem-solving performance in the GATTeB was related to more time spent using learning apps, replicating the cross-sectional findings from Chapter Two.

3.1 Introduction

Children's media use has been consistently and hotly contested across research and society for decades (Healey et al., 2019; Royal College of Paediatrics & Child Health, 2019). There has been concern about how media use could impact on children's creativity (Singer & Singer, 1990). This is an important consideration as creativity and creative thinking skills are valuable and useful assets in everyday life across the lifespan (Sternberg & Lubart, 1996). For children, their development of these skills is actively encouraged and even embedded in educational curriculum (Department for Education, 2017). At face value, media use has been viewed as a behaviour that could distract from other activities which are perceived as more beneficial (American Academy of Pediatrics [AAP] Council on Communications and Media, 2016). Yet, there has been suggestion that there could be positive aspects of media use, for example through educational content (Anderson et al., 2001; Courage & Howe, 2010). Thus, when discussing children's media use, there is much uncertainty as to whether it is a help or hinderance to creative thinking skills, leading to recommendations of avoiding media use in favour of non-digital activities that are known to be beneficial (Yogman et al., 2018). However, a limitation of this is that there is inadequate evidence to conclusively reject media use as either a beneficial or harmful activity. Previous research has examined the impact of media use, such as television-watching, on aspects of children's creative thinking, including divergent thinking and problem solving (Anderson et al., 2001; Chen & Siegler, 2013; Harrison & Williams, 1986). However, little is known about how touchscreens could relate to creative thinking. Therefore, the current study sought to explore this in 24- to 47-month-olds using behavioural measures of divergent thinking and problem solving.

Previous research has examined the influence of media use on aspects of creative thinking, such as problem solving and divergent thinking. Much of the focus has been on children's television-watching, as television has been a highly prevalent form of media in children's lives for decades (Pecora, 2007; Rideout, 2013). It has been theorised that television might negatively affect creativity in a variety of ways, including displacement of other beneficial activities (Vandewater et al., 2006) or ready-made visual images reducing children's imaginative thinking (Valkenburg & van der Voort, 1994). Studies examining the influence of television on creativity have revealed a mixed set of findings. Some studies have indicated that television-watching has a negative influence on creative thinking. For example, Harrison and Williams (1986) found 14- to 15-year-olds' divergent thinking scores were lower after television was introduced in a community compared to scores recorded two years before television was accessible. The main suggestion for these findings was that television does not offer opportunities to develop creative thinking and, combined with displacing activities that theoretically offer these opportunities, had a negative impact on these skills (Vandewater et al., 2006). In contrast, other studies have shown there can be positive associations with television-watching when examining the specific content consumed. For example, Chen and Siegler (2013) showed 2.5-year-old children were able to successfully complete a problem-solving task after watching a video demonstration of the solution, provided the goal intention was made clear. For divergent thinking, Anderson et al., (2001) demonstrated watching educational content at preschool age was a positive predictor of higher divergent thinking scores at adolescence. In a separate study, Subbotsky et al., (2010) found watching magical content was associated with higher divergent thinking scores compared to watching non-magical content in 4- to 6-year-olds, which may also challenge theoretical assumptions about how ready-made television images affect creativity (Valkenburg & van der Voort, 1994). Additionally, some studies have shown that television-watching does not have any influence, positive or negative, on creative thinking when compared to radio, a medium where it is expected children will use their imagination and consequently perform better on divergent thinking tasks (Runco & Pezdek, 1984). Furthermore, Rose et al., (2021) showed 3- to 4-year-olds' problem solving was not negatively impacted by fast-paced television and could have the potential to facilitate problem solving. Thus, the understanding of how television use can have an influence on creative thinking is mixed and seemingly dependent on various factors, including content.

Presently, the influence of touchscreens and apps on creative thinking is unclear. There has been progression in outlining the conditions in which digital content might be beneficial for children, for example, interactivity, meaningful engagement, and appropriately targeted content (Hirsh-Pasek et al., 2015; Valkenburg & Cantor, 2000). However, there is still limited understanding about the impact they could have on cognition and creative thinking more specifically. It has been suggested that the interactive nature of touchscreens and the ability to tailor them to the user might offer a different experience to television use, consequently affecting children's ability to learn and develop skills from them in different ways (Christakis, 2014). Qualitative work has indicated that touchscreens and their associated apps have the potential to facilitate creativity (Marsh et al., 2018). Psychological research has examined the effect of touchscreens on older children's creative thinking, including divergent thinking and problem solving. Huber et al., (2016) and Tarasuik et al., (2017) found 4- to 6-year-olds were able to learn problem-solving strategies from touchscreens and apply them to a physical version of a task, suggesting touchscreens may not hinder problem solving. For divergent thinking, Kandemirci (2018) found no significant differences in 5- to 7-year-olds' divergent thinking (as measured through storytelling) after children either played a physical version of a storytelling game or an app version. Additionally, Piotrowski and Meester (2018) found no differences in 8- to 10-year-olds' divergent thinking after using open-ended creative apps that were targeted for their age range compared to if they used apps aimed at preschoolers. Thus, the evidence suggests that apps do not appear to hinder creative thinking but may not facilitate it either. While these studies have undoubtedly contributed to our understanding about the effect of apps on older children's creative thinking, they do not necessarily indicate what the baseline and general influence might be. Additionally, the influence on young children's creative thinking is still unknown. The findings from Chapter Two address this and showed reported problem solving was positively related to learning apps and creative apps. Furthermore, novelty seeking, which could be considered as a precursor to exploration and divergent thinking (Carr et al., 2016), was also related to these apps and independent touchscreen use. The findings from these studies suggest it may be reasonable to assume that touchscreens could influence young children's creative thinking. This is particularly pertinent to explore as digital media has been identified as a form of children's play (Marsh et al., 2016) and may be positively associated with creative thinking, as other forms of play have been found to be (Fehr & Russ, 2016; Pepler

& Ross, 1981; Russ et al., 1999). Additionally, the social elements that touchscreens could afford, such as scaffolding, contingency, and feedback, may also have a beneficial influence (Hoicka et al., 2018; Kirkorian et al., 2016). Thus, touchscreens may have the potential to facilitate young children's creative thinking, justifying the exploration of the relationships that could underlie this.

The current study explored the relationship between creative thinking and media use in 24- to 47-month-olds. Advancing on Chapter Two, it specifically explored whether there were significant relationships between touchscreen use and behavioural measures of creative thinking in a laboratory setting. This was an important development as the validity of self-reported creative thinking measures has been questioned (Baer, 2011). Additionally, it has been suggested that self-report measures could benefit from being accompanied by other measures of creative thinking (Silvia et al., 2012). Thus, although parents are thought to be reasonably accurate in reporting their children's behaviour (Waschbusch et al., 2000), using behavioural tasks allows direct examination of children's creative thinking abilities. This also aligned the current study more closely with previous research which also used behavioural measures of creative thinking when examining media use (Anderson et al., 2001; Chen & Siegler, 2013; Harrison & Williams, 1986). The study also expanded on previous research by investigating the relationship between creative thinking and touchscreen use in young children, allowing a novel contribution to an under-researched area.

The primary aim of this study was to explore whether there were significant relationships between children's creative thinking and reported media use and whether creative thinking performance was predicted by these variables. To do this, caregivers of 24- to 47-month-olds were asked about their children's access to media and how long they spend engaged in different activities on a typical day. Children were asked to complete two separate behavioural measures of creative thinking: a divergent thinking task and a problem solving task battery. The total scores of these measures were calculated and correlated with the caregiver survey responses.

3.2 Method

3.2.1 Participants

A power analysis showed 84 children were required to observe a medium effect size (*r* = .03, α = 0.05, power =.08; Faul et al., 2007). Eighty-five children aged between 24- and 47-months were recruited using the Sheffield Cognitive Development research volunteer database and its accompanying social media pages. The average age of the sample was 36 months 13 days (*SD* = 7 months 4 days). The sample consisted of 41 female participants and 44 male participants. Most children in the sample were White (91.8%), followed by children of mixed ethnicity (5.9%) and Asian backgrounds (2.4%). In terms of caregiver education, 44.7% reported undergraduate degree as their highest level of education, followed by postgraduate degree (36.5%), A-Level or equivalent (11.8%) and GCSE or equivalent (5.9%). One caregiver did not disclose their education level (1.2%).

3.2.2 Materials

To measure children's media use, caregivers completed an online survey. Two behavioural measures of creative thinking were used; the Unusual Box Test to measure divergent thinking (Bijvoet van den Berg & Hoicka, 2014) and the Great Ape Tool Test Battery to measure problem solving (Reindl et al., 2016). Both creative thinking tasks were video recorded using two video cameras set on tripods.

Activities survey

Caregivers completed a survey asking about their children's media use, which was administered using Qualtrics survey software (see Appendix E for all survey questions). They were asked about children's access to devices, such as smartphones and tablets. They were also asked about the amount of time children spent engaged in different activities on a typical day at home[1], for example, using touchscreens, both independently and with an adult. To account for different touchscreen content, caregivers were asked about their children's use of learning

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[1] Note, the phrasing was different to the survey used in Chapter Two as an earlier version of the survey was used. Additionally, both using video call software and multi-screen use questions were originally separated by independent and joint use. As data collection had started, the decision was made to continue the study with "typical day" phrasing. However, this phrasing is not uncommon and has been used in previous developmental media research (see Ahearne et al., 2016; Bedford et al., 2016; Rideout, 2016). To better compare with findings from Chapter Two, the questions regarding independent and joint video call use and independent and joint multi-screen use were merged, resulting in an overall video call use variable and an overall multi-screen use variable. Appendix F shows the descriptive statistics for engagement in different activities for this sample and a similar sample of UK-based 24- to 47-month-olds from Chapter Two (*n* = 75) to allow comparisons between the two.

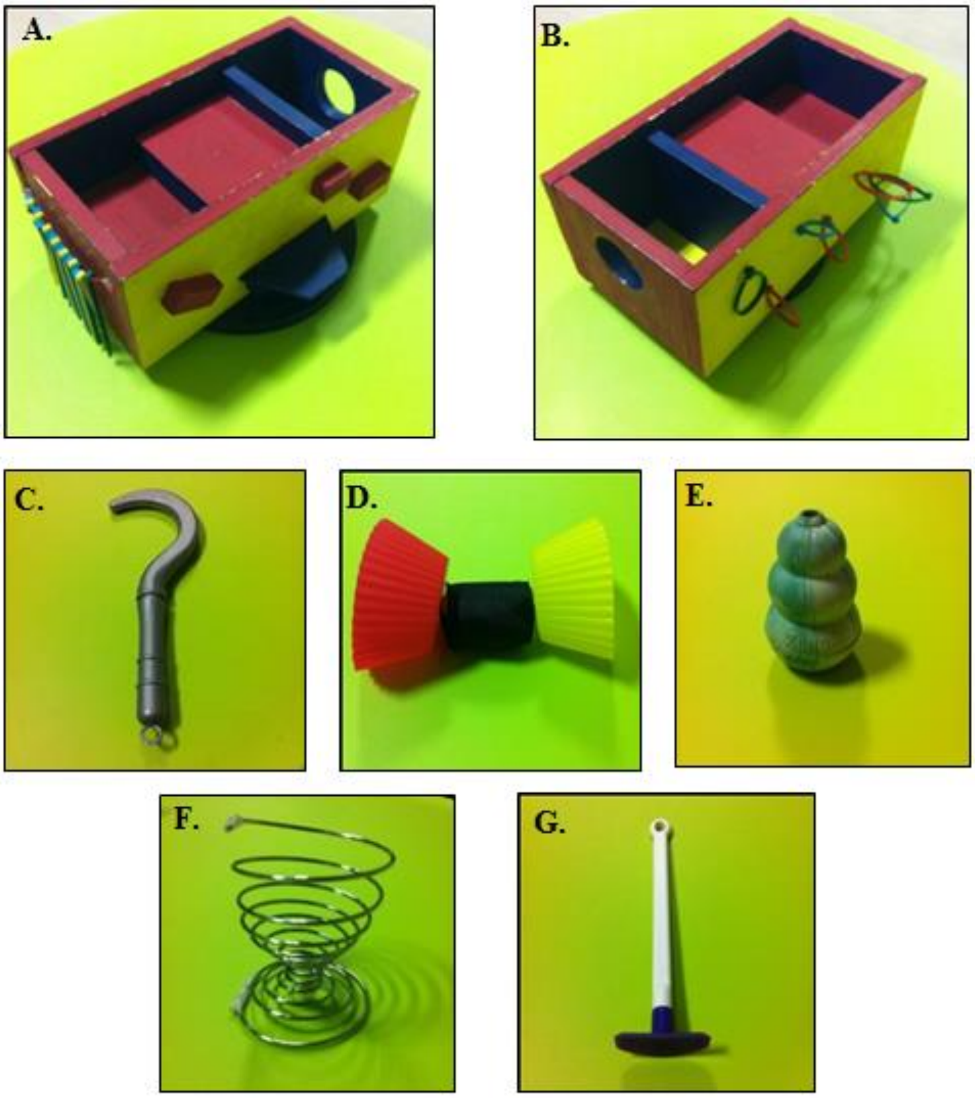
apps, gaming apps and creative apps. They were also asked about video calls and multi-screen use, which have been of interest in past developmental media research (Marsh et al., 2015; Rideout, 2017; Roseberry et al., 2014). As the most recent guidelines from the American Academy of Pediatrics suggested media use should be supervised (AAP, 2016), they were also asked about their children's engagement in independent and joint engagement in watching video content. Finally, they were asked about their children's independent and joint engagement in non-digital activities (reading, creative activities, and playing with toys), to assess whether these activities were more strongly associated with divergent thinking and problem solving, as has been previously insinuated (Healey et al., 2019).

Unusual Box Test

The Unusual Box Test (UBT) is a physical measure of divergent thinking intended for children aged between 1 and 4 years (Bijvoet-van den Berg & Hoicka, 2014; Hoicka et al., 2016). The UBT consists of a colourful wooden box with various attachments, including strings, blocks, a round hole, rings, stairs, and a rectangular room (Figure 4). Five additional items are used in the procedure: a plastic hook, a shaker, a rubber toy, an egg cup, and a spatula. The box was presented on a turntable to allow children to easily turn and access the different areas on the box.

Figure 4.

The Unusual Box Test. A: View of the blocks, rings, and stairs. B: View of the round hole, rings, and rectangular room. C: Plastic hook. D: Shaker. E: Rubber toy. F: Egg cup. G: Spatula.

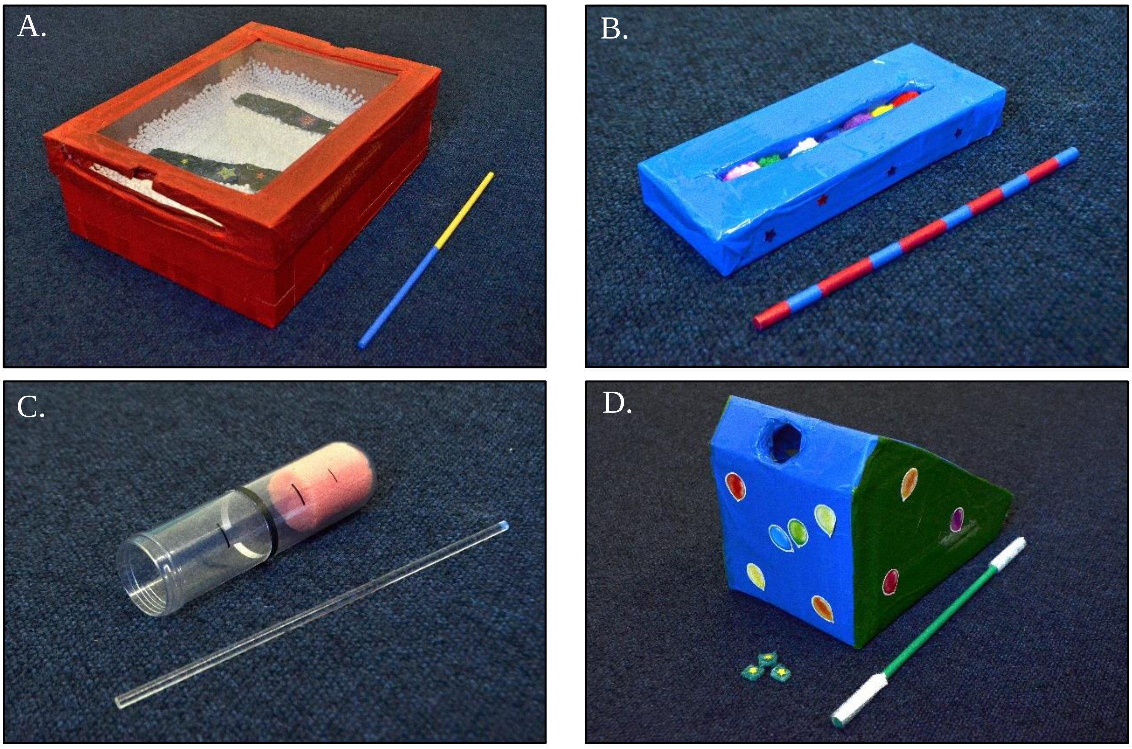


Great Ape Tool Test Battery

The Great Ape Tool Test Battery (GATTeB) is a physical measure of problem solving, originally used with children aged from 2 to 3.5 years (Reindl et al., 2016). It is a tool-use task, where participants can use a provided tool (in this case, a stick) to help achieve the goal set by the experimenter. The tasks were designed to emulate the natural behaviours of great apes observed in the wild, such as termite fishing and scooping algae. Four tasks were used in the current study: Algae Scoop, Seed Extraction, Termite Fish, and Marrow Pick (see Figure 5). The four tasks used in the current study were chosen from the original 12-item battery because of the variable task success rate observed in the original study; 60% success in Termite Fish, 40% in Algae Scoop, 29.4% in Seed Extraction and 17.9% in Marrow Pick, which allowed for varying levels of difficulty in the current study.

Figure 5.

The Great Ape Tool Test Battery (GATTeB) tasks. A: Algae Scoop. B: Seed Extraction. C: Marrow Pick. D: Termite Fish.



Two tasks had a two-minute time limit; the Algae Scoop task (Photo A) required children to extract a black strip of plastic from inside the box, and the Seed Extraction task (Photo B) required children to extract a minimum of one of the balls from the box. Two tasks had a one-minute time limit; the Marrow Pick task (Photo C) required children to extract the sponge from the bottom of the tube, and the Termite Fish task (Photo D) required children to extract at least one star that had been dropped into the hole in the box. All tasks included a stick, which if used appropriately, would be helpful in achieving the set goal. The stick from the Termite Fish had Velcro at both ends so the stars could adhere to the stick during the task.

Child Development Inventory

Both creative thinking tasks were physical measures of divergent thinking and problem solving. Therefore, it is possible that children who have more developed motor skills may have performed better in the tasks. To account for this, caregivers were asked to complete the gross and fine motor development scales of the Child Development Inventory (CDI; Ireton, 1992). The scales consist of two columns that describe key behavioural milestones for motor control. For example, a behaviour for gross motor control was “Stands on one foot without support” and a behaviour for fine motor control was “Turns pages of picture books, one at a time”. The behaviours at the bottom of the columns describe early milestones, progressing through to more developmentally advanced behaviours towards the top of the columns. Starting from the bottom of the column for gross motor or fine motor control, caregivers were asked to work their way up through the behaviours, indicating their children’s ability to perform the behaviour using a tick (comfortably completing the behaviour), a ‘B’ (beginning to complete the behaviour) or a cross (not completing the behaviour yet), until they wrote three crosses in a row or reached the top of the column. Then, they moved on to the other motor control scale, observing the same instructions. Following the CDI coding scheme, the cut-off point for motor ability was the highest behaviour at which caregivers gave a tick. Then, the tick was matched with the corresponding age to give an estimate of motor age. This age was correlated with the creative thinking measures to assess whether performance was associated with motor skills.

3.2.3 Design

The UBT and GATTeB were presented in a counterbalanced order and the order of tasks within the measures were counterbalanced as well. For full details, including task orders and scripts, see Appendix G for the UBT and Appendix H for the GATTeB.

3.2.4 Procedure

Children and their caregivers were greeted by the experimenter and taken to a warm-up room. Caregivers were asked to give consent to their child participating in the study and were also informed of their right to withdraw from the study at any point. The experimenter engaged in a brief free-play warm-up session with the child. During this time, the caregiver was asked to complete the gross and fine motor measures from the CDI. Once the experimenter was satisfied that the child was happy to continue, the caregiver and child were led into the testing room. Caregivers were asked to sit at a desk with a laptop and complete the activities survey on Qualtrics. Caregivers always remained in the child's view to avoid causing distress. Children were seated at a toddler table in view of two cameras and told that they would be playing some games. The experimenter then placed either the UBT or the first GATTeB task on the table in front of the child. For the UBT, the experimenter pointed out the different features of the box according to the task script (Appendix G) and children were encouraged to turn the box themselves. Then the experimenter handed one of the five items to the child, beginning a 90 second free-play period in which the child was able to independently explore the box. After 90 seconds elapsed, the experimenter took back the first item and handed them the second item for another 90 seconds. This was repeated until all five items had been given to the child.

For the GATTeB, the experimenter placed one of the tasks on the table in front of the child and drew their attention to the goal of the task according to the corresponding script (for example, for the Termite Fish "…if you can get the stars out the box, you'll win a sticker!"; see Appendix H for full script). The child was then given one minute (Termite Fish and Marrow Pick) or two minutes (Algae Scoop and Seed Extraction) to solve the task. Importantly, no reference was made to the stick provided and children were only told what the aim of the task was. Thus, it was up to participants to work out the stick was a potentially helpful tool that could enable them to successfully complete the task. The child was encouraged to try and complete the task during the allocated time. If the child completed the task or if the time allocated to complete the task elapsed, they were given a sticker and the experimenter took away the first task and introduced the next one, again giving them the aim of the task. This was repeated until all four tasks had been presented. Children were given a sticker regardless of whether they successfully completed the task to avoid distress and to encourage them to engage with all the tasks. Once both creative thinking measures had been completed, the child and their caregiver were taken back to the warm-up area where caregivers were given a verbal debrief and had the opportunity to ask questions about the study. At the end of the session, the experimenter let the child choose a book to take home as a gift for taking part in the study.

3.2.5 Coding

Two video cameras set on tripods were used to record children's performance during the UBT and GATTeB to allow accurate coding following study completion. The coding schemes for both measures are described below.

UBT

The UBT was coded using a fluency index, where the number of unique action-box area combinations produced by children during the free-play periods were totalled, giving a divergent thinking score. There are 10 areas children can operate in and 18 possible actions, which were combined to code a unique action-box area combination, for example, using the spatula to "jump on the edge of the box", "drop in the rectangular room" or "guide through the strings". Each unique action-box area combination was given a score of 1 and was totalled with other unique action-box area combinations to give an overall divergent thinking score.

GATTeB

The GATTeB was coded according to appropriate tool use and task success. Points were allocated based on the actions completed with the tool. One point was awarded if the participant picked up the tool (in this instance, a stick). One point was awarded if the child used the stick correctly (that is, using it in a way that could potentially lead to goal achievement, for example, in the Marrow Pick task, inserting the stick into the tube and touching the sponge). Finally, they were awarded two points for successfully completing the task with the stick, one point for an alternative method (for example, using their fingers instead of the stick in the Seed Extraction task) or no points if they did not successfully complete the task. The maximum score that could be awarded for each task was 4. Scores for each task were added together to produce a total score, making 16 the maximum possible problem-solving score.

The coding scheme for the GATTeB broadly follows that suggested by Reindl et al., (2016) in that it is noted when a child picks up a tool, uses it in a way that may potentially lead to success and if they are successful in completing a task with a tool. However, it was noted that in the original study, children who completed the task without the tool were coded as "incorrect success" and were excluded from the analyses. It was therefore decided that an additional coding feature would be added, where children who successfully completed the task but without using a tool or according to the desired sequence described in Appendix H, were coded as "alternative success". This was done in the interest of retaining a larger sample size and to distinguish between children who were not successful at completing the task at all compared to children who completed the tasks using an alternative, non-tool-based method. The reason for a higher score for successful tool use is because tool use is seen as a sophisticated behaviour and indicative of greater planning abilities and ability to understand causality in both humans and non-humans (Chen et al., 2010; Keen, 2011; Seed & Call, 2009). For example, in the GATTeB, if a child sees the small hole in the side of the box in Algae

Scoop, they could try and fit their hand through the hole to reach the plastic strip, even though the hole is too small for their hand to comfortably fit. Instead, they might identify the provided stick as a potential tool they can use to try and reach the plastic through the hole. This saves potential effort and discomfort after putting their hand through a narrow hole by recognising that the provided stick could act as a potential extension of their body. Thus, successful tool use in the GATTeB is arguably easier, could be considered as more skilled and therefore worthy of a higher score. Additionally, Kahrs et al., (2014) highlighted the wrist as an important feature that contributes to uniquely human tool-use performance. They argued the wrist potentially allows greater precision in tasks involving fine motor skills. Furthermore, they highlighted that wrist movement when using a tool may allow children to better learn how to control the extension of their body to achieve a task. Given that successful tool use in the GATTeB does rely on precision fine motor movement, aided by precision wrist movement (particularly for the Algae Scoop and Seed Extraction tasks), it was deemed appropriate to acknowledge the higher level of fine motor movement and planning required in the coding scheme.

Reliability

To assess reliability for both the UBT and GATTeB, 20% of the videos (n = 17) were coded for agreement by a second coder and analysed for consistency using intra-class correlations. Following the criteria for intraclass correlation coefficients outlined by Koo and Li (2016), reliability for the UBT was good (ICC = .849, CIs = .633, .943) and reliability for the GATTeB was excellent (ICC = .988, CIs = .968, .996).

3.3 Results

First, the descriptive statistics for the creative thinking measures, the activities survey, and fine and gross motor control are presented. Secondly, bootstrapped correlations are reported to investigate the relationship between creative thinking and time spent engaged in different activities. Finally, bootstrapped hierarchical regression analyses were used to assess which activities best predicted creative thinking.

Creative thinking. The mean number of novel actions produced in the Unusual Box Test was 26.46 (*SD* = 6.13, 95% CIs = 17.3, 35.7). The mean problem-solving score on the GATTeB was 9.67 (*SD* = 3.81; 95% CIs = 2.3, 15.7). Scores from the creative thinking measures were normally distributed. *T*-test analyses were used to determine whether there were differences between gender and no significant differences were observed (*p*s > .05). A *t*-test was run to investigate whether there were significant differences between creative thinking scores based on the order measures were presented in. Task order did not affect divergent thinking scores ($p > .05$). However, there was a significant difference between problem solving scores $t(83) = 3.076$, $p = .003$. Specifically, problem solving scores were significantly higher if the UBT was completed first (*M* = 10.84, *SD* = 3.28) compared to if the GATTeB was completed first (*M* = 8.41, *SD* = 3.98). As a result, task order was controlled for in later correlations and regression analyses.

Activities survey. Figure 6 illustrates 24- to 47-month-old's access to devices at home. Caregiver reports revealed the majority of children had access to a tablet computer at home while over a fifth did not have access to a tablet at all. A large majority of children had access to a smartphone in their house. In contrast, a smaller proportion did not have access to a smartphone. Additionally, children's tablets did not seem to be a popular choice in the sample, with most children not having access to these kinds of devices.

Figure 6.

Percentage of children's access to different touchscreen devices.

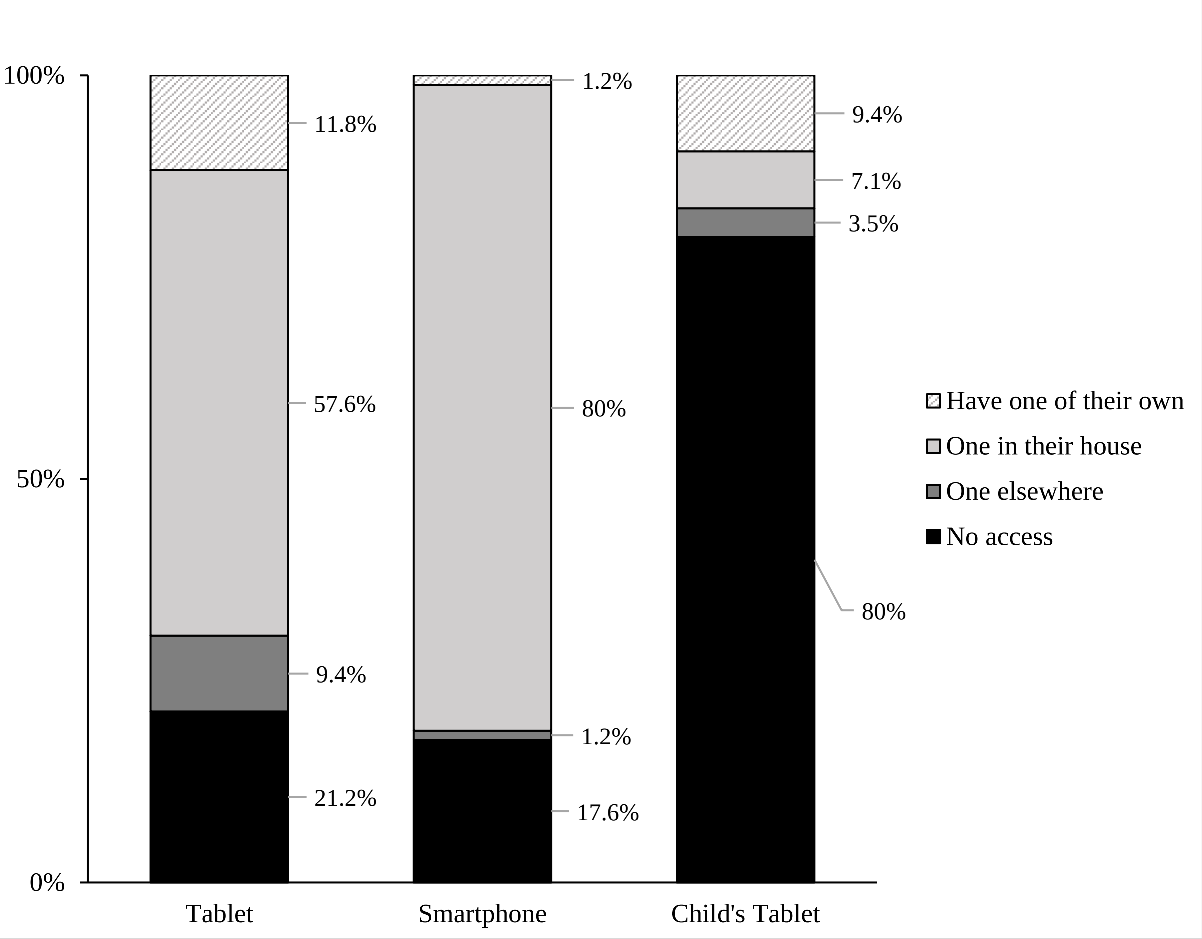


Table 12 displays the descriptive statistics for variables included in the activities survey, including means, medians, standard deviation, range, skewness, and kurtosis. As shown by the standard deviation, skewness, and kurtosis values in the table, data from the survey were not normally distributed. To account for this, bootstrapping was used in later analyses (Wright et al., 2011).

Motor control. Mean gross motor control for the sample was 33.44 months (*SD* = 9.73, CIs = 20, 55). Fine motor control was not reported for two cases, however, the average fine motor control for the remaining 83 cases in the sample was 35.78 months *(SD* = 10.46, CIs = 23, 58).

Table 12.

Descriptive statistics for minutes spent engaged in different activities on a typical day at home.

Activity	**M**	**SD**	**Median**	**Range**	**Skewness**	**Kurtosis**
Touchscreen use (independent)	18.67	27.00	10	0 – 120	2.15	5.19
Touchscreen use (with an adult)	14.55	23.69	10	0 – 150	3.66	16.36
Learning apps	10.21	15.89	5	0 – 90	2.77	9.73
Gaming apps	1.88	6.45	0	0 – 50	5.52	37.38
Creative apps	4.46	7.83	0	0 – 40	2.30	6.08
Child-directed video content (independent)	29.98	29.32	30	0 – 150	1.67	3.67
Child-directed video content (with an adult)	30.21	31.20	30	0 – 150	2.00	4.85
Non-child-directed video content (independent)	2.65	10.71	0	0 – 60	4.60	21.26
Non-child-directed video content (with an adult)	6.66	15.33	0	0 – 60	2.70	6.57
Video call use	3.93	8.32	0	0 – 60	4.33	24.97
Multi-screen use	10.12	28.00	0	0 – 150	3.69	14.30
Playing with toys (independent)	101.06	90.32	60	0 – 480	2.07	5.19
Playing with toys (with an adult)	65.41	56.99	60	0 – 300	1.75	3.70
Reading (independent)	12.92	15.10	10	0 – 90	2.54	8.49
Reading (with an adult)	23.29	15.33	20	0 – 90	1.27	4.61
Creative activities (independent)	18.46	21.84	10	0 – 120	2.50	7.66
Creative activities (with an adult)	32.24	23.48	30	0 – 120	1.22	1.66

Note: M = Mean; SD = Standard Deviation.

3.3.1 Relationships between activities and creative thinking

Bootstrapped correlations were used to investigate the relationship between creative thinking and touchscreen use. Initial correlations showed significant relationships between age, motor ability and creative thinking. Age was positively related to gross motor ability (*r* (83) = .669, p < .001), fine motor ability (*r* (81) = .664, p < .001) and divergent thinking (*r* (83) = .418, p < .001). Fine motor ability was also positively related to divergent thinking (*r* (81) = .384, p < .001). As age was more strongly related to divergent thinking than fine motor skills, it was decided that age would be controlled for in later bootstrapped correlations between divergent thinking and children's engagement in different activities. After controlling for age, the relationship between fine motor skills and divergent thinking was no longer significant (*r'* (80) = .156, p > .05). With regards to problem solving, gross motor skills were positively related to problem solving (*r* (83) = .269, p = .013). Therefore, gross motor skills were used as a covariate in analyses concerning problem solving. To assess whether controlling for gross motor skills accounted for the significant differences in problem solving between task order, an ANCOVA controlling for gross motor control was run. Gross motor skills remained significantly related to problem solving (*F* (1, 82) = 6.409, p = .013, η^2_{part} = .072) and even after controlling for this, problem solving was still significantly higher in the condition where the Unusual Box Test was presented first (*F* (1, 82) = 9.373, p = .003, η^2_{part} = .103). Thus, task order was also controlled for in later bootstrapped correlations involving problem solving.

Table 13 summarises the bootstrapped correlation and partial correlation analyses. Overall, no significant correlations were observed between divergent thinking and any activity, whether media-based or non-media-based (*p*s all > .05). However, there was a significant positive relationship between problem solving and time spent using learning apps (*r'* (81) = .274, *p* = .012; see Figure 7). No further significant correlations were observed between problem solving and other media-based activities (*p*s all > .05). Interestingly, no significant relationships were observed between either of the creative thinking measures and non-digital activities (*p*s all > .05).

Table 13.

Bootstrapped Pearson's correlations and bootstrapped partial correlations between creative thinking and time spent engaged in different activities.

	Divergent Thinking				Problem Solving			
Activity	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Touchscreen use (independent)	.128 (.073)	.244 (.507)	-.048 (-.083)	.291 (.239)	.158 (.127)	.149 (.251)	-.040 (-.134)	.349 (.358)
Touchscreen use (with an adult)	.010 (.057)	.930 (.609)	-.163 (-.104)	.184 (.166)	.144 (.152)	.189 (.169)	-.064 (-.150)	.284 (.340)
Learning Apps	.062 (.123)	.574 (.266)	-.108 (-.028)	.262 (.265)	.241* (.274)*	.026 (.012)	.068 (-.021)	.398 (.462)
Gaming Apps	.043 (-.074)	.698 (.505)	-.279 (-.400)	.229 (.101)	.149 (.099)	.174 (.372)	-.064 (-.146)	.294 (.249)
Creative Apps	-.012 (-.021)	.916 (.852)	-.198 (-.189)	.187 (.127)	.169 (.146)	.123 (.187)	.024 (-.041)	.325 (.325)
Child-directed video content (independent)	.063 (-.053)	.568 (.629)	-.127 (-.245)	.263 (.168)	.176 (.030)	.107 (.785)	-.007 (-.165)	.366 (.260)
Child-directed video content (with an adult)	-.145 (-.126)	.187 (.252)	-.299 (-.301)	.025 (.039)	.134 (.104)	.223 (.347)	-.048 (-.109)	.302 (.318)
Non-child-directed video content (independent)	-.099 (-.095)	.365 (.392)	-.456 (-.536)	.137 (.244)	-.067 (-.075)	.540 (.501)	-.230 (-.184)	.091 (.062)
Non-child-directed video content (with an adult)	-.068 (-.060)	.537 (.589)	-.227 (-.221)	.090 (.106)	.013 (-.001)	.909 (.989)	-.168 (-.157)	.200 (.180)

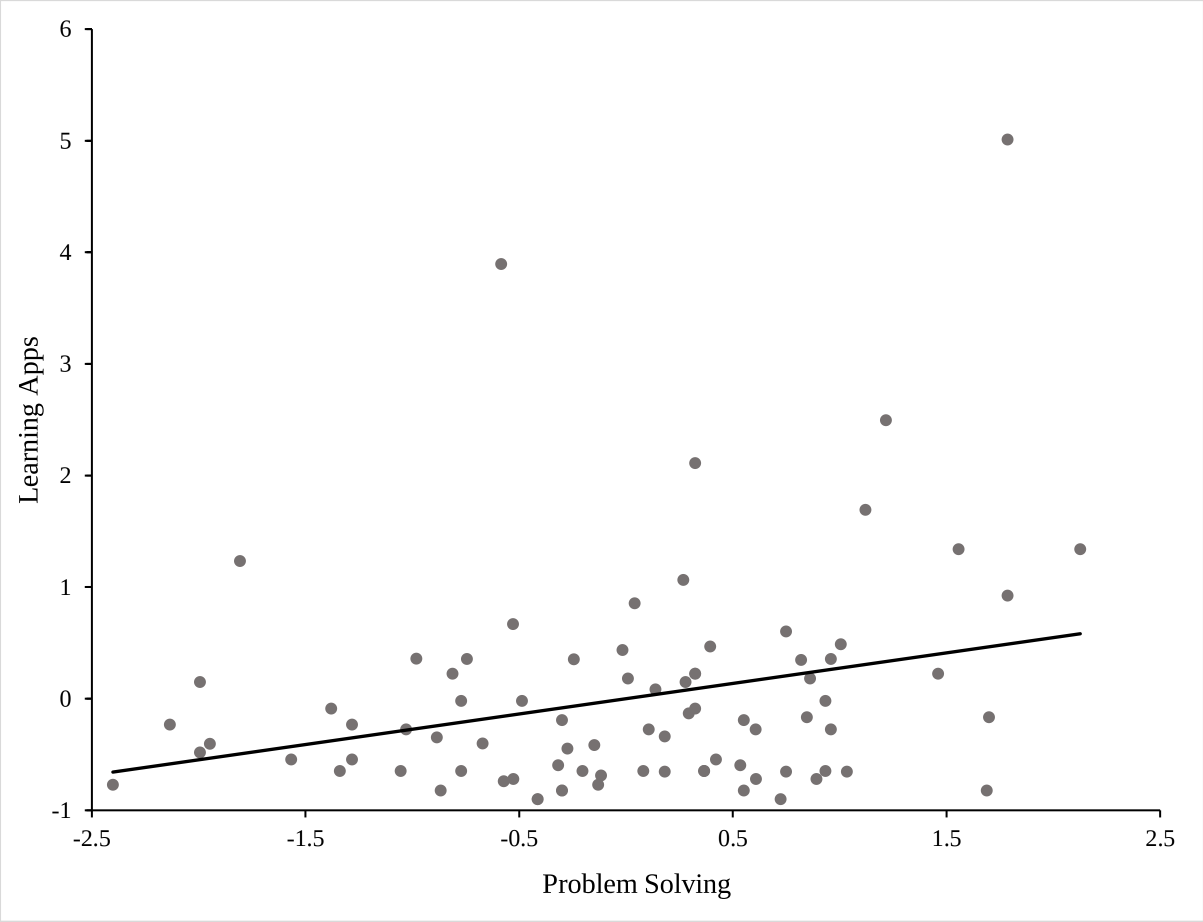
Note. Values in parentheses are from bootstrapped partial correlations. Child age was controlled for in analyses involved divergent thinking. Gross motor control and task order were controlled for in analyses involving problem solving. 95% CI (L) = lower 95% confidence interval; 95% CI (U) = upper 95% confidence interval. * $p < .05$.

	Divergent Thinking				Problem Solving			
Activity	*r*	*p*	95% CI (L)	95% CI (U)	*r*	*p*	95% CI (L)	95% CI (U)
Video call use	-.026 (-.041)	.814 (.714)	-.197 (-.235)	.122 (.131)	-.090 (-.066)	.412 (.555)	-.326 (-.354)	.053 (.137)
Multi-screen use	.017 (.000)	.880 (.999)	-.125 (-.144)	.148 (.106)	.111 (.115)	.310 (.301)	-.044 (-.126)	.251 (.330)
Reading (independent)	-.067 (.022)	.544 (.840)	-.237 (-.179)	.098 (.179)	.061 (.142)	.577 (.200)	-.171 (-.127)	.247 (.341)
Reading (with an adult)	.024 (.052)	.830 (.642)	-.178 (-.172)	.217 (.252)	-.058 (-.047)	.600 (.674)	-.233 (-.261)	.115 (.149)
Non-digital toys (independent)	.090 (.131)	.414 (.237)	-.145 (-.091)	.265 (.302)	.061 (.080)	.580 (.473)	-.142 (-.138)	.307 (.323)
Non-digital toys (with an adult)	-.196 (-.108)	.072 (.329)	-.382 (-.303)	-.003 (.078)	-.178 (-.210)	.103 (.057)	-.373 (-.406)	.003 -(.009)
Creative activities (independent)	-.025 (-.089)	.819 (.421)	-.219 (-.296)	.149 (.091)	.074 (.069)	.502 (.537)	-.097 (-.134)	.236 (.277)
Creative activities (with an adult)	-.056 (-.061)	.608 (.584)	-.239 (-.229)	.138 (.115)	-.006 (-.020)	.954 (.857)	-.167 (-.227)	.173 (.203)

Note. Values in parentheses are from bootstrapped partial correlations. Child age was controlled for in analyses involved divergent thinking. Gross motor control and task order were controlled for in analyses involving problem solving. 95% CI (L) = lower 95% confidence interval; 95% CI (U) = upper 95% confidence interval. * $p < .05$.

Figure 7.

The relationship between standardised residuals of learning apps and problem solving after controlling for gross motor skills and task order.



3.3.2 Predicting creative thinking with activities

Bootstrapped hierarchical regressions were used to investigate which activity variables best predicted divergent thinking and problem solving. Data were assessed for heteroscedasticity, but no evidence was found, so simple bootstrapping was used. Table 14 summarises the results from the bootstrapped hierarchical regression analyses for divergent thinking. For divergent thinking, age was entered at Step 1, followed by variables from the survey at Step 2. Table 15 summarises the results from the bootstrapped hierarchical regression analyses for problem solving. For problem solving, gross motor control and task order were entered at Step 1, followed by the survey variables at Step 2. For both analyses, variables from the survey were entered in order of relationship strength observed in the previous bootstrapped correlations from absolute strongest to weakest relationship (Table 13).

Divergent thinking

The overall model at Step 1 was significant and explained 17.5% of the variance (F (1, 83) = 17.574, p < .001). Age was a significant positive predictor of divergent thinking at Step 1. The addition of survey variables at Step 2 explained an additional 13.9% of the variance, but this was not a significant contribution to the model (F (17, 66) = .785, p = .704). and the overall model at Step 2 was not significant (F (18, 66) = 1.674, p = .067).

Problem solving

At Step 1, the overall model was significant (F (2, 82) = 8.244, p = .001) and explained 14.7% of the variance. Task order was observed as a significant negative predictor of problem solving, where GATTeB scores were lower if the GATTeB was completed first compared to if the UBT was completed first. Gross motor control was a significant positive predictor at Step 1, where greater motor control predicted higher scores on the GATTeB. Adding the survey variables at Step 2 increased variance explained by 17.5%, however, this was not a significant contribution to the model (F (17, 65) = 1.019, p = .451). The overall model at Step 2 was significant (F (19, 65) = 1.783, p = .044) and several significant predictors were observed. Gross motor skills and task order remained significant predictors of problem solving. Additionally, playing with toys with an adult was a significant negative predictor of problem solving, where more time spent playing with toys with an adult was associated with lower problem-solving scores. Despite having the strongest relationship with problem solving initially, using learning apps was not a significant predictor of problem solving in Step 2. No other variables were found to be significant predictors of problem solving.

Table 14.

Bootstrapped hierarchical regression analysis of predictors of divergent thinking with 95% confidence intervals reported. Confidence intervals and standard errors are based on 1000 bootstrap samples.

Step	Variable	*B*	*95% CIs (L)*	*95% CIs (U)*	*SE B*	*β*	*p*
Step 1	(Constant)	13.389	7.913	19.112	2.845		.001
	Age	.359	.200	.516	.080	.418**	.001
Step 2	(Constant)	13.340	6.221	21.177	3.789		.004
	Age	.382	.172	.613	.110	.445**	.004
	Playing with toys (independent)	.021	-.002	.043	.012	.317	.070
	Child-directed video content (with an adult)	-.048	-.106	.038	.036	-.246	.178
	Learning apps	.048	-.085	.231	.080	.124	.520
	Playing with toys (with an adult)	-.020	-.048	.003	.013	-.183	.165
	Non-child-directed video content (independent)	-.068	-.541	.252	.202	-.118	.652
	Creative activities (independent)	-.056	-.147	.028	.044	-.200	.190
	Gaming apps	-.068	-.567	.145	.181	-.072	.572
	Touchscreen use (independent)	-.003	-.083	.094	.043	-.014	.941
	Creative activities (with an adult)	.003	-.064	.070	.035	.010	.940
	Non-child-directed video content (with an adult)	.025	-.174	.189	.093	.062	.804
	Touchscreen use (with an adult)	.053	-.087	.144	.058	.207	.294
	Child-directed video content (independent)	-.003	-.071	.072	.035	-.016	.904
	Reading (with an adult)	.029	-.106	.135	.056	.073	.567
	Video call use	-.012	-.272	.225	.110	-.017	.889
	Reading (independent)	-.041	-.189	.091	.069	-.101	.507
	Creative apps	-.108	-.411	.244	.160	-.137	.445
	Multi-screen use	.016	-.079	.130	.051	.073	.686
DV	Divergent thinking	R^2 = .175** for Step 1; ΔR^2 = .139 for Step 2					

Note. 95% CIs (L) = Lower 95% Confidence Interval. 95% CIs (U) = Upper 95% Confidence Interval; DV = dependent variable. * $p < .05$, ** $p < .01$.

Table 15.

Bootstrapped hierarchical regression analysis of predictors of problem solving with 95% confidence intervals reported. Confidence intervals and standard errors based on 1000 bootstrap samples.

Step	Variable	*B*	*95% CIs (L)*	*95% CIs (U)*	*SE B*	β	*p*
Step 1	(Constant)	7.446	5.180	9.694	1.125		.001
	Task order	-2.342	-3.894	-.930	.754	-.309**	.006
	Gross motor control	.100	.038	.158	.030	.255**	.004
Step 2	(Constant)	8.554	5.151	12.274	1.819		.001
	Task order	-2.574	-4.492	-.954	.931	-.339*	.011
	Gross motor control	.097	.019	.175	.039	.248*	.023
	Learning apps	.056	-.033	.201	.062	.235	.372
	Playing with toys (with an adult)	-.020	-.038	-.004	.009	-.293*	.026
	Touchscreen use (with an adult)	-.026	-.124	.034	.041	-.164	.475
	Creative apps	.031	-.154	.207	.091	.064	.722
	Reading (independent)	.052	-.044	.151	.048	.204	.231
	Touchscreen use (independent)	.002	-.059	.092	.040	.011	.973
	Multi-screen use	-.003	-.069	.048	.030	-.025	.892
	Child-directed video content (with an adult)	.007	-.027	.056	.021	.058	.712
	Gaming apps	.074	-.238	.295	.140	.126	.483
	Playing with toys (independent)	.004	-.011	.024	.009	.098	.600
	Non-child-directed video content (independent)	-.043	-.148	.066	.097	-.120	.209
	Creative activities (independent)	.010	-.030	.058	.021	.058	.614
	Video call use	-.077	-.360	.041	.116	-.169	.422
	Reading (with an adult)	-.036	-.111	.024	.034	-.144	.261
	Child-directed video content (independent)	-.006	-.041	.043	.021	-.046	.760
	Creative activities (with an adult)	-.003	-.050	.046	.024	-.018	.886
	Non-child-directed video content (with an adult)	-.005	-.072	.071	.038	-.022	.867
DV	Problem solving	R^2 = .167** for Step 1; ΔR^2 = .175 for Step 2					

Note. 95% CIs (L) = Lower 95% Confidence Interval. 95% CIs (U) = Upper 95% Confidence Interval; DV = dependent variable. * $p < .05$, ** $p < .01$.

3.4 Discussion

3.4.1 Overview

This study aimed to explore the potential relationships between in 24- to 47-month-olds' performance in behavioural measures of creative thinking and their reported engagement in different activities, including touchscreen and app use. The results of the current study showed mixed associations between creative thinking and caregiver reports of time spent engaged in different activities on a typical day at home. Divergent thinking, as measured by the Unusual Box Test, was not significantly correlated to any measures of touchscreen use or non-digital activities. Conversely, problem solving (measured by the GATTeB) was significantly related to time spent using learning apps, where more time spent using learning apps was associated with higher problem-solving scores. This significant relationship was maintained after controlling for task order and gross motor skills. Interestingly, regression analyses showed learning apps were not a significant predictor of problem solving but playing with toys with an adult was a negative predictor. No other activities from the survey were significant predictors of divergent thinking or problem solving.

The partial correlation between problem solving and learning apps could be supported by previous findings showing that educational content can be positively associated with children's problem solving. For example, Anderson et al., (2000) suggested that *Blue's Clues* (a popular preschool television programme) encouraged problem solving in young children, with more children exhibiting problem-solving behaviours after watching the program compared to those who did not view the content. Although the relationship concerns learning apps as opposed to television programmes, the essence of this relationship could be due to learning apps containing specific features that foster problem solving behaviour. Alternatively, it is also possible that children who are better problem solvers spend more time engaging with this type of content. While using learning apps was not a significant positive predictor of problem solving, the correlational findings from the present study are consistent with Chapter Two. That is, the finding from this study is supported by the cross-sectional findings from Chapter Two, where a positive relationship between learning apps and reported problem solving behaviour was observed in 12- to 47-month-olds. This suggests some consistency in the direct relationship between problem solving and learning apps within the research undertaken for this thesis. This is particularly important to consider as the current study could be seen as more controlled due to the study settings and measures used, whereas the study in

Chapter Two measured more naturalistic behaviours that could relate to problem solving, reflecting everyday life.

Some observed findings in the current study contrast with previous literature. Harrison and Williams (1986) found divergent thinking was lower after the introduction of television. Additionally, Anderson et al., (2001) demonstrated educational television content watched at preschool age was positively associated with divergent thinking later in adolescence. However, no positive or negative relationships were observed between divergent thinking and any activity in the current study, though it is important to note these studies were longitudinal and the present study used cross-sectional methods. The lack of significant findings between divergent thinking and app use may be supported to some extent by some previous research which found no benefits or limitations of using apps in relation to children's divergent thinking (Kandemirci. 2018; Piotrowski & Meester, 2018). However, it is important to note that while these studies examined divergent thinking, they do not necessarily give insight into the fundamental associations between divergent thinking and touchscreens because of the experimental manipulations. Other research has suggested open-ended apps, such as painting, music, and construction apps, may foster creativity through exploration (Carrell Moore, 2017). In the present study, no significant positive relationships were observed that may indicate this, for example, if creative apps were positively related to divergent thinking, as measured through the Unusual Box Test, an exploration-based task. In relation to cross-sectional findings from Chapter Two, no further relationships were observed between problem solving and different activities. This differs from Chapter Two because there were a variety of findings observed, including reported problem solving relating to other behaviours, such as creative apps and independent reading. Additionally, novelty seeking was found to relate to several different behaviours, including app use and watching video content. If novelty seeking is taken to relate to exploration as has been suggested (Piotrowski et al., 2014), then the lack of significant relationships between divergent thinking (that is, performance on a physical exploration task) could be considered at odds with previous findings from Chapter Two. However, it is important to consider that the sample from Chapter Two was much larger than the present study and the lack of findings could therefore be due to less statistical power.

The following section discusses the findings in greater detail. Firstly, the findings relating to problem solving and their potential explanations are explored. Next, the findings regarding divergent thinking are considered, followed by a discussion of the non-significant findings. Finally, the influence of task order is briefly considered and the overall limitations and opportunities for future research are discussed.

3.4.2 Problem solving

A potential explanation for the positive relationship between learning apps and problem solving is that learning apps are beneficial for problem solving. This could be through the content offering appropriate opportunities to develop these skills. For example, it may consist of structured scenarios that require children to identify problems, generate solutions, then implement and evaluate them. Thus, activities within the app may allow children to practise skills that are beneficial for problem solving. Additionally, it is possible that learning apps used at home fulfil the conditions for good quality educational apps. For example, the apps may provide meaningful engagement and require interactivity to work, making it an active learning experience and therefore beneficial for children’s learning and development (Hirsh-Pasek et al., 2015). Additionally, caregivers may download apps that they perceive to be developmentally appropriate and thus, children are able to successfully engage with and benefit from that content (Valkenburg & Cantor, 2000). Alternatively, it is possible that children who are better problem solvers play with learning apps more because they enjoy solving problems. Buschman (2003) suggested that children enjoy solving problems and take pride in developing their own methods of approaching and solving the problem. Thus, it is possible that children who are better problems solvers seek out activities that offer problem solving opportunities, such as learning apps, leading to a positive association.

While the correlation between learning apps and problem solving was significant, it is important to note that this was not reflected in the regression analyses. Specifically, learning apps was not a significant predictor of problem solving, whereas task order, gross motor ability and, interestingly, playing with toys with an adult were significant predictors. It is possible that because the activities were entered into the regression in the same step, the variable variance overlapped, thus altering the contribution of learning apps, making it non-significant in the context of this regression. Additionally, it is also possible that the introduction of survey variables introduced statistical noise and reduced the overall power of the analysis, resulting in the loss of a main effect. This is important to consider because when examined along with other variables, as opposed to a specific relationship in correlational analyses, it is possible that association between learning apps and problem solving is not as robust. Therefore, it would be beneficial for future research to attempt to replicate the procedure and examine whether the same findings are obtained.

In terms of the regression findings, it is also interesting to note that playing with toys with an adult became a significant negative predictor of problem solving, having been observed as non-significant (though close to the .05 *p* significance threshold, see Table 13) in the bootstrapped correlations. Here, more time spent engaging in joint play with adult was associated with lower problem-solving scores. A potential reason for this could relate to the idea of scaffolding, where a joint play scenario between an adult and a child presents limited opportunities for independent problem solving. This could be purely that problem-solving scenarios do not appear frequently during these play sessions and therefore there is little opportunity to practice independent problem solving. It is also possible that scaffolding could be a factor, where if the child experiences difficulty, the adult may assist and teach the child how to negotiate the obstacle. Indeed, scaffolding is seen as an integral part of children's development and learning (Vygotsky, 1978). However, it has also been noted that until children internalise skills taught by caregivers, they are reliant on their assistance (Mermelshtine, 2017). This could be what is being observed in the present study. While the GATTeB was supported by an experimenter to some extent (for example, highlighting the goal to be achieved), participants were expected to attempt the GATTeB tasks independently. Therefore, it is possible that children who are still partially reliant scaffolding may not perform as well in independent problem-solving tasks. Thus, this could showcase a situation where children with lower independent problem-solving abilities engage in more joint play because they are still partially reliant on scaffolding.

While these findings are of interest, it is important to generally consider the lack of consistency between correlational and regression findings. One potential reason for this could relate to the nature of analyses. By including all survey variables in the regression analyses, it is possible that underlying relationships between the different activities altered the contribution of these variables in the overall problem-solving model. As previously mentioned, it is possible that the variance of each variable overlapped, which may also explain why the change in variance explained was not significant at Step 2. Additionally, it is possible that the smaller sample size and consequent reduced statistical power (compared to Chapter Two) may mean the analyses were more susceptible to fluctuations. Thus, the findings should be interpreted with a degree of caution. However, it would be of interest to further explore the mechanisms underlying these relationships and how they interact with each other and influence problem solving.

3.4.3 Divergent thinking

For divergent thinking, no significant relationships were observed. This contrasts with previous research that has found both positive and negative associations with media use (Anderson et al., 2001; Harrison & Williams, 1986). Other studies have shown that apps do not necessarily facilitate or hinder divergent thinking (Kandemirci, 2018; Piotrowski & Meester, 2018), which may support the neutral findings observed in the current study. It is possible that apps do not necessarily provide an optimal environment for divergent thinking to flourish compared to problem solving. For example, a problem-solving app may be linear and have clear goals (a condition critical for children being able to successfully learn and apply information to problem solving scenarios; Chen & Siegler, 2013) and therefore provides an environment for problem solving skills to be practiced. However, the same environment may not be present for the development of divergent thinking skills. Considering the nature of divergent thinking tasks, although the aim is to generate different ideas, there is still a certain amount of directed thinking required. For example, participants in the Unusual Box Test explore and generate actions within the context of the box and its associated items; participants in the Unusual Uses Task generate ideas based on the characteristics of a brick (Guilford, 1967, as cited in Hoicka et al., 2018). Thus, participants operate within the parameters of the task given to them. Indeed, Piotrowski and Meester (2018) suggested their findings may have been due to the distance between their divergent thinking measures and the app content. It is therefore possible that apps do not yet offer this balance of providing a broad framework whilst also encouraging the generation of diverse ideas. For example, learning and gaming apps likely have an outcome and so are structured towards achieving that outcome; creative apps can be completely open-ended and so lack a degree of structure, but promote total exploration and experimentation (Carrell Moore, 2017). Therefore, it is possible that apps and other activities do not provide the fine balance required to facilitate divergent thinking, resulting in a lack of positive associations.

3.4.4 Non-significant findings

The most abundant observations in the current study were non-significant relationships. It is important to acknowledge that in the absence of positive associations between divergent thinking, problem solving and different activities, there was also an absence of negative associations. Specifically, in the context of touchscreens, this could suggest that though there may not be observable benefits, there is also no indication of these activities being detrimental to divergent thinking and problem solving. As previously mentioned, this could be because these activities do not provide the optimal environment for developing the respective skills needed for divergent thinking or problem solving. This is particularly relevant considering that the only significant relationship observed was between problem solving and time spent using learning apps on a touchscreen, where apps might provide optimal conditions to develop problem solving skills. Therefore, it is possible that the other activities caregivers were asked about are not necessarily structured in such a way that they facilitate or impede creative thinking abilities. This is an important consideration as much of the discussion surrounding children's touchscreen use frames it as an activity that can be detrimental to children's creativity and development generally (AAP, 2016; Yogman et al., 2018), despite the evidence supporting these views being very limited (Calvert & Valkenburg, 2013; Royal College of Paediatrics & Child Health, 2019; Stiglic & Viner, 2019). Previous work has suggested media use can be detrimental to creative thinking and that non-media-based activities should be favoured over and above media (Healey et al., 2019). However, the evidence from the current study and observations from Chapter Two could suggest there may not be drawbacks nor any particular benefits in engaging in media activities in relation to creative thinking. On a similar note, non-media-based activities also appear to be neutral in terms of their influence on divergent thinking and problem solving and may not necessarily facilitate creative thinking. Therefore, these activities could all be considered as neutral in terms of whether they influence creative thinking and consequently, could be treated equally. This is an important reflection as it could mean that activities involving media are on a similar level to non-media activities, refuting a key assumption of the displacement hypothesis. Therefore, media-based activities could be included as part of a diverse activity repertoire with relatively limited concerns regarding negative influences on creative thinking.

3.4.5 Task order

An interesting secondary finding of the study was that problem-solving scores were significantly higher if the GATTeB was preceded by the Unusual Box Test (UBT). This was accounted for in the analyses, but it is worth noting the potential reasons for this as well. It has been suggested that divergent thinking and convergent thinking, such as the problem-solving skills that were required of the children in the study, are inextricably connected and both contribute to creativity (Cropley, 2006). Additionally, Pepler and Ross (1981) found that 3- to 4-year-olds who engaged in divergent play prior to solving a puzzle were more flexible in their approach in a subsequent problem-solving task compared to children who engaged in convergent play. In the current study, it is possible that in promoting exploration, the UBT allowed children to come up with new ideas about how to engage with the box. Consequently, this may have primed or 'warmed up' children for generating ideas or adopting a more flexible, trial-and-error approach when engaging with the GATTeB tasks. As a result, children performed better after completing the UBT compared to children who completed the GATTeB first. Another possibility is that because the Unusual Box Test involves engaging with different physical objects in the test period, children may have more readily experimented with the tools provided in the GATTeB. This may have increased the likelihood of children completing the tasks within the allotted time compared to children who had not engaged with different objects before completing the GATTeB. This raises interesting questions about how activities prior to engaging in a problem-solving task might affect subsequent problem-solving abilities.

3.4.6 Limitations

The current study presents some limitations that should be noted when considering the findings. Firstly, the study's correlational design means it is not possible to assign causal explanations to the findings. Specifically, it is not possible to say with certainty if the positive relationship observed between learning apps and problem solving is because the apps facilitate problem solving, or if children who are better problem solvers use these apps more. Despite this, the observed relationship between learning apps and problem solving is consistent with cross-sectional findings from Chapter Two, suggesting the relationship between problem solving and learning apps has merit. It is, however, important to acknowledge that unlike Chapter Two, learning apps was not a significant predictor of children's problem solving in regression analyses. Thus, it is important to be cautious when interpreting the findings. Indeed, it would be beneficial for future research to attempt to replicate the procedure to see whether the same findings would be observed to ascertain the robustness of the findings. A second consideration is the use of caregiver reports to measure engagement in activities. While the phrasing of the questions reflected previous research into children's media use (for example, Ahearne et al., 2016; Bedford et al., 2016; Rideout, 2017), there could be concerns about response accuracy, particularly as research has suggested reported use may not be the most accurate estimation of actual media use (Andrews et al., 2015; Vandewater & Lee, 2009). However, as highlighted in Chapter Two, caregivers can be accurate reporters of their children's behaviour (Waschbusch et al., 2000) and there are benefits to using survey methods when measuring media use, including convenience (Rideout, 2016; Vandewater & Lee, 2009). On balance, the approach taken in the present study was appropriate given the study aims and available resources, but it is also important to be mindful about the validity of caregiver reports, particularly in terms of media use measurement.

Similar to Chapter Two, caregiver education was largely represented by those with undergraduate and postgraduate qualifications (81.2% of caregivers). This proportion of well-educated caregivers may account for the observed findings, where higher economic status may reflect lower levels of media use (see median values in Table 12), as has been illustrated in previous studies (Ribner & McHarg, 2021; Rideout & Robb, 2020). This may have important implications in terms of applying the findings to wider populations as it may only represent those who match the demographics of the present sample. It is possible that samples with more varied caregiver education may yield different results. For example, access to devices may differ, there may be higher overall use and children may engage with different activities for variable amounts of times. Due to the skewed representation of education levels, it was not in the scope of this thesis to statistically address children's media use differences in terms of socioeconomic status. However, it is possible that the socioeconomic profiles of the participants may have a bearing on the findings. For this reason, the findings may only be generalisable to children from families from higher education levels. Future research would benefit from examining the potential interactions between socioeconomic status, children's media use and their creative thinking abilities. Additionally, it would be beneficial for future studies to diversify samples to better understand the behaviour of children from different backgrounds, including across different socioeconomic backgrounds, ethnicities, and countries (Jordan & Prendella, 2019; Nielsen et al., 2017).

A further consideration involves third variables not accounted for in the research which may hold some influence on the findings. For example, caregiver attitudes towards media use and the resulting home environment may play a role in both children's media use and creative thinking. Indeed, previous research has suggested positive caregiver attitudes towards media are associated with higher levels of children's media use (Lauricella et al., 2015; Nikken & Schols, 2015). It is therefore possible that caregivers with favourable views of media may allow more access and use of devices compared to caregivers who do not perceive media use as beneficial, who may instead encourage engagement in other non-media-based activities. These different approaches to media use may be connected with the home environment generally and may also have a subsequent impact on creative thinking. For example, if caregivers value children's creativity and feel media can provide opportunities to develop creative thinking (as observed in LEGO Foundation, 2020) then they may also provide other activities to help develop these skills, consequently creating an enriching environment that facilitates both media use and creative thinking more generally. Thus, while the findings in the present study are of great interest, it is also important to acknowledge that other variables that were not measured in the present study may play a role in both children's media use and creative thinking abilities. It would therefore be beneficial for future research to address this in more detail to understand how other variables, such as parental attitudes and home environments, influence relationships between children's media use and creative thinking.

Future research should build on the current study by attempting to replicate the findings to ascertain how robust the findings are, given the results from regression analyses. To progress the research more generally, future studies would benefit from incorporating experimental methods that would allow causality to be explored to ascertain whether learning apps could have a positive effect on problem solving. Additionally, it would be of interest to address the question of whether positive associations between apps and behavioural measures of creative thinking are sustained over time. Another fruitful avenue of research would be to examine the research questions across different populations. The sample in this study was very specific and skewed towards White and highly educated caregivers. It would of great interest to expand on this by working with participants from other backgrounds to ascertain whether there are potential similarities or differences in observed relationships. In terms of methods, it would be of great interest to incorporate measures of actual media use to gain a more objective estimate of how children use media. By improving how young children's media use is measured, it will be possible to gain a clearer understanding of how it can influence their creative thinking.

3.4.7 Conclusion

To conclude, the current study successfully implemented behavioural creative thinking measures to explore the relationships between divergent thinking, problem solving, and touchscreen use. As such, it makes a significant contribution to the literature and enhances our understanding of the potential influence of touchscreens on children's creative thinking. The evidence from this study suggests there may not be a detrimental influence of touchscreens or other media on either divergent thinking or problem solving. Additionally, there may be some indication of a positive influence regarding learning apps and problem solving. In this case, it is possible that learning apps may have a positive influence on problem solving. Alternatively, it is possible children who are better at problem solving use learning apps more. However, given the lack of consistent findings between correlation and regression findings, further investigation is needed to determine both the strength and direction of the relationship and understand its underlying mechanisms. Furthermore, there were no observed negative relationships between children's media use and their performance in the creative thinking measures. Given that previous work has regarded media use as potentially damaging to children's creativity (Singer & Singer, 1990; Valkenburg & van der Voort, 1994), the non-significant relationships are important to acknowledge. This is because that while they do not necessarily indicate any potential benefits, they also do not indicate any potential detriment to children's creative thinking. Thus, the current study builds on previous research and enhances the understanding of how touchscreens might influence divergent thinking and problem solving in 24- to 47-month-olds.

CHAPTER FOUR:

The effect of apps on 36- to 47-month-olds' problem solving

Building on the positive findings regarding problem solving and learning apps observed in the previous chapters, this study used an experimental design to address how different app content can affect problem solving. Children aged between 36 and 47 months used either a problem-solving app or an open-ended exploration app before completing the Great Ape Tool Test Battery. A baseline condition consisting of data from Chapter Three was also used to assess whether using apps was better than not using apps at all. The results showed problem solving was significantly higher after using the problem-solving app compared to using the exploration app. After analysing the baseline condition, this difference was no longer significant, but problem-solving performance after using the problem-solving app was significantly higher than not using an app at all.

4.1 Introduction

Children's use of touchscreens has increased substantially in recent years. The Common Sense Media report observed that in 2020, 75% of 0- to 8-year-olds in the US lived in houses with access to tablets compared to 40% in 2013 (Rideout & Robb, 2020). Additionally, the report showed 2- to 4-year-olds spent an average of 58 minutes per day using mobile devices. With this rise in use, concerns about the impact of touchscreens and their associated apps on young children's development has been ardently discussed. It has been observed that claims made by media developers about their product being beneficial for children's cognitive development are not necessarily supported by evidence and should therefore be avoided (Healey et al., 2019). However, there has also been suggestion that apps could be beneficial for children, provided they fulfil certain conditions (Hirsh-Pasek et al., 2015). Thus, the perspectives on the impact of media, such as touchscreens and apps, are mixed. One cause of concern is that media use has an adverse impact on children's creativity (Singer & Singer, 1990; Yogman et al., 2018). However, the empirical evidence to support these claims are relatively weak and there are conflicting suggestions that some media, such as touchscreens, may facilitate children's creativity (Marsh et al., 2018). This study aims to investigate whether engaging with problem-solving and exploration apps affects subsequent problem solving in 36- to 47-month-old children.

Previous research investigating television-watching and children's creativity has been mixed and much research has focused on divergent thinking. For example, Harrison & Williams (1986) found that two years after the introduction of television in a North American community, verbal divergent thinking scores in 14- to 15-year-olds decreased. Additionally, a review by Valkenburg & van den Voort (1994) indicated negative, albeit weak, associations between television-watching and divergent thinking scores across a range of studies. However, a key limitation of these studies is that much of the focus was on general television time and did not consider different types of content. Other studies that have focused on different types of content and features of programming have shown that there can be positive associations between media use and creative thinking. For example, educational content and fantastical content have been positively associated with children's divergent thinking (Anderson, Huston et al., 2001; Subbotsky et al., 2010). In relation to problem solving, Rose et al., (2021) found no significant difference between fast-paced and slow-paced television programming on 3- to 4-year-olds' subsequent problem-solving performance, though the authors noted a trend towards more correct solutions in the fast-paced condition. In another study, Anderson, Bryant et al., (2000) suggested the preschooler television programme *Blue's Clues* facilitated problem solving in young children by providing support, such as audience participation and encouragement, to help them engage with the content and thus practise problem solving skills. Furthermore, Chen and Siegler (2013) found that 2.5-year-olds who watched a video involving a problem-solving task were able to learn and apply the problem-solving strategy to a similar real-world task if the goal direction was clear. Thus, the influence of televisions on creative thinking may be more dependent on the media content being consumed and the features within that content.

Most research has focused on television use. Thus far, research involving touchscreens and apps has been lacking, likely because of the discrepancy between research timelines and technology development, the latter of which is significantly faster (Orben, 2020). This is of particular importance since policy has suggested media may not provide opportunities to develop these skills, such as problem solving, despite there being little evidence to directly support these claims (Healey et al., 2019). It is of great interest to explore touchscreens in research, as the inherently interactive features may have potentially different effects on cognitive development compared to television (Christakis, 2014). Indeed, research with adults has shown touchscreens may offer the optimal platform for problem solving compared to physical or traditional computer-and-mouse set-ups as they provide an ideal balance between speed and efficiency (Donahue et al., 2013). Education research has suggested touchscreens could encourage children's problem-solving behaviour in classroom settings (Kucirkova et al., 2014). Additionally, Marsh et al., (2018) used ethnographic observations of children's touchscreen use in the home and concluded touchscreens and apps could facilitate preschooler creativity, particularly if they embedded problem solving and critical thinking activities. Psychological research has also examined touchscreens and children's problem solving. Huber et al., (2016) found that 4- to 6-year-olds' ability to complete a problem-solving task (the Tower of Hanoi) was not impeded by practising on a touchscreen compared to practising on a 3D version of the task, suggesting touchscreens did not negatively affect problem solving. This was replicated by Tarasuik et al., (2017), strengthening the conclusion that children can learn problem solving strategies from touchscreens equally as well as equivalent physical activities. Huber et al., (2016) proposed the interactivity and contingency afforded by touchscreens may have allowed children to successfully practise and acquire the strategies needed to complete the tasks. This could reflect previous suggestions that children need to be actively and meaningfully engaged in apps to benefit from them (Hirsh-Pasek et al., 2015). Additionally, evidence regarding preschooler problem solving and app use can be derived from the research presented in this thesis. The studies from Chapters Two and Three showed more time spent using learning apps was associated with higher problem-solving scores. Therefore, touchscreens and apps may have a positive influence on children's problem solving.

Although research has started to address the influence of touchscreens on children's problem solving, the evidence base remains limited, particularly for preschoolers. Indeed, the relationships observed in Chapters Two and Three are limited by their correlational design and require further exploration with experimental methods. Another consideration is that previous research paradigms used isometric tasks, where the tasks were identical across platforms (for example, using 2D and 3D versions of the Tower of Hanoi or simple puzzles; see Huber et al., 2016 and Zimmermann et al., 2017). This could be seen as a limitation as it is only possible to make conclusions about transfer relating to that specific task. Additionally, analogous tasks, where the tasks are different but comparable (see Chen & Siegler, 2013), present a similar issue. Given the specificity of tasks, it may not therefore reflect children's day-to-day touchscreen activity at home and the more general effect certain apps may have on young children's problem solving. Indeed, Huber et al., (2016) recommended research should explore whether digitally learned problem-solving strategies apply to non-isometric problems, a suggestion that was incorporated into the present study.

The current study sought to build on the findings of the previous chapters and address whether different types of app content affect problem-solving ability in 36- to 47-month-olds. Specifically, it explored whether children who used a problem-solving app performed better on non-isometric physical problem-solving tasks (the Great Ape Tool Test Battery) compared to children who used an exploration app. Though the activities were different, both the problem-solving app and problem-solving tasks had clear goals and required participants to generate ideas, implement them and evaluate them to achieve the goal. Conversely, the exploration app was open-ended and did not have a specific goal and therefore may not have required the same type of thinking as the problem-solving app. It was also decided that having a comparison group would be of interest to understand whether app use was beneficial for problem solving compared to not using an app at all. Thus, a secondary aim was to compare problem solving scores after app use to a baseline condition. This was completed using a selection of 36- to 47-month-old participants from Chapter Two who completed the Great Ape Tool Test Battery first in the study procedure and thus had no activity prior to completing the problem-solving tasks.

It was predicted that using the problem-solving app will lead to higher scores on the problem-solving task compared to the exploration app. Pepler and Ross (1981) observed that engaging in convergent play led to more strategic approaches in a problem-solving task compared to divergent play, which led to more flexible approaches. This suggests engaging in these separate types of play could potentially prime approaches to subsequent tasks that mirror key characteristics of the play, which is what is hypothesised in the current study. Coupled with the small positive relationships between problem solving and time spent using learning apps observed in Chapters Two and Three, it is possible that apps promoting problem solving could lead to greater problem-solving performance. As a result, it is expected that the potential priming from the problem-solving app will facilitate performance in the GATTeB.

4.2 Method

4.2.1 Participants

A power analysis showed 52 participants (26 participants per condition) would be required to observe a large effect size (d = 0.8, α = 0.05, power = 0.8; Faul et al., 2007). The study was powered for a large effect due to potential practical limitations of the research. Given the narrower age range and timing of the study in relation to the study in Chapter Two, there was concern about the number of potential eligible participants from the volunteer list being limited and insufficient to power for medium or small effect sizes. Therefore, it was decided that for the purposes of establishing preliminary findings regarding app content, powering for a large effect size would be sufficient. In total, 53 children aged between 36 and 47 months and their caregivers were recruited to take part in the study from the Sheffield Cognitive Development research volunteer list. The average age of the 53 children included in the analysis was 42 months 1 days (*SD* = 3 months 2 days). The sample consisted of 35 male and 18 female children overall. There were 19 male children and 7 female children in the problem-solving app condition (total *n* = 26). There were 16 male and 11 female children in the exploration app condition (total *n* = 27). Most participants were White (90.6%), followed by children of Mixed Ethnicity (9.4%). Most caregivers had completed education up to undergraduate level (50.9%), followed by A-Levels or equivalent (26.4%), postgraduate level (20.8%) and one caregiver reported education at GCSE level or equivalent (1.9%). Average household income for the sample was reported as £52,236.81 (*SD* = £6101.85) with six caregivers choosing not to disclose income. Five additional children were excluded from analysis for lack of engagement with the touchscreen. Children received a book as a gift for taking part in the study.

Baseline data from Chapter Three was included in this study as a comparison group. Before including a baseline condition, a power analysis was completed to establish the number of participants needed to observe a large effect size. It was revealed that 66 participants across three groups (22 participants per condition) would be required in total (f = 0.4, α = 0.05, power = 0.8; Faul et al., 2007). Corresponding data from Chapter Three met the minimum threshold of 22 participants and because using previously collected data as baseline conditions has been done before in developmental media research (see Zimmermann et al., 2017 as an example), it was decided that the data from Chapter Three could serve as a baseline condition in the current study. Therefore, data from children aged between 36- and 47-months who completed the GATTeB first during the Chapter Three procedure were extracted and merged with the current study data (*n* = 22). The average age of this baseline condition was 42 months and 23 days (*SD* = 3 months 2 days). The sample in the baseline condition consisted of 8 male participants and 14 female participants. The majority of children were White (95.5%) followed by Mixed Ethnicity, which was reported for 4.5% of the sample. Similar to the participants recruited for the app conditions, most caregivers were educated up to undergraduate level (45.5%) and postgraduate level (36.4%), with a further 9.1% each for A-Level or equivalent and GCSE or equivalent qualifications. Household income was not available for this baseline condition.

Design

The main dependent variable of the study was problem solving, operationalised by performance on the Great Ape Tool Test Battery (GATTeB; Reindl et al., 2016). The independent variable was app use prior to completing the GATTeB. Using a between-participant design, participants either played with a problem-solving app or an exploration app for approximately 10 minutes before completing the problem-solving measure. The baseline condition did not complete any activity prior to completing the GATTeB.

4.2.2 Materials

Apps

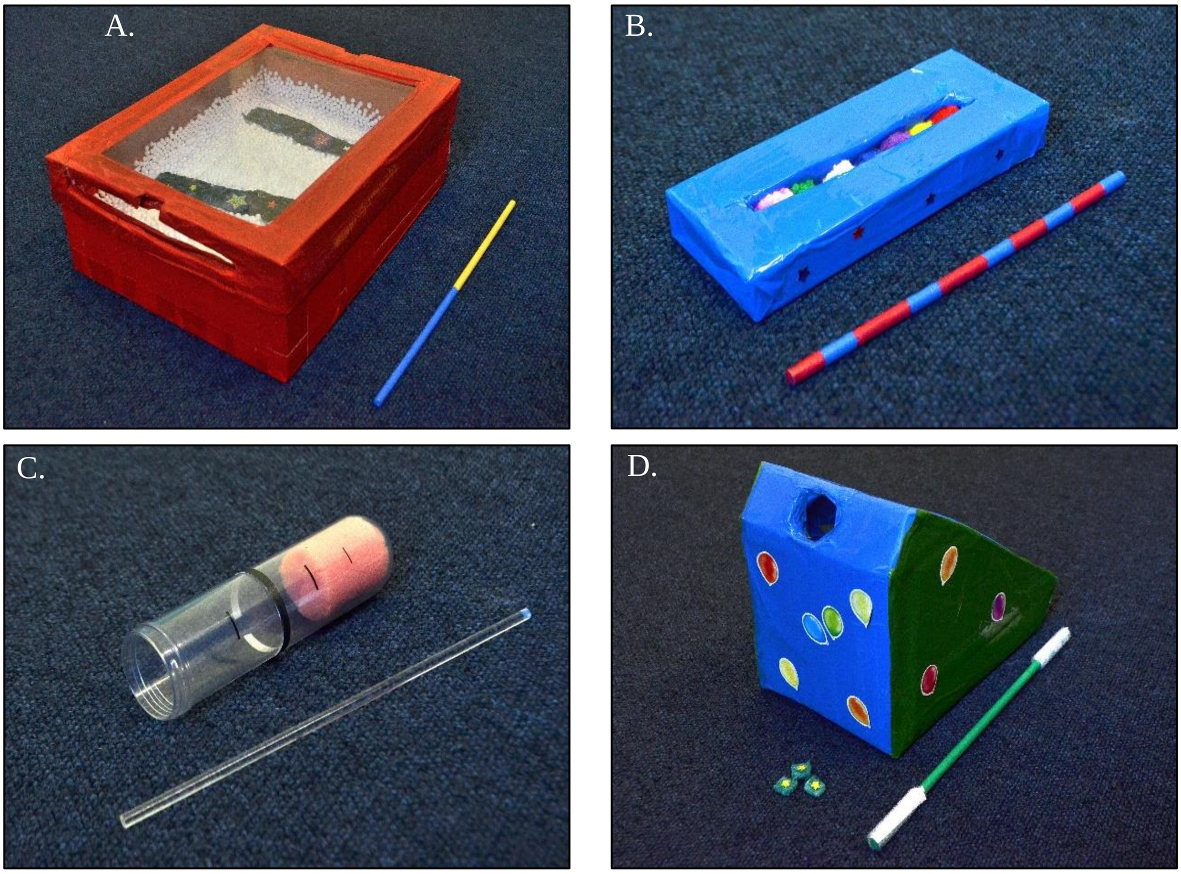
The apps used in the procedure were *Pango Blocks* (problem-solving app) and *Pango Playground* (exploration app), both of which were commercially available across different online app stores. Both apps were designed for young children by the same studio and were presented on a Huawei MediaPad T3 10" touchscreen device. The app studio website describes *Pango Blocks* as a way of learning to judge distances by choosing "logic blocks" and building a path for the character Pango, where if successful, he will pick up an item for a friend (Studio Pango, 2018a). *Pango Playground* is described as a way for children to increase curiosity and imagination and emphasises the variety of possible activities to engage in when using the app, such as catching trains or collecting treasure (Studio Pango, 2018b). Therefore, it was decided these apps were acceptable representations of a problem-solving app and an app that integrated exploration, respectively. In *Pango Blocks*, as described on the website, participants were asked to help the game's character Pango reach an object on the other side of the screen. As participants progressed through the levels, the difficulty increased with new challenges, such as gaps between platforms and obstacles that the character would need to 'climb' over. Participants had to work out where to place different blocks to help the character reach the object, for example, creating a ramp with a triangular block to help Pango climb over an obstacle or stacking the provided blocks to create a bridge over a gap. In *Pango Playground*, participants were able to explore a scene containing many interactive features, such as blocks, trees, and cars. There were four different scenes that could be explored in the app, each containing distinct features. Touching a feature caused it to perform an action, for example, touching a car caused it to drive around the scene, or touching a block transformed it into another object or changed its colour. Additionally, the scenes featured characters which could be used as part of a specific sequence of actions, resulting in an interesting outcome. For instance, in one scene, touching a block would transform it into a swing set and placing a character on the set would cause the character to start using the swing. Thus, there were a variety of different ways of engaging with the objects in the app scenes.

Great Ape Tool Test Battery

Four tasks from the Great Ape Tool Test Battery (GATTeB; Reindl et al., 2016) were used to measure problem solving. The same four tasks used in Chapter Three were also used in the current study: Algae Scoop, Seed Extraction, Marrow Pick and Termite Fish (Figure 8). In each task, participants are given a goal to achieve. For example, in the Termite Fish task, the box and stick are placed on the table in front of the child. Participants are shown the box and the three stars, which are then individually placed into the box. Participants are then asked to retrieve the stars from the box (see Appendix H for script). All tasks are accompanied by a stick which can be used as a tool to help achieve the goal. However, no reference is made to the stick so participants must work out for themselves that it may be helpful. The GATTeB was video recorded to allow coding to take place after the study had been completed.

Figure 8.

The Great Ape Tool Test Battery (GATTeB) tasks. A: Algae Scoop. B: Seed Extraction. C: Marrow Pick. D: Termite Fish.



Touchscreen use survey

A short survey was used to collect demographic data and information on children's access and use of touchscreens via Qualtrics (see Appendix I). Caregivers were asked if their child had access to a touchscreen at home. They were also asked "How many minutes did your child use these different kinds of apps on touchscreens yesterday?" with caregivers able to enter a value for learning and educational apps, creative apps, gaming apps and video-watching apps. There was also an option for "Other" apps where caregivers could specify other app-based activities and how long they estimated their child had participated in them for on the previous day.

Motor skills survey

To account for motor ability as a potential covariate for performance in the GATTeB, caregivers completed the fine motor and gross motor scales from the Child Development Inventory (Ireton, 1992). Example items include "stands on one foot without support" as a gross motor behaviour and "cuts with small scissors" as a fine motor behaviour, which corresponded with an estimated age. Caregivers were asked to work through the behaviours, starting from the earliest milestones, working towards more developmentally advanced behaviours. They were asked to indicate whether their children were able to perform these behaviours comfortably, if they were beginning to perform these behaviours, or if they were not yet able to complete them. Following the manual's suggestion and the approach used in Chapter Three, the most developmentally advanced behaviours that caregivers indicated their children could comfortably perform were noted. The corresponding ages to those behaviours were used as an estimate of fine and gross motor skills.

4.2.3 Procedure

Participants were welcomed into a warm-up area and the experimenter engaged in a short warm-up session to help the participant feel comfortable with them. During this time, the caregiver also filled in a consent form and the gross and fine motor scales from the Child Development Inventory. They were then invited into the testing space, where the caregiver was invited to sit at a table (in view of the child) and complete the touchscreen use survey on a laptop. The participant was invited to choose a chair and sit at a toddler table. The experimenter then switched on the video cameras and proceeded with the study. The experimenter told the child they would play a game on a tablet and after the game had finished, the tablet would be put away and new games brought out. The experimenter presented the touchscreen device to the child with either *Pango Playground* or *Pango Blocks* loaded. The experimenter guided the child through the app according to the condition script (see Appendix J for full scripts). For *Pango Blocks*, the experimenter explained the game, ("Pango is upset that there is rubbish on the floor. We're going to help Pango pick up the rubbish") and guided participants through the first two levels. The experimenter gave instructions on how to make the character move and how the blocks could assist with achieving the goal, so participants were able to engage with the app. After the first two practice levels, they received no further instructions on how to complete the levels. If they were unable to complete the level within two minutes, the experimenter moved on to the next level. For *Pango Playground*, participants were encouraged to explore the scenes and find things to do. The instructions for the Unusual Box Test (Bijvoet-van den Berg & Hoicka, 2014; Appendix G) were used as inspiration for the script in this condition to encourage exploration, for example "You keep playing and show me what you can do in the town!" or "What can you do in the town?" (see Appendix J for scripts during app use). Children were given two and a half minutes to explore the different scenes, after which the experimenter allowed participants to choose the next level to explore until all levels had been seen. After 10 minutes had elapsed, the experimenter moved the touchscreen away from the table and place it out of sight and out of reach of the participant. Following the occlusion of the tablet, the experimenter brought the first GATTeB task to the table. They drew the child's attention to the goal of the task according to the corresponding script (for example, for the Termite Fish task "…if you can get the stars out, you'll win a sticker!"). For the Termite Fish and Marrow Pick tasks, participants were given one minute to complete each task. For Algae Scoop and Seed Extraction, children were given two minutes to solve each task. If the participant completed the task or if the time limit elapsed, they were given a sticker and the experimenter took away the first task and introduced the next one. This was repeated until all tasks had been presented. Participants were given a sticker regardless of whether they were successful to avoid distress and to encourage them to engage in all the tasks. Upon completion of the GATTeB, the experiment ended, and caregivers were debriefed on the study. Participants were able to choose a book to take home as a gift for participating in the study.

4.2.4 Coding

The GATTeB was video recorded to allow agreement coding to take place after the study session. The coding procedure was identical to the one used in Chapter Three (see Appendix H). Each task in the GATTeB was coded from video in three ways (Reindl et al., 2016):

1) Whether or not the child picked up the stick during the allotted time at all; zero points for not picking up the stick, one point for picking up the stick.

2) Whether or not the child attempted to use the tool in a way that could be potentially correct, for example, touching the pom-poms with the stick in the Seed Extraction task; zero points for not using the tool in a potentially successful way, one point for using the stick in a potentially successful way.

3) Whether the child successfully completed the task using the tool; whether they used an alternative method for completing the task; or if they did not complete the task in the allotted time. No points were given if they did not complete the task, one point was given if they used an alternative method to complete the task and two points were given if they successfully completed the task using the correct action with the tool.

As described in Chapter Three, successful tool-users were awarded higher scores compared to those who completed the tasks using alternative methods. This is because tool-use is seen as an advanced behaviour that potentially demonstrates higher levels of skills in areas such as planning, causal knowledge and adapting behaviour to increase the chances of success (Chen, et al, 2010; Keen, 2011; Seed & Call, 2009). The scores from each coding index were combined to produce a problem-solving score; the maximum score for each task was four points, thus the maximum possible score for the GATTeB was sixteen.

Reliability

The GATTeB was coded for agreement by a second coder for 20% of the included participant videos (n = 13) and agreement was excellent (Koo & Li, 2016), ICC = .994 (CIs = .980 - .998).

4.3 Results

The following section describes the findings from the current study and are split into three parts. Firstly, descriptive statistics for each app condition are presented, along with analyses aiming to identify potential covariates. Secondly, the initial analyses between the two app conditions are reported. Finally, analyses using the baseline data from Chapter Three investigate the differences between app conditions and a baseline condition.

4.3.1 Descriptive statistics and initial analyses

Table 16 summarises the descriptive statistics for problem solving, motor ability, and touchscreen use in the app conditions. In terms of access to touchscreens, 83% of participants (n = 44) had access to touchscreens at home. When examining access by condition, 76.9% of participants (n = 20) in the problem-solving app condition and 88.9% (n = 24) in the exploration app condition had touchscreen access. To identify possible covariates with problem solving, correlations were used to assess whether there were significant relationships across the sample and *t*-tests were used to assess differences between the conditions.

Table 16.

Descriptive statistics for key study variables for participants in the problem-solving app condition and the exploration app condition.

	Problem-solving app (n = 26)				Exploration app (n = 27)			
Variable	M	Med	SD	Range	M	Med	SD	Range
Problem solving	12.81	14	2.61	6 - 16	10.67	10	3.21	3 - 16
Fine motor ability (months)	36.58	36.5	7.70	26 - 58	37.96	40	7.33	26 - 58
Gross motor ability (months)	36.27	34	9.38	21 - 58	37.11	34	8.32	26 - 58
Learning apps (mins)	4.27	0	7.42	0 - 20	3.89	0	6.70	0 - 20
Gaming apps (mins)	2.00	0	6.32	0 - 30	2.04	0	5.59	0 - 20
Creative apps (mins)	2.12	0	6.66	0 - 30	1.85	0	3.71	0 - 10
Video apps (mins)	19.23	0	30.06	0 - 120	25.93	20	29.09	0 - 120
Other apps (mins)	0.04	0	0.2	0 - 1	2.78	0	11.63	0 - 60
Total app use (mins)	27.65	11.5	38.7	0 - 150	36.48	30	40.19	0 - 160

Note. M = Mean; Med = Median; SD = Standard Deviation; mins = minutes.

No significant differences were observed between conditions in terms of age, motor ability, or the different touchscreen activities (*p*s all > .05). Due to the non-normality of the touchscreen variables, bootstrapped correlations were used to assess whether there were potential covariates of problem solving in terms of age, motor ability, and touchscreen use. A significant relationship between problem solving and age (r (51) = .279, p = .043) was observed, but no other variables were related to problem solving (*p*s > .05). Additional *t*-tests showed there were no significant differences between gender or access to touchscreen use in terms of problem solving (*p*s > .05).

4.3.2 Problem-solving app versus exploration app

Children in the problem-solving app condition scored higher in the problem-solving measure (*M* = 12.81, *SD* = 2.61, *CIs* = 11.56 – 13.83) compared to children in the exploration app condition (*M* = 10.63, *SD* = 3.2, *CIs* = 9.62 – 11.85). An initial independent samples *t*-test was conducted to explore whether this difference was significant. The results showed that problem solving was significantly higher in the group who used the problem-solving app compared to the group who used the exploration app (*t* (51) = 2.659, *p* = .01). Due to the significant relationship between age and problem solving, a one-way ANCOVA was also performed to investigate the difference between the problem-solving app and the exploration app while controlling for participant age. The covariate, participant age, was not significantly related to problem solving, *F* (1, 50) = 3.148, *p* = .082, η^2_{part} = .059. Even after controlling for age, the difference between participants who used the problem-solving app compared to participants who used the exploration app remained significant (*F* (1, 50) = 5.745, *p* = .02, η^2_{part} = .103). The effect size was also calculated using Cohen's *d* and revealed a medium effect (*d* = .73; Cohen, 1988; 1992).

4.3.3 App and baseline comparisons

The previous analyses showed an interesting difference between app content in terms of subsequent performance in the GATTeB. However, it is theoretically possible that apps reduce problem solving overall, even if problem solving apps are better than exploration apps. Therefore, it was decided that it would also be of value to compare a baseline condition, where no app use took place, to the app conditions. Following a power analysis, it was decided that data from Chapter Three would be used as a baseline condition to investigate whether using apps was beneficial for problem solving compared to not using an app at all. Participants aged between 36 and 47 months who completed the GATTeB first in the Chapter Three procedure (*n* = 22) were extracted and merged with the sample from the current study. In relation to touchscreen access, 86.4% (*n* = 19) of participants in the baseline had access to touchscreens. The mean GATTeB score for this condition was 9.18 (*SD* = 4.27, *CIs* = 7.29 – 11.08). Correlations were run to investigate whether age related to problem solving, however, no significant relationships were observed (*r* (73) = .118, *p* = .313). Furthermore, no significant gender differences in problem solving were observed in the baseline condition (*t* (20) = -1.089, *p* = .289). Table 17 shows the descriptive statistics for key variables for this baseline sample. However, it is important to note that the survey used to measure touchscreen and app use in the present study was different to the survey used in Chapter Three (see Appendices E and I). As video apps and "other" apps were not asked about directly in Chapter Three, only the data for learning apps, creative apps and gaming apps are presented.

Table 17.

Descriptive statistics for key study variables for participants in the baseline condition (n = 22).

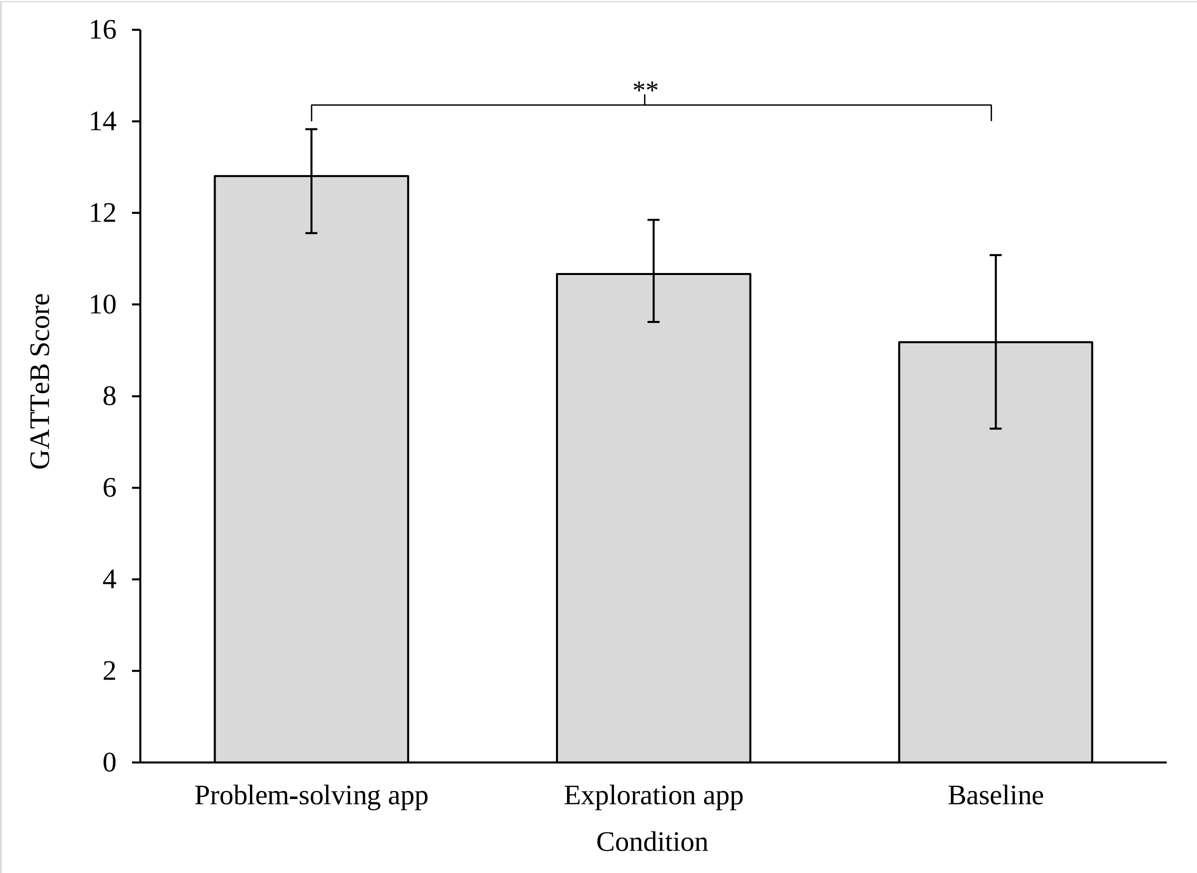
Variable	M	Med	SD	Range
Problem solving	9.18	9.5	4.27	2 – 16
Fine motor ability (months)	43.73	44	9.36	26 - 58
Gross motor ability (months)	38.73	36.5	10.26	26 - 55
Learning Apps (minutes)	6.36	3	9.02	0 - 30
Gaming Apps (minutes)	2.05	0	4.27	0 - 15
Creative Apps (minutes)	4.32	0	7.12	0 - 30

Note. M = Mean; Med = Median; SD = Standard Deviation.

Prior to analysis, Levene's homogeneity of variance test was run to assess whether the assumption of equality of variance had been violated as a result of unequal sample sizes in each condition. However, Levene's test showed that variance was equal across the different conditions (F (2, 72) = 2.893, $p > .05$). Therefore, a one-way ANOVA was used to investigate the differences between the app conditions and the baseline condition. Figure 9 presents the averages across conditions. The results indicated a significant effect of condition (F (2, 72) = 7.041, p = .002, η^2_{part} = .164). Post-hoc comparisons using Bonferroni corrections showed problem solving was significantly higher in the problem-solving app condition (M = 12.81, SD = 2.61) compared to the baseline condition (M = 9.18, SD = 4.27; p = .001), revealing a large effect size (d = 1.03). However, due to the Bonferroni correction, there was no longer a significant difference between the problem-solving app and the exploration app (M = 10.67, SD = 3.21, p = .072). Additionally, there was no significant difference between the exploration app and the baseline condition (p = .391).

Figure 9.

*Mean GATTeB scores in each condition. Error bars represent 95% confidence intervals. Note. ** = p < .01.*



4.4 Discussion

4.4.1 Overview

The present study sought to explore whether using a problem-solving app would affect performance in the GATTeB, a physical problem-solving task, compared to an exploration app in 36- to 47-month-olds. Additionally, it examined whether there were differences between the app conditions and a baseline condition. The initial findings showed problem solving scores were significantly higher after using a problem-solving app compared to an exploration app, supporting the study hypothesis. However, in a second analysis that used an additional baseline condition where no app was used before the GATTeB, the difference between apps was no longer significant. Interestingly, the results instead showed problem-solving was significantly higher after using the problem-solving app compared to children who did not use an app before completing the GATTeB. Thus, as problem solving was not significantly worse after using either app compared to the baseline, it is possible to infer that apps may not necessarily be detrimental for young children's problem solving. Indeed, the significant difference with the problem-solving app may suggest potential for these types of apps to beneficial for children's problem solving.

The reported findings converge with previous research that suggest children's problem solving is not necessarily negatively impacted by media, and in some cases, may be beneficial for it. For example, Anderson, Bryant et al., (2000) showed preschoolers exhibit problem solving behaviours after exposure to media such as *Blue's Clues*, likely due to the embedded features designed to promote problem solving behaviours, such as encouraging audience participation and positive reinforcement. Chen and Siegler (2013) showed 2.5-year-olds were able to successfully learn problem solving strategies from a video and apply them to an analogous problem-solving task, provided there was a clear goal. In relation to touchscreens, Huber et al., (2016) and Tarasuik et al., (2017) found there was no difference in physical problem-solving performance after practicing the task on a touchscreen or with a 3D version of the task, suggesting that touchscreens did not negatively impact on children's problem solving. Other supporting, but non-media-based research, includes Pepler and Ross (1981) who demonstrated that engaging in convergent play led to more strategic approaches in a subsequent convergent thinking task. In this case, problem solving after using the problem-solving app was higher compared to not engaging in an app at all.

The following section will discuss the findings presented in the current study in turn, starting with the problem-solving app and then the exploration app. It will also discuss limitations of the research and how future research may improve and expand on the study.

4.4.2 Problem-solving app

A possible explanation for the findings is that the problem-solving app primed a convergent way of thinking. Media priming, defined as the effect media content has on individual's later behaviour, has been of topic of interest in research, particularly in terms of violent television content and subsequent aggression (Roskos-Ewoldsen et al., 2002). Roskos-Ewoldsen and colleagues highlighted that media content may activate relevant cognitive processes, leading to certain behaviours being performed. For example, in the case of violent television content, the content may activate concepts relating to hostility and aggression, increasing the chance that an individual will engage in those behaviours. It is possible to apply the same basic logic to problem solving and the findings from the current study. By engaging with a problem-solving app, concepts relating to problem solving may be activated, for example, generation and evaluation of ideas or using trial-and-error approaches. Thus, problem solving performance may have been enhanced in the problem-solving app condition because the content had primed a convergent way of thinking. This would mirror explanations provided by examples of creativity research. Pepler and Ross (1981) observed that children who engaged in play with convergent materials had more strategic and proficient approaches to subsequent tasks compared to children who played with divergent materials. Thus, it is plausible that the linear, problem-solving nature of the app led to better performance as it allowed children to practice those skills or prime them to a convergent way of thinking prior to completing the GATTeB. A finer-grained exploration of the possible mechanisms underlying increased problem solving could be associated with the specific features of the problem-solving app. Hirsh-Pasek et al., (2015) proposed four features apps need for them to be beneficial for children: active learning, engagement in the learning process, meaningful learning, and social interaction. Connectedly, Huber et al., (2016) suggested children's learning and performance in their study may have been enhanced through active engagement with the app and the contingency that is inherent when using touchscreens. Additionally, Chen and Siegler (2013) suggested goal direction was crucial in enabling young children to learn and apply problem solving strategies successfully. It could be argued that the problem-solving app fulfils all these criteria. While the exploration app does contain some of these more general features, they may not necessarily be relevant or conducive to facilitating problem solving. To illustrate this point, Table 18 gives examples of features observed in each app and aligns them with previous research. As can be seen from the table, the apps share similar features, such as interactivity, aesthetic appeal, and contingency. However, the exploration app places more emphasis on variety and producing different outcomes based on input and does not contain features such as goal direction, linearity, or a feeling of progression within the game itself. These features could be critical in encouraging convergent thinking and potentially benefitting problem solving skills generally.

Table 18.

Summary of beneficial media features highlighted in previous research and how the problem-solving app and exploration app compare.

Study	Feature	Examples from problem solving app	Examples from exploration app
Chen and Siegler (2013)	Goal Direction	• Background lines (showing where block will line up if dropped). • Character (periodic vocalisations to draw attention to screen, pointing at object they want to reach).	• No examples observed e.g., no direction from characters.
Hirsh-Pasek et al., (2015)	Active learning	• Aesthetics (bright colours, background music, cartoon style, sound effects) • Input required (need to touch screen for things to happen). • Linearity.	• Aesthetics (bright colours, background music, cartoon style, sound effects). • Input required (need to touch screen for things to happen).
	Engagement	• Reward when successfully completed (music change, lots of stars). • Feedback (stars and music if successful, character vocalisation and reset if unsuccessful, noise if block not placed in compatible space).	• Sound effects when objects touched. • Touching same object repeatedly can sometimes lead to different outcomes (e.g., tower being built, object changing into different colours) and unique sound can also occur if this happens.
	Meaningful learning	• Progression (change in task difficulty over time). • Variety (different scenes, objects, and blocks).	• Variety (different scenes, objects, and blocks to interact with).
	Social Interaction	• Character ("eye contact" throughout). • Character (periodic vocalisations relating to goal e.g., drawing attention to screen or pointing to object being reached).	• Variety of different characters in scene (but small and not necessarily making "eye contact" with user or giving indication of action).
Huber et al., (2016)	Contingency and interactivity	• Input required (need to touch screen for things to happen). • Content reacts to touch (e.g., block is picked up and moved around).	• Input required (need to touch screen in order for things to happen). • Majority of content reacts to touch (e.g., changing colour, making a sound). • Some require other objects to do other actions (e.g., moving character to sit on rope swing).

Therefore, there are several potential contributory factors. Firstly, the app could be considered as an active and engaging task, since the participants need to physically touch and interact with the screen to progress through the levels, making it inherently active. This is also supported by previous research, where touchscreens are observed to provide a balance between speed and efficiency in problem solving compared to more traditional methods of input, such as computer mice and physical tasks (Donahue et al., 2013). Touchscreens may therefore be an optimal platform on which to complete problem solving activities and may foster subsequent problem solving in other tasks. Secondly, they were supported by social interaction, in this instance, by the experimenter who outlined the context of the app and how to use it. This social support may have facilitated problem solving, for example, through encouragement and moving them on if the time limit for the level elapsed. Indeed, scaffolding has been previously highlighted as a potential factor that facilitates problem solving (Huber et al., 2016), as well divergent thinking (Hoicka et al., 2018) and learning from media more generally (Strouse et al., 2013; Zack & Barr, 2016). Finally, participants were given some goal direction where the experimenter indicated what the aim of the level was, for example, to reach the tin can at the other side of the screen. This may have been beneficial as it allowed participants to focus immediately on generating ideas to solve the problem, creating a more focused approach (Chen & Siegler, 2013). The combination of these factors may have led to better performance in the GATTeB after using the problem-solving app.

4.4.3 Exploration app

For findings relating to the exploration app, it is possible that, in contrast to the problem-solving app, it did not provide an optimal opportunity to develop problem solving skills. This could be due to the open-ended and abstract nature of the activity. Pepler and Ross (1981) highlighted that engaging in divergent activities before a problem-solving task led to fewer strategic approaches, but more flexibility. It is possible that using the exploration app led to fewer strategic and focused approaches, resulting in fewer solved problems. Alternatively, it is possible that increased flexibility in approaches led to more alternative, non-tool-based solutions to the problems, resulting in lower scores. To investigate this, post-hoc inspection of the data on how participants completed the GATTeB tasks (that is, whether they used the correct method, an alternative method or did not successfully complete the task) was completed (see Appendix K). Of note, a higher percentage of participants who used the exploration app were coded as using alternative methods in the Seed Extraction task (48.1%) and Termite Fish task (37%) compared to participants who used the problem-solving app (30.8% and 19.2%

respectively). However, Fisher's Exact test suggested that the difference in approaches was only significant in the Termite Fish task (p = .045, Fisher's exact test). Consequently, there could be some limited evidence to suggest that in tasks that allow for alternative methods, participants who used the exploration app may have been able to generate and implement alternative methods to a greater extent compared to those who used the problem-solving app. However, it is important to note that alternative methods did not surpass the proportion of correct methods used in the tasks in the exploration app condition, suggesting the method using the tool was still the most popular option. Additionally, participants in the problem-solving app used a higher proportion of correct methods across all tasks. As previously mentioned, the problem-solving app may have primed a convergent way of thinking, where participants opted for more strategic and efficient approaches compared to the exploration app. However, it would be of future interest to examine the fine-grained behaviour sequences to identify specific approaches during the tasks. For instance, whether participants opted for an alternative strategy from the start, their persistence with different methods, and how these approaches vary after engaging with different types of app content.

4.4.4 Limitations

It is important to reflect on some of the current study's limitations. Firstly, the exposure to the apps was relatively short and took place immediately before completing the GATTeB, so it is not clear whether the observed effect could be sustained over a longer period. However, when effect sizes were calculated, medium to large effect sizes were observed, giving some confidence that this is a robust effect. Secondly, while it was possible to create a baseline condition using data from Chapter 3, it would have been beneficial to include a within-participants design element and have a pre-test baseline measurement of problem solving for the app conditions. Currently, the study informs us that there was a significant difference between problem solving scores after using a problem-solving app. However, it is possible that the significant difference reflects the overall participant problem solving ability of each respective condition. Thus, the inclusion of a baseline measurement for the app conditions would be useful in establishing whether the problem-solving app improves problem solving generally.

Another consideration concerning the study design is that the experimenter supported participant app use to a degree, for example giving context to the app, instructions and highlighting the goal to be achieved. Given that social interaction is thought to be important in allowing children to learn from apps (Hirsh-Pasek et al., 2015; Zack & Barr, 2016), this could be an important factor underlying the results. Additionally, the experimenter highlighting goals is particularly pertinent as Chen and Siegler (2013) suggested that goal direction was an important factor in children's ability to successfully apply digitally learned problem solving strategies. It is therefore possible that if children were left to use the app on their own, the same findings may not be observed because it would lack these important learning conditions. However, due to the lack of in-app instructions, it was deemed necessary to allow children an equal opportunity to engage with the app. Additionally, experimenter support was used for both apps in the interest of providing as much of a balanced experience for participants as possible. For this reason, it would be beneficial for future research to consider including rigorous research methods such as blind outcome testing and preregistration of the study and the proposed analyses to increase both clarity and confidence in the research findings.

A final limitation is that the current study focuses on only one aspect of creative thinking: problem solving, or convergent thinking. Thus, the findings cannot be discussed in relation to divergent thinking or generalised to "creativity" overall. Additionally, no equivalent physical tasks were used to compare with the apps. For example, Huber et al., (2016) and Tarasuik et al., (2017) compared touchscreen and 3D versions of the same tasks. Relatedly, Antrilli and Wang (2018) compared how young children's executive function differed after touchscreen used compared to other activities, such as drawing and physical activity. Thus, it may be of interest to examine whether engaging in physical problem-solving or exploration tasks would yield the same results as using equivalent apps. This could be particularly fruitful given that task order in Chapter Three seemed to affect problem solving, where participants who completed the Unusual Box Test before being presented with the GATTeB produced higher problem-solving scores. However, since the main aim of the study was to compare the potential differences in problem solving after using certain apps, this could be addressed in future research. Nevertheless, the results from the current study are of great value and enhance our understanding of how apps could be beneficial for young children's problem solving.

4.4.5 Implications and future directions

Overall, the current study gives insight into how different types of apps might influence children's problem solving and it contributes to the ongoing debate about children's media use. Specifically, it shows a potential positive effect of using a problem-solving app on a subsequent problem-solving task, suggesting that certain apps could be beneficial for problem solving. Additionally, it explores the potential transfer of problem-solving cultivated in digital play to a non-isometric physical problem-solving task. This is a particularly important consideration for the area as many transfer studies have used isometric, or identical, tasks in their paradigms (Huber et al., 2016; Moser et al., 2015). This is valuable in understanding how children learn and transfer from specific tasks but does not give any insight into a more general effect of touchscreens on cognition. As it is unlikely that children will transfer directly between digital and non-digital versions of the same task at home, it is pertinent to investigate the more general effects of media use. In the current study, by using a non-isometric task to follow the apps, it was possible to observe higher GATTeB scores after using a problem-solving app. Consequently, it may be possible to suggest that the app could have contributed towards better performance in a separate and non-isometric physical problem-solving task, though this would need to be confirmed in a study using pre-test measurements of problem solving. This is a vital contribution to the literature as there is suggestion that touchscreens and apps hinder creative thinking, including problem solving (Healey et al, 2019; Yogman et al., 2018). However, the findings from this study suggest that apps, are at the very least, not detrimental to problem solving and that problem solving apps may have the potential to be beneficial for problem solving. This offers an important, alternative perspective regarding the influence of touchscreens on young children's creative thinking.

Future studies could consider exploring the specific features of apps that may contribute to children's problem solving abilities. As noted in the presented research, the problem-solving app contained several features that link with previous suggestions of how children can learn from media (Chen & Siegler, 2013; Hirsh-Pasek et al., 2015; Huber et al., 2016). Isolating and testing individual features, such as linearity or in-app goal direction, and whether their presence or absence affects subsequent problem solving would be of great interest. This could have exciting implications, particularly for app development and understanding how fine-grained aspects of app design can influence problem solving. Another direction for future research to consider involves the longevity of the observed positive effect of the problem-solving app. The current study is valuable insofar as identifying a potentially positive effect of this kind of app in the short-term. It would be of interest to further examine whether the effect is long-term or short-term. The longitudinal findings in Chapter Two indicated that touchscreen use and its associated apps generally did not have longer-term relationships with reported problem solving. Thus, one could infer that the effects may be short-term. However, it would be of interest to assess whether the effect of apps on children's actual problem-solving skills is acute in the short-term and dissipates over time. Another avenue for future exploration would be to compare the effect of apps to equivalent physical activities, allowing more insight into which activities might best facilitate problem solving and the underlying features that promote it. Finally, as scaffolding has been identified as an important contributory factor in children's media use (Hirsh-Pasek et al., 2015; Zack & Barr, 2016), it would be of interest to explore whether children's individual app use may lead to different observations. For example, it is possible co-use of a touchscreen could lead to increased problem-solving performance because of greater support during app use. Together, these avenues for future research could contribute to a growing literature on children's app use and inform understanding about how apps could be beneficial for children's cognitive skills, as well as the critical contextual features that support the development of digitally learned skills.

4.4.6 Conclusion

To conclude, the current study aimed to investigate the effect of using specific apps on problem-solving performance in 36- to 47-month-olds. Participants used either a problem-solving app or an exploration app before completing the GATTeB. The initial findings showed problem solving was higher after children used the problem-solving app compared to the exploration app. However, after the inclusion of a baseline condition where children did not use any app, the difference was no longer significant. There was, however, a significant difference between children who used the problem-solving app and children who did not use an app, where app-users scored higher on the problem-solving task. This may suggest that using the app could have had beneficial effects on problem solving compared to not using an app at all. This could be due to the features present in the problem-solving app that allow children to exercise the cognitive abilities that underlie problem solving, for example, generating potential solutions, trialling and evaluating them and adjusting their approach if necessary. However, to make a decisive conclusion about whether the problem-solving app facilitated children's problem solving, future research containing baseline measurements of problem solving is required. In terms of other findings, the fact that there was no significant difference between the exploration app and the baseline condition suggests that the exploration app did not have a negative impact on problem solving, but nor did it necessarily facilitate it. Thus, apps may not be detrimental to problem solving overall and problem-solving apps may potentially be beneficial for problem solving in 36- to 47-month-olds. This insight is valuable and could suggest that apps containing problem solving elements may be a viable activity to include in young children's repertoire as one way of fostering problem-solving abilities.

CHAPTER FIVE:

General Discussion

The aim of this thesis was to explore the potential influences of touchscreens and apps on young children's creative thinking. Across three studies, creative thinking was examined through problem solving, novelty seeking behaviours and divergent thinking. This was an important topic to investigate as children's touchscreen use has significantly increased over recent years (Ofcom, 2017; 2019a; Rideout & Robb, 2020). Despite the increase, there is relatively little understanding about how touchscreens could influence cognition generally, nor creative thinking more specifically. It is vital to consider this because creative thinking is seen as an important skill in society and everyday life (Moran, 2010; Sternberg & Lubart, 1996). Additionally, it is seen as a quality that should be cultivated in young children's lives, both in terms of cognition and being able to access opportunities that allow creative thinking to be developed (Department for Education, 2017; Hoicka et al., 2016; OECD, 2015). The findings reported in this thesis reveal interesting observations, particularly concerning apps and problem solving. The general discussion is organised in the following way. Firstly, there is a summary of each of the three studies and their main findings. Secondly, key findings are highlighted and considered in relation to previous research, including observations about problem solving and learning apps and the potential benefits of using problem-solving apps. Finally, the strengths and limitations of the studies are reviewed, followed by the implications of the thesis, areas for future research to consider and an overall conclusion to the thesis.

5.1 Study overview and main findings

Three separate studies were conducted to support this thesis using various methods of investigation to examine the influence of touchscreens on young children's creative thinking. The first study used a correlational design operationalised entirely through an online survey, which was enhanced by the inclusion of a longitudinal element. The second study used a cross-sectional correlational design and advanced on the first study by using behavioural measures of creative thinking. The final study in this thesis used a between-participants experiment to investigate the effect of using different apps on problem solving.

The first study reported in Chapter Two aimed to explore the potential relationships between caregiver reports of their 12- to 47-month-olds' problem solving and novelty seeking behaviours and engagement in different home activities. This was completed using an online survey, where caregivers were asked to report on their children's propensity to engage in problem solving and novelty seeking behaviours using the Early Problem Solving Scale and the Early Novelty Seeking Scale (Hoicka et al., in prep). In terms of activities, caregivers were asked to report on how long their child had engaged in different activities at home, including touchscreen and app use, watching different types of video content, and non-screen-based pursuits, such as reading and creative activities. This study also incorporated a longitudinal element by offering respondents the opportunity to complete the survey again six months later. After controlling for age, the cross-sectional data at Time 1 revealed reported problem solving was positively associated with using touchscreens with an adult and time spent using learning and creative apps. Additionally, problem solving was also positively associated with reading independently. After entering all activity variables into a bootstrapped hierarchical regression, independent reading, and using learning apps were found to be positive predictors of problem solving. However, negative predictors included watching child-directed video content with an adult and independent touchscreen use. Novelty seeking was positively correlated with time spent using touchscreens independently and using learning apps and creative apps. It was also positively related to using multiple screens simultaneously and watching non-child-directed video content independently. Regression analyses showed watching non-child-directed video content on their own was also a significant positive predictor of reported novelty seeking. In terms of longitudinal findings, problem solving at Time 2 was positively related to time spent using gaming apps at Time 1. Additionally, problem solving was negatively related to watching non-child-directed video content with an adult at Time 1. However, these variables were not significant predictors of problem solving at Time 2. No significant relationships were observed between activities at Time 1 and novelty seeking at Time 2, however, novelty seeking was positively predicted by time spent using video call software at Time 1. No further significant cross-sectional or longitudinal relationships were observed.

The second study, in Chapter Three, also used a correlational design, but advanced on Chapter Two by using behavioural tasks to measure creative thinking in 24- to 47-month-olds. This was important as previous research had used behavioural measures of divergent thinking and problem solving to explore the effect of media on these abilities. Thus, by using direct behavioural measures of creative thinking, it is possible to align the findings from this study with that of previous research. The study's procedure consisted of participants completing the Unusual Box Test (Bijvoet-van den Berg & Hoicka, 2014) and the Great Ape Tool Test Battery (GATTeB; Reindl et al., 2016) to measure divergent thinking and problem solving, respectively. Caregivers filled in an online survey similar to the one used in Chapter Two asking them about the amount of time their children spent engaged in different activities on a typical day. Performance on the creative thinking measures were correlated with reported activity engagement. The results showed that higher problem-solving scores in the GATTeB were associated with more time spent using learning apps. Interestingly, divergent thinking was not significantly related to any media activities, such as touchscreens, app use or watching video content, or any non-digital activities like reading and creative activities.

The studies from Chapters Two and Three showed a consistent finding insofar as that problem solving, whether measured through caregiver reports or behavioural tasks, was positively related to time spent engaged in learning apps. Specifically, higher problem-solving scores were associated with increased engagement with learning apps. However, because the findings were correlational, it was not possible to discern direction of effect. Thus, there were two potential explanations for the significant relationship. One was that it could be due to a facilitative effect of the apps, and the other was that it could be due to better problem solvers engaging in these apps more often. This finding was therefore of great interest and warranted further exploration. Consequently, the study in Chapter Four progresses on the preceding chapters by using a between-participants experiment to investigate the effect of apps on problem solving. Specifically, it examined whether using a problem-solving app would have a facilitative effect on 36- to 47-month-olds' problem solving compared to an open-ended exploration app. Participants either used a problem-solving app or an exploration app before completing the GATTeB and the problem-solving scores from the two groups were compared. It was also decided that it would be of interest to compare the app conditions with a baseline condition. Data from participants in Chapter Three's study who fit the criteria for a baseline condition (36- to 47-month-olds who did not complete an activity before the GATTeB) were extracted and entered into additional analyses. The initial analysis between the two app conditions showed problem solving scores in the GATTeB were significantly higher in the group who used the problem-solving app compared to those who used the exploration app. When incorporating the baseline condition where no app was used before the GATTeB, it was found that the difference between the two groups of participants who used the apps was no longer significant. However, there was a significant difference between participants in the baseline condition compared to the problem-solving app, where problem solving was significantly higher after using the app compared to not using an app at all.

5.2 Exploring the findings and their contribution to existing literature

The following section explores the main findings from this thesis and the potential reasons for these observations. Additionally, it discusses the contribution of the studies from the thesis to the wider literature. Firstly, observations relating to problem solving and learning apps are discussed, followed by the positive effect of using a problem-solving app on subsequent problem solving. Secondly, findings concerning divergent thinking and novelty seeking are discussed. Then, relationships between other media activities and naturalistic problem solving and novelty seeking behaviours are reviewed. Finally, findings relating to creative thinking and non-media-based activities are considered, followed by observations regarding displacement. Overall, the findings enhance our understanding of how apps relate to and affect problem solving, how they relate to divergent thinking and novelty seeking and how other, non-touchscreen-based activities relate to creative thinking and touchscreen use.

5.2.1 Learning apps are positively associated with problem solving

A key contribution of this thesis is to the understanding of how learning apps relate to young children's problem solving specifically. Problem solving, measured through caregiver reports in Chapter Two and the GATTEB in Chapter Three, was correlated with time spent engaged with different activities. In Chapter Two, caregiver reports of problem-solving behaviour were significantly and positively associated with reported time spent using learning apps and this was also a positive predictor of children's problem solving. This was further supported by Chapter Three, where reported engagement with learning apps was significantly and positively correlated with performance in the GATTeB, though it was not a significant predictor of problem solving. These findings could broadly converge with previous research that shows problem solving can either be enhanced by media use (Anderson et al., 2000) or at the very least, not negatively affected by it (Chen & Siegler, 2013; Huber et al., 2016; Tarasuik et al., 2017).

There are two main perspectives that could be taken when interpreting these findings. Firstly, it could be that children who are better problem solvers or engage in more problem-solving behaviour in everyday life spend more time using learning apps. This could be because young children find it a stimulating and enjoyable activity as they are capable of successfully engaging with the apps. Indeed, Buschman (2003) suggested that children enjoy problem solving and get satisfaction from generating their own solutions to a problem. Perhaps children who do not exhibit stronger problem-solving behaviours find engaging with learning apps more challenging and less enjoyable, resulting in less engagement with them compared to children who are better problem solvers. Thus, learning apps may offer children who are adept at problem solving an additional opportunity to use their skills and apps are therefore engaged with more frequently. The second perspective that could be taken is that learning apps may provide an environment in which young children can practice problem solving and problem-solving behaviour through different content and functional features. For example, the inclusion of scenarios that promote problem solving or convergent thinking may benefit problem solving. This view could be supported by previous research that has proposed media content is beneficial for creative thinking. For example, Anderson et al., (2000) found the television program *Blue's Clues* promoted problem solving in preschoolers due to the accessibility of the content and the features embedded in the program that promoted engagement and opportunity to practice the skills. This could also apply to apps, perhaps even more so, given the inherently interactive and contingent features that are thought to aid learning from touchscreens (Hirsh-Pasek et al., 2015; Huber et al., 2016). Thus, it is this combination of educational content and features that may provide a good environment in which children can hone problem solving skills. This prospect is particularly interesting to consider in light of the positive longitudinal relationship observed between gaming apps and problem solving in Chapter Two. The finding suggested time spent using gaming apps was associated with higher reported problem-solving behaviour six months later. As discussed in Chapter Two, this relationship could be because gaming experiences can contain problem solving scenarios or opportunities to develop strategies to progress through the game (Granic et al., 2014). However, the potential reason for the discrepancy between this finding and observing the cross-sectional relationship between learning apps and problem solving could relate to how problem solving is presented in the respective apps. Gaming apps could be seen as primarily for entertainment purposes, with problem solving features being secondary or implicit elements of the activity. Therefore, as gaming apps are used more, problem solving may increase over time. Conversely, learning apps may have explicit problem-solving aims, for example, *Pango Blocks* (the problem-solving app used in Chapter Four) is specifically described as involving challenges and logic, directly highlighting its problem-solving nature (Studio Pango, 2018a). The direct and explicit nature of problem solving in learning apps may therefore have a more acute short-term influence on problem solving skills, resulting in the observation of significant cross-sectional relationships. This notion is further discussed in the next section where the findings from Chapter Four are reviewed.

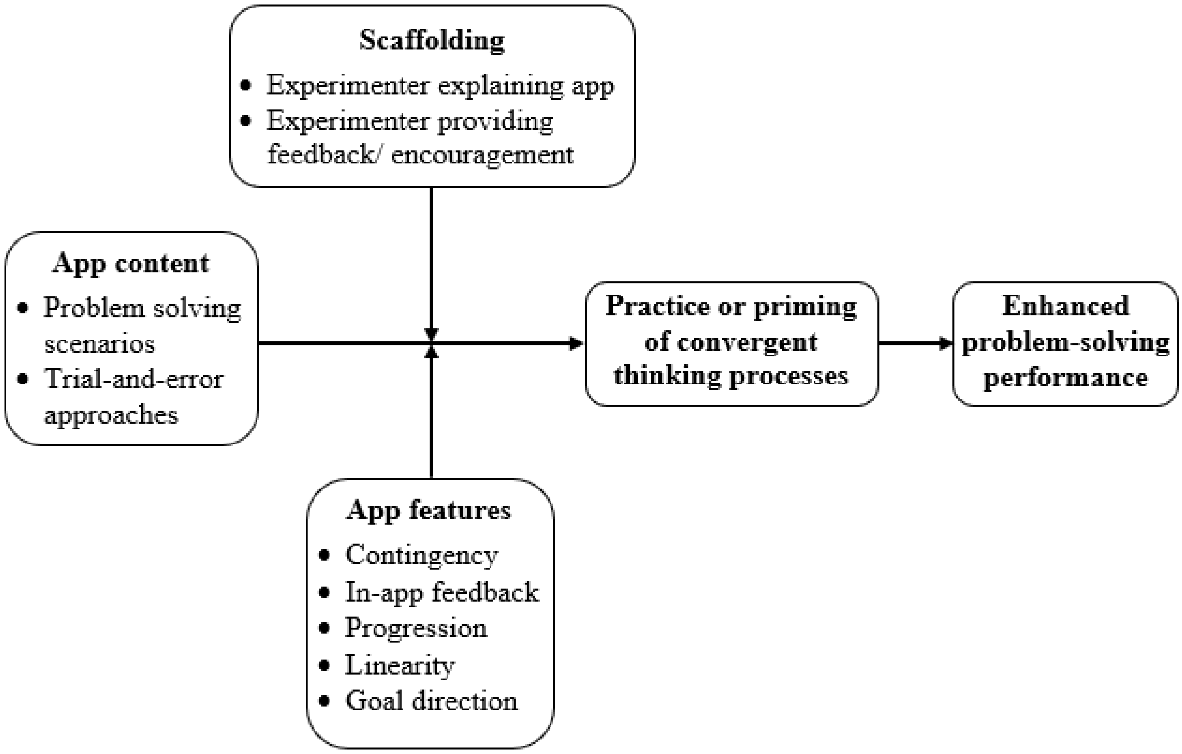
These observations are important to consider, particularly since the positive associations between problem solving and learning apps were observed in both naturalistic and experimental settings. Chapter Two asked about young children's propensity to engage in problem-solving behaviours in everyday life and Chapter Three used a specific behavioural measure of problem solving. The consistency across studies between the different facets of problem solving and the use of learning apps gives confidence in the findings. However, the lack of consistency in regression analyses in Chapter Three may mean the findings should be interpreted with a degree of caution. Additionally, it is important to acknowledge that these findings are a result of correlational analyses. Therefore, it is not possible to make definitive conclusions about why these positive significant relationships exist. Despite this, the correlational findings are an important contribution to developmental media research as it has provided some evidence that touchscreens are potentially beneficial for problem solving. This is a critical consideration in light of different perspectives that has suggested media use is detrimental to problem solving or creativity more generally (Healey et al., 2019; Valkenburg & van der Voort, 1994). This thesis provides evidence that may counteract those conclusions and suggests that touchscreens, and more specifically learning apps, may instead offer an opportunity to enhance those skills, a proposal that could be supported by the findings from Chapter Four.

5.2.2 Using problem solving apps leads to higher problem-solving scores compared to other conditions

The research presented in this thesis also contributes to the understanding of how apps may affect problem solving. Advancing on the findings observed in Chapters Two and Three, problem solving performance in the GATTeB was measured and compared after using different apps in Chapter Four. The major finding from Chapter Four was that problem solving was significantly higher after using a problem-solving app. Initially, problem solving was significantly higher after using the problem-solving app compared to using an exploration app. While this significant difference disappeared after including a baseline condition, performance after using the problem-solving app was significantly higher than if children had not used an app at all. Similar to the evidence presented regarding positive associations between problem solving and learning apps, this finding is supported by previous work that has shown touchscreens do not negatively impact on children's problem solving (Huber et al., 2016; Tarasuik et al., 2017). Indeed, the findings from Chapter Four could suggest problem solving apps have the potential to be beneficial for problem solving. Figure 10 illustrates key elements that could contribute to the explanation of these findings. One potential factor for these findings may relate to the content and features of the problem-solving app. Firstly, the app content itself presented various problem-solving scenarios that would have encouraged children to use trial-and-error approaches. This in of itself may have fostered problem solving in children who used this app. Additionally, certain app features may have enhanced the effect of the problem-solving content. Table 18 in Chapter Four highlighted elements of the problem-solving app and how they aligned with previous suggestions of features needed for children to benefit from media (Chen & Siegler, 2013; Hirsh-Pasek et al., 2015 and Huber et al., 2016). From this, it was possible to see the problem-solving app contained content and features that could enhance user experience and engagement, such as attractive aesthetics.

Figure 1.

A hypothetical model of how the problem-solving app led to problem solving performance in Chapter Four.



Additionally, the inherent interactivity and contingency may have contributed to children's overall engagement, therefore magnifying the benefits gained from interacting with a problem-solving app. In contrast, it could be argued that due to the open-ended nature of the exploration app, it did not contain key features that could have enhanced problem solving, such as linearity, goal direction or clear feedback and rewards. Furthermore, compared to not using an app at all, it could be interpreted that engaging in an activity that promotes convergent thinking, even on a touchscreen, may be beneficial for problem solving. It is also important to note that problem solving was not worse after using an app compared to the baseline. This could suggest that generally, problem-solving and exploration apps may not have a negative impact on problem solving, though problem-solving apps may have the potential to be beneficial. In order to conclude whether problem-solving apps can directly facilitate problem solving, it would be beneficial for future research to include a pre-test measurement of children's problem-solving abilities. This was not included in the design of Chapter Four and consequently it is not possible to decisively conclude that the problem-solving app led to better performance in the GATTeB. An additional consideration is the role of the experimenter, where the support provided to help children use the apps may have facilitated their ability to meaningfully engage with them as well (Hirsh-Pasek et al., 2015). Indeed, social learning has been found to be beneficial in media research (Roseberry et al., 2014; Strouse et al., 2013; Zack & Barr, 2016) and creative thinking (Flynn et al., 2016; Hoicka et al., 2018). Therefore, it is possible that scaffolding from the experimenter, or indeed from the app, may have been beneficial for children's learning and problem solving.

Another possible explanation of how a problem-solving app may facilitate problem solving is that of media priming. As discussed in Chapter Four, learning apps or indeed problem-solving apps may prime a convergent way of thinking which consequently facilitates performance in problem-solving tasks. Previous work has suggested that media can prime subsequent behaviour, for example, watching violent content could activate processes associated with violence and lead to aggressive behaviour (Roskos-Ewoldsen et al., 2002), and this could theoretically apply to apps and problem solving. As the study participants in Chapter Four were engaging in an activity that required a similar way of thinking to the physical problem-solving task, it is possible that this primed or perhaps "warmed up" their convergent thinking skills (such as generating, evaluating, and modifying ideas; Cropley, 2006; Keen, 2011), leading to better performance in the problem-solving task. Equally, it is possible that it is a practice effect, where engaging in a logical task requiring problem solving simply led to better problem solving because they had been practicing the skills required beforehand. However, the priming explanation may have more merit in this instance as the problem-solving app was not identical to the physical problem-solving task. One might reasonably expect that practicing on an identical task may lead to better performance in the same task later. However, the physical problem-solving tasks were novel to the participants and while the fundamental thinking skills required to solve the problems in the GATTeB may have also applied in the app, participants were not able to practice the GATTeB tasks in any way before they were presented. Additionally, research such as Pepler and Ross (1981) showed convergent play led to more strategic or convergent approaches to a subsequent task. Thus, priming seems to be a viable explanation in terms of understanding how problem solving may be benefitted by a problem-solving app.

To summarise the findings concerning apps and problem solving, it is possible that the positive findings observed throughout this thesis could be due to app content and app features combining to potentially facilitate problem solving skills. With learning apps, it is possible that the content has a positive influence on problem solving, where it is pitched at a level that is understandable yet still a challenge for children. Alternatively, children who are better problem solvers may engage with these apps more because they enjoy them. The finding that using a problem-solving app led to significantly higher problem-solving scores may offer some support for the correlational findings and demonstrates how apps may potentially facilitate problem solving. It is suggested that the app content and features inherent in app use, such as interactivity, may have helped foster subsequent problem solving. Additionally, priming is highlighted as a potential explanation, where engaging in an activity requiring convergent thinking skills may have led to better performance in other problem-solving tasks. These findings have important implications for understanding how apps can benefit problem solving as it suggests learning apps may be a positive activity to undertake while using a touchscreen. Furthermore, it calls into question the claims made by policymakers regarding touchscreens and their influence on creativity. There have been suggestions that young children should avoid using touchscreens and other media as they may have a detrimental impact on creativity by distracting from activities thought to be of more value (Valkenburg & van der Voort, 1994; Yogman et al., 2018). However, the findings from the presented research suggest that certain apps may potentially be beneficial for problem solving. This is further enhanced by using commercially available apps to address the research questions in Chapter Four as it may improve the ecological validity of the study. Thus, it would be of value to enter discussions about how apps could be used to develop problem solving skills. To support this, future research could identify and test specific app features to ascertain how they could affect problem solving. It would also be important to include baseline measurements of problem solving to increase confidence in any subsequent findings that demonstrate differences in terms of children's problem solving performance. This could involve collaboration between app developers and researchers to synthesise their respective expertise and properly assess how apps be can optimised to effectively support children's problem solving and learning (Dore et al., 2018). This would give detailed insight into characteristics of app use that enhance problem solving, which would be of interest to stakeholders such as caregivers and educators so they can support young children's problem solving in their respective settings.

5.2.3 Divergent thinking is not related to app use, but novelty seeking is

Another important contribution from this thesis is the finding that divergent thinking is not significantly related to app use, positively or negatively. In Chapter Three, partial bootstrapped correlations controlling for age were run between divergent thinking scores, as measured by the Unusual Box Test, and time spent engaging in different activities, including touchscreen use. The results from these analyses showed that there were no significant relationships between divergent thinking scores and using touchscreens or apps. This finding is in line with some evidence where divergent thinking was not observed to have been negatively impacted nor benefitted by media (Kandemirci, 2018; Piotrowski & Meester, 2018; Runco & Pezdek, 1984). However, it does diverge from previous studies that have investigated divergent thinking and media use. For example, Harrison and Williams (1986) showed divergent thinking scores in older children were lower two years after television was introduced. In contrast, Anderson, Huston et al., (2001) found educational content viewed at preschool age was positively associated with later divergent thinking. However, it is important to note these are longitudinal studies and divergent thinking was not examined longitudinally in this thesis. Additionally, suggestions that touchscreens may benefit creativity by way of providing opportunities to explore and experiment with ideas may not necessarily be supported by these findings (Carrell Moore, 2017; Marsh et al., 2018).

The lack of significant associations may be due to touchscreens and apps being relatively neutral activities in relation to divergent thinking. Specifically, it is possible that touchscreens do not offer the optimal environment to facilitate divergent thinking. A defining characteristic of divergent thinking is generating ideas in response to problems or questions (Hennessey & Amabile, 2010). It is possible that although touchscreen devices and apps might promote exploration within a digital space (particularly open-ended apps), this does not necessarily translate to divergent thinking as a cognitive skill. Divergent thinking tasks tend to involve working a specific context in an open-ended manner, for example, generating alternative uses for a specific object or completing a drawing that incorporates a specific shape. This is a complex behaviour and may be difficult to mirror in apps or other forms of media.

Indeed, Piotrowski and Meester (2018) observed that divergent thinking in 8- to 10-year-olds was not fostered by moderately discrepant open-ended apps. They suggested one reason for this could be that the distance between the apps and divergent thinking task was too great. That is, there were too many differences between the apps and tasks for them to have a facilitative effect on divergent thinking. However, because there is still an opportunity to experiment and generate new ideas within an app space, apps may not have a negative influence on divergent thinking either. This idea could also apply to the presented research, where the activities caregivers were asked about are simply not able to provide optimal environments or content in which to support the development of divergent thinking skills. In explaining this lack of relationship, it may also be helpful to consider the findings regarding problem solving. Learning apps were positively associated with problem solving and Chapter Four showed problem solving was significantly higher after using a problem-solving app. It is important to note that these kinds of apps may contain more features that foster problem-solving compared to divergent thinking. Indeed, Table 18 in Chapter Four explored features in the problem-solving app that may have contributed to enhanced problem-solving performance, such as linearity, progression, and guidance towards a goal. However, open-ended or creative apps may not incorporate these features and are more focused on allowing children to freely experiment with content. Therefore, while this might promote novelty seeking and experimentation, which is discussed in the next section, it may not facilitate divergent thinking, as unlike traditional divergent thinking tasks, there are no boundaries to contextualise the activity.

Connected to divergent thinking is the idea of novelty seeking, where the desire to obtain new information or experiences is thought to lead to exploration and consequently provide ideas and insight that could be utilised in divergent thinking processes (Carr et al., 2016). Indeed, personality traits characterised by novelty seeking, such as openness to experience, have been found to positively relate to divergent thinking (Batey & Furnham, 2006). Chapter Two examined relationships between 12- to 47-month-olds' reported novelty seeking behaviours and media use. Interestingly, some positive relationships were observed in cross-sectional data, for example, novelty seeking was significantly related to independent touchscreen use, learning and creative apps, and using multiple screens simultaneously. As discussed in Chapter Two, it is possible that these different forms of media use could facilitate novelty seeking. For example, the learning and creative apps may facilitate novelty seeking by way of their content. Learning apps may satisfy the desire to obtain new knowledge by providing opportunities to develop and learn new skills or information through different activities. This could be enhanced through the provision of further challenges by progressively increasing difficulty across different levels. Creative apps, such as drawing and music apps, may provide a space for children to explore and experiment with new ideas, and thus foster the desire to seek out new experiences (Carrell Moore, 2017). Alternatively, it is possible that children who prefer novelty to familiarity engage in these activities more frequently because it satisfies their desire for new experiences. Indeed, the questions used in the novelty seeking scale centred around children's preferences for novelty, for example, whether they preferred reading new books compared to familiar books (see Appendix B). This may be further enhanced by touchscreen features such as tailorability, where content on a touchscreen can be aligned to children's preferences or abilities (Christakis, 2014), potentially increasing the likelihood of them seeking out these experiences. It is interesting to note that while some positive relationships were observed between media use and novelty seeking, this may not necessarily translate into exploration and divergent thinking. As previously highlighted, no significant relationships were observed between touchscreen use and divergent thinking, which was measured using the Unusual Box Test, and is based on the extent to which participants physically explore a series of novel objects. It is possible that while media use may foster novelty seeking, it does not necessarily translate to the generation of ideas because, as previously discussed, apps and other media content may not provide the optimal environment for divergent thinking skills to be developed. Therefore, it is possible that apps could support novelty seeking, leading children to pursue opportunities that could theoretically enhance exploration, such as open-ended creative apps and apps that offer different learning experiences. However, this may not necessarily translate to higher levels of divergent thinking. As has been mentioned across the thesis, it is also important to acknowledge that there were inconsistencies across different analyses and novelty seeking was a variable that experienced these inconsistencies. That is, while there were observations of significant relationships between novelty seeking and different media-based activities, this did not translate over to regression analyses and these activities were not significant predictors of novelty seeking. This is important to bear in mind it is possible that these relationships are more susceptible to the influence of other variables, meaning the associations between them are not particularly robust.

In sum, novelty seeking is positively related to some media behaviours, including touchscreen and app use, though it was not predicted by the majority of these activities. It is possible that on one hand, children who engage in novelty seeking behaviours more often engage in these activities more frequently. On the other hand, as touchscreens can offer a variety of engaging activities, such as open-ended apps that allow exploration and experimentation, children may be attracted to the opportunity to participate in these activities (Carrell Moore, 2017). Additionally, touchscreens and apps can contain features such as tailorability and progression, which could encourage repeated engagement to find out what the next challenge is (Christakis, 2014). Therefore, it is not overly surprising that novelty seeking is positively associated with these behaviours, though it is important to mindful of the lack of consistency across correlation and regression analyses and small amount of variance explained. However, it appears that this does not necessarily translate to exploration to the point where it could facilitate divergent thinking. Divergent thinking is a complex cognitive process, and it is possible that apps are not yet capable of providing an environment where the development of divergent thinking skills can be properly supported. This could be due to apps being too distant to divergent thinking tasks (Piotrowski & Meester, 2018) and that currently, apps may better support other skills, such as problem solving. Namely, touchscreens and apps may better serve the development of problem-solving skills as it could be easier to implement beneficial app features such as linear and progressive activities and feedback during engagement. Conversely, divergent thinking may require a fine balance between working in a free, open-ended space and working with an objective. It is worth noting that divergent thinking was measured through a fluency score only. This was the only index used for divergent thinking as other indices, such as originality where participants receive scores based on the uniqueness of their actions compared to other participants, has been observed to be collinear with fluency in the Unusual Box Test (Bijvoet-van den Berg & Hoicka, 2014). Despite this, understanding that touchscreen and app use does not relate to divergent thinking in terms of fluency and the number of actions produced is an interesting finding. This is because little research has examined divergent thinking and touchscreen use directly and therefore provides new insight into how touchscreens influence this skill. It is an important contribution to previous literature, particularly in terms of policy making where there has been suggestion that media use is detrimental for aspects of creative thinking (Healey et al., 2019; Yogman et al., 2018). In contrast with those claims, the present findings suggest touchscreens are not negatively associated with divergent thinking, but nor are they positively associated. However, it would be of great interest to revisit this in the future to assess whether it is possible to build digital environments that could support divergent thinking and creativity generally as has been previously suggested (Carrell Moore, 2017; Marsh et al., 2018).

5.2.4 Other media activities may have a differential influence on naturalistic problem solving and novelty seeking behaviours

Chapter Two offered a myriad of findings regarding other forms of media and their relationships to reported problem solving and novelty seeking. Cross-sectional findings revealed that reported problem solving was negatively predicted by watching child-directed video content with an adult, and longitudinal findings showed watching more non-child-directed video content with an adult was associated with lower problem-solving scores. In contrast, higher levels of novelty seeking were associated with watching more non-child-directed video content independently. Additionally, using multiple screens simultaneously was positively associated with novelty seeking. Longitudinally, the use of video call software at Time 1, such as Skype, predicted more novelty seeking behaviours at Time 2.

The findings regarding video content were somewhat unexpected, particularly in terms of the co-use elements of the relationships and the child-directed video content. The observations have mixed support from previous research. On one hand, Barr, Lauricella et al., (2010) found adult-directed content was negatively associated with children's developmental outcomes, potentially supporting the findings regarding non-child-directed content. On the other hand, they found child-directed content was positively associated with outcomes, opposing the child-directed video content findings. While Barr, Lauricella et al., (2010) did not specifically address creative thinking, the notion that child-directed media is beneficial for children's outcomes is generally well-supported (Anderson, Bryant et al., 2000; Anderson, Huston et al., 2001; Rice et al., 1990). Additionally, co-use has been shown to help children learn from content and potentially mitigate the negative impact of media (Mendelsohn et al., 2010; Strouse et al., 2013), again at odds with the findings observed in Chapter Two.

As discussed in Chapter Two, the overall reasons for the findings relating to problem solving and watching video content could have been due to the content itself, particularly when it is not aimed at children (Barr, Lauricella et al., 2010). However, given that the negative associations were with activities that involved an adult, co-use could explain these relationships. On one hand, it is possible that even with an adult, scaffolding was not taking place and therefore children were not gaining as much from watching the content. For example, it is possible that the quantity and quality of interactions between the adult and child may not have been sufficient in allowing them to learn from the video (Courage et al., 2010; Zack & Barr, 2016). Conversely, it is possible that children who exhibit fewer problem-solving behaviours may be perceived by their caregivers as needing additional support while engaging with video content until they have developed the skills needed to do this independently (Nikken & Schols, 2015). This also connects with the novelty seeking findings as it is possible that children who engage in novelty seeking more often are perceived as more curious, and potentially more independent, consequently engaging in other behaviours independently more often, including watching video content that is not necessarily targeted at them. Another reason for the positive associations with novelty seeking could be that the activities themselves promote novelty seeking, perhaps by fostering I-type curiosity, where information is sought out for the enjoyment of learning new information from more unusual sources (Litman, 2008; Piotrowski et al., 2014). That is, one would generally consider that child-directed content is a typical way for children to learn new information and skills (Anderson, Bryant et al., 2000; Barr, Lauricella et al., 2010). However, activities such as watching content not aimed at children and video calls may offer a way of learning in a less typical fashion, which may consequently facilitate novelty seeking. Conversely, it is possible that children who engage in novelty seeking more often, engage in activities that satisfy their desire for novelty. For example, video call software may afford opportunities to learn new information (Roseberry et al., 2014) and using multiple screens may provide different sources of stimulation that may lead to the development of strategies that reduce distraction and increase focus (Courage et al., 2015). Therefore, different activities may have contrasting influences on young children's day-to-day problem solving and novelty seeking behaviours.

It is interesting to note these relationships were not replicated in Chapter Three with the behavioural creative thinking measures. This discrepancy could be because media use in the home may influence naturalistic day-to-day behaviours more compared to task-based behaviours. However, it could also be associated with different levels of statistical power in each study or perhaps represents differences between caregiver reports of behaviour compared to direct measurement. Indeed, novelty seeking should not be misconstrued as directly synonymous with divergent thinking, rather it is a distinct trait that could contribute towards it (Carr et al., 2016). Nevertheless, these findings contribute to our understanding of how other media-based activities might relate to naturalistic problem solving and novelty seeking behaviours and how co-use with adults could further influence these relationships. It would be of interest to expand on these findings with experimental designs to ascertain a possible direction of effect and further understand how media use could affect young children's everyday problem solving and novelty seeking behaviours, which could have further implications for creative thinking skills.

5.2.5 Independent reading is positively related to naturalistic problem solving, but non-digital activities are not generally related to creative thinking

A connected contribution to this thesis involves the substantial lack of relationships between creative thinking and non-digital activities. The only significant relationship observed was in Chapter Two, where higher problem-solving scores were associated with more independent reading. This was further supported by cross-sectional regression analyses, where after age, independent reading was the strongest significant positive predictor of problem solving. The potential reason underlying this relationship may have been due to reading facilitating problem solving, or that children who engaged in more problem-solving behaviours read independently more often. However, this is the only significant cross-sectional relationship observed between a measure of creative thinking and non-digital activities. This finding is supported by prior research that also observed positive associations between reading and creative thinking across different age groups (Gosen et al., 2015; Mourgues et al., 2014; Ritchie et al., 2013). As discussed in Chapter Two, this may be because reading allows individuals to generate and explore ideas, which could have subsequent benefits for problem solving (Gosen et al., 2015; Ritchie et al., 2013). This could also apply to children who read independently, where they are practising these processes individually, hence the positive relationship with problem solving. Alternatively, it is possible that children who are better problem solvers tend to engage in independent reading more often. However, it is important to note that some participants would be considered as prereaders and would still be developing their reading abilities. Thus, as discussed in previous chapters, it is possible that other extraneous variables may underlie this relationship. For example, in being able to access books and engage with them independently, this could be indicative of caregivers attempting to provide a high-quality environment for their children to support their cognitive development (Department for Education, 2018; Kluczniok et al., 2013). In providing a high-quality home learning environment, this may also have a positive influence on elements of children's cognition, such as problem solving, potentially resulting in the observation of significant positive associations between independent reading and problem solving.

Generally, this positive association between independent reading and problem solving is a valuable contribution to the literature as it suggests independent reading may be an important activity for problem solving, and generally supports the idea that reading is likely to be a beneficial pursuit (Billington, 2015; Poitras et al., 2017). However, it would be beneficial to explore this further in relation to other variables, such as socioeconomic status and the quality of the home learning environment, to enhance the understanding of the potential features underlying this relationship.

The lack of significant associations between creative thinking and other activities is somewhat surprising, particularly since some of the questions centred around creative activities. For example, there is ample research that suggests play is positively related to creativity and divergent thinking specifically (Fehr & Russ, 2016; Russ et al., 1999). Additionally, Vandewater et al., (2006) suggested creative activities may be important for the development of creativity and a lack of these activities could have deleterious consequences. However, the observations highlighted in this thesis do not necessarily align with this research. Similar to the potential explanations for a lack of significant relationships between divergent thinking and touchscreens, it is possible the activities that caregivers were asked to report on were relatively neutral in affecting creative thinking. To take the example of creative activities, an endeavour one might expect to be correlated with creativity, it is possible that while children can explore and experiment with the properties of different colours, materials, or sounds, this does not necessarily lead to the development of skills like divergent thinking or problem solving. This could be because the likelihood of needing to use these specific skills during these activities is relatively low, meaning there is limited opportunity to practice and develop them further. This may be particularly applicable to divergent thinking where, again, the balance of responding to open-ended scenarios whilst adhering to a specific context may not be optimally supported in non-digital activities. Another consideration is the detail in which activities were addressed. In a similar vein to addressing media content, rather than just the quantity, it may be beneficial to examine activities that fall under the broader umbrellas of "playing with toys" or "creative activities". While these broad activities may inherently capture some behaviours that could be construed as creative, examining activities in greater detail in future research may be beneficial in identifying relationships. For example, Russ et al., (1999) and Fehr and Russ (2016) examined imaginative play in relation to divergent thinking. Additionally, fantasy play has been relevant in studies examining the influence of media on children's creativity (van der Voort & Valkenburg, 1994). Thus, taking a more detailed perspective on the specific types of activities that children engage in may reveal differential relationships with creative thinking.

The lack of significant associations between creative thinking and non-digital activities is a valuable contribution to the literature. It is often suggested that young children should engage in activities that do not involve media, partly because media use has previously been thought as detrimental for creativity (Singer & Singer, 1990; Valkenburg & van der Voort,

1994) but also because other activities are thought to be more beneficial (Yogman et al., 2018). However, the evidence presented in this thesis suggests that while there is not necessarily a disadvantage, there is also not a particularly facilitative effect of non-digital activities. This is not to say that children should not engage in these non-digital activities. Indeed, if the same logic used by policymakers was applied here, where no evidence of benefit leads to caution about children engaging with media (Strasburger, 1989), children would be advised against engaging in creative activities, which would be an unrealistic recommendation. Rather, it is a suggestion that touchscreens and their associated apps appear to be on an equivalent pedestal with non-digital activities, or perhaps a superior position when considering problem solving. Therefore, touchscreens and apps could be considered as an acceptable activity to include in children's play repertoires alongside more non-media-based activities.

5.2.6 Media use may displace some joint activities, but may also facilitate other activities

Another contribution from this thesis involves the observations of relationships between media use and other non-media-based activities. Reported media use and non-media-based behaviour, such as reading and engaging in creative activities, were correlated to investigate possible displacement. The results from Chapter Two showed that while there was a mixture of significant positive and negative relationships, there were also null findings. A striking pattern in these observations was that only positive and null relationships were recorded between media activities and independent non-digital activities. This contrasts with findings where some negative relationships were also observed between media use and engaging in non-media-based activities with an adult.

The negative relationships observed in Chapter Two mainly concerned playing with toys with an adult, which is an important point to note. Less time spent playing with toys with an adult was related to more time engaged in independent touchscreen use, learning and gaming apps, and watching non-child-directed video content. Additionally, negative relationships were observed between using a touchscreen independently and reading with an adult. Finally, a small negative relationship was noted between watching non-child-directed video content independently and engaging in creative activities with an adult. On one hand, it is possible that media did impact on these joint activities and meant that children spent less time engaging with their caregivers because they were using media, a conclusion that may be supported by previous research (Vandewater et al., 2006). However, the fact that no negative relationships were observed between media activities and independent activities could suggest there needs to be a more nuanced explanation. It is possible that children spent less time engaging in these joint activities because using touchscreens and other forms of media could be considered as less taxing on caregiver time. For example, in explaining their own negative relationships between creative activities and television watching, Vandewater et al., (2006) point out that creative activities such as painting can take a long time to set up and clear away after the activity is completed. The time required to engage in creative activities could be further extended if the caregiver is supervising the activity. Thus, when there is another activity available that potentially takes less time to set up, such as using a touchscreen, this may be a more desirable option. Additionally, research has shown that caregivers can sometimes use media as a way of occupying children while they have errands or jobs to complete (Rideout & Robb, 2020). Other research has also suggested that a major barrier to caregivers playing with their children is time, where busier caregivers may have fewer opportunities to play with their children (LEGO Foundation, 2018). Thus, in the absence of joint activities, there may be a greater reliance on media use and consequently, children may engage in media use more, suggesting that simple displacement of activities may not be sufficient in explaining these negative relationships.

Interestingly, several positive relationships between touchscreen activities and non-digital activities were also observed in Chapter Two, particularly in relation to independent non-digital activities (see Table 10 in Chapter Two for all observations). For example, independent reading was positively related to independent touchscreen use, using creative apps, and watching child-directed video content independently. Independent creative activities were associated with individual touchscreen use, creative apps, and watching non-child-directed content independently. Additionally, watching child-directed video content was positively associated with reading and playing with toys with an adult. One potential reason for these relationships could be that one activity is facilitating the other. Taking independent reading and touchscreen use as an example, it is possible that reading a book raised questions about a topic and a touchscreen was then used to explore and answer those questions. Additionally, the positive relationship between creative apps and creative activities might lend support to the notion that touchscreens can promote creative play (Marsh et al., 2018). Alternatively, it is possible that generally, children who use media more, engage in other activities more often. For example, Wright and Huston (1995) (as cited in Wright et al., 2001) found that children who watched educational media more also spent more time engaged in other educational activities, like reading, compared to those who did not use educational media as often. The positive associations between different independent activities may indicate that children who spend more time completing activities alone may be content with this type of engagement and therefore participate in individual activities more often. Likewise, relationships between watching child-directed media being associated with reading and playing with adults may suggest children enjoy activities where interaction is a key part of engagement. This could be seen as representing clusters of activities that share similar characteristics, and it could be inferred that children's engagement in one activity may facilitate engagement in other similar activities. Therefore, these positive relationships may represent engagement being driven by children's enjoyment of participating in similar sets of activities that appeal to them and suit their preferred level of adult involvement.

Finally, it is important to discuss the lack of significant relationships between different activities. One explanation could be that using media simply does not negatively impact on other activities, but nor does it encourage engagement in them. As displacement is a popular theory in developmental media research, these findings largely contradict previous thoughts on how media use might affect other beneficial activities. For example, Vandewater et al., (2006) also suggested that the negative relationship between television-watching and creative activities was because children were more likely to watch television. However, this relies on the idea that engagement in activities is symmetrical, for example, ten minutes using learning apps takes ten minutes away from another activity (Mutz et al., 1993). This is a flawed assumption because it suggests that, for example, if children were not using a touchscreen, they would be reading instead, which is not necessarily the case as they could also be eating, sleeping, or playing outside instead of reading. Given the wide range of activities that young children can engage in, whether media-based or not, it would be logical to assume their time is spread across many different activities. Therefore, rather than just one activity directly reducing time spent in another, as displacement would suggest, the relationship between activities is more likely to be asymmetrical. This could explain the lack of significant relationships between non-digital activities and touchscreen use observed in Chapter Two.

To summarise, displacement is often cited as a reason for young children to avoid using touchscreens or other media, a perspective that has prevailed for decades (AAP, 2016; Mutz et al., 1993; Valkenburg & van der Voort, 1994). However, the findings presented in the thesis show limited evidence to support this notion. Indeed, the mixture of findings regarding different activities and how they relate to touchscreen and other media-based activities suggests media could affect independent and joint activities in different ways. For example, where negative relationships were observed, it is important to consider contextual factors that could underlie these findings, rather than automatically assuming that touchscreens or other media are a hinderance. This is an interesting contribution to the children's media use debate as it suggests that touchscreens may not necessarily have a large impact on other activities. However, it is also important to note that this was a simplistic examination of displacement and would have benefitted from more detailed methods to accurately measure all activities young children engage in, such as 24-hour diaries (Vandewater et al., 2006; Vandewater & Lee, 2009). Nevertheless, the accompanying findings regarding creative thinking introduce an important counterpoint to displacement. If there were negative correlations between touchscreen activities, non-digital activities, and creative thinking measures, it could be reasonable to hypothesise these relationships could be connected, perhaps by displacement. However, no such concurrent correlations were found during the course of this research, suggesting that negative relationships may only relate to time and may not necessarily have a detrimental influence over creative thinking.

5.3 Strengths and limitations of the thesis

The research presented in this thesis has various strengths and limitations. In terms of strengths, the diversity of research methods could be seen as advantageous. Each chapter used slightly different methods to address the respective research question and were therefore able to build on the foundations set out by other chapters. For example, Chapter Two used more naturalistic measures of day-to-day behaviours, whereas Chapters Three and Four used more controlled behavioural measures of creative thinking. Additionally, Chapter Four used an experimental design as Chapters Two and Three used correlational designs, allowing a causal explanation to be ascertained from the observations. Incorporating a longitudinal element in Chapter Two also allowed insight into whether relationships at the first time point were observed six months later, enhancing our understanding of how relationships between creative thinking and touchscreens changed over time. A further strength relating to study design involves the consistency of findings. Observing similar findings across the different studies and measurements of creative thinking, such as the positive relationships between learning apps and problem solving observed in Chapters Two and Three, could suggest relatively robust observations. This is further bolstered by observing differences in children's problem solving after using a problem-solving app in Chapter Four, suggesting some potential consistency across both naturalistic and laboratory tasks. This enhances the understanding of how apps relate to different aspects of creative thinking and by using experimental methods in Chapter Four, gives insight into how apps could affect problem solving, which is a vital contribution to the area.

As previously mentioned, Chapters Three and Four use behavioural measures of creative thinking. Creativity research has been previously admonished for using single divergent thinking tasks and attributing this as “creativity”, rather than just divergent thinking (Piffer, 2012). Additionally, Baer (1993) suggested that divergent thinking tasks are not necessarily representative of real-world creativity. Thus, using naturalistic self-report in Chapter Two, where caregivers were asked about children’s behaviour in real-world scenarios, gave insight into everyday behaviour that could underlie creativity. Additionally, the inclusion of both divergent thinking and problem-solving measures in Chapter Three ensured that two important aspects of creative thinking could be examined. Indeed, Cropley (2006) highlighted that while divergent thinking and convergent thinking are distinct skills, they are both equally important in the creative process. By measuring both, it revealed differences in how touchscreens might influence the respective skills, where problem solving may benefit from learning apps and divergent thinking is neither facilitated nor hindered by media use, making an important contribution to the literature. Additionally, few studies have focused on 24- to 47-month-old children in terms of creative thinking and media use. This is despite it being an important developmental period and an age at which young children are known to use touchscreens (Ofcom, 2019a; Rideout & Robb, 2020). To address this, the Unusual Box Test and the Great Ape Tool Test Battery were used, which are both developmentally appropriate and valid measures of divergent thinking and problem solving respectively (Bijvoet-van den Berg & Hoicka, 2014; Reindl et al., 2016). This allowed novel insight into how media use could influence these skills in young children. Therefore, the measures used in this thesis present a critical strength and contribute meaningful findings that advance our understanding of how creative thinking, touchscreens, and other activities are connected.

In terms of the decisions made throughout the thesis, a notable strength was addressing media content. Previous research has been limited by a lack of nuance when approaching media use by focusing on the quantity of device use generally, instead of examining how the devices are being used as well (Schmidt et al., 2009). Content has been highlighted repeatedly as an important consideration and one of the ways in which to advance media research (Courage & Howe, 2010; Kirkorian et al., 2008). Additionally, there has been evidence to suggest that there are differential relationships between cognition and different types of media content (Barr, Lauricella et al., 2010). It was therefore of paramount importance to address this, both in terms of touchscreen use and video content. Indeed, the research presented in this thesis has shown the benefit of examining content as most of the key findings concerned learning apps. Had the questions about these different types of apps not been included, there could have been very different findings to report. Thus, it provides detailed insight into whether touchscreens influence creative thinking and more specifically, how different apps may have an influence. This has important implications in terms of guiding what apps could provide benefits, which is likely to be of interest to caregivers and educators.

Chapter Four presents several strengths; it used an experimental design and a behavioural measure of problem solving and incorporated non-isometric tasks. Previous research focusing on transfer have used isometric (that is, identical) tasks across platforms, for example, using both physical and touchscreen versions of the Tower of Hanoi (Huber et al., 2016; Tarasuik et al., 2017). Additionally, analogical problem-solving paradigms have been used in research where the tasks, though not identical, bear strong resemblance across different platforms (Chen & Siegler, 2013). This is important in understanding children's ability to transfer information between platforms and identifying specific features that may impede or facilitate learning. However, these approaches may not be as applicable when discussing effects of touchscreens more generally (Huber et al., 2016). Indeed, Piotrowski and Meester (2018) saw the "far distance" between the apps and divergent thinking tasks as a limitation to their study. However, it is not necessarily a disadvantage to address the more general effects apps can have on creative thinking. By choosing to use commercially available apps in Chapter Four, with the additional strength of being developed by the same studio, it could be argued that the findings could be more closely aligned to children's real-world touchscreen use, potentially improving ecological validity and generalisability of the findings. Additionally, the observation of a large effect size is a strength of Chapter Four as it suggests a robust effect involving a problem-solving app on problem solving. This reinforces the potentially positive overall findings regarding apps and problem solving and has important implications in enriching our understanding of how apps could be beneficial for young children's cognitive skills. It also provides a foundation on which future research could reinforce and build on these conclusions by including more in-depth study elements such as pre-test measures of problem solving and blind outcome testing.

There are also some limitations to the presented research. As highlighted across the thesis, measuring media use through global time estimates in caregiver reports presents potential disadvantages in terms of accuracy (Vandewater & Lee, 2009). Specifically, the reliance of retrospective estimation of media use may mean that reported use is not completely accurate and other methods, such as using 24-hour diaries or recording actual media use, may offer better accuracy (Andrews et al., 2015; Vandewater & Lee, 2009). Additionally, methods such as 24-hour diaries may better test potential displacement of activities (Vandewater et al., 2006). However, self-report measures do present advantages in efficiency, resources and obtaining large sample sizes (Evans & Mathur, 2005). This was evidenced in Chapter Two, where over 500 respondents were obtained at Time 1, which may not have been possible with diary methods. Additionally, parents are thought to be fairly accurate in reporting their children's behaviour (Waschbusch et al., 2000). Thus, for the purposes of establishing a foundation on which future research can build, the survey method adopted throughout the thesis could be considered as appropriate. However, it would be of great interest to examine actual media use amongst young children to gain detailed insight into how and when they use media and how it might influence creative thinking and cognition generally.

Another limitation of the thesis involves elements of the study design. For example, one consideration may involve the short-term nature of some of the research. Chapter Three used behavioural measures of creative thinking in a cross-sectional correlational study, whereas other studies have examined relationships between behavioural measures across multiple time points. These studies have revealed seminal findings and enhanced our understanding of the potential long-term effects of television, particularly in terms of divergent thinking (Anderson, Huston et al., 2001; Harrison & Williams, 1986). Although Chapter Two contained a longitudinal element, it would be beneficial to expand on the research presented in Chapter Three with longitudinal examination of behavioural creative thinking. This could provide further support for the findings in Chapter Two, as well as allowing comparisons with previous television-watching research. Additionally, in Chapter Four, children completed the GATTeB after a single ten-minute session of playing with an app and there was no pre-test measurement of problem solving. Firstly, it would be beneficial for future research to include a pre-test measure of problem solving. Though a baseline condition was used in Chapter Four, it is not possible to conclude that the problem solving app directly facilitated performance in the GATTeB. Thus, establishing problem-solving levels before using the app would lend great strength to the observations and subsequent conclusions. Secondly, although a large effect size was observed, it would be of interest to ascertain whether this is maintained over time, or if it is a short-term effect. It could be inferred from the findings in Chapter Two, where no significant longitudinal relationships were observed between learning apps and reported problem solving, that it is short-term. However, it would be beneficial to confirm whether an effect of such magnitude is sustained over time, or whether it diminishes. Furthermore, similar to Anderson, Bryant et al., (2000), it would be useful to understand whether repeated exposures to apps could have a cumulative effect on children's problem solving. A final consideration involving the design of the research is blind outcome testing. Due to practical limitations and a lack of appropriate resources, it was not possible to include blind outcome testing in the design of the lab-based studies. However, this rigorous approach to research would be valuable to include as it can provide an additional layer of confidence in the findings, particularly in Chapter Four where the experimenter was involved with setting up the app for children to use and was present throughout the test session. This would be further enhanced by using other rigorous and transparent methods, such as preregistration, more generally. These aspects of research design would therefore be beneficial and highly recommended for future research to incorporate to improve the quality of the research, as well as confidence in subsequent observations.

Another consideration of the research presented in this thesis is the potential influence of third variables. As has been noted throughout the chapters, it is possible that extraneous variables that were not accounted for in the analyses or in the research more generally may have influenced the data in some ways. For example, when discussing children's media use, it is important to acknowledge that caregivers will likely play a key role in children's ability to access and use media. Indeed, positive caregiver attitudes towards media have been found to be associated with higher levels of children's media use (Lauricella et al., 2015; Nikken & Schols, 2015). Additionally, caregiver views of what constitutes beneficial activities may influence the surrounding home environment and the type of activities permitted. For example, caregivers may value certain activities (such as non-media-based activities) and view them as more beneficial for their children's cognitive development over and above other activities (like media-based activities) or they may see media activities as an educational opportunity. Consequently, they may try to ensure they are able to facilitate this in the home, perhaps through the provision of appropriate resources or mediating engagement in certain activities, such as having rules on the amount and type of media that can be consumed (Livingstone et al., 2015). Therefore, caregivers could have a key role in their children's media use and potentially children's creative thinking through their attitudes towards activities, as well as the environment they provide for their children. This would be important for future research to consider as this could be a moderating factor in analyses.

Connected to the previous section regarding extraneous variables potentially influencing observations, it is important to note that children's media use and other factors, such as caregiver attitudes and home environments, can vary as a function of characteristics such as socioeconomic status (Department for Education, 2018; Nikken & Opree, 2018; Ribner & McHarg, 2021; Rideout & Robb, 2020). This relates to a final limitation of this thesis concerning the diversity of samples used across the studies. Most respondents and participants would be classified as belonging to Western, Educated, Industrialised, Rich, and Democratic (WEIRD) settings. This has been noted as an in issue in developmental psychology generally (Nielsen et al., 2017). Additionally, Jordan and Prendella (2019) highlight the issue of WEIRD samples in media research, stating that the lack of variation within a sample can create a limited view of what is typical and thus limit the generalisability of the research. When examining the characteristics of the samples used in this thesis, some participants could be classified as having non-WEIRD characteristics. However, most participants would be considered as representing WEIRD settings, which could be a limitation of the research. For example, Chapters Three and Four consist of mostly White participants residing in the United Kingdom, and a minimum of three-quarters of caregivers in each study had been educated to at least undergraduate level. In Chapter Two, using an online survey that could reach a global audience yielded a slightly more diverse sample than if it had been distributed locally or nationally, with 57.4% of caregivers reported having completed at least undergraduate education. However, 92.9% of respondents resided in the United Kingdom or the United States. Thus, while it would be possible to make some comparisons, for example, between the US and the UK (as seen in Ribner & McHarg, 2021), it is debateable as to whether meaningful comparisons can be made with other groups. However, it is also important to acknowledge that although it is a WEIRD sample, it could be considered as a more diverse compared to other samples from other studies that have investigated children's media use with online surveys (Bedford et al., 2016; Cristia & Seidl, 2015; Huber et al., 2018).

Nevertheless, it is of great interest and importance to explore similar research questions using more diverse samples and participants from non-WEIRD settings to investigate any commonalities or differences in how touchscreens might influence children's creative thinking. Indeed, the Lego Foundation investigated children's digital play in the UK and South Africa (LEGO Foundation, 2020). Key findings included South African children having less access to media such as tablet computers, where 21% of South African children had access compared to 94% in the UK. Additionally, the report highlighted that a higher proportion of UK children play branded games such as Minecraft compared to South African children. There were also differences in parent attitudes towards technology use. For example, 23% of South African parents strongly agreed that technology helped their children be creative compared to 60% of UK parents. This could potentially impact on how much their children access and use technology and the type of activities they engage in on the devices. The LEGO Foundation report demonstrates clear differences between countries. It also highlights additional considerations such as ethnicity and socioeconomic status which could have further implications on children's media behaviour depending on the country's cultural context. It would therefore be reasonable to expect that if the research presented in this thesis were to be examined in other countries, differences could be observed between samples. This might be in terms of device access, the amount of use and content engaged with, which could also lead to differences in observed relationships with creative thinking. Indeed, differences in children's media access and use have been observed between the US and UK, which are both countries that would be considered as WEIRD (Ribner & McHarg, 2021). This also underscores the importance of examining the nuances within samples of the WEIRD and non-WEIRD umbrella labels, as well as between them. By simply categorising experiences under one broad label, even if there are differences within that label, there is a risk that important and nuanced information representing samples in more fine-grained groups would be lost, limiting the usability and generalisability of the research. Therefore, it is of great interest to examine how media use in children across different contexts are similar and different, and whether this also relates to their creative thinking abilities. This could be achieved through multi-laboratory research, where developmental research institutes across different countries could collaborate and corroborate their data to create larger and more diverse samples (Frank et al., 2017).

5.4 Implications and future directions

The research presented in this thesis has contributed additional understanding to how young children's touchscreen use might influence their creative thinking. The findings have important implications, particularly when considering the positive observations between apps and problem solving. The findings suggest that apps and more specifically, learning and problem-solving apps, may be valuable in encouraging young children's problem solving. Previous qualitative research has shown that touchscreens can promote problem solving and creative behaviours in different settings (Kucirkova et al., 2014; Marsh et al., 2018). Therefore, it might be possible to tentatively suggest that using these kinds of apps in a balanced way could be permissible in the home and potentially in other environments, such as educational settings. However, more research is required to fully understand the mechanisms of these relationships and how apps could be used in an in optimal way to benefit children's problem solving. This thesis supports these findings and highlights touchscreens as a positive way in which problem solving could be facilitated. Additionally, it also suggests that generally, touchscreens and apps may not be detrimental for children's creative thinking. This is an important consideration given the resistance to young children using media that is often observed in policy. However, a better understanding of how apps might facilitate problem solving, such as the conclusions observed in Chapter Four, may lead to more acceptance of touchscreens as a viable tool for cultivating cognitive skills.

There are various exciting avenues that future research could explore. A primary objective would be to try and replicate the findings presented in this thesis with other samples, including from more diverse and non-WEIRD populations. Additionally, it would be beneficial to examine potential differences in terms of socioeconomic status in more detail. This would establish whether the relationships and effects observed during this research are consistent in other groups and strengthen the conclusions of this thesis. Furthermore, it would enrich the current knowledge base through the inclusion of participants from backgrounds that are less well-represented in children's media research and developmental psychology more generally. Additionally, there are various ways in which the studies can be expanded. One way is to extend Chapter Three and complete longitudinal analyses with behavioural measures. This would correspond with previous research that have addressed similar questions using longitudinal methods (Anderson, Bryant et al., 2000; Anderson, Huston et al., 2001). Similar to Chapter Two, it would be of interest to ascertain whether the relationships observed in Chapter Three would be maintained over time using a direct behavioural measure of children's problem-solving abilities. Indeed, it may also reveal longitudinal relationships between divergent thinking and different activities, which would be consistent with previous longitudinal research (Anderson, Huston et al., 2001). Another way of expanding the research presented in this thesis would be to examine novelty seeking and investigate whether the findings observed in Chapter Two, where reported novelty seeking was positively associated with some touchscreen activities, are replicated with behavioural measures in laboratory settings.

Another consideration for future work that would have enormous value is to ascertain whether measuring actual screen use can be incorporated into developmental media research. Much media research has relied on self-report methods, such as caregiver reports via surveys and diary methods (Vandewater & Lee, 2009). While they do present advantages in cost and convenience, there are limitations in terms of how accurately these methods measure use compared to actual screen use, such as device-logged measurement (Andrews et al., 2015;

Parry et al., 2021). At the point of writing, similar methods have not yet been deployed in developmental media research with preschool samples. However, it is the opinion of the author that there are several considerations to make before it is implemented with developmental samples. Firstly, the demographic information collected in Chapters Two and Three showed that although most children have access to a touchscreen, a much smaller proportion had their own devices. This is important to consider because if devices are shared amongst family members, it may be difficult to distinguish between different users. A potential solution to this may be to note the specific apps being used, for example, if it is an app targeted at preschoolers, which may indicate who is using the app. However, this links into another issue concerning context of touchscreen use. It has been repeatedly emphasised that context is a critical part of understanding children's media use, for example, if they are using media with a caregiver (Zack & Barr, 2016). Arguably, this nuance may be missed if actual screen use is applied because even if time spent using an app is logged by the device, it may not necessarily identify the number of people engaged in the task. Thus, some self-report measures may be required to supplement information about the context of app use. Finally, if the measurement involves examining detailed touchscreen use on a shared device, including apps used, it may raise ethical considerations if caregivers are happy to share their child's touchscreen use, but not their own use. In this case, identifying the device user would be important so that the privacy of those users is protected and respected. Therefore, it would be prudent to explore this method in detail and ascertain whether its use is feasible with samples of young children and their caregivers.

Another recommended direction for future research would be to conduct a more detailed analysis of the factors that could underlie the relationships observed in this thesis. Firstly, research could investigate 'intrinsic' factors of children's media use and how they relate to creative thinking. One key area of exploration could be epistemic curiosity, or the desire to obtain new knowledge (Litman, 2008). For example, novelty seeking was related to some touchscreen activities in Chapter Two. Due to the hypothesised links between curiosity, novelty seeking, and creativity (Carr et al., 2016; Hardy et al., 2017; Piotrowski et al., 2014), investigating the role of curiosity in children's touchscreen use may enhance our understanding of what motivates young children to engage with touchscreens, what sustains their engagement, and how this engagement affects their creative thinking. Additionally, it would provide information on the factors that might identify children as being more likely to engage with touchscreens and their associated apps. This would have important implications in understanding how different groups of children could benefit from using touchscreens. This could be useful in educational settings, where activities could be tailored so that children who do benefit from using touchscreens are able to use them in a way that fosters important skills.

The second approach could involve exploring ‘extrinsic’ factors of touchscreen use, including app features that might facilitate creative thinking. This could involve a detailed content analysis of popular apps to identify features that promote creative thinking, for example, if there are clear instructions and goals and directions to achieving those goals, in-app scaffolding through parasocial interaction, and developmentally appropriate challenges (Hirsh-Pasek et al., 2015). This has approach has already been adopted in the UK, where a panel of experts examined apps that may be beneficial for children’s language and literacy development (Department for Education, 2019). Additionally, Kolak et al., (2020) developed tools to evaluate the educational potential of apps aimed at preschoolers, by taking features such as feedback, appropriate language, and adjustable content into account. Thus, it would be possible to apply similar approaches to apps that claim to enhance aspects of creative thinking. Another important consideration for future research is to further explore the role of scaffolding during app use and how this may moderate the effect of apps on creative thinking. Furthermore, as previously discussed, it is possible that the presence of the experimenter may have promoted problem solving, for example, by providing context to the app and general encouragement. Given that social learning has been found to be beneficial in both children’s media use and creative thinking (Flynn et al., 2016; Hoicka et al., 2018; Strouse et al., 2013; Zack & Barr, 2016), this could be an important factor in children’s ability to benefit from touchscreens. Thus, it would be pertinent to closely examine the role of social interaction during app use compared to independent use, and how this may affect later creative thinking. A final extrinsic factor to consider may be caregiver attitudes towards media use as well as their perspectives on children’s creative thinking. For example, what they believe is beneficial, what is a cause for concern and how these areas may intersect in the home environment in terms of the activities they provide. Given the critical role caregivers play in children’s media use, this would be an excellent opportunity to examine how their perspectives may moderate children’s media use and the potential influence it has on their creative thinking.

Overall, the research presented in this thesis has important implications in terms of enhancing the understanding on how touchscreens and apps may influence young children’s creative thinking. This is particularly crucial to consider given that most perspectives have been relatively pessimistic towards touchscreens, apps and other forms of media (AAP, 2016; Valkenburg & van der Voort, 1994). However, the findings in this thesis may offer an alternative perspective which may be of interest to caregivers, educators, and app developers. The present research can be expanded on in a variety of ways. Of particular importance, improving on design by including elements such as pre-test measurements, blind outcome testing, and more accurate measures of children's media use would be beneficial for enhancing the quality and robustness of future research. It would also be of interest to explore factors that could underlie children's media use and creative thinking as well as diversifying samples to improve the representativeness and generalisability of research.

5.5 Conclusion

To conclude, the research presented in this thesis gives valuable insight into how touchscreens might influence creative thinking in preschoolers. From the findings observed across the chapters, it would appear that there are few indications that touchscreens are detrimental to young children's creative thinking. Indeed, the amount of null findings across the thesis suggest there is neither a particular benefit nor detriment to young children's creative thinking. However, the positive relationships from Chapter Two and Three and the differences observed in Chapter Four could indicate that learning apps and problem-solving apps may have a potentially positive influence on children's problem solving. It has also shown touchscreen use does not appear to have a negative influence on divergent thinking. Furthermore, novelty seeking was positively associated with several media-based activities, including learning and creative apps, suggesting that touchscreens may offer interesting opportunities to engage in a variety of activities, potentially having a positive influence on children's novelty seeking. Finally, it has demonstrated that generally, touchscreen use does not seem to displace other non-digital activities. Thus, the research presented in thesis suggests touchscreens and apps do not seem to have a detrimental influence on young children's creative thinking. Additionally, there may also be some indications that certain apps could potentially be a positive influence, particularly in terms of children's problem solving. However, further studies using more in-depth research methods, such as pre-test baseline measures and blind outcome testing, would be beneficial in understanding the precise effect apps could have on problem solving. The findings observed across this programme of research improve our understanding of how touchscreens may have a positive role in young children's cognitive skills. Additionally, the findings lay a foundation on which future research can investigate the factors that contribute to this, such as scaffolding, socioeconomic status, and caregiver attitudes towards media. The research presented in this thesis has important implications in understanding how touchscreens could be used to benefit young children's cognitive development, potentially dispelling some concerns about touchscreen use. Additionally, it opens opportunities to further explore and discuss how touchscreens could be a helpful tool to support young children's creative thinking skills as part of a diverse play repertoire.

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Appendices

Appendix A

Chapter Two Activity Survey.

“**The following questions ask which devices your child has access to in your household. If your child has no access to the device, you can save time by leaving the item blank.**

Tablet computer (e.g., iPad, Samsung Galaxy Tab etc).

- o We have one in the house which they can use.
- o There is one elsewhere (e.g., grandparents home) which they can use.
- o They have one of their own.
- o They do not have access to this device at all.

Smart Phone

- o We have one in the house which they can use.
- o There is one elsewhere (e.g., grandparents home) which they can use.
- o They have one of their own.
- o They do not have access to this device at all.

Children’s tablet computer (e.g., Leapfrog LeapPad, VTech Innotab etc).

- o We have one in the house which they can use.
- o There is one elsewhere (e.g., grandparents home) which they can use.
- o They have one of their own.
- o They do not have access to this device at all.

The next section asks about the number of minutes your child spent engaging in different activities yesterday. If you did not spend much time with your child yesterday (e.g., at day care all day), please think back to the last day you spent a significant amount of time together. Please feel free to leave a question blank if the answer is 0 minutes.

How many minutes did your child use a touchscreen (e.g., iPad or other touchscreen, smartphone, children's tablet) to use apps (excluding watching videos)

On their own ______

With you or another adult ______

How many minutes did your child use the following types of apps on touchscreen devices?

Learning (e.g., matching shapes, learning numbers/ letters/ words/animal names etc)	______
Playing games (e.g., Angry Birds, Temple Run, Flick Kick Rugby)	______
Creative apps (e.g., creating virtual spaces, Minecraft, drawing, colouring in, making music)	______

How many minutes did your child watch child-directed video content on a television, tablet, computer, or other device?

On their own ______

With you or another adult ______

How many minutes did your child watch non-child directed video content on a television, tablet, computer, or other device?

On their own ______

With you or another adult ______

How many minutes did your child use video-chatting software (such as Skype) on any device?

______

How many minutes did your child spend using more than one screen at a time (e.g., using a tablet while watching TV)?

______

How many minutes did your child look at or read non-digital books?

On their own ______

With you or another adult ______

How many minutes did your child play with non-digital toys (e.g., building blocks, cars, dolls)?

On their own ______

With you or another adult ______

How many minutes did your child engage in non-digital creative activities (e.g., arts and craft, painting, drawing, playing musical instruments)?

On their own ______

With you or another adult ______

Appendix B

Problem Solving and Novelty Seeking questions from the Early Creativity Survey (ECS; Hoicka et al., in preparation).

Caregivers could select either:
“Strongly Agree”, “Agree”, “Disagree”, “Strongly, Disagree” or “Not Applicable (NA)” in response to the statements. Note that * indicates question is reverse-scored.

Problem solving

1. My child makes difficult structures with blocks or megablocks on his/her own.
2. My child needs help from others when figuring out how new toys work. *
3. When it is physically difficult to reach a toy, my child will not try to figure out a way to reach it. *
4. My child does not like to take things apart and put them back together. *
5. My child sorts objects in logical ways on his/her own, e.g., cutlery next to plates; toy bed in dollhouse.
6. My child puts away objects correctly on his/her own.
7. My child looks at the mechanisms of how things work, e.g., how wheels are connected to toy cars.
8. My child needs help to sort objects by, e.g., shape, colour. *
9. If a toy breaks, my child tries to fix it before asking for help.
10. My child needs help completing simple puzzles. *

Novelty seeking

1. My child likes to look at new pictures/pieces of art more than familiar pictures/pieces of art.
2. My child likes playing new games more than familiar games.
3. My child likes to look at new people more than familiar people.
4. My child likes to eat new foods more than familiar foods.
5. My child likes watching new television shows more than familiar shows.
6. My child likes to sing new songs more than familiar songs.
7. My child likes going to new locations (e.g., park) more than familiar locations.
8. My child likes to eat from new dishes more than familiar dishes.
9. My child likes to listen to new songs more than familiar songs.
10. My child likes to play with new children more than familiar children.
11. My child likes to look at new books more than familiar books.

Appendix C

Correlations between all survey variables in Chapter Two at Time 1.

Table 19 summarises bootstrapped correlations between children's problem solving, novelty seeking, and engagement in different activities at Time 1 (n = 564). Table 20 summarises bootstrapped partial correlations between problem solving and engagement in activities at Time 1, after controlling for age. Only partial correlations for problem solving are displayed as novelty seeking did not require other variables to be controlled and thus the values would not change. For brevity and clarity, only the bootstrapped *r* values are reported.

See tables on the following page.

Table 18.

Bootstrapped Pearson's correlations between problem solving (PS), novelty seeking (NS) and activities at Time 1.

	PS	NS	Age	Activity															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	.031	-																	
3	.456**	.006	-																
4	.076	.083*	.151**	-															
5	.101*	.045	.049	.299**	-														
6	.171**	.105*	.129**	.523**	.287**	-													
7	.071	.076	.139**	.416**	.244**	.345**	-												
8	.164**	.128**	.141**	.422**	.300**	.472**	.447**	-											
9	.081	.029	.270**	.256**	.059	.106*	.163**	.142**	-										
10	-.026	-.019	.032	-.051	.145**	.017	.142**	.211**	.004	-									
11	.037	.142**	.031	.121**	.028	.059	.145**	.081	.210**	-.086*	-								
12	-.061	.050	-.051	.104*	.066	-.001	-.018	-.003	.033	.047	.132**	-							
13	-.067	.010	-.135**	-.021	.014	.021	-.014	-.006	-.007	.018	-.020	.019	-						
14	.069	.133**	.092*	.244**	.154**	.131**	.295**	.317**	.355**	.111**	.442**	.130**	.039	-					
15	.108*	.016	-.017	.087*	.070	.267**	.039	.184**	.148**	.166**	-.031	.027	.077	.102*	-				
16	.025	.009	.021	-.088*	.016	-.006	-.006	.025	-.020	.151**	-.071	-.027	.137**	-.020	.330**	-			
17	.080	-.042	.085*	.044	.028	.041	.047	.017	.252**	.022	.108*	.060	-.023	.059	.128**	-.026	-		
18	.010	.008	-.128**	-.125**	.048	-.115**	-.099*	-.091*	-.041	.130**	-.130**	-.087*	.072	-.065	.084*	.225**	.102*	-	
19	.137**	.064	.150**	.134**	.130**	.091*	.021	.137**	.068	.047	.198**	.027	-.019	.086*	.100*	.043	.297**	.013	-
20	.122**	-.029	.114**	-.052	-.003	-.015	-.019	.057	-.046	.062	-.085*	-.029	.109**	-.060	.093*	.237**	.066	.253**	.279**

Note. 1 = Problem solving; 2 = Novelty seeking; 3 = Age; 4 = Touchscreen use (independent); 5 = Touchscreen use (with an adult); 6 = Learning apps; 7 = Gaming apps; 8 = Creative apps; 9 = Child-directed video content (independent); 10 = Child-directed video content (with an adult); 11 = Non-child-directed video content (independent); 12 = Non-child-directed video content (with an adult); 13 = Video call software; 14 = Multi-screen use; 15 = Reading (independent); 16 = Reading (with an adult); 17 = Non-digital toys (independent); 18 = Non-digital toys (with an adult); 19 = Creative activities (independent); 20 = Creative activities (with an adult). * = $p < .05$. ** = $p < .01$.

Table 19.

Bootstrapped partial correlations between problem solving (PS) and activities at Time 1.

	PS	Activity															
	1	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
4	.008	-															
5	.088*	.295**															
6	.127**	.514**	.284**	-													
7	.008	.404**	.239**	.333**	-												
8	.113**	.409**	.296**	.462**	.436**	-											
9	-.049	.226**	.047	.075	.131	.108**	-										
10	-.046	-.056	.144**	.013	.139**	.209**	-.004	-									
11	.026	.117**	.026	.056	.143**	.078	.210**	-.087*	-								
12	-.043	.113**	.068	.006	-.011	.004	.049	.049	.134**	-							
13	-.006	.000	.021	.039	.005	.014	.031	.022	-.016	.012	-						
14	.031	.234**	.151**	.121**	.286**	.308**	.344**	.109**	.441**	.136**	.052	-					
15	.130**	.091*	.071	.271**	.042	.189**	.158**	.167**	-.031	.026	.075	.104*	-				
16	.017	-.092*	.015	-.009	-.009	.022	-.027	.150**	-.072	-.026	.141**	-.022	.331**	-			
17	.046	.032	.024	.030	.036	.005	.239**	.019	.106*	.064	-.011	.052	.130**	-.028	-		
18	.078	-.108**	.055	-.100*	-.083*	-.074	-.007	.135**	-.127	-.094*	.056	-.054	.083*	.229	.114	-	
19	.078	.114**	.124**	.073	.000	.118**	.029	.042	.195**	.035	.001	.073	.104*	.040	.288**	.033	-
20	.079	-.070	-.009	-.030	-.036	.041	-.080	.059	-.090*	-.024	.127**	-.071	.095*	.236**	.056	.272**	.266**

Note. 1 = Problem solving; 4 = Touchscreen use (independent); 5 = Touchscreen use (with an adult); 6 = Learning apps; 7 = Gaming apps; 8 = Creative apps; 9 = Child-directed video content (independent); 10 = Child-directed video content (with an adult); 11 = Non-child-directed video content (independent); 12 = Non-child-directed video content (with an adult); 13 = Video call software; 14 = Multi-screen use; 15 = Reading (independent); 16 = Reading (with an adult); 17 = Non-digital toys (independent); 18 = Non-digital toys (with an adult); 19 = Creative activities (independent); 20 = Creative activities (with an adult). * = $p < .05$. ** = $p < .01$.

Appendix D

Correlations between Time 1 activities, problem solving and novelty seeking and problem solving and novelty seeking at Time 2.

Table 21 summarises the correlations between problem solving, novelty seeking and activities at Time 1 with problem solving, novelty seeking and child age at Time 2. Table 22 summarises the partial correlations between activities at Time 1 and problem solving at Time 2, after controlling for age and problem solving at Time 1. Table 23 summarises the partial correlations between activities at Time 1 and novelty seeking at Time 2, after controlling for novelty seeking at Time 1. For brevity and clarity, only the bootstrapped *r* values are reported.

See tables on the following page.

Table 20.

Bootstrapped Pearson's correlations between problem solving (PS) and novelty seeking (NS) at Times 1 and 2, age at Time 2, and activities at Time 1.

	PS (T1/ T2)		NS (T1/ T2)		Age	Activity															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2	.695**	-																			
3	.003	.032	-																		
4	.113	.186*	.590**	-																	
5	.474**	.353**	.012	.065	-																
6	.129	.123	.043	.041	.186*	-															
7	.103	.077	.028	.089	.051	.130	-														
8	.240**	.197**	.014	-.001	.112	.755**	.126	-													
9	.071	.191*	.147	.133	.184*	.274**	.208**	.242**	-												
10	.168*	.221**	.164*	.099	.121	.515**	.221**	.583**	.657**	-											
11	.181*	.175*	.039	.064	.331**	.348**	.003	.116	.209**	.158*	-										
12	-.026	.008	.051	.001	.088	.024	.331**	.084	.514**	.505**	.093	-									
13	-.038	-.133	.010	.017	-.108	.103	.088	.030	-.036	-.007	.022	-.074	-								
14	-.095	-.220**	-.004	-.066	-.085	.111	.078	-.076	-.046	-.042	-.029	.016	.370**	-							
15	.138	.111	.038	.135	-.043	-.076	-.028	-.079	-.079	-.068	-.063	-.057	-.022	.065	-						
16	.037	.072	.240**	.144	.130	.249**	.313**	.140	.438**	.364**	.358**	.438**	.026	.022	.093	-					
17	.163*	.210**	.041	.023	.007	.471**	.112	.548**	.283**	.533**	.072	.307**	-.023	-.080	-.002	.325**	-				
18	.094	.154*	.093	.079	-.063	-.003	.129	.053	.169*	.167*	-.121	.225**	-.135	-.120	.025	.193*	.373**	-			
19	-.103	-.100	-.015	-.073	.031	.146	-.048	.032	.042	.012	.229**	.123	.280**	.218**	-.018	.130	.045	-.085	-		
20	.092	.118	-.029	.012	-.054	-.157*	.162*	-.105	-.031	-.067	-.017	.093	-.142	-.063	-.024	.068	-.043	.104	.036	-	
21	.127	.030	.050	.034	.148	.184*	.073	.102	.118	.181*	.127	.168*	.373**	.118	-.072	.244**	.262**	.093	.321**	-.112	-
22	.140	.162*	-.085	-.063	.144	-.047	.071	.017	.116	.125	-.109	.085	-.072	-.074	.162*	-.009	.071	.103	-.062	.267**	.048

Note. T1 = Time 1; T2 = Time 2; 1 = Problem solving (Time 1); 2 = Problem solving (Time 2); 3 = Novelty seeking (Time 1); 4 = Novelty seeking (Time 2); 5 = Age (Time 2); 6 = Touchscreen use (independent); 7 = Touchscreen use (with an adult); 8 = Learning apps; 9 = Gaming apps; 10 = Creative apps; 11 = Child-directed video content (independent); 12 = Child-directed video content (with an adult); 13 = Non-child-directed video content (independent); 14 = Non-child-directed video content (with an adult); 15 = Video call software; 16 = Multi-screen use; 17 = Reading (independent); 18 = Reading (with an adult); 19 = Non-digital toys (independent); 20 = Non-digital toys (with an adult); 21 = Creative activities (independent); 22 = Creative activities (with an adult). * = $p < .05$. ** = $p < .01$.

Table 21.

Bootstrapped partial correlations between problem solving (PS) at Time 2 and activities at Time 1, after controlling for problem solving at Time 1 and age at Time 2.

	PS	Activity															
	2	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
6	.042	-															
7	.007	.119	-														
8	.043	.760**	.105	-													
9	.194*	.249**	.205**	.236**	-												
10	.145	.504**	.208**	.568**	.658**	-											
11	.062	.308**	-.017	.080	.160*	.123	-										
12	.033	.011	.337**	.094	.508**	.516**	.070	-									
13	-.145	.126	.093	.040	-.017	.004	.061	-.064	-								
14	-.214**	.133	.089	-.055	-.033	-.024	.001	.019	.365**	-							
15	.026	-.079	-.043	-.118	-.070	-.088	-.058	-.041	-.030	.075	-						
16	.060	.232**	.313**	.137	.425**	.361**	.338**	.431**	.041	.032	.106	-					
17	.140	.479**	.097	.533**	.295**	.526**	.070	.328**	-.025	-.070	-.035	.337**	-				
18	.130	.002	.121	.031	.189*	.161*	-.112	.247**	-.146	-.118	-.003	.210**	.358**	-			
19	-.043	.151*	-.038	.059	.035	.026	.238**	.112	.289**	.216**	.008	.125	.071	-.066	-		
20	.079	-.158*	.156*	-.132	-.019	-.079	-.003	.110	-.153*	-.060	-.051	.080	-.068	.084	.057	-	
21	-.086	.158*	.061	.075	.095	.159*	.082	.163*	.395**	.137	-.080	.232**	.257**	.095	.333**	-.115	-
22	.087	-.080	.057	-.017	.094	.100	-.171*	.081	-.059	-.058	.158*	-.026	.057	.103	-.057	.270**	.022

Note. 2 = Problem solving (Time 2); 6 = Touchscreen use (independent); 7 = Touchscreen use (with an adult); 8 = Learning apps; 9 = Gaming apps; 10 = Creative apps; 11 = Child-directed video content (independent); 12 = Child-directed video content (with an adult); 13 = Non-child-directed video content (independent); 14 = Non-child-directed video content (with an adult); 15 = Video call software; 16 = Multi-screen use; 17 = Reading (independent); 18 = Reading (with an adult); 19 = Non-digital toys (independent); 20 = Non-digital toys (with an adult); 21 = Creative activities (independent); 22 = Creative activities (with an adult). * = $p < .05$. ** = $p < .01$.

Table 22.

Bootstrapped partial correlations between novelty seeking (NS) at Time 2 and activities at Time 1, after controlling for novelty seeking at Time 1.

	NS	Activity															
	4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
4	-																
6	.021	-															
7	.090	.130	-														
8	-.011	.755**	.127	-													
9	.059	.271**	.207**	.243**	-												
10	.005	.517**	.220**	.589**	.649**	-											
11	.054	.349**	.004	.118	.207**	.156	-										
12	-.034	.024	.331**	.084	.513**	.505**	.094	-									
13	.014	.104	.088	.031	-.037	-.008	.024	-.073	-								
14	-.076	.113	.079	-.075	-.045	-.040	-.025	.019	.370**	-							
15	.141	-.076	-.030	-.080	-.085	-.074	-.062	-.059	-.021	.067	-						
16	.005	.247**	.315**	.141	.420**	.340**	.361**	.440**	.025	.026	.087	-					
17	.000	.467**	.112	.543**	.279**	.531**	.069	.306**	-.023	-.080	-.006	.323**	-				
18	.035	-.004	.129	.052	.159*	.156*	-.119	.226**	-.134	-.115	.022	.179*	.375**	-			
19	-.085	.141	-.045	.036	.042	.011	.222**	.119	.273**	.211**	-.022	.132	.039	-.091	-		
20	.032	-.158*	.159*	-.105	-.029	-.065	-.020	.088	-.143	-.066	-.022	.074	-.048	.096	.038	-	
21	.009	.184*	.074	.102	.113	.177*	.128	.169*	.373**	.121	-.073	.240**	.263**	.095	.309**	-.116	-
22	-.015	-.042	.076	.019	.131	.141	-.104	.092	-.071	-.074	.163*	.012	.080	.116	-.059	.257**	.055

Note. 4 = Novelty seeking (Time 2); 6 = Touchscreen use (independent); 7 = Touchscreen use (with an adult); 8 = Learning apps; 9 = Gaming apps; 10 = Creative apps; 11 = Child-directed video content (independent); 12 = Child-directed video content (with an adult); 13 = Non-child-directed video content (independent); 14 = Non-child-directed video content (with an adult); 15 = Video call software; 16 = Multi-screen use; 17 = Reading (independent); 18 = Reading (with an adult); 19 = Non-digital toys (independent); 20 = Non-digital toys (with an adult); 21 = Creative activities (independent); 22 = Creative activities (with an adult). * = $p < .05$. ** = $p < .01$.

Appendix E

Survey questions used in Chapter Three. Note that questions regarding the use of video call software and multi-screen use were initially separated by independent use and use with an adult. However, as described in the chapter, these variables were collapsed together to give an overall variable for video call use and an overall variable for multi-screen use.

"This survey asks about your child's technology use, as well as engagement in other activities.

The following questions ask which devices your child has access to in your household.

Tablet computer (e.g., iPad, Samsung Galaxy Tab etc).

- o We have one in the house which they can use.
- o There is one elsewhere (e.g., grandparents home) which they can use.
- o They have one of their own.
- o They do not have access to this device at all.

Smart Phone

- o We have one in the house which they can use.
- o There is one elsewhere (e.g., grandparents home) which they can use.
- o They have one of their own.
- o They do not have access to this device at all.

Children's tablet computer (e.g., Leapfrog LeapPad, VTech Innotab etc).

- o We have one in the house which they can use.
- o There is one elsewhere (e.g., grandparents home) which they can use.
- o They have one of their own.
- o They do not have access to this device at all."

The next section asks about the number of <u>minutes</u> your child spends engaging in different activities on a typical day at home.

Please give your answer in numbers (e.g., 10 minutes = "10").

How many minutes did your child use a touchscreen (e.g., iPad or other touchscreen, smartphone, children's tablet) to use apps…

On their own ______

With you or another adult ______

How many minutes did your child use the following types of apps on touchscreen devices?

Learning (e.g., matching shapes, learning numbers/ letters/ words/animal names etc) ______

Playing games (e.g., Angry Birds, Temple Run, Flick Kick Rugby) ______

Creative apps (e.g., creating virtual spaces, Minecraft, drawing, colouring in, making music) ______

How many minutes did your child watch child-directed video content on a television, tablet, computer, or other device…

On their own ______

With you or another adult ______

How many minutes did your child watch non-child directed video content on a television, tablet, computer, or other device…

On their own ______

With you or another adult ______

How many minutes did your child use video-chatting software (such as Skype) on any device…

On their own ______

With you or another adult ______

How many minutes did your child spend using more than one screen at a time (e.g., using a tablet while watching TV) …

On their own ______

With you or another adult ______

How many minutes did your child look at or read non-digital books…

On their own ______

With you or another adult ______

How many minutes did your child play with non-digital toys (e.g., building blocks, cars, dolls) …

On their own ______

With you or another adult ______

How many minutes did your child engage in non-digital creative activities (e.g., arts and craft, painting, drawing, playing musical instruments)…

On their own ______

With you or another adult ______

Appendix F

Comparison between Chapter Two and Three samples.

As the phrasing of the survey questions differed between chapters, the table below presents a comparison between average activity times in samples from Chapters Two (n = 76) and Three (n = 85).

Table 23.

Descriptive statistics for activities to compare data from Chapter Two and Three samples.

Activity	Chapter	Mean	Med	SD	Range	S	K
Touchscreen use - on their own	Three	18.67	10	27.00	0 - 120	2.15	5.19
	Two (Time 1)	15.72	0	33.89	0 - 240	4.48	26.13
	Two (Time 2)	17.76	0	27.35	0 - 120	1.72	2.58
Touchscreen use - with adult	Three	14.55	10	23.69	0 - 150	3.66	16.36
	Two (Time 1)	12.96	0	26.22	0 - 180	4.10	22.27
	Two (Time 2)	16.34	1	41.57	0 - 300	5.26	31.85
Learning apps	Three	10.21	5	15.89	0 - 90	2.77	9.73
	Two (Time 1)	10.26	0	25.31	0 - 200	5.92	42.82
	Two (Time 2)	11.36	0	24.21	0 - 180	5.11	32.57
Gaming apps	Three	1.88	0	6.45	0 - 50	5.52	37.38
	Two (Time 1)	2.43	0	8.93	0 - 60	4.69	24.95
	Two (Time 2)	3.75	0	11.72	0 - 60	3.74	14.28
Creative apps	Three	4.46	0	7.82	0 - 40	2.30	6.08
	Two (Time 1)	2.43	0	9.11	0 - 60	4.84	25.37
	Two (Time 2)	2.66	0	6.85	0 - 30	2.99	8.79
Child-directed video content (independent)	Three	29.98	30	29.32	0 - 150	1.67	3.67
	Two (Time 1)	29.87	20	36.95	0 - 180	2.25	6.19
	Two (Time 2)	24.21	15	35.25	0 - 240	3.44	17.96
Child-directed video content (with an adult)	Three	30.21	30	31.20	0 - 150	2.00	4.85
	Two (Time 1)	48.13	30	80.70	0 - 600	4.92	30.50
	Two (Time 2)	28.96	20	31.94	0 - 180	1.89	5.84
Non-child-directed video content (independent)	Three	2.65	0	10.71	0 - 60	4.60	21.26
	Two (Time 1)	0.86	0	5.25	0 - 35	6.10	36.35
	Two (Time 2)	0.86	0	4.11	0 - 30	5.72	35.98
Non-child-directed video content (with an adult)	Three	6.66	0	15.33	0 - 60	2.70	6.57
	Two (Time 1)	7.21	0	17.79	0 - 90	2.77	7.70
	Two (Time 2)	7.50	0	18.32	0 - 90	2.69	7.05
Video call software	Three	3.93	0	8.32	0 - 60	4.33	24.97
	Two (Time 1)	2.83	0	9.03	0 - 60	4.42	22.86
	Two (Time 2)	3.20	0	8.70	0 - 60	4.47	24.92

Note. Med = Median; SD = Standard Deviation; S = Skewness; K = Kurtosis.

Activity	Chapter	Mean	Med	SD	Range	S	K
Multi-screen use	Three	10.12	0	28.00	0 - 150	3.69	14.30
	Two (Time 1)	4.21	0	13.59	0 - 90	4.59	24.28
	Two (Time 2)	1.45	0	5.82	0 - 30	4.15	16.66
Reading (independent)	Three	12.92	10	15.10	0 - 90	2.54	8.49
	Two (Time 1)	12.39	10	19.07	0 - 120	3.56	16.18
	Two (Time 2)	11.97	10	14.35	0 - 90	2.43	10.36
Reading (with an adult)	Three	23.29	20	15.32	0 - 90	1.27	4.61
	Two (Time 1)	23.36	20	16.68	0 - 90	1.45	3.56
	Two (Time 2)	21.51	20	15.14	0 - 70	0.89	1.11
Playing with toys (independent)	Three	101.06	60	90.32	0 - 480	2.07	5.19
	Two (Time 1)	88.88	60	67.59	0 - 400	2.03	6.02
	Two (Time 2)	87.50	60	68.92	0 - 350	1.59	3.07
Playing with toys (with an adult)	Three	65.41	60	56.99	0 - 300	1.75	3.70
	Two (Time 1)	73.95	60	73.69	0 - 360	2.03	5.26
	Two (Time 2)	60.79	30	59.39	0 - 240	1.30	1.47
Creative activities (independent)	Three	18.46	10	21.84	0 - 120	2.50	7.66
	Two (Time 1)	14.41	10	20.20	0 - 120	2.68	9.75
	Two (Time 2)	16.05	10	22.02	0 - 120	2.07	5.84
Creative activities (with an adult)	Three	32.24	30	23.48	0 - 120	1.22	1.66
	Two (Time 1)	19.61	15	22.52	0 - 90	1.41	1.62
	Two (Time 2)	20.53	10	30.41	0 - 180	2.70	10.25

Note. Med = Median; SD = Standard Deviation; S = Skewness; K = Kurtosis.

Appendix G

Unusual Box Test (UBT) procedure and script (created by Bijvoet-van den Berg & Hoicka, 2014) used in Chapter Three.

Procedure

Participants are shown the different features of the box according to the script below. They are then presented with one object at a time in one of the following orders:

Order	Object 1	Object 2	Object 3	Object 4	Object 5
1	Egg Holder	Spatula	Shaker	Rubber Toy	Hook
2	Spatula	Rubber Toy	Egg Holder	Hook	Shaker
3	Shaker	Hook	Spatula	Egg holder	Rubber Toy
4	Rubber Toy	Spatula	Hook	Egg Holder	Shaker
5	Hook	Rubber Toy	Shaker	Spatula	Egg Holder

Participants are given 90 seconds free-play with the box and object. After the 90 seconds have elapsed, the experimenter will give them the next object to play with until all objects have been used.

Script

Experimenter (E) puts the Unusual Box on the turning table in front of the child so they can reach it easily and makes sure the cameras are on, pointed in the right direction.

E: "Here I have got a box where you can play with for a while. It's got all these things attached to it. On this side there are blocks of different sizes. Can you pull them, see if they are tight to the box?"

Experimenter shows the side with the blocks and point to all four of them.

E: "Here you can see some strings. Can you see the different colours as well?"

Experimenter turns turning table to the side with the strings and point to them.

E: "On this side you can see there are rings of different sizes. Here are some smaller ones and some bigger ones."

Experimenter shows the side with the rings and point to them.

E: “Now, if we turn it around again, what is there? There is a hole isn’t there?”

Experimenter turns the box to the side of the hole and point to it.

E: “And can you see what’s on the other side of the hole? There is a little room.”

Experimenter points to the room.

E: “And there is something else inside the box. There are stairs in the box. That’s funny isn’t it?”

Experimenter points to the stairs.

E: “Now, can you see if you can turn the box all the way around? So you can see all the different sides.”

Let the child try out turning the box. Encourage child to turn it when it does not want to do it immediately.

E: “That’s really good. Now you can play with the box for a while, but I have something else for you to play with. Look.”

If child doesn’t start playing automatically:

E: “Now you play with the toys for a while and I will tell you when to stop.”

Let the child play with the box and the object for 90 seconds. Make sure it is not too obvious you are keeping track of the time. After 90 seconds:

E: Ok, you are doing great! Now I have a new toy for you to play with. Can I have the other one back?

Take the old toy before you give child the new toy.

Repeat this procedure until the child has played with all the objects.

Additional Prompts

If child asks what object is:

E: I don’t know, you see what you can do with it.

Encouragement, if needed:

E: You’re doing a great job.

E: You’re doing really good.

E: Just play a little while longer.

Appendix H

Great Ape Tool Test Battery (GATTeB; Reindl et al., 2016) procedure, script and coding scheme.

Procedure

Participants were presented with one task at a time in one of the following orders:

Order	Task 1	Task 2	Task 3	Task 4
1	Algae Scoop	Seed Extraction	Marrow Pick	Termite Fish
2	Seed Extraction	Algae Scoop	Termite Fish	Marrow Pick
3	Marrow Pick	Termite Fish	Seed Extraction	Algae Scoop
4	Termite Fish	Marrow Pick	Seed Extraction	Algae Scoop
5	Algae Scoop	Seed Extraction	Termite Fish	Marrow Pick
6	Seed Extraction	Algae Scoop	Marrow Pick	Termite Fish
7	Marrow Pick	Termite Fish	Algae Scoop	Seed Extraction
8	Termite Fish	Marrow Pick	Algae Scoop	Seed Extraction

Tasks are intended to be completed within a time limit. The Algae Scoop task and the Seed Extraction task are 2 minutes long; the Marrow Pick and the Termite Fish tasks are 1 minute long. After the time has elapsed, children are rewarded with a sticker, regardless of whether they completed the task successfully. Then, they are presented with the next task until they have attempted all four tasks.

Script

Category	Script
Introducing GATTeB	"We've got some games to play."
Algae Scoop	"Here is our first/ next game. We have a box and inside the box are some stickers. If you can get the stickers out of the box, you will win a sticker!"
Seed Extraction	"Here is our first/ next game. We have a little box here and inside there are some colourful balls. If you can get the balls out of the box, you'll win a sticker!"
Marrow Pick	"Here is our first/ next game. We have a tube here and inside the tube there's a sponge. If you can get the sponge out of tube box, you'll win a sticker!"
Termite Fish	"Here is our first/ next game. We have a box here and I have these stars. Look what I do – one, two, three! If you can get the stars out the box, you'll win a sticker!"
Successful Task Completion	"Well done, you got the sticker/ star/ sponge out! Now you can choose a sticker!"
Unsuccessful Task Completion	"That one is a bit tricky isn't it? Don't worry, you had a really good try so you can choose a sticker while I get the next game out!"
End of GATTeB	"We've finished playing games now, well done! Have you had fun?"
Additional Prompts	"You're doing really well" "Keep trying" "Can you try?" "Good job!"
If child asks for help	"I'm not sure how to do it, what do you think?"

Coding

GATTeB performance was coded using the criteria described below. For task success, an alternative method was classified as any method participant achieved the goal without using the stick to assist them, for example, extracting pom-poms from the Seed Extraction task using their fingers or tipping the box over to make the stars fall out in the Termite Fish task. Then, an overall score was calculated by summing the scores of each task, meaning there was a maximum possible score of 16.

Coding Category	Value	Description	Actions			
			Algae Scoop	Seed Extraction	Marrow Pick	Termite Fish
Tool pick up	0	Did not pick-up tool	-	-	-	-
	1	Picked up tool	-	-	-	-
Correct tool use	0	Did not use tool in a way that could potentially lead to success	-	-	-	-
	1	Used tool in a way that could potentially lead to success	Inserted stick into one of the side entrances and touched the plastic strip.	Inserted stick into the apparatus and attempted to lever the balls (pom-poms) out of the box.	Inserted stick into the tube and touched the sponge.	Inserted the stick into the hole in the box.
Task success	0	Did not complete task	-	-	-	-
	1	Succeeded by using alternative method that did not involve tool	E.g., inserted hand into side entrance of box and retrieved plastic strip.	E.g., used pincer grip with fingers to remove ball from apparatus.	E.g., bashing tube on table and sponge fell out as a result.	E.g., tipping box upside down to shake stars out of the hole.
	2	Succeeded by using the tool in the correct way	Strip of plastic fully removed after inserting stick into side entrances and moving strip of plastic with stick.	At least one ball removed after levering ball out of apparatus with stick.	Sponge fully retrieved from tube with stick.	At least one star retrieved from hole with stick.

Appendix I

Touchscreen use survey used in Chapter Four.

Technology Use

This section asks about your child's touchscreen use.

Does your child have access to a touchscreen at home that they can use? (for example, iPad or other tablet computer, smartphone, children's tablet).

- Yes
- No

How many minutes did your child use these different kind of apps on touchscreens yesterday?

Learning Apps (e.g., educational content like matching shapes, learning numbers/ letters/ words/animal names)	___
Playing Games (e.g., Angry Birds, Temple Run, Flick Kick Rugby)	___
Creative Apps (e.g., creating virtual spaces, Minecraft, drawing, colouring in, making music)	___
Video Apps (e.g., watching movies/ TV shows, YouTube, Netflix, Amazon Video)	___
Other (please state if the activity does not fit in the above categories): ______________________	___

Appendix J

Scripts for app activities in Chapter Four.

Pango Blocks Script

Stage in procedure	Experimenter Prompts
Introducing the app and first level	"Pango is upset that there is rubbish on the floor. We're going to help Pango pick up the rubbish so he can put it in the bin. Here's Pango now – if you touch the apple, Pango will go pick it up - can you help him reach the apple?"
Introducing app – second level	"Great! Now he wants to reach this banana but Pango needs your help to walk over this hole. We can use this blue block to help Pango cross. Can you try and move it to help Pango?"
If no response, encourage child to try pressing something so they can see how app works	"What happens if you touch the [object]? Can you try?"
Prompts for when block is not put in correct position and Pango can't reach object.	"Uh-oh! Pango can't reach it! Let's try again." "Can you keep trying?"
When object reached	"Alright! /Great! You got it! Let's look at the next game!"
Start of next level	"Can you help Pango reach [*object*]?
If level is not completed in 2 minutes.	"This one is a bit tricky isn't it? Shall we try a different game?" [*navigate to menu and choose next level*]"
If whole game complete in allotted time	"Shall we play another game? Let's try this one!"
Additional prompts for encouragement (intermittent throughout session)	"You're doing a great job" "Good job" "You're doing really well"

Pango Playground Script

Stage in procedure	Experimenter Prompts
Introducing the app	"There are lots of different towns in this game. Which one would you like to choose – 1, 2, 3 or 4?"
When child picks a town	"Okay, great! Oh, I've never seen this town before. There are lots of different things to do in this town – I can see a [*depending on scene*] train/ car/ balloon **or** boat/ sea/ train **or** rocket/ sun/ train **or** train/ lorry/ clouds. What can you see? Can you touch it and see what it does? Great, now you can play the game - see what you can do in the town!"
If no response, encourage child to try pressing something so they can see how app works	"How about that [object]?" "What happens if you touch [object]?"
When object pressed	"Oh wow, that's cool! You keep playing and show me what you can do in the town!"
Additional prompts for encouragement (intermittent throughout session)	"You're doing a great job, keep on playing!" "What can you do in the town?" "Good job" "You're doing really well"
Moving on to next scene after 2 minutes 30 seconds	"Okay we've finished looking in this town now. Shall we look at another town? Which town would you like to see?"

Appendix K

Percentage of different approaches used in GATTeB between app conditions in Chapter Four.

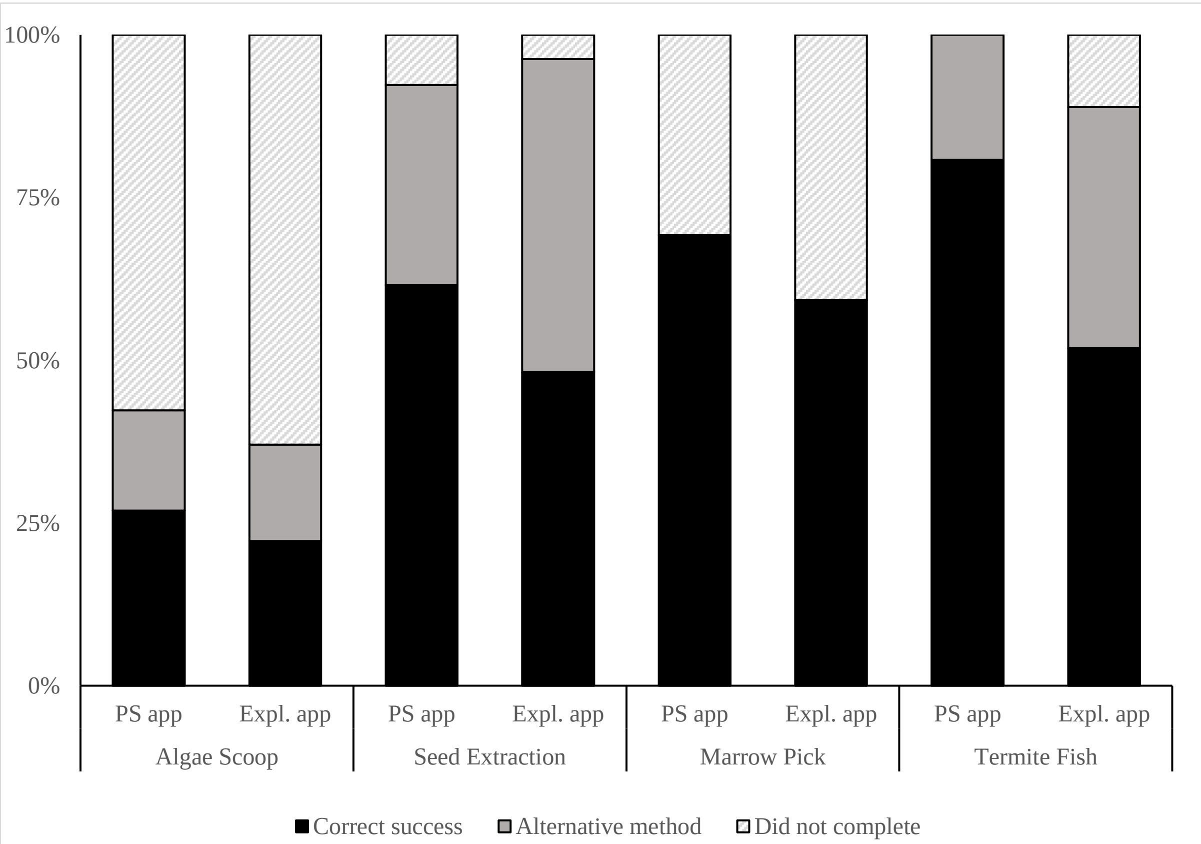
Table 24.

Percentage of correct, alternative, and incomplete solutions in GATTeB tasks by condition.

		Task result		
Task	Condition	Correct method	Alternative method	Did not complete
Algae Scoop	Problem-solving app	26.9%	15.4%	57.7%
	Exploration app	22.2%	14.8%	63%
Seed Extraction	Problem-solving app	61.5%	30.8%	7.7%
	Exploration app	48.1%	48.1%	3.7%
Marrow Pick	Problem-solving app	69.2%	0%	30.8%
	Exploration app	59.3%	0%	40.7%
Termite Fish	Problem-solving app	80.8%	19.2%	0%
	Exploration app	51.9%	37.0%	11.1%

Figure 10.

Percentage of correct, alternative, and incomplete solutions in GATTeB tasks by condition.



Note. PS app = Problem-solving app. Expl. App = Exploration app.