The influence of technology on social interaction and play in autistic children

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Abstract

The social and communication differences associated with autism can make engaging in social play difficult for autistic children. However, it has been suggested that digital technologies could motivate or inspire autistic children to communicate with other people and engage in collaborative play. This conflicts with the increasing concerns from parents and practitioners around the impact of technologies on social interaction in children and young people, which could be exacerbated in autistic children due to the aforementioned difficulties in social interaction. This thesis includes five studies which aim to explore *whether* and *how* technology can provide opportunities for autistic children to engage in social play with peers.

Chapter 1 outlines the context and rationale for exploring the influence of technology on social play and interaction in autistic children. In neurotypical children, technology is likely to have small or negligible effects on social development. A number of studies have shown that features of technology, such as the interface and the software design, can encourage social interaction. Autism is associated with social differences and difficulties in social interaction, and a number of technologies have been designed to teach or mediate social interaction in autistic children, with relative success. A further number of studies have suggested that autistic children are more likely to engage in social play and interaction when using digital technologies. Chapter 2 provides a brief overview of key issues in autism research and justifies some of the research methodologies chosen in the remainder of the thesis.

Chapter 3 explored how educational practitioners used technology in classrooms with autistic students. In an online survey, practitioners said that they more frequently used technology to teach social skills to autistic students, rather than to facilitate peer interactions. Respondents also said that technologies such as smart boards, tablets, and computers were used more widely than more recently developed technologies, such as tangibles and robotics. These results were followed up by focus groups,

where practitioners highlighted that different features of interfaces made children more aware of social partners and could sometimes encourage or inhibit interactions depending on children's social interaction style and technological preferences. According to practitioners, children who were interested in technology would be more likely to socially benefit from it, than others who were less interested in technology.

Chapters 4 and 5 reported on a design-based research study, in collaboration with educational practitioners, to explore the influence of different technologies and classroom environments on children's social interactions and play. The main finding was that children interacted differently both with technologies and with other people, and that different apps and technological interfaces produced unique patterns of social interactions. Children engaged in more social play with peers while using the iPad and Code-A-Pillar technologies, and more social play with adults while using Osmo. Novelty appeared to have the strongest environmental influence on social interactions in digital environments, even more than creating collaborative spaces and having practitioners directing children's social play.

Chapters 6 and 7 compared social play and joint engagement in pairs of children while they played with digital and non-digital toys and explored the effect of enforced collaboration. The results showed that children engaged in more social play and joint engagement when using digital toys. Enforcing collaboration led to more interactive play and joint engagement in both digital and non-digital conditions. This suggests that technology itself can strongly mediate social interaction in autistic children, perhaps more than the children's own interests and social interaction styles.

Together, the studies within this thesis highlight that there are many ways in which autistic children engage with other people while using digital technologies, and many opportunities to foster these interactions in classroom settings. In conclusion, as summarised in chapter 8, technologies do influence social interaction in autistic children, but so do children's social interaction styles and preferences, the wider classroom environment including adult roles, and so do particular technological interfaces and software. In terms of *how* technology mediates interaction, it can provide a socially inclusive space where children can jointly engage with others on devices and activities which interest them, provide an engaging environment where others can scaffold interaction (i.e. practitioners), or the technology itself can mediate child-led interactions through children's interests.

Lay Summary

Social interaction and play refer to a broad range of behaviours describing the way in which two people interact and collaborate with others. Digital technology refers to a wide range of electrical tools which are often used by children and young people to engage in social interaction, such as social media, text messengers, and video games. Some people think that digital technology may have a negative impact on social interaction in children and young people. When children have social and communication difficulties, such as autism, there is an even greater concern about how such technologies may affect social interaction.

This thesis has explored how autistic children interact with other people when they use different types of technology, and how technology can be used to provide opportunities for autistic children to engage in social interaction and play. The first study asked people who work with autistic children in school about the impact of technology on children's social interactions. It found that sometimes technology could be socially isolating for some children, but other times it could encourage and promote interaction. The second study looked at autistic children's interactions while using different types of technologies, to see if this influenced the way that children interacted with others. It looked at a range of technologies with and without a screen and found that children interacted differently on the different toys. The third study then compared autistic children's social play whilst using a digital toy and a very similar, but non-digital toy. It found that children engaged in more social play when using the digital toy, compared to the non-digital toy.

These results are important because they show the ways in which technology can create social opportunities for autistic children. It encourages people to think about the positive aspects of technology for autistic children, not just the (potential) negative aspects. It also makes people think about how different types of technology could be used in classrooms to support social interactions in children who find these difficult.

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Author’s declaration

I confirm that this thesis presented for the degree of PhD in Clinical Brain Sciences, has

I. Been composed entirely by myself
II. Been solely the result of my own work
III. Not been submitted for any other degree or professional qualification

Preliminary findings from this work have been published in *Psychology of Education Review* (chapter 3) and the *Proceedings of the ACM Interaction and Design for Children 2019* conference (chapter 5).

Signed …………………………………

(Margaret H. Laurie)

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-	Laurie, M. H. (2019). Parental Attitudes to Technology Use. In F. R. Volkmar (Ed.), *Encyclopedia of Autism Spectrum Disorders* New York: SpringerLink. https://doi.org/10.1007/978-1-4614-6435-8_102387-1
-	Laurie, M. H., Border, P. (2020). Autism. Parliamentary Office of Science and Technology: *POSTnotes.* Available at https://www.parliament.uk/postnotes

Language statement

The language used to talk about autism, and those with a diagnosis of autism, has been heavily debated (Kenny et al., 2016). It is often simplistically portrayed as a choice between two terms: person-first ("person with autism") or identity-first ("autistic person"), but there are, perhaps more neutral, alternatives such as "people on the autism spectrum." Each of these terms has different levels of acceptance and preference between different individuals, and across stakeholder groups, including autistic people, parents, and professionals. A survey on the language preferences of each of these three groups concluded "the data clearly show that there is not one preferred term to describe autism" (Kenny et al., 2016). The participants within this thesis - young autistic children who have learning disability and some of which are non-verbal - have so far seldom been represented in the debate on language and may not know their own language preferences. I will therefore be using a mixture of terms throughout this thesis, including "autistic children", "children with autism", and "children on the autism spectrum". Where research on children without autism is described, I will use a mixture of terms such as "non-autistic children", "children without autism", and "neurotypical children."

As recommended by Gernsbacher (2017), I will not use different language constructions in the same sentence to describe different groups, to avoid stigmatisation. I will also not use functioning labels, such as "high/low functioning". Rather than reflecting on a person's day to day skills and abilities, functioning labels largely depend on a myriad of external environmental factors and internal states, and can be inconsistent and misrepresentative, leading a majority of the autistic community to reject these terms (Silberman, 2015). Instead, where appropriate, I will refer to "autistic people with or without learning disability," or "with or without additional support needs."

1 Introduction

The overarching aim of this thesis is to explore the influence of digital technologies on social play and interaction in children with autism. Concerns about the impact of digital technologies are common among researchers, policy-makers, and the general public, with particular questions about the way that technology might influence social development in children and young people (Bell et al., 2015; Livingstone et al., 2020). For children with autism, who have difficulties in social interaction and communication, these worries may be exacerbated (Laurie, Warreyn, et al., 2019; Ramdoss, Lang, et al., 2011). The first section of this introduction will define key terminology before presenting work that has looked at the influence of technology on social interaction in non-autistic children. The subsequent sections will cover autism, including characteristics of social interaction and play, and discuss theoretical explanations of social development in autism. Finally, I will discuss work which has looked at autism, technology, and social interaction before presenting the research questions covered by this thesis.

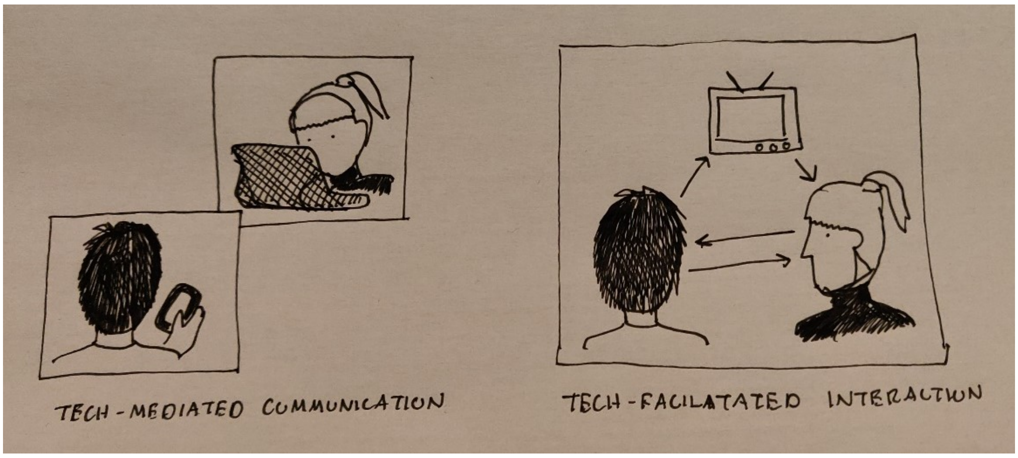
1.1 Definition of key concepts

Technology is a broad term, encompassing basic tools for everyday purposes, and complex systems for processing and interacting with data and information. Technology systems (e.g. machines) refer to devices or software which take input (i.e. information, such as the push of a button), process or change this information, and produce an output (i.e. a response, such as changing the channel on a television, or new information). Such systems can include devices which people typically use in everyday modern life, such as smartphones, tablets, and computers. Human-computer interaction is the study of how humans engage with machines, while human-centred computing is the study of how the human experience is shaped by the presence of these machines in everyday life (Jaimes et al., 2007). A person can "interact" or engage with these technologies, through the use of pushing buttons, swiping across screens or even through spoken words or gestures, to process and receive information and data. Interaction with technology can include ‘passive engagement’, such as television shows or movies, more ‘interactive engagement’ such as a video game where a person is interacting with a technological system or agent (e.g. in a computer game) or a system which mediates social interaction between two or more people (e.g. through virtual communications), or through shared experiences with digital technologies, where the interaction is triaged between technology and two or more people (e.g. two children playing on an iPad together).

Technology systems and devices can vary widely, by the type of technical hardware or physical interface (e.g. the physical form, such as a smartphone, a tablet, or a computer), and by the features and elements of the technical software (e.g. the particular app or system that the device is running). In this thesis, I will explore whether some of these different types of technology, or technical features, influence children’s social interactions and play. I will focus on three particular technological interfaces, as these vary in the ways that user(s) can engage with the technology and may have implications for the way that people engage with others in their presence. Briefly, the first is screen-based devices, where users engage with the technology primarily through a touchscreen, such as tablets and smartphones, allowing users to interact with the software through swiping and other gestures. The second is tangible-screen devices, where players interact with the software partly through physical means, such as arranging pieces of paper or card in front of the technology or by interacting with a physical sensor. This “physical” information is processed by the inbuilt software, which then relays information back to the player via a screen-based device, such as a tablet (Ishii, 2008). The third type of device is a ‘fully’ tangible system, where smart technology is embedded into items which a person can physically manipulate, and the interaction between human and computer is primarily physical, through a sensor-based system of action perception (e.g. connecting particular pieces together or doing specific gestures) (Horn et al., 2012).

Technology has the potential to mediate the way that people interact with others, and many every day technologies have applications which support human to human interaction. Social interaction is a broad term which generally refers to a range of communicative behaviours, information (e.g. conversations, gestures), intended to be received or processed by another human. Social interaction includes both verbal and non-verbal components, such as spoken words and body language, and usually refers to in-person, face-to-face, and human to human interaction or experiences which are shared by two or more people. As mentioned above, technology can successfully *mediate* social interactions with other people, allowing two people to engage in social interaction across a range of physical and social platforms. For instance, video calling software can mean that two people across the sides of the world can exchange facial expressions, and social media or messaging software means that someone can start a conversation with another person while on the move, or without the pressure or expectations of a face to face conversation. But technology can also *facilitate* interpersonal, co-located social interaction – for example, two people watching a movie and conversing about it, or two children taking turns to play on a shared tablet. For an illustration of technology-mediated and technology-facilitated interaction, see Figure 1.1. This thesis will focus on if and how technology *facilitates* social interaction and play in autistic children.

Figure 1.1: Illustration of technology-mediated and technology-facilitated communication and interaction



Social play is a particular type of social interaction, often used to refer to social exchanges between children which are structured around a game or common goal and are collaborative and bring joy. Social play can refer to two children playing with a dolls house or a set of building blocks, and it can also refer to children taking turns on an iPad game or building a robotic construction toy together. More importantly, due to the flexibility of play as an activity, play can also mean that digital and non-digital elements are combined, for instance, having plush toys sit around an iPad for an afternoon tea party, or by using tangible-screen technologies as described above. This thesis focuses on children's play with "digital toys", which are games or activities where technology is a primary component, and can include tablets, tangibles, and other electronic toys. This term will mostly be used to refer to tangible systems which incorporate both digital and physical elements of play (Plowman, 2019). This thesis will explore the influence of different types and features of technology on social interaction and play in autistic children. The remainder of this thesis introduction will focus on the influence of technology on social interaction and play in children, leading to a focus on how technology shapes social interaction and play in autistic children.

1.2 Technology and social interaction in neurotypical children

This section will provide some broad context for the thesis, by discussing specific concerns about the implications of technology use for social interaction and development in neurotypical children (see the Language statement included at the beginning of this thesis, on page xv). Using technology, including various apps, devices, and interfaces, has become ubiquitous in the lives of children and young people (Livingstone et al., 2020; Plowman, 2016a). A concern often reported by parents and teachers is whether or how this will affect the learning and development of children. In the social domain, particular concern has been expressed towards the uptake of social media as a primary source of interpersonal communication between young people, and the increased amount of time that children and teenagers spend engaged in using screen-based media (Orben, 2020; Przybylski & Weinstein, 2017).

1.2.1 **Concerns about technology and social interactions**

There is growing concern about how technology is changing the way that people interact with others, and whether this will have implications for the social development or well-being of children and young people. Such societal views have been recycled many times before, and for many different technologies, including pen and paper, radio, television, and more recently, smartphones and touch screens (Livingstone et al., 2020; Orben, 2020). While a large focus in recent years has been on the general impact of technology use, there has also been very targeted backlash against specific social media platforms (e.g. Facebook, Instagram, Snapchat), and particular technological interfaces (e.g. touchscreen devices) (Orben, 2020).

Concerns about technology use have largely focused on its potential impact on quantity and quality of human social interactions (Kardefelt-Winther, 2019). The amount of time that a person engages with technology, in particular screen-based devices, is widely believed to have an inverse relationship with the amount of time that people spend engaged in human social interactions. This is otherwise known as the “displacement hypothesis” (Kraut et al., 1998, 2002). However, a number of studies have shown instead that adolescents use interactive media and technology to strengthen their existing relationships, rather than replace time spent engaging in them. It has been shown that there is no evidence of a relationship between time spent engaging in digital media and time spent on other activities, including socialising with peers (Endestad et al., 2011). In other words, rather than avoiding social interaction, teenagers are using technology to communicate, share interests, and develop relationships which will carry over into the offline social world. This is more commonly known as the “stimulation hypothesis” (Valkenburg & Peter, 2007, 2009).

Since young people are increasingly using technology to socialise and connect with others, the next question is whether people who experience difficulties engaging in real-world, offline, social interactions have similar experiences in the online world.

The rich-get-richer hypothesis suggests that young people who have affluent social opportunities use technology to extend their social network, while people who experience fewer social opportunities in the offline world will also experience fewer opportunities in the online world. One study found that children and young people who experience higher levels of social anxiety were less likely to engage in online communication (Valkenburg & Peter, 2007). While participants who reported higher levels of social anxiety were less likely to use social media, participants with more social anxiety also reported that they found it easier to talk about difficult topics online, compared to participants who reported less social anxiety. This finding was later partly replicated in a study which showed that adolescent social self-esteem is correlated with increased use of social networking sites (Valkenburg et al., 2017). This lends support to the stimulation hypothesis, where people who experience social difficulties may mitigate these differences in the online world, and therefore find it easier to connect with others. Therefore, there is some evidence that technology can be beneficial for overall social engagement and provide more accessible opportunities to those who experience social difficulties. Valkenburg & Peter (2009) suggest that there are other factors which may drive whether or not someone engages in online communications, and if and how their offline social engagements are affected. These factors include personal levels of anxiety, self-esteem, and social relationships, and the context of technology use, such as an individual’s reason for using that particular technology or media platform.

While the technology which is available and used in the present day has changed significantly since these theories were developed, they still reflect the majority of public concern about technology use in children and young people (Bell et al., 2015). They also frame some predictions about how technology might impact on the social well-being of people who interact and engage with the social world differently, such as autistic people, who may be more prone to the effect of the displacement or the rich-get-richer hypotheses (Ramdoss, Lang, et al., 2011). However, so far, the evidence for these hypotheses in non-autistic children comes from work on technologies which mediate online communication, and has so far relied on participants' own reporting of their own or their child's technology and social preferences, both of which are difficult to estimate (Przybylski & Weinstein, 2017). There remains other concerns about technology and social interaction, which may be more relevant for parents of young children, for instance about the influence of technology on child development in the early years, or about the long-term impact of technology use on children's social development. The next section will describe studies which have examined the impact of screen-time and technology use on social behaviour and explore if these hypotheses of technology-mediated communication can be applied in infant studies.

1.2.2 **Screen time and social development**

"Screen time" is a widely used phrase, which refers to amount of time that a person engages with televisions, smartphones, computers and other screen-based devices throughout the day. The average time that a person engages in screen time has increased since the proliferation of screen-based devices in modern life, particularly for younger children and adolescents, some of whom will now not know a world without these technologies (Sigman, 2012). As discussed previously, there is a prediction that the time spent on screen-based devices will displace time spent on other activities, and there is a widely held belief that increased screen use has negative implications for children and young people's learning and social development (Przybylski et al., 2019; Sigman, 2012). Several national and international campaigns have recommended that screen time for young children be supervised and restricted (Przybylski & Weinstein, 2017). Technology trends change quickly, leading to a lag in up to date scientific evidence on current technological devices commonly used by children and young people, such as tablets (Przybylski & Weinstein, 2019).

The most informative studies on the effect of screen time, and those that draw on longitudinal analyses with statistically powered samples, are often based on television use. While television still plays a fairly dominant role in children's lives today, the impact of more recent technological innovations which offer more diverse interfaces for engagement and interaction with technology, is still unknown (Przybylski & Weinstein, 2019). Parkes *et al.* (2013) conducted an analysis of over 11,000 children's screen use (television and video games) at five years and tested whether screen-time was related to a range of developmental difficulties and delays, including conduct problems and peer relationships. They found only a small increase in watching television for more than 3 hours per day at five-years and conduct problems at seven years, but no other associations were found to be statistically significant. Other large-scale studies have reported weak or no association between screen time and a range of social outcomes, including socio-emotional development (Sanders et al., 2019) and friendship quality (Thakkar et al., 2006).

There is a concern that early exposure to screen-based technologies will have a maladaptive influence on brain development across social and cognitive development, and thus affect children's everyday learning and skills (Sigman, 2012). Some evidence from physiological research has suggested that early technology use in infancy shapes brain structure and potentially functioning (Hutton et al., 2020), but as yet this data has not been linked to behavioural measures and performance outcomes. A UK based study which recruited over 700 toddlers aged between 6 months and 3 years found no relationship between the age at which children first started using touch screen devices, and attainment of gross motor skills or language production (Bedford et al., 2016). The authors actually found a positive relationship between early touch screen use and acquisition of fine motor skills. However, further analysis has reported an association between the age at which children start using touch screens and poorer quality of sleep, in terms of later sleep onset and smaller sleep durations (Cheung et al., 2017).

Other work has looked at "dose-dependent" effects of screen time in longitudinal studies, following children throughout early childhood. Madigan *et al.* (2019) found that children who spent more time using screen-based devices at two and three years of age, had the lowest attainment of developmental outcomes at age five. However, a reverse relationship between developmental outcomes at five years and previous technology use at 2-3 years was not found, suggesting that children who have developmental delays go on to use more technology, rather than increased technology use being associated with later developmental delay. However, a response to this article by Browne *et al.* (2019) highlighted that there are potentially other factors which explain this result – such as the diversity of toys (both digital and non-digital) that children play with as they get older, whose combined influence may be larger on developmental attainments than only digital play.

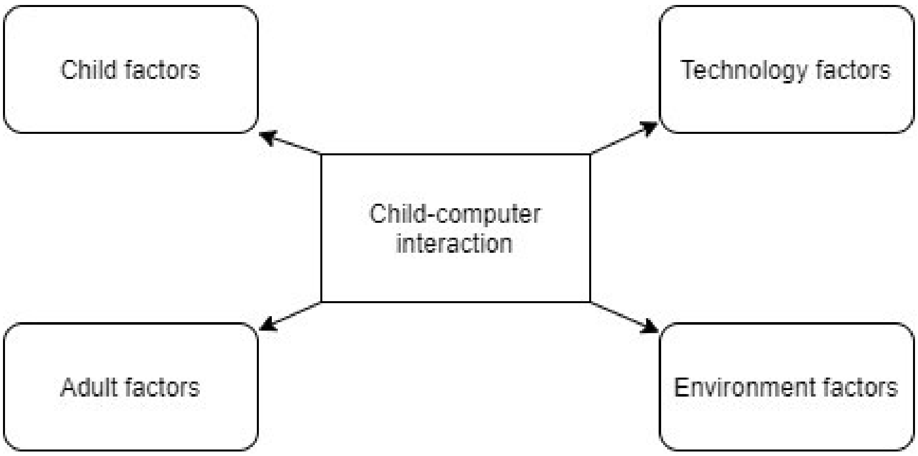
So far, the evidence from studies in television use suggested small or no associations between screen-time and social outcomes in childhood, while newer studies on touch screen tablets provide even smaller effect sizes. Studies with more statistical power generally seem to show no or very small effects of screen-time on developmental outcomes, suggesting that the effect may be smaller than is reported in the broader literature (Przybylski & Weinstein, 2017). Orben and Przybylski (2019) go on to argue that overall, the effects of technology on child development and social well-being appear "too small" to justify concerns over negative implications, and to set restrictive limits on children's technology use. They show that other factors, such as socioeconomic status and quality of diet, have a much greater influence on adolescent well-being than time spent using screen-based media. Overall, findings suggest that the effect of screen time is either very small or negligible, and may even provide benefits to children and young people (Stiglic & Viner, 2019).

1.2.3 Beyond "technocentric" technology research

The screen time debate is a prime example of a "technocentric approach", where it is assumed that technology has the largest independent influence on children's learning and development (Papert, 1988). This argument that technology, and in particular screen time, has the same effect on each and every single person is largely debunked, by several studies exploring contextual and personal factors that influence if and how technology has an effect on social interactions and developmental outcomes (Przybylski & Weinstein, 2017; Valkenburg & Peter, 2009). There are many factors thought to influence both *whether* and *how* technology has an effect on social interaction. One framework to characterise these factors is "the three C's", proposed by Guernsey (2012). Guernsey argues that these three factors have a large influence of the possible effects of children using technology: namely content, context, and the child. To give an example, a child could use the same computer to do their schoolwork, and to play a video game. That same computer could be used in the classroom to support group learning and could be located in the spare room of a family home, where the child uses it by themselves. And finally, that child could be extremely engaged and motivated by technology, and another child could prefer to have a mix of digital and non-digital play. Hence, content, context, and the child will each affect technology's influence on behaviour, and potentially outcome of using technology.

It is well agreed, by theorists and researchers, that adults play a crucial role in supporting children's learning and development, with and without the use of digital technologies (Luckin et al., 2012). Manches (2018) highlighted the independent contribution of adult supervision and engagement on children's use of, engagement with, and potential benefit from using technology, and redefines four key influences on children's use of technology (see Figure 1.2). For instance, some caregivers or teachers may have more positive attitudes towards technology and have a more active role in choosing, setting up, and using technology in their home with their children, while other parents may have a more ‘passive’ approach, allowing more solitary technology use in the family home (Plowman, 2016b). Work has also explored the extent to which features of technology, such as the physical aspects of interface or the scaffolding of collaboration in software design, influence how children interact and collaborate with others while using technology (Bekker et al., 2010), which will be discussed further below.

Figure 1.2: Manches (2018)'s factors which influence children's engagement with technology



1.2.4 **Technology-facilitated interactions in neurotypical children**

While many parents, teachers and policymakers are concerned that technology has a negative impact on social development, there is no clear evidence that technology displaces social interaction and leads to adverse social developmental outcomes. Instead, literature shows that children and young people regularly mediate communication with peers and other people via technology, such as text-based messengers and social media, and there is no strong evidence that using technology in infancy leads to poorer social outcomes in childhood. Previously in this thesis, a distinction was made between technology-mediated interactions, and technology-facilitated interactions (see section 1.1 on page 1). Technology-facilitated interactions refer to interpersonal and co-located interactions (i.e. face to face), while in the presence of technologies. For instance, two children taking turns to play a digital game and talking to each other about how they are going to progress to the next level, compared to two children, in separate locations, playing an online game and discussing team strategies via an online messenger.

Technology-facilitated interactions involve face to face interaction, where attention is mediated between both the technology and another person within the collaboration. Although there are several 'grey areas' to this distinction between mediated and facilitated interactions, such as video calling (which include some element of face to face interaction, without co-location), this section will focus on collaboration and interaction between children using technology in the same physical space. A wealth of studies in the human-computer interaction literature have explored the ways in which technologies can scaffold and provide opportunities for children to engage in collaboration and joint interactions while sharing digital technologies (Bekker et al., 2010; Cole & Stanton, 2003; Scheepmaker et al., 2018). I will draw out elements of factors discussed previously, such as features of the technology, which shape collaboration in non-autistic children. This will include findings from comparison groups in studies which observed both autistic and non-autistic children. The same literature for autistic children will be discussed further below, in section 1.4 on page 28.

1.2.4.1 **Screen-based mobile devices**

As mentioned previously, there is a widely held concern by parents and teachers that using screen-based technology will displace social interactions. This has led, in some places, to the restriction of technology use in the classroom or in the home (Przybylski & Weinstein, 2019). However, home observation studies have shown that young children typically engage in a range of digital and non-digital play (Lee et al., 2018), and that play on tablet devices mostly occurs in shared spaces and in collaboration with others, for instance, in the family living room rather than the child's bedroom, and with siblings and parents rather than in isolation (Plowman, 2016a).

Mobile and touch-screen devices have proliferated the personal technology market and are now widely used by and available to children and young people, in both home and in school (Bell et al., 2015; Blackwell et al., 2013). The fact that many of these devices have a screen may lead to the presumption that children's attention is 'sucked in', and therefore mediated away from other people (Sigman, 2012). As illustrated above, this does not seem to be true at home, because children often play with their technologies in shared spaces and with others, mirroring traditional play that is observed with non-digital toys (Plowman, 2016a). The portable element of these devices, such as tablets and smartphones, allows children to physically "roam around", choosing where to play and offering collaborative opportunities – children can more easily show others what they're doing (Inkpen et al., 1999; Mandryk et al., 2001). However, others have suggested that the small size of this device may prohibit children from effectively 'sharing' one device in the same physical space (e.g. by bumping heads to both look closely at a mobile screen) (Cole & Stanton, 2003). Other work has demonstrated that 'screen-sharing', or wireless connection of co-located tablets, promotes social interaction (Holt & Yuill, 2017). Together, these studies illustrate the potential effect of physical interface, and suggests that mobile and screen-based interfaces can provide opportunities for collaboration or social play.

A further large body of research has focused on how elements of the software or app within a screen-based technology could facilitate children's interactions. The concept of "head up games", coined by Soute, Makopoulos and Magielse (2010), refers to how principles of technology design can foster and encourage children to engage in inter-personal interactions (Brosnan et al., 2019). One example of such a design feature which promotes interpersonal interaction is "enforced collaboration" (Gal et al., 2016), whereby a game will not allow players to progress further without explicit collaboration or agreement, thus encouraging children to attend to what other players are doing, e.g. through discussion. Holt and Yuill (2017) show that, in a picture-sorting game on wireless connected tablets, more interaction and joint attention is observed when children have to click 'agree' on their (collaborative) responses before proceeding to the next level. By enforcing this agreement between players across different devices, this encourages children to look at what another person is doing, and potentially engage and discuss with that other person so that their responses match before level progression (Holt & Yuill, 2017).

Finally, the socio-cultural relevance of these devices plays an important role in children's social relationships and connectedness with others. For instance, shared interest in media and apps can foster conversations and relationships between peers (Hutchby, 2001), with children taking part in group activities which centre on technology and media, such as clubs for learning computing skills such as programming (Brodin & Jonson, 2000), and clubs for playing video games, such as Minecraft (Ringland, 2019). The experience of engaging in collaborative technology play in classrooms positively influences preschool children's ratings of their own and their peer's social skills and friendliness (Parsons & Karakosta, 2019).

1.2.4.2 **The potential of tangible technologies**

Tangible technologies, hereon referred to as "tangibles", are digitally augmented physical objects, where players can physically engage with or manipulate objects which produce digital outputs (Antle, 2007; Fishkin, 2004; Hengeveld et al., 2007; Ishii, 2008). Tangibles are increasingly popular on the children's toy market and refer to a wide range of devices and toys, which offer many ways for children to physically engage with technology (Soute et al., 2010; Soute & Markopoulos, 2007). For instance, some tangibles are 'purely physical', whereby users physically manipulate objects which contain digital technologies. An example of this is interactive building blocks, which light up when they are connected together. Other types of tangible toys interact with screen-based or other devices to produce digitally augmented toys. An example of this is construction toys such as LEGO Mindstorms, where players can build robotic creatures which can then be controlled using a tablet or smartphone. Other examples of blending screen and tangible interfaces include toys such as

Osmo™, where children arrange physical pieces in front of a tablet camera, which produces feedback and gameplay on the screen. In each of these examples, children physically manipulate objects which then interact with a screen device.

It is widely believed that tangibles provide increased opportunities for children to learn, and to interact with others (Price et al., 2003). By incorporating physical objects into digital play, children can "keep their heads up" and interact with others (Soute et al., 2010), and physical objects mean that it is easy to see what other players are doing (Cherek et al., 2018; Mahmud et al., 2007), and to show playthings to another person (Bekker et al., 2010, 2014). In a large study of over 100 children, Hinske *et al.* (2010) found that when children played with an augmented Playmobil® set, they were better able to recall history factors and showed more interactive play compared to children who played with a non-augmented version of the same set. Similar work by Yuill, Hinske Williams and Leith (2014) showed that a tangible augmented toy supported more cooperative play between children compared to group play on the same toy without the augmented features. An evaluation of the same Playmobil set showed that pairs of sighted and visually impaired children engaged in more collaborative play when using the augmented toy, compared to when they played with the non-augmented toy, furthering the idea that augmented toys can support socially inclusive play, including between students with and without disabilities (Verver et al., 2020).

The physical component of tangible toys may naturally enforce collaboration, whereby certain features of the technology are unlocked through tangible interfaces with "active parts". In a case study, Olson *et al.* (2010) found that children would argue during play on a screen-based interface, but that the implementation of a tangible object (which unlocked certain features of the game), spontaneously encouraged turn-taking. Similarly, Farr *et al.* (2010) and Francis *et al.* (2019) compared children's social play when they played with a tangible toy, Topobo, and a non-augmented and non-digital equivalent, LEGO. They both found more social and collaborative play when children used the tangible toy, Topobo. Topobo is a construction toy where children build creatures, and these creatures are activated, and come to life, by connecting to an "active piece", which contains the power and the mechanics to make the creature move on its own. Since these "active pieces" were limited within a particular Topobo set (e.g. only one active part was included with a handful of non-active parts), this was thought to enforce collaboration and promote sharing (Farr, Yuill, & Raffle, 2010).

1.2.4.3 **General summary**

So far, research has shown that technology and digital toys can facilitate social interaction in children. One design feature thought to specifically encourage collaborative play is enforced collaboration, which can be executed through the design of software, the arrangement of different interfaces (e.g. by playing on two separate devices next to each other), or by implementing physical objects into digital play. When children use technology which enforces collaboration, more social awareness, interaction, and play are observed (Holt & Yuill, 2017). I will now turn to the specific case of autism, first describing this neurodevelopmental condition and then exploring how technology can mediate and facilitate social interaction in autistic children.

1.2.5 **The specific case of autism**

As discussed previously, factors related to the individual child may shape the way they engage with technology, and technology's potential impact on their learning, development, and social opportunities within environments that contain technology. This may be particularly significant for children who have neurodevelopmental conditions which affect their social development and learning, such as autism (Fletcher-Watson & Durkin, 2015). Autism is associated with difficulties in initiating and engaging in social interactions with others (American Psychiatric Association, 2013), but autistic people are also believed to have strong interests in technology and are highly skilled in using technology (Clark & Adams, 2020; Ramdoss, Lang, et al., 2011). Concerns about the impact of technology on the social interaction of autistic children have been shared by both parents (Mazurek & Engelhardt, 2013; Mazurek & Wenstrup, 2013) and educational practitioners (Clark et al., 2015; King et al., 2014, 2017). However, other studies have suggested that technology could be a beneficial way for autistic people to socially connect with others, particularly through online platforms such as social media and video games (Durkin & Conti-Ramsden, 2014; Gillespie-Lynch et al., 2014; Mazurek et al., 2015), but also through developing connections with others through shared media interests, such as cartoons (Fletcher-Watson & Durkin, 2015).

The central question to this thesis is: how does technology influence the social interactions of autistic children? As discussed in previous sections (particularly sections 1.2.1, on page 5 and 1.2.2 on page 7), there are a number of concerns about the influence of technology and media of children and young people's interpersonal interactions. These issues shape the debate on how technology influences social interactions in autistic children and young people, who generally have difficulties with social communication and interaction, and have affinities and interests in technology and media. This will be discussed in depth throughout later sections – but first, I will provide an overview of how autism is defined and understood.

1.3 What is autism?

Autism is a neurodevelopmental condition which affects the way in which an individual engages with the world around them, on a social, cognitive and perceptual level (Lord et al., 2020; McGregor et al., 2007). In the current diagnostic criteria, autism is characterised by a dyad of impairment (American Psychiatric Association, 2013), where there are "persistent deficits in social communication and interaction across multiple contexts", and the presence of "restricted and repetitive patterns of behaviour, interests, or activities" (World Health Organisation, 2018). It is thought that around 1 in 100 people in the UK are autistic (Baird et al., 2006; Baron-Cohen et al., 2009), although more recent estimates suggest that the prevalence rate is higher, up to around 1.5-2% of the population (Christensen et al., 2016). The gaps between current estimated prevalence and true prevalence of autism are likely caused by changing diagnostic criteria (Wing et al., 2011), improved recognition of autism without learning difficulties (Gernsbacher et al., 2005), and "diagnostic over-shadowing" of autism over other conditions such as learning disabilities and mental health conditions (Charman et al., 2009). Barriers to receiving or accessing an autism diagnosis, which may also influence estimates of prevalence, may come from intersectional factors such as being from a minority community, socioeconomic status, and "patchy" provision of services across the UK (Crane et al., 2016).

1.3.1 **Social interaction and communication in autism**

The diagnostic criteria for autism present three main areas in which social interaction and communication differs from those who are not autistic, namely: non-verbal communication, social reciprocity, and social relationships (American Psychiatric Association, 2013; World Health Organisation, 2018). Qualitative and quantitative differences in the development of social behaviours appear early in life, and can be observed in interactions with caregivers, siblings and peers, and engagement with play and other activities (Elsabbagh & Johnson, 2016). A core part of the diagnostic criteria is that these differences cause "significant impairment in areas of functioning", including across development, education, employment, health and well-being (World Health Organisation, 2018).

Non-verbal communication refers to a range of behaviours, which are executed with the intention of interacting with others without using words or vocalisations. It includes behaviour such as making eye contact, expressing emotion, or communicating via gesture or body language (Tomasello, 2010). Reduced eye contact is thought to be a hallmark feature of autism (Adolphs et al., 2001; Klin et al., 2009) which emerges in early development and potentially has a cascading effect on later social development (Elsabbagh, Fernandes, et al., 2013). Autism is associated with reduced use of gesture and body language (Gotham et al., 2007), and difficulty interpreting the non-verbal communication of others, such as recognising emotional expressions (Harms et al., 2010). A difference in the understanding or the executing of non-verbal behaviours may lead to misunderstandings in communication (Van Overwalle & Baetens, 2009). Non-verbal communication strategies, particularly gesture, are necessary for communicating with caregivers before language development – for instance, infants pointing at interesting objects to get their caregiver's attention (Mundy et al., 2007), which is also reduced children who are later diagnosed with autism.

Reciprocity is a broad term which describes an interaction between two or more people who are in physical synchrony, where partners are "responsive and empathetic" to each other, and where the interaction between them is a mutual exchange containing a shared goal (Gernsbacher, 2006). According to Gernsbacher (2006), interactions are classified as reciprocal *only* when they contain this mutual exchange, which must be achieved by all partners in the interaction. Much research on reciprocity has focused on the actions, or "faults", of the autistic person within an interaction (typically with a non-autistic partner), rather than on the mutual responsibility of interactive partners to achieve reciprocity (Heasman & Gillespie, 2018; Milton, 2012; Sasson et al., 2017). For instance, autistic people may make fewer social initiations or responses to others and may have difficulty understanding or responding to what others are thinking and feeling, which can inhibit the achievement of mutual reciprocity (Constantino et al., 2000). There is a growing argument that difficulties with social reciprocity result from exchanges between people with different neurotypes (i.e. between autistic and non-autistic people, rather than exchanges between autistic people), and therefore difficulties with reciprocity are not a key feature of autism, per say (Crompton et al., 2019). However, the ongoing experience of non-reciprocal interactions may have consequences for social relationships and mental health in autistic people, and increase the risk of bullying and adverse social experiences (Dean et al., 2014; Locke et al., 2010; Mazurek, 2014).

Establishing and maintaining social relationships are thought to be particularly challenging for autistic people. This difficulty may result from a lack of awareness of 'unwritten social rules' or etiquette, difficulty understanding other people's emotions and behaviour, or a reduced interest in sustaining or developing social relationships (Chang et al., 2016; Orsmond et al., 2004). Autistic people report higher levels of loneliness compared to non-autistic people (Hedley & Dissanayake, 2017; Locke et al., 2010), and generally report lower satisfaction with their social lives (van Heijst & Geurts, 2015). The social experience varies widely among autistic people, from those who lead thriving social lives and have a range of high quality social relationships, to those who are happy in smaller social circles, and from those who find social interactions draining and exhausting, to those who would like to be more socially active (Calder et al., 2013; Jaswal & Akhtar, 2019; Locke et al., 2017).

1.3.2 Characteristics of social play in autistic children

As defined previously, social play is a particular type of social interaction, which takes place in a context where there is a shared activity or game enjoyed between two or more people. The definition of play is "fuzzy" (Lillard, 2015), and scientific and empirical literature has struggled to produce a concrete definition of play (Miller, 2017). In early childhood, children make sense of themselves and others through play, and use play as a means to understand the world around them. Play therefore serves as a pathway to achieving milestones in cognitive and motor development, but at the same time, children play "for the sake of play", therefore pursuing play for enjoyment and curiosity, rather than for specific learning opportunities. Children play to explore the world around them without restriction or instruction from adults, and play does not require a specific intention, goal, or structure (Hughes, 2009).

Despite this woolly definition of play, there have been a number of frameworks and tools developed to characterise, measure, and describe children’s play in developmental psychology. Play is primarily measured through observation, either live or video-recorded, where an observer can code what the child is attending to and what object(s), if any, they are playing with. Although a qualitative construct, research mostly focuses on quantitative and discrete categories of play, such as the presence and/or frequency of particular types of play. The complexity of play, and sophistication of the use of objects and toys, and interaction with others, generally increases as children’s understanding of others and their imaginations develop (Lillard, 2015). It is these dimensions – social and cognitive development – on which play is often discussed (Hughes, 2009). Play can provide an opportunity for children to learn about the world around them and begin to understand concepts and object relationships, such as object permanence. Play activities with caregivers and siblings help children to understand other people, how they think, feel, and interact with the world around them, and develop the foundation for further social skills and development (Lillard, 2015). These two dimensions are often mapped in in an independent, linear fashion, increasing in complexity and the expected age at which this type of play is typically observed. However, social and cognitive play are much more dependent and inter-connected than traditionally illustrated, and one can influence the development of the other dimension (Howes et al., 1988; Rubin et al., 2007). Table 1.1 provides an overview and some brief definitions of play stages across social and cognitive development.

In this thesis, the terms “social play,” “cooperative play”, and “collaborative play”, are used interchangeably, given the social context of this thesis. However, the terms “cooperative” and “collaborative” play may have different meanings when considered from a social-cognitive perspective (Verba, 1994; Yuill & Rogers, 2012). To engage in collaborative play refers to a joint attention between two or more players on the same activity, more akin to the concept of joint engagement which is discussed in chapter 7. But to engage in *cooperative* play implies a cognitive understanding of the perspective or goals of (an)other player(s), which may not always result in sustained joint engagement, or when two or more players have different roles or goals in a game. For instance, consider children *cooperating* in a game of cops and robbers, with a mutual understanding of each other's different roles and perspectives, and *collaborating* to build a LEGO kit, where both players have the same role and goal, and are trying to build the same construction, but perhaps have less dependency on the other player or consideration of their perspective. Both cooperative and collaborative play could be considered specific types of social play and could potentially occur simultaneously, i.e. that both terms could describe children's play in some contexts. In a number of tools to measure social play, the "highest" level of social play, such as Games with Rules and social role-play (see Appendix 5: Peer Play Scale by Howes & Matheson (1992) on page 216), often refer to 'other-awareness', which is more directly underpinned by a social cognitive ability (Yuill & Rogers, 2012), rather purely a level of social motivation or interest.

Table 1.1: Overview and definitions of social and cognitive play

Social play stages	**Definition**
Unoccupied behaviour	The infant engages in random movements, seemingly not paying attention to or engaging with other people or their surroundings
Solitary	The child begins to play independently – they do not seem to notice other people around them
Onlooker behaviour	The child begins to watch other people whilst they play, but they do not join in
Parallel	Children will play next to or near someone else who is playing, without engaging with or looking at what they're doing. They may be engaged in similar things (e.g. both playing with LEGO), but they do not show awareness of other people or their play.
Simple social play / associative play	Children begin to engage in other people's play. They may ask questions about what others are doing and start to take turns or share toys.
Cooperative / collaborative	Children will engage in play with others which has clear shared goals and rules regarding children's involvement in play. For instance, children will take on roles in their play (e.g. you are the catcher) and begin to delegate and discuss shared play activities with others.
Cognitive play stages	**Definition**
Exploratory / sensory	The child will engage with all or part of a toy, seemingly with a lack of purpose or understanding of what the toy or object is
Functional / construction	The child will begin to play with a toy in a manger that matches its intended purpose or function – for instance, wheeling a car backwards and forwards or stacking blocks
Pretend / symbolic	The child can assign labels to toys which don't match their physicality, e.g. pretending a toy car is a space rocket and flying it through the air, and may engage in imaginary or role-playing games (e.g. tea parties with teddy bears and empty tea pots, or pretending to be a fairy)
Games with rules	Children can assign rules to gameplay and manage the adherence to these rules. They might also engage in more complex role-play with added rules, such as playing cops and robbers.

These definitions of play, and their hierarchical structure, are summarised from various sources (Howes & Matheson, 1992; Lillard, 2015; Parten, 1932; Rubin et al., 2007; Scheepmaker et al., 2018).

The play of autistic children is traditionally described as more solitary and repetitive in nature, with a lack of pretend or imaginative play, and increased sensory or exploratory play (Jordan, 2016). Differences in play behaviours are one of the first signs in which caregivers report concerns about their child's development (Elsabbagh & Johnson, 2016). Differences in the way that autistic children interact and engage in playful contexts could be attributed to a developmental delay in social or cognitive domains, or a preference for particular types of play, where this preference inhibits autistic children from expanding on or developing through their play experiences (Kasari et al., 2013). Throughout early play experiences with caregivers, siblings and peers, autistic children generally pay less attention to the play or actions of others, are less responsive to other people's invitations to play (Zwaigenbaum et al., 2005). As a result, autistic children often engage in more basic levels of social play or might only engage in more interactive play in very specific circumstances (e.g. in highly structured environments, or only with particular toys or objects which interest the child) (Jordan, 2016; Kasari et al., 2013).

Differences in social development and play are thought to have more long-term consequences for social well-being in autistic children (Masten & Cicchetti, 2010). For instance, autistic children who engage in more social play at three years old have been found to have more quality friendships, and less adverse social experiences, at seven years old (Freeman et al., 2015). Autistic children are more likely to experience bullying and peer exclusion (Calder et al., 2013; Chamberlain et al., 2007; Locke et al., 2010; Sedgewick et al., 2016), and are at increased risk of social isolation across the lifespan (Ayres et al., 2017). Teaching children social play skills, i.e. through behavioural intervention, is thought to benefit future outcomes in cognitive and language skills, and increase educational attainment and quality of social experience (Freeman et al., 2015). There is much debate on if and how play should be taught to children who have different play experiences, such as autistic children – because inherently play is an experience not necessarily driven by the child for a particular purpose or developmental goal in mind – e.g. children don't always play to learn, but they do learn through play. "Teaching" play might provide an artificial experience or take away the freedom of playful experiences if dictated by someone else, for instance, an intervention setting (Kasari et al., 2013; Luckett et al., 2007).

There has been a recent cultural shift within a research context on the merits and purpose of interventions for autistic people, most notably interventions for very young children and interventions which target "core" areas of autism, such as social communication and repetitive behaviour (Fletcher-Watson, 2018). This shift has been that interventions should not seek to make someone less autistic, by virtue of having these core traits, but rather should provide autistic children with the opportunity to learn the skills they need to succeed in life. In the wider context of play research, this therefore suggests that differences in play and play development need not be pathologized, and researchers and practitioners should aim to provide autistic children with positive play experiences, which set the foundations for an individual's personal development, so that they can live their full potential as an autistic person.

1.3.3 **Early social development and theoretical explanations of autism**

Before finally proceeding to talk about technology and play in autistic children, I want to briefly discuss theoretical explanations for differences in social development in autism. Differences in social behaviour are present from infancy in autistic children, and common observations include reduced eye contact and less time engaging with other people, including caregivers and siblings (Elsabbagh & Johnson, 2016; Zwaigenbaum et al., 2005). Other signs include differences in play behaviours and the unusual development of fine motor skills, but while these non-social aspects clearly have an important role in the development of autism (E. J. H. Jones et al., 2014), they will not be discussed here. These early behavioural and attentional differences are thought to have a cascading impact on subsequent social development in autism and may have an influence on the emergence (or lack of) later social skills, such as engaging in interactive play or forming relationships (Dawson et al., 1998). There is a further assumption that this reduced social engagement early in life limits the opportunities that children have to learn and develop social skills through early social experiences (Dawson et al., 1998; Johnson, 2011). These early behavioural markers have potential applications in supporting early diagnoses of autism and provide implications for skills which would most benefit from early intervention (E. J. H. Jones et al., 2014). I will later discuss what these theories mean for the development or implementation of digital technologies in supporting social development in autistic children.

The social orienting hypothesis of autism proposes that social differences emerge from an innate disposition to pay less attention to social information (Dawson et al., 2004, 2005). Studies have shown that autistic infants will typically spend less time looking at the eyes within a face (W. Jones et al., 2008), and pay more attention to 'non-social aspects' of visual and auditory information (Klin et al., 2009). Dawson *et al.* (1998) proposed that social orienting differences in autism could have a cascading effect on later social development, and therefore intervening on social attention could be a promising intervention route. However, further studies with younger infants have found that orienting to faces is present in the first two months of life, but later declines after six months (W. Jones & Klin, 2013). Further work has shown that the most "predictive" signs that children will go on to receive a diagnosis do not emerge until the second year of life, across both social and non-social domains (Elsabbagh & Johnson, 2016). These findings led Johnson (2014) to refute the social orienting hypothesis, and to suggest that social orienting was perhaps a consequence of autism, rather than a cause.

An alternative explanation for social orienting differences in autism is reduced motivation or interest to engage in social interaction (Chevallier et al., 2012; Dawson et al., 2005; Kohls et al., 2012). Evidence for the social motivation hypothesis has been proposed in neuro-imaging studies, which show that areas and circuits which process social reward are atypical in autism (Kohls et al., 2012), however, other studies have questioned whether atypical motivation in autism is specific to the social domain (Scott-Van Zeeland et al., 2010). On a behavioural level, reduced social interest in others is reflected in some personal accounts of autistic people, which report that they are less interested in playing or engaging with others (Calder et al., 2013; Jaswal & Akhtar, 2019; Locke et al., 2010). But there are also many personal accounts which deviate from the predictions of the social motivation hypothesis, showing that many autistic people want to have relationships and engage with others (Jaswal & Akhtar, 2019; Locke et al., 2017). Amounting evidence which further suggests that reduced social motivation is neither persistent or consistent in autistic people comes from studies which show that autistic people will adjust or mask their behaviour in line with the (presumed) expectations of others (Cage et al., 2016; Hull et al., 2017).

Returning to the central theme of this thesis, how do these developmental theories of autism relate to autism and technology? Despite each theory not having a particularly strong evidence base in the literature, they each provide implications on how we might support learning and social development in autistic children, and the role of technology in providing social support for autistic children. The social orienting hypothesis suggests that autism interventions should target very specific skills to trigger developmental cascades which may impact other areas, such as communication. In terms of technology-based interventions, this suggests that social skills could be mediated by direct instruction and outcomes could be observed across multiple areas. However, a common critique of such technology-based interventions is that results and skills rarely transfer to non-digital settings or tasks (Fletcher-Watson, 2014; Grynszpan et al., 2014; Odom et al., 2015), suggesting that direct instruction (via technology, at least) does not necessarily "unlock" a developmental cascade of learning. The social motivation hypothesis instead suggests that learning is more likely to occur in environments which are engaging and interesting to the autistic child. This idea that digital technologies are appealing for autistic children is largely supported by parental surveys of their autistic child's hobbies and interests, which often include technology and digital media (Baron-Cohen & Wheelwright, 1999; Clark & Adams, 2020; Laurie, Warreyn, et al., 2019), and observational studies showing that engagement with learning and social interaction in the classroom is increased while using technology (Heimann et al., 1995; Neely et al., 2013; Tjus et al., 2001). These findings will be discussed in more detail in the following section.

1.4 Autism, technology and social play

So far, it has been established that technology can influence social interaction in non-autistic children, by mediating communication with peers, and facilitating face to face interaction in playful and collaborative contexts. While the influence of technology is a topic of great concern, there is little evidence that technology has a negative impact on social development, and it may even provide social interaction opportunities by encouraging collaboration. Children with autism have a different social interaction style, and it is thought that motivating or engaging environments which encourage interaction within the child's own interests will provide opportunities to learn and develop social skills. What this thesis will explore is if or how these environments could be provided by using digital technologies.

Digital technologies and media are thought to be common interests for autistic people, as shown by several surveys and parental reports (Baron-Cohen & Wheelwright, 1999; Clark & Adams, 2020; Grove et al., 2018; Laurie, Warreyn, et al., 2019). Technology is commonly used to mediate social interventions for autistic children and young people through explicit training of skills such as joint attention (Fletcher-Watson, Petrou, et al., 2016) and emotion recognition (Ramdoss et al., 2012), and to encourage student engagement in the classroom (Allen et al., 2016; King et al., 2014; Neely et al., 2013). This final section of the thesis introduction will discuss how using technology could influence social interaction in autistic children, with a specific focus on interpersonal interactions and collaborative play. First, the reasons why technology is thought to be engaging for autistic children will be discussed. Next, literature which has looked at face to face collaboration and interaction while autistic children using technology will be presented, drawing on key factors which may mediate the interactive benefits of technology. Finally, literature comparing autistic children's social interactions and play in digital and non-digital environments will be evaluated.

1.4.1 Rationale for computer-mediated interaction in autistic children

Evidence from self-report studies of autistic adults suggest that technology can mediate interactions in a way in which these interactions become less stressful and easier to navigate (Gillespie-Lynch et al., 2014). For instance, autistic people often report a preference for text-based communications, such as online forums and social media, as it gives people more time to respond, in a manner which is more socially accepted (e.g. waiting a few minutes to reply to a text message, compared to pausing a conversation in silence for a few minutes before replying) (Gillespie-Lynch et al., 2014). Face to face conversations rely on rapid processing of verbal and non-verbal information, which (can be) greatly reduced in online interactions. Some autistic people may have difficulty processing information in unpredictable or socially complex environments, such as having a conversation with someone in a busy café and may then prefer to 'simplify' this interaction using technology. In the context of online dating, one study found that autistic people felt more confident managing their online social profile compared to how they manage the impression they give to others in a face to face interaction (Gavin et al., 2019). This idea that technology can simplify human communication could be extended into interpersonal interactions. For instance, technology could provide a means to filter attention away from information which is more difficult to process, such as social interactions by others (e.g. "I can look at the screen rather than always watch or attend to what others are doing"). This idea of filtering out noisy environments and choosing to focus attention in a way which increases an autistic person's capacity for interaction and attention, is one which fits with other theoretical models of autism such as monotropism (Murray et al., 2005).

It is often claimed that autistic people are more interested in and engaged with digital technologies (Baron-Cohen, 2009; Colby, 1973; Fletcher-Watson, 2014; Fletcher-Watson & Durkin, 2015). A number of studies have asked parents about their autistic child's interests, as well as surveying autistic adults, and technology and related media are recurrent themes (Baron-Cohen & Wheelwright, 1999; Grove et al., 2018). In a recent study which asked autistic children about what they were good, the second most commonly referenced topic was technology or digital skills, reinforcing the idea of high engagement and strong skills in digital pursuits among autistic children (Clark & Adams, 2020). A few parental surveys which ask about technology use in the home have suggested that autistic children spend more time using media and video games for leisure than their non-autistic siblings (Mazurek et al., 2012; Mazurek & Wenstrup, 2013). However, other work drawing on large population samples have shown that autistic and non-autistic children are indifferent in the amount of screen-time they engage in, or in amounts of digital and non-digital activities (Montes, 2016). This lack of difference between uses of technology by autistic and non-autistic children has perhaps been shaped by the proliferation of media in the lives of all children, and the development of technology and media as a playful and leisurely activity, rather than more narrow applications in intervention or assistance for children with disabilities.

Early literature on technology-mediated learning environments for autistic children proposed that technology could provide a space which suited the learning style of autistic children, particularly those with high levels of support needs (Colby, 1973; Fletcher-Watson, 2014). The argument was that technology is predictable and logical, and that it provides a space where children can repeat actions and achieve the same results (Baron-Cohen, 2009; Baron-Cohen & Wheelwright, 1999). Another key aspect of technology, or at least of devices available at that time, was that it presented information visually by screens, words and images, which are thought to suit the learning style of some autistic people (Allen et al., 2016; Cumming et al., 2014). These features of technology were thought to be more appealing to autistic people, building on strengths of visual processing, and therefore would lead to increase use and engagement with digital technologies (Colby, 1973). However, while these ideas have certainly been influential in focusing on the potential of technology to support learning and interactions, the advancement of technology has perhaps outgrown these specific theories on visual mediums and direct cause and effect systems. For instance, now there are many more diverse types of technology available, including devices without screens or much visual information at all, which may lead to technology being less predictable.

1.4.2 **Technology-facilitated interactions in autistic children**

Technology has the potential to teach social skills and provide opportunities for social engagement for autistic children (Bölte et al., 2010; Grynszpan et al., 2014). A number of systematic reviews which evaluate technology-mediated social interventions for autism have indicated that technology can successfully teach social skills (including face to face interactions) (Bölte et al., 2010; Grynszpan et al., 2014; Ramdoss et al., 2012). While this falls into the realm of technology-mediated interactions, where the technology is providing some enforcement or teaching on social skills, the following work has explicitly measured interpersonal and face to face engagement while children use these technologies, and hence also provides evidence for technology-facilitated interaction.

A large-scale randomized controlled trial found no significant effect of an iPad intervention targeting joint attention on parent-child play in preschool autistic children (Fletcher-Watson, Petrou, et al., 2016). There were no significant differences in groups who did and did not experience the intervention, and no long-term benefits to using the app on children’s social behaviours in a non-digital and independent observation at six months follow-up. But this particular study did not observe children using the specific technology, and some parent reports suggested that there was some skill transfer within home settings, perhaps not captured by the chosen outcome measure in the follow-up appointment. It is possible that there were individual differences in terms of whether the app was used collaboratively between families and children at home, and, knowing how heterogenous autism is, that there was individual variance in the outcome measures of parent-child play which led to a statistically non-significant finding. The report concluded that their findings do not mean that "no gains were made" by autistic children in the social domain (Fletcher-Watson, Petrou, et al., 2016), and suggested that further work could explore interaction while children were using digital technologies. The focus of the following section will be on studies which observe autistic children *while* using technology, to explore whether and how social interactions are supported in digital environments, and whether these transfer to non-digital settings.

1.4.2.1 **Screen-based devices**

A series of studies which evaluate computer-mediated language and educational interventions have reported that autistic children engage in social interactions with peers while using these programs. Heimann, Nelson, Tjus & Gillberg (1995) reported that while using a computer-based reading and vocabulary intervention, autistic children would seek help from others, engage in verbal conversations, and express enjoyment to peers within the classroom setting. Eleven autistic children, who varied in developmental ages and verbal abilities, were given an approximately 3-month block of training on the language software, followed by a 4-month block of using the program, and then a post-intervention follow-up at 3-months. Observation of children's verbal and communication was conducted at the end of the training block, the end of the testing block, and then at a follow-up appointment, and observations of the same children were compared at each time-point in a case-series design. While the overall results in terms of language acquisition and intervention target are mixed among the autistic children, the authors note that "children's actual behaviour during the lessons, as shown by video recordings, indicate that their verbal expressions increased significantly over time [between the training and intervention blocks].” In other words, compared to previous sessions, there was a notable change in verbal expression and enjoyment for autistic children across the sessions, compared to the initial trials with the computer program. This behaviour change was specifically marked for autistic children, where the authors finally conclude that “interactive microcomputer program[s] like Alpha [could have] a strong motivational potential for [autistic] children” (Heimann et al., 1995).

A similar study by Tjus, Heimann & Nelson (2001) also showed that autistic children engaged in more conversations with peers during a computer-mediated literacy intervention. In another case-series design study, more verbal exchanges were observed by the same children in later sessions, compared to earlier observation sessions with the software. They also report that children who had more language difficulties at baseline assessment also showed more interaction and verbal expression by the end of the study (e.g. in later sessions), further showing that technology can provide accessible social opportunities to children with significant communication difficulties. Hirano *et al.* (2010) evaluated the use of a digital visual scheduling app in a classroom of autistic children who attended a special education service. In the initial developmental stages of the app, the classroom practitioners expressed concerns that if the students were going to use the digital apps more, this would take away opportunities for peer to peer interaction. However, classroom observations showed that the app prompted autistic children to interact with others. For instance, when the app provided feedback to one child, another student would initiate interaction with them, saying “look, you’ve got fireworks [on your screen]!” (Hirano et al., 2010). What these studies suggest is that using technology in spaces shared by others provides the opportunity for autistic children in special education settings to engage in social interaction and communication with peers and adults, even without the technology itself or adults mediating such interactions.

The effect of shared interfaces has been explored in work by Holt and Yuill (2014), who compared autistic children's social attention and awareness during a collaborative task on tablet devices. In one condition, pairs of children had to share one device and complete a picture-sorting task, and in the other condition, the children had their own devices which were wirelessly connected (i.e. children could see what the other person was doing on their own screen). A case study with four autistic children who had learning disabilities showed that when children had their own device in each pair, they engaged in more joint attention and social awareness, than when children had to share one device (Holt & Yuill, 2014). This finding was replicated in a study which used a similar set up on a tablet device, showing that both non-autistic and autistic children engaged in more joint attention when they had their own separate devices, with shared control (Holt & Yuill, 2017). This further study also showed that other awareness and joint attention between children increased when the partner was a peer, compared to conditions when children were partnered with an adult. What these studies further demonstrate is that in situations where collaboration is mediated by technology, autistic children with learning disabilities will engage in more social interaction (e.g. looking at other people's actions, conversing about game strategies).

A number of studies have reported on autistic children's social interactions while using table-top interfaces which enforce collaboration between players. Piper, O'Brien, Morris and Winograd (2006) developed an application called SIDES, where each of the four players were given a different set of puzzle pieces to solve a puzzle together, thereby encouraging discussion and collaboration. The rules of the game were enforced either by an adult observer, the software / computer, or there was no external enforcement of collaboration. In a group of children with Asperger's Syndrome, the most positive social conversations took place when the rules were enforced by the computer, and there was some evidence that cooperative play transferred to a second observation of free play (no rules) with the technology. Gal *et* *al.* (2009) evaluated a tabletop application which enforced collaboration in a story-telling game. The app was evaluated as an intervention for social skills in autistic children without learning disabilities, where instructions for specific target behaviours (i.e. sharing activities) were given to the students during each session. The effect of the collaborative table-top intervention was measured by pre- and post-assessment of a non-digital story-telling activity. *Gal* et al. (2009) found that the frequency of simple social and collaborative play increased after the story-telling tabletop intervention. Bauminger-Zviely *et al.* (2013) evaluated similar technologies which enforced collaboration in a school environment, and found some evidence that social engagement transferred from the digital enforced collaboration environment to a non-digital free-play environment.

So far, studies have shown that screen-based devices which enforce collaboration promotes interpersonal interaction and collaborative play in autistic children across a range of developmental ages and social and communication abilities (e.g. Gal *et al.* (2009)*,* Holt and Yuill (2017)), and some work has also shown that when using technology-mediated interventions, children will engage in more social interaction with peers (Heimann et al., 1995; Tjus et al., 2001). One question is whether the effect of enforced collaboration is something which is specific to digital devices, such as particular apps, or whether enforcing collaboration on non-digital toys is either possible or effective in the same way. Another question is whether engagement with technologies which teach or enforce collaborative skills have long-term effects on children's social behaviours. Preliminary evidence from some work evaluating tabletop social interventions suggest that children transfer skills taught in digital settings to free play and non-digital settings (Bauminger-Zviely et al., 2013; Gal et al., 2009), but longer term follow-up suggests that results are not sustained (Fletcher-Watson, Petrou, et al., 2016). However, so far studies have not compared enforced collaboration on digital and non-digital conditions, nor compared baseline social interactions and skills relative to engagement while playing with digital and non-digital toys.

1.4.2.2 **Tangible devices**

Tangible technologies combine digital and physical components to create a hybrid device which users can physically interact with (Horn et al., 2012; Ishii, 2008). For children with autism, it has been proposed that tangible technologies may be useful for increasing learning through visual and physical representation of objects (which may be easier to process than on a 2-dimensional representation), and by the promotion of embodied cognition, whereby children's interactions are encouraged through physical engagement (Farr, Yuill, & Raffle, 2010). The multi-modal nature of tangible toys, such as the combination of lights, sounds and physical actions, is thought to be appealing for autistic children (Brok & Barakova, 2010), and work has shown that autistic children find it easier to use and learn from tangible systems compared to other interfaces, such as a keyboard and mouse on a standard computer (Sitdhisanguan et al., 2012).

Brok and Barakova (2010) found that tangible blocks could be incorporated successfully as part of an intervention to teach autistic children turn-taking and cooperative play. An adult teacher demonstrated turn-taking and cooperative play using the interactive light-up blocks, and Brok and Barakova (2010) found that some autistic children could imitate this social behaviour using the same light up blocks. Children who successfully imitated the turn-taking behaviour also demonstrated cooperative play in a follow-up analogue version of the same task. Farr, Yuill and Hinske (2010) found similar transfer effects in a free-play setting for autistic children who played with the Augmented Knights Castle™. The Augmented Knights Castle is a construction set, which provides auditory interactions when children connect certain pieces together and can provide opportunities for imaginative play or storytelling. In an elegantly designed study, Farr, Yuill and Hinske tested whether having the augmented features (i.e. the additional audio interactions) increased autistic children's social play, compared to the same Knights Castle set without the augmented features. Participants included autistic children across a range of developmental profiles and were recruited into the study based on teacher-reported interest in technology. What they found was that autistic children who played with the augmented set engaged in more social play on both Augmented Knights Castle and the comparison toy Playmobil™ than autistic children who played with the non-augmented Knights Castle. These studies suggest that there may be immediate transfer effects on social interaction in digital settings to non-digital environments.

Further work has shown that tangible technologies can provide social opportunities for autistic children. Soysa & Al Mahmud (2019) found that both autistic and non-autistic children would engage in turn-taking and cooperative play while using a tangible toy, which involved placing physical pieces onto an iPad. When the app specifically enforced turn-taking, both autistic and non-autistic children increased their cooperative play, but only a small number of the autistic children would engage with peers in this mode, and instead would engage in turn-taking with a practitioner. Soysa & Al Mahmud (2019) observed that autistic children needed more help from practitioners and assistants to use the tangible interface, however, they also found that autistic children were likely to explicitly ask for help when they needed it. However, what is striking is that the autistic and non-autistic children engaged in a similar amount of turn-taking behaviour, which was not significantly different between groups, when using the tangible toy. This suggests that social differences in autistic children were perhaps ameliorated while using digital toys, and comparable to the play of non-autistic children.

In summary, tangible technologies combine physical and digital interactions, and are thought to encourage learning and social interaction in autistic children (Farr, Yuill, Harris, et al., 2010; Soysa & Al Mahmud, 2019). While some autistic children can struggle to use and manipulate tangible objects (Brok & Barakova, 2010; Soysa & Al Mahmud, 2019), there is some evidence that tangibles may provide more social opportunities to autistic children compared to non-tangible equivalents (Farr, Yuill, Harris, et al., 2010; Farr & Yuill, 2012) and non-digital toys (Farr, Yuill, & Raffle, 2010; Francis et al., 2019). This can be seen in both peer and adult interactions, where children seem more motivated to collaborate with peers, and are willing to ask adults for help to use new and unfamiliar technologies, such as tangibles (Soysa & Al Mahmud, 2019).

1.4.2.3 Virtual environments

Virtual environments are large-scale digital environments which players can typically interact with using their whole body, and refer to specific technologies such as virtual reality, mixed-reality and augmented reality interfaces. They are commonly used in education settings to provide sensory play opportunities to autistic children, and the multi-media and multi-sensory opportunities within virtual environments are thought to be captivating to autistic people, particularly young children and those with learning disabilities (Leekam et al., 2007). A series of studies have shown that these virtual environments have the potential to provide a space for autistic children to 'practice' social interaction with others in collaborative virtual environments (Good et al., 2016; Parsons, 2015; Parsons & Mitchell, 2002).

One example of a virtual environment which provided social opportunities is described in the ECHOES project, which examined the effect of a virtual learning environment on autistic children's joint attention skills. Teaching was conducted by a virtual agent who appeared on a large wall-mounted touchscreen display, designed to be used in a classroom setting (Bernardini et al., 2014; Porayska-Pomsta et al., 2018). The virtual environment was designed to teach children how to initiate and respond to joint attention, through playful interactions with a virtual agent in a series of mini games. Preliminary video analysis of children using the ECHOES system showed that autistic children would treat the agent like another human-being, directing greetings and comments to this virtual character (Alcorn et al., 2011). The ECHOES environment was controlled by a research assistant who manipulated the agents' behaviour in response to children’s actions. Further video analysis showed that when the agent ‘misbehaved’ (e.g. if there was a glitch or a break in the software, or the agent acted surprisingly), children would initiate interaction with the research assistant (Alcorn et al., 2011, 2014), telling them about the mistake ECHOES had made, or initiating interaction with the researcher (e.g. “Look what [the agent] did!”). This was an intriguing finding, since autism is often associated with an intolerance to surprise or uncertainty, and it was a significant finding that children would a) respond to these mistakes positively, and b) sometimes choose to laugh about them with the researcher (Alcorn, 2016). To test this idea further, Alcorn, Pain and Good (2014) developed a series of tablet games which specifically contained these types of ‘bugs’ and ‘errors’, and replicated this finding that autistic children would often initiate interaction with other people in response to surprises in digital environments.

A series of studies have explored the social initiation behaviours of autistic children when playing in a virtual environment with a non-autistic peer (Crowell et al., 2018, 2019; Mora Guiard et al., 2016). This work separated out design features of games which *enforced* collaboration and *encouraged* collaboration. Enforced collaboration was when players could only progress through the game when they interacted with each other, but encouraged collaboration provided “incentives” for collaboration, but still offered opportunity for players to play the game alone (Crowell et al., 2019). When collaboration was enforced in the digital environment, there was no evidence that social behaviours changed between different sessions, however, when players interacted in games which *encouraged* collaboration, there was a significant increase in social behaviour (Crowell et al., 2019). Further work showed that when collaboration was encouraged, rather than enforced, autistic children would make more social initiations and responses, and engage in more collaborative behaviour (Mora Guiard et al., 2016).

To summarise, virtual environments can provide opportunities for autistic children to interact with other people. The ECHOES project suggested that these interactions were driven by novelty or humour, and that novel experiences within an otherwise controlled (and predictable) environment could provide opportunities for interaction (Alcorn et al., 2014). On the other hand, the work from Crowell *et al.* (2019) and Mora Guiard *et al.* (2016) illustrated that the software design could influence and inspire autistic children to engage with (non-autistic) peers. Their work went further to suggest that enforced collaboration was less successful in facilitating social interaction than encouraged interaction. This finding is interesting since, on screen-based devices and tangibles, enforced collaboration has been shown to encourage social interaction and engagement in autistic and non-autistic children (Farr, Yuill, & Raffle, 2010; Gal et al., 2009; Holt & Yuill, 2017). In summary, features of the software and interests of the children can drive social initiations and interactions in virtual environments between autistic children.

1.4.3 **Comparing digital and non-digital interactions**

So far, I have discussed research which looks at how technology can facilitate social interactions and play in autistic children. I have argued for a less “technocentric” approach to research, to uncover specific features which create positive social experiences for autistic children, one example being enforced collaboration. However, a handful of studies have shown that autistic children interact and engage in more social play while using digital toys, compared to playing with matched non-digital toys. That is, that technology itself is suggested to mediate and influence autistic children’s social play in free-play settings, without the constraints of enforced collaboration or technologies designed to teach or scaffold interaction.

Hourcade *et al.* (2013) compared autistic children’s social interactions in a group setting while using a set of tablet apps, and using a set of similar, non-digital toys. One example of matched conditions was a music-making app, and a musical keyboard (NB: within this study, this was considered ‘non-digital’). A small group of children with mixed developmental abilities were observed playing with the tablet apps, the non-digital toys, and then the tablet apps again. The authors used a bespoke scheme to measure social interaction and found that autistic children engaged in more conversations while using the tablet apps, in both sessions, compared to the non-digital toys. They also found that when children used particular apps, such as the Music app, they made more supportive comments to others, compared to other apps included in the study. However, while some of the toys were very closely matched (i.e. the music-making app and the keyboard), the authors also compared some app's interactions to those made when the children played in the "regular activities at the program, which included board games…". Hourcade *et al.* (2013) concluded that autistic children engaged in more social interaction while using the apps because they are more "interest[ed] in computers and technology." They also reasoned that the predictable environment offered by apps and different technologies enable autistic children to feel less anxious and more confident, thus providing opportunity for social interaction.

Two studies have compared autistic children's social play on a tangible toy, Topobo, and on non-digital LEGO bricks. Farr, Yuill and Raffle (2010) observed autistic children, recruited from a special education school, in groups of three in a session where children were explicitly instructed by an adult to build specific models with the tangible and non-digital toy as a team. While using Topobo, the autistic children were observed engaging in more parallel play, and less solitary play. Sequence analysis of children's patterns of play showed that the probability of autistic children switching from less social to more social states of play was increased when using Topobo, compared to LEGO (Farr, Yuill, & Raffle, 2010). Further work from the same group and using the same toys, where children were playing in a free-play setting without explicit instructions, found a similar pattern of results (Francis et al., 2019). In both studies, the authors argue that Topobo provides more "pathways to social play" due to enforced collaboration. The tangible toy contains a singular "active part", meaning that children would be encouraged to collaborate with each other in order to use the

Topobo toy. The same constraints are not applied in the non-digital, LEGO, condition, since multiple children could build several ‘functional’ LEGO builds.

What these studies suggest is that autistic children with a range of learning profiles engage in more social play and interaction when using digital toys, compared to similar, non-digital, toys. The studies highlight features of technology which might help mediate collaboration and interaction, such as being motivating and interesting for autistic children, and enforcing collaboration through limited “active parts” of tangible toys. However, given the heterogeneity associated with autism, it seems likely that not all autistic children are engaged with technology. For instance, perhaps social profile or level of social motivation would be a more influential factor on how technology shapes social collaboration. Previous work in this area has already highlighted that there is variance in children’s social interaction while using technology (Brok & Barakova, 2010). Another interesting avenue for research is the notion of enforced collaboration and whether this is something specific to digital toys, or whether other, non-digital, toys could be used to scaffold interaction in a similar way. In answering this question, it could be understood whether increased social play in digital settings is due to mediation of the digital environment (e.g. enforced collaboration), or due to motivation of autistic children. This has implications for theoretical explanations of autism and providing optimal environments to encourage social interaction in this group, and the effective design and implementation of technologies in education settings to support collaborative play.

1.5 Research questions

The overall aim of this thesis is to explore the influence of technology on social play and interaction in autistic children. Previous research has suggested that autistic children are more motivated to engage in digital environments and may find it easier to interact while using digital toys compared to non-digital activities. It is thought that this is in part driven by stereotyped interests in technology which are associated with autism, as well as the way that technology can scaffold social interaction in an accessible and engaging way, through the design of the technological interface and software. This thesis aims to understand how different technologies and digital environments shape social interactions in autistic children with learning disabilities, with insights into how educational practitioners could use technologies to provide social opportunities for autistic students.

1.5.1 How is technology used in education settings to support autistic children?

In order to ground studies within a school environment, and make recommendations to education practitioners, it seems appropriate to explore how technology is used and perceived within these settings. There are many technologies available for autistic children to support learning and education, although few have an evidence base (Kim et al., 2018), and it is unclear which technologies are used by autistic children in their everyday lives, including in education settings (Parsons et al., 2017, 2019). Understanding whether and how practitioners' use technology in their classrooms can help shape decisions about which technologies to study further, and which technologies or research questions have the most direct relevance to practice. An online survey, as well as focus groups with practitioners, were used to explore practitioners' attitudes and experience of using technology in education settings.

1.5.2 What is the influence of different technologies and environments on autistic children's social interaction and play?

There are a number of ways in which technology can support social interaction in autistic children, including at the level of technological interface and software. For instance, technologies which force children to share close physical spaces can support social interaction, while apps which enforce collaboration between players can also encourage social awareness and joint engagement. Some work has compared autistic children's social interactions where specific features of a technology were present or absent, such as enforced collaboration (Gal et al., 2016) or augmented play (Farr & Yuill, 2012), but no work has actually compared different technological hardware or devices on social interaction in autistic children.

In addition to technology itself, there are a number of additional factors which can influence the way that children interact with other people in digital environments. These include features of the environment, the role of the adult, and the profile of the child, including their own social interaction style and preference for technology (see Figure 1.2 on page 11). Given the complexity of what could shape autistic children's social play in digital environments, a multi-faceted and collaborative project was conducted in a school setting, to explore how practitioners could use new technologies (including tangibles and tangible-screen devices) to promote social interaction in their autistic students, and compare social interaction in play while children used different types of digital technologies.

1.5.3 What is the effect of enforced collaboration on social interaction in digital and non-digital contexts?

A number of studies have suggested that enforced collaboration, through augmentation of software, can successfully support social interaction and collaboration in autistic children. This has been demonstrated on table-top interfaces (Bauminger-Zviely et al., 2013; Gal et al., 2016; Piper et al., 2006), on computer and tablet interfaces (Holt & Yuill, 2014, 2017), and on tangible toys (Farr, Yuill, & Raffle, 2010; Francis et al., 2019). One question is whether enforced collaboration is specific to digital environments, or whether effects can be replicated in non-digital toys. Answering this question helps understand whether technology itself has the 'strongest' effect on social interaction in autistic children, or whether the explicit scaffolding of interaction, in both digital and non-digital contexts, has the largest influence on interaction. This has implications for understanding whether social motivation or technological mediation is driving social interaction in digital environments for autistic children.

2 Methodological considerations

2.1 Chapter summary

Having established the research questions for this thesis, and their justification, I want to briefly turn to the consideration of more general issues within autism research, which have influenced the way in which the research that follows has been delivered. The two main topics of this thesis – namely autism, and how (autistic) children use technology – as discussed in the introduction, are tricky to define, are highly variable and complex, and each depend on a plethora of environmental and individual factors. Combining these areas and asking how autistic children might use and interact with digital technologies is therefore delving into an area which is potentially even more variable, context-dependent, and hard to address with traditional research methods. This brief chapter discusses five methodological choices made in this thesis, and how they fit into more general debates in research on autism, technology, and child-computer interaction.

2.2 Single-case methodologies

Autism is a heterogeneous condition, where each person is affected differently and has a different experience. The wide varying spectrum has prompted much debate about whether autism is a single condition, unified by the observed impairments in social interaction and repetitive behaviours, or whether it is a group of conditions which share some aspects, but have different underlying aetiologies, impact, and comorbidities (e.g. learning disability). Arguments that autism is a group of different conditions have been made at a genetic level, where the social and non-social traits of autism are thought to have different genetic underpinnings (Happé et al., 2006) and further work has also subtyped autism into distinct social and cognitive profiles (Bal et al., 2016; Lai et al., 2013). Researchers have argued that understanding autism at the level of an individual, rather than as a homogenous but varied group, will aid service planning and accelerate the potential for individualised support and personalised medicine (Lai et al., 2013).

In the context of research, an individualised approach may seem contradictory to the empirical standard of having a clinical and comparative participant group. Clinical research often aims to identify or explain differences between typical and atypical populations, in order to, for example, better understand an atypical condition (such as autism), or to identify areas which might be meaningful for intervention. For instance, identifying that autistic children experience difficulties with understanding how others think or feel, i.e. theory of mind, has had widespread applications across intervention and general public understanding of autism (Baron-Cohen, 2000; Charman & Baird, 2002). Whilst comparative research *can* be useful, it is potentially limited in its relevance to social care and education practice, where a practitioner may only work with a clinical population (e.g. in a school for autistic children), and want to understand *how, when,* or *which* practices might be useful for a particular individual (Dingfelder & Mandell, 2011). Knowledge of within-population predictors of good outcomes, such as social communication, language, and developmental milestones, would appear to have more direct relevance to teachers, social care staff, and policymakers. For instance, asking questions such as *who benefits best from a given intervention*, or *what foundational skills underpin more complex social-cognitive development*, yields more practical recommendations than simply identifying that there is a difference in these variables between clinical and non-clinical populations. Furthermore, the diagnostic boundaries between different neurodevelopmental conditions have significant overlap, as many features are shared between different clinical labels (e.g. traits of cognitive and language difficulties), which limits the practical value of comparing clinical groups (Harper & Spiers, 2019).

To address limitations with heterogeneity and better understand predictive factors and outcomes, autism research studies have recruited large sample sizes, increasing statistical power, rigor and representation of diversity (Lombardo et al., 2019).

However, there is also a strong case for the use of individual case-series designs, which recruit small sample sizes but collect rich demographic and participant data (Matson et al., 2012; Odom et al., 2016; Wendt & Miller, 2012). The case-series design has potential to provide more clinically useful information, particularly when it comes to predictors of response to intervention (J. Green et al., 2013). One report analysed their dataset using a group-comparison between non-autistic and autistic groups, and a case-series analysis of individual variance within the autistic group (Towgood et al., 2009). Their group-level analysis showed that autistic people had lower scores on neurocognitive tests than non-autistic people. However, their case-series analysis showed that within each participant, there was a range of performances on each task, showing that the task and measurements were having a larger influence on test performance than the effect of whether a person was autistic or not. Since multiple factors, both internal and external, are thought to influence autistic children's social interactions in digital environments, this thesis took the approach of taking a small sample and conducting detailed individual analysis.

2.3 Multidimensional measures of interaction, play, and context

Social play is a particular type of social interaction, usually in a context of a game or a joyful exchange, but both are dynamic multi-modal exchanges between two or more people, which can vary widely, have different communicative intentions, and have both qualitative and quantitative features. In observational research, there are a number of different methodological approaches to assessing social play in children, which typically use a quantitative approach to measure the frequency or social complexity of a child's behaviour in a playful context (see section 1.3.2 on page 20 for a more general introduction to play).

Can measures of play developed in a typically developing population be used to assess social play in a population with differences in social development, such as autistic children? It has been established that autistic children have a different development of social ability, different ways of engaging in social interaction, and often experience difficulties in social interaction, communication, and play (Jordan, 2016). Therefore, perhaps in using a measure traditionally designed for a non-autistic population it would be expected that autistic children would have more variance or inconsistency in the ratings of social play, and that autistic children would be less likely to engage in socially complex levels of play, if these are defined by neurotypical norms. However, this thesis is also focusing environments which contain digital technologies, which are thought to increase opportunity for social play and interaction in autistic children, and where play may be equivalent to that observed in neurotypical children (Soysa & Al Mahmud, 2019). Therefore, autistic children's social play in digital environments potentially could be appropriately described by a scheme developed for typically developing children. Whilst this sets the bar much higher for the children's social interactions in order to be coded as "social," according to a neurotypical norm, and may not fully capture an autistic child's way of engaging, it does mean that a stronger conclusion can be drawn about what kind of impact technology might be having on autistic children's social interactions. If a coding scheme not designed for autistic children can describe their social play in digital environments, this suggests that the digital environment may be providing some form of social benefit.

However, the approach of using a standardised and neurotypical measure may still fail to capture the nuance of autistic social interactions, and environmental or individual factors which may influence the child's play (Fletcher-Watson, 2018). For instance, it is perhaps more important, to the individual child or parent or practitioner, to look at moments where children are happily enjoying what they are playing with, rather than focusing on if they're playing with other people. It may be that certain aspects of the environment, such as a feature in the game or toy they're playing with or the action of someone else, may influence how they behave in that particular moment, and explain whether they engage in social play or not. In complex and interdependent environments such as those in which children interact with technologies, it may therefore be more appropriate to take more dynamic, nuanced and contextual measurements of children's behaviour, and aspects of the wider environment into consideration (Manches & Plowman, 2017; Plowman, 2016a). Therefore, it might be relevant to simultaneously measure and record multiple factors within a given interaction (such as taking notes about what the technology or software is doing, what other people in the environment are saying, etc.), rather than to focus on one specific aspect (i.e. the level of social play). In this thesis, a two-pronged approach was taken in each observational study to measure interaction. In each case, a general measure of social play was used to assess differences between different play conditions (e.g. with different toys), and a more focused and sensitive measure additionally taken as follow-up.

2.4 Focus on autistic children with intellectual disability

Autism research has historically lacked representation of the multi-dimensional spectrum, despite knowing for a long time that it is a spectrum condition with wide variability and that it commonly co-occurs with other neurodevelopmental conditions. For instance, much of autism research had historically focused on children, with little understanding or acknowledgement of autism in adulthood, and there has been a lack of representation of individuals with autism and intellectual disability or other neurodevelopmental conditions (such as co-occurring autism and ADHD, despite this being the norm rather than the exception (Harper & Spiers, 2019; Russell et al., 2019)). That said, there are likely to be methodological or logistical reasons for maintaining robust control over certain factors, such as the challenge in adapting or administering certain tests to those with a learning disability, or excluding co-occurring conditions which influence the variable of interest, such as excluding those with co-occurring ADHD or visual impairment from studies of attention or face perception.

A small majority of autistic people are thought to have a learning disability, and these are the people more likely to be in contact with services, including special education and health services. It is imperative that we at least understand how autism varies all across the constellation and improve practical recommendations for those who work with people who have significant support needs (Dingfelder & Mandell, 2011; Long et al., 2017). With this said, it is an interesting observation that representation of autism with co-occurring learning disability, and studies of disabled groups more broadly, appears to be much more evident in some areas of human-computer interaction research, such as the participatory design of technologies (Brosnan et al., 2017; Fletcher-Watson, Pain, et al., 2016; Frauenberger et al., 2019, 2012; Parsons et al., 2019; Wilson, 2019). While concerns have been raised within participatory research literature on the agency of the participants involved in design research (Spiel et al., 2017, 2019), there is at least a more apparent evidence of participatory and community consultation with neurodivergent people, than in other areas of autism research.

It is with this consideration that I have chosen to focus my studies on autistic children who attend special education services, and many of whom have an intellectual disability. As discussed previously, there is a question about whether more significant social difficulties will be impacted differently by digital technologies. Overall, the research to practice gap in autism services and provision is thought to be much wider for people with learning disabilities, in part due to their exclusion from research and evaluation studies (Russell et al., 2019).

2.5 Embedding research within an educational context

The issues discussed in this chapter centre around the goal to conduct autism research which is ecologically valid and has practical implications for the community, and those who support autistic people in day to day life. In order to achieve this, the decision was made to carry out the following research studies within an education setting. By narrowing down the context in which children use technology, it means that the research can focus on how practitioners may use technology within a classroom or school environment. Previous research on autism and technology has largely focused on learning applications, and social opportunities within a classroom setting (Allen et al., 2016; Farr, Yuill, & Raffle, 2010; Francis et al., 2019). The logistical advantages to focusing on a classroom context are that children are likely to be familiar with each other, rather than bringing participants into a laboratory or an artificial environment (e.g. an after-school club established for the purposes of research, was an option considered at one point of this research). It also means that practitioners who know the children well are on hand to inform the research and interpretation, such as reflecting on whether this is "typical" behaviour for a particular child, or if and how the technology could be implemented with other children they work with. Combined with decisions discussed above, such as conducting individual participant analysis and using comprehensive measures of interaction and context, school-based research enhances ecological validity and translation of the current research into practice.

To further this direct translation into practice, the decision was made to use technologies which are readily available to purchase, hereon referred to as "off-the-shelf" toys and apps. The majority of technology which has been evaluated by research isn't readily available to families, practitioners, or to individuals who may want to use them (Kim et al., 2018; Ramdoss et al., 2012), which is a significant barrier to understanding if and how technology is used in the everyday lives of autistic people. There is a mismatch between the technologies subjected to research evaluation, and technologies which are most widely used by autistic people and their families – most notably in the realm of assistive technology devices (Spiel et al., 2017) and the use of technology for recreational purposes (Laurie, Warreyn, et al., 2019; Mazurek & Wenstrup, 2013). There are drawbacks to choosing to use commercially designed and off-the-shelf technologies rather than bespoke devices or technologies more explicitly designed for autistic children, such as reduced opportunity to experimentally manipulate design features of the toy or software. However, it is important that the tools currently used by practitioners have an evidence base, or that practitioners can realise how they can use currently available tools to provide social benefits to the students they work with. Previous research exploring practitioners' perceptions of technology in special education settings has highlighted that practitioners would value more technology-related training and hands-on demonstrations, even with technologies which are widely used such as tablets and related apps (Alarcon-Licona & Loke, 2017; King et al., 2017).

2.6 Educational context in Scotland

The studies reported in this thesis take place in special education services across the central belt of Scotland. The schools involved in this research include schools which specifically cater for children on the autism spectrum, and schools which have a roll of students with a range of developmental and educational support needs. Scotland's national Curriculum for Excellence, which applies to all schools, and students aged between 3 and 18 years of age, includes information and computing technologies (ICT) as a key curriculum area. This includes for example, the understanding of how technologies are designed and developed, how ICT is used and applied in everyday life, and how children and young people can protect themselves and others online (Scottish Government, 2016). It is recommended by the Scottish Government that school leavers have obtained a sufficient understanding of ICT in regard to the outcomes outlined by the Curriculum for Excellence. In the context of this thesis, this means that the schools involved in the research have support from the Scottish Government to implement a curriculum which includes ICT, and will have access to various ICT equipment (see chapter 3 for more detail).

Scotland's inclusive educational policies centre around the Getting It Right For Every Child (GIRFEC) framework, which is embedded within the Children and Families Act

2014, an act of UK Parliament (Education Scotland, 2014). These policies apply equally to children who attend mainstream education services, and those who attend special education services or home school programs. GIRFEC aims to ensure that children and young people receive the appropriate help and support that they need, at the right time, and from the most appropriate service. For children and young people with complex support needs, the support they receive in education will be outlined by a Coordinated Support Plan and implemented (e.g. costed) by their local authority (rather than a specific school, per say), as outlined in the Education (Additional Support for Learning) (Scotland) Act 2009. This plan will outline an individual's support needs in education or social care where relevant, personalised objectives or targets around the GIRFEC framework (e.g. based on development of knowledge, autonomy, well-being, etc.), and the support that they need to achieve these goals. This means that the practitioners and teachers who were involved in this research are primed to think about individual children, their needs and interests, and that the educational curriculum readily includes areas related to social and emotional well-being and recreational opportunities.

3 Perspectives from practitioners on the use of technology by autistic children in education settings

3.1 Chapter acknowledgements

A preliminary version of the results reported here have been published in the *Psychology of Education Review* (Laurie et al., 2018).

3.2 Introduction

Colby (1973) first presented the notion that technology could be beneficial for teaching autistic children in classroom settings. His rationale for using computers to support autistic children's learning was based on a theory that technology could present information in an appealing and accessible format, which would lead to an increase in child-directed learning (Allen et al., 2016; Fletcher-Watson, 2014). Since then, the availability of computer technologies for autistic children has rapidly increased (Fletcher-Watson, 2015; Fletcher-Watson & Durkin, 2015), and new recent technological innovations, such as touch-screen and tangible interfaces, means that technology has never been more accessible to children with additional support needs (Alper et al., 2016). Similarly, the amount of research that is conducted on understanding how to use technology effectively to provide accessible learning opportunities in the classroom for autistic students has increased in recent years (Fletcher-Watson, 2014; Neely et al., 2013; Ramdoss, Mulloy, et al., 2011).

3.2.1 **Using technology in education settings with autistic students**

Digital technologies have the potential to support a range of educational goals for autistic children (Bölte et al., 2010). These include: supporting children to communicate through speech-generation devices (Ramdoss, Lang, et al., 2011), supporting academic learning (Kagohara et al., 2013; Pennington, 2010; Ramdoss, Mulloy, et al., 2011), and developing social skills such as emotion recognition (Ramdoss et al., 2012). There is mixed evidence for whether technology supports learning in autistic children (Allen et al., 2016; Grynszpan et al., 2014; Pennington, 2010; Ramdoss, Lang, et al., 2011), but technology is increasingly used to support autistic children's learning in school (Alarcon-Licona & Loke, 2017; Hedges et al., 2017). Beyond social-skills training, providing social opportunities to autistic children in education settings is viewed by academics as a priority, because of the potential consequences of a lack of opportunities to connect and engage with others in a playful way (Parsons & Kasari, 2013). Beyond social skills training, technology can provide social opportunities, and the facilitation of interaction, creating a motivating environment for autistic children to engage in social play (Farr, Yuill, & Raffle, 2010). While technology is frequently used to support academic and social skill development in autistic children (King et al., 2017; Pennington, 2010), it is currently not known whether practitioners use technology for other, non-academic, applications, such as facilitating social interaction and peer connection in their students.

3.2.2 **Attitudes to autistic children's technology use at home and school**

A range of studies have explored the attitudes of parents and practitioners about the use of technology by autistic children. While research more readily depicts the positive potential of using technology to support autistic children, parents and practitioners have reported concerns about using technology at home and in education settings (Clark et al., 2015; Engelhardt & Mazurek, 2014; Mazurek & Wenstrup, 2013). Early work aimed to characterise concerns about technology use, and identified that concerns primarily focused on the amount that autistic children spend on technology (Mazurek et al., 2012). Other studies have found that there are concerns about the content that children can access online, and whether autistic children's digital activities are fairly balanced with non-digital leisure pursuits (Just & Berg, 2017). In school settings, practitioners have reported concerns about whether technology enhances or hinders learning, whether technology is distracting, and whether the skills learned from technology-mediated support transfer to non-digital contexts. Durkin and Conti-Ramdden (2014) also highlighted that practitioners are concerned about the social implications of technology use, in terms of digital media “displacing” children’s social interactions, in both school and home settings.

Previous work on parental attitudes and technology use in autistic children suggests that there is a relationship between children’s use of technology and parental attitudes and concerns about such technology use (Clark et al., 2015; Mazurek et al., 2012). Clark *et al.* (2015) found that both parents and professionals who reported more technology-related anxiety also reported more positive attitudes towards technology use in autistic children. The authors speculate that there is a relationship between the amount that technology is used at home or in services by practitioners, and both positive and negative attitudes about technology. In other words, practitioners who use technology more frequently will develop either more positive *or* negative attitudes, to practitioners who use technology less frequently. Parents of autistic children who exhibit more “problematic technology use,” according to parental reports, are more likely to enforce rules and restrictions on their autistic child’s use of video games (Engelhardt & Mazurek, 2014). In regards to attitudes, Laurie *et al.* (2019) found that parents who reported that their autistic child used more technology (as measured by time spent on media) also reported more concern about the time their autistic child spend using technology. However, Laurie *et al.* (2019) did not find any significant effect of children’s age, gender, language level or developmental level on attitudes towards children’s use of technology.

A few studies have explored the perceptions of technology use by professionals working with autistic children, and found that while professionals have positive attitudes to technology there are additional considerations to make when using technology in schools and services (Alarcon-Licona & Loke, 2017; Clark et al., 2015). Across several studies, practitioners have agreed that technology can benefit autistic children’s learning, by providing an engaging activity which children enjoy using, which can be particularly useful for motivating children to engage in learning activities, such as skill-building activities (King et al., 2014, 2017). But Alarcorn-Licona and Loke (2017) found that practitioners felt limited in how they could use technology effectively in school, because of the associated costs and durability of devices. Practitioners said that the autistic children that they worked with could become “overstimulated” by using technology, engaging in more repetitive behaviours, and having difficulty transitioning from digital activities to non-digital activities. In a qualitative research study, King *et al.* (2017) found other factors such as school policies, staff confidence and training, and the behavioural profiles of the children may influence practitioner’s attitudes and views about technology.

Most of these studies have focused on more ‘traditional’ technology applications, such as tablets and computers, but technology is developing at such a fast pace and there is a rising evidence base for new tools to support learning in autistic children, such as virtual reality, tangible toys, and robotics (Good et al., 2016; Parsons et al., 2017). A recent study exploring the attitudes of education practitioners to using robotic tools to support autistic children in school showed that while practitioners had overall positive perceptions, they also reported concerns about using robotic technologies (Alcorn et al., 2019). For instance, according to education practitioners, robotics should not replace the role of staff in education settings, robotics could be distracting in classroom settings, and social skills learnt through robotics may have limited transfer to real-world, interpersonal, social interactions.

3.2.3 **Current study**

An online survey was used to explore the technologies used by practitioners working with autistic students in education settings, and the attitudes of those practitioners towards technology. A range of technologies have been developed for autistic children to support learning, but it is not known exactly how these devices have been implemented beyond research evaluations, and whether practitioners feel that they would benefit learning and social interaction (Alcorn et al., 2019; Fletcher-Watson, 2014; Kim et al., 2018; Zervogianni et al., 2020). According to qualitative studies, it is likely that attitudes towards technology are shaped by the way that children use technology in class (Alarcon-Licona & Loke, 2017; King et al., 2014), and external factors such as access to technology-related training (King et al., 2017). Previous work has shown that the social differences and repetitive behaviours associated with autism are linked to technology attitudes, as technology can be seen to exacerbate these difficulties in education settings (Alarcon-Licona & Loke, 2017; Alcorn et al., 2019; King et al., 2014). Knowing what predicts educators' attitudes to technology has implications for how staff training and support could be provided in an ever-changing area of technology for autistic people, particularly where the evidence base for new technological innovations is inaccessible to practitioners (Zervogianni et al., 2020).

The survey was followed up by a focus group study which specifically explored practitioners' attitudes and perceptions on the social impact of technology use in autistic children. The focus group explicitly recruited practitioners who worked with autistic children who also had learning disabilities, as this was the key group the research was going to focus on, and nuanced attitudes within these contexts were not adequately captured in the online survey. Previous studies have highlighted that practitioners are concerned that technology could distract children from engaging in social interactions (Alarcon-Licona & Loke, 2017; King et al., 2017), and practitioners report social implications of technology use as a major concern when evaluating new technologies, such as robotics (Alcorn et al., 2019).

3.3 Practitioner survey

The research questions for the survey were as follows:

- What technologies do practitioners use in educational settings with autistic children? For what purpose and how are they used?
- What are practitioners' attitudes and concerns about using technology with autistic children, and how does this compare to more general attitudes about educational technology?
- What demographic factors, including practitioner or student profiles, predict attitudes to technology in educational settings?

3.3.1 **Participants**

Survey respondents were from a range of demographic and vocational backgrounds (see Table 3.1). The length of time participants reported being in their current role ranged from 6 months to 34 years (*median* = 4 years, *mean* = 6.35 years).

3.3.2 **Survey design and development**

An online survey (developed and circulated in English) was designed to explore the uses of technology in education settings by practitioners who work with autistic children. An initial version of the survey was developed, based on a previous online survey which explored parental attitudes to technology use by parents of autistic children, from the same research group (Laurie, Warreyn, et al., 2019). An initial version of the current survey was taken to a teacher who worked in a specialist school for autistic children and tested using a 'walk-through' method, where the teacher went through the survey and provided feedback, comments, and thought processes when answering survey questions. Feedback from the teacher was implemented by reducing the number of questions and the amount of detail being asked, and providing more open-ended text response options rather than categorical answers. This new version of the survey was then piloted with a small group (n = 4) of researchers and practitioners in special education. The survey pilot participants gave no further recommendations for improving the survey at this time. A copy of the final survey version, which was circulated within this study, is included in Appendix 1: Practitioner survey on educational technology on page 204.

Survey participants were recruited through online circulation, via research networks and social media. Recruitment sources included social media groups for teachers working in SEN, twitter hashtags #EdTech and #ASDTech, online special interest groups such as Building Evidence for Technology and Autism (BETA; beta-project.org/en/home/), community and research mailing lists such as the Scottish Autism Research Group (SARG; http://www.sarg.ed.ac.uk/home/), and direct invitation to services (e.g. researcher contacts within Scottish Autism and the National Autistic Society). For reimbursement, participants were entered into a prize draw for Amazon gift vouchers, worth £25 and £50.

Responses to the survey were a mix of closed- and open-ended questions, to collect both qualitative and quantitative data about the technology used by autistic children within education settings. The survey collected information about respondents' demographic information (including age, and job role), the students or individuals they typically support (i.e. age, communication and learning profiles), the technology-related training received within their role, what and how technologies (including specific devices) are used, what educational areas or functions technology is used for, and attitudes to technology. Questions about technology attitudes were asked twice: once in a general context (e.g. attitudes about children and technology – e.g. "I'm concerned about the content children can access on technology") and in an autism-specific context (e.g. attitudes about autistic children and technology – e.g. "I'm worried about the content that autistic children can access on technology") to see whether there were specific concerns around using technology with autistic children. The order in which the questions about attitudes were asked was randomized within a block for each participant, as well as the order of the blocks of question contexts (e.g. block of questions in a general context, followed by a block of questions in an autism context). The survey was hosted online by www.surveymonkey.com and a copy is included in Appendix 1: Practitioner survey on educational technology on page 204).

Table 3.1: Practitioner demographics

Respondent gender (*n* = 159)	**Count (%)**
Female	139 (87.42%)
Male	19 (11.95%)
Not listed	1 (.63%)
Respondent age (*n* = 154)	**Count (%)**
Up to 35 years old	85 (55.19%)
Between 25 and 51 years old	45 (29.22%)
51 years old and older	24 (15.58%)
Location (*n* = 154)	**Count (%)**
Canada	6 (3.9%)
England	25 (16.23%)
Republic of Ireland	1 (.65%)
Scotland	100 (64.94%)
United Kingdom [sic]*	5 (3.25%)
United States of America	15 (9.74%)
Wales	2 (1.3%)
Job role (*n* = 153)	**Count (%)**
Behaviour Therapist (e.g. in applied behavioural analysis)	6 (3.92%)
Other role (e.g. Service manager)	10 (6.54%)
Psychologist (e.g. occupational, educational) & trainees (e.g. Assistant Psychologist)	7 (4.58%)
Senior Support Worker	8 (5.23%)
Speech & Language Therapist	19 (12.42%)
Support Worker / Classroom Assistant	27 (17.65%)
Teacher / Support Teacher	59 (38.56%)
Teaching Management (e.g. deputy, head teacher)	17 (11.11%)
Highest qualification achieved (*n* = 161)	**Count (%)**
Doctoral degree	3 (1.86%)
Highschool	2 (1.24%)
Postgraduate degree	78 (48.45%)
Professional training	10 (6.21%)
Undergraduate degree	54 (33.54%)
Vocational qualification (e.g. Higher National Certificate)	14 (8.7%)

* Refers to those who listed “United Kingdom” as an answer

3.3.3 **Procedure**

Ethical approval was granted from Moray House School of Education at the University of Edinburgh. Participants provided consent for their data to be collected, analysed, and shared in academic outputs, via an in-built consent form which preceded the survey (see Appendix 1: Practitioner survey on educational technology on page 204). The survey was open during Spring 2017 and educators and practitioners were invited to complete it through the author networks, social media, and relevant mailing list. According to in-built surveymonkey.com data logs, respondents spent on average 12 minutes completing the survey.

3.3.4 **Analysis methods**

Survey data were downloaded from surveymonkey.com in .csv format, and imported into RStudio for analysis (RStudio Team, 2016). In each case, analyses are run on the data which are available on a case by case basis (including demographic information, information on technology use, technology attitudes, etc.).

First, survey responses about the children and students that practitioners work with are reported, followed by reporting of technology-related training, including the number, types, and sources of participants' training received in their workplace. Then, survey responses are reported about the types of technology available and used, including types of device, and whether students can use these devices independently. Also reported are the ranked functions of technology use (here, 'function' refers to the purpose of the technology use, e.g. to support academic learning, as a communication tool), and respondents' perceived impact on using technology in the classroom (rated from a Likert scale, with options "very positive, somewhat positive, neutral, somewhat negative, and very negative").

Responses to questions about technology attitudes, in both a general and autism-specific context are reported. The order of each block of questions was randomized for each participant, but potential order effects could not be measured due to a technical error where the order of blocks was not collected for many of the participants. Cronbach's alpha is used on each scale (general and autism-specific questions) to measure consistency of responses. Following reversal of some items, responses are converted to a numerical value (where a higher value indicates more positive attitudes about technology) and statistically analysed. A Shapiro-Wilk test was used to check that these data were normally distributed. A non-parametric paired Mann-Whitney U test was used to assess whether attitudes were different on questions about general and autism-specific technology attitudes. A Kruskal-Wallis chi-squared test assessed whether attitudes varied by the amount of training that respondents had received in work.

Finally, a linear regression is used to test whether the degree of negative attitudes towards technology in an autism-context is predicted by practitioner demographics (age, gender), the profile of the pupils taught (e.g. with or without learning disability), and the length of time that respondents had worked with autistic children. These predictors were adopted from a previous study which had used a similar survey method to explore parental attitudes to technology use in autistic children (Laurie, Warreyn, et al., 2019).

3.3.5 **Results**

3.3.5.1 **Child demographics**

The information reported about the pupils that participants worked with is presented in Table 3.2. This includes the age range of students, their language ability, and the prevalence of learning disabilities. Note that respondents could select as many options as were applicable, so percentages are calculated from the total number of answers to that question (e.g. 18% said they worked with preschool-aged children, 33% said they worked with early primary-school aged children), except for the question about prevalence of learning disability, which was a discrete question (e.g. responses were limited to one).

Table 3.2: Child demographics represented by survey respondents

Pupil age group	**Count (%)**
Preschool	35 (18.82%)
Early primary school	62 (33.33%)
Late primary school	63 (33.87%)
Early secondary school	49 (26.34%)
Late secondary school	40 (21.51%)
Language ability	**Count (%)**
Primarily non-verbal	56 (30.11%)
Single-word production	65 (34.95%)
Babbling	49 (26.34%)
Short phrases	52 (27.96%)
Sentences	67 (36.02%)
Fluent	70 (37.63%)
Learning disability	**Count (%)**
Majority of students	57 (48.31%)
Minority of students	46 (38.96%)
No learning disabilities	15 (12.71%)

3.3.5.2 **Technology-related training**

Table 3.3 shows the type of technology-related training that respondents reported they had received at their current employer. Sources for training were selected from the following options: commercial, external, internal, service policy, service management, colleagues and staff, and parents of children. Note that respondents could select multiple options that were applicable to their situation and experience. Percentages here are calculated based on available data, as reported in the far-right column in Table 3.3. The median number of training types survey respondents received was 4 (interquartile range = [3, 6]). A small number of survey respondents (n = 6; 5.83%) said that they had received no training related to technology.

Table 3.3: Reported amounts of technology-related training

	Type of training			
Source of training	Did not receive (%)	Formal (%)	Informal (%)	***n* sample**
Colleagues and staff	22 (17.88%)	15 (12.19%)	86 (69.91%)	123
Commercial	68 (54.83%)	39 (31.45%)	17 (13.7%)	124
External	52 (42.97%)	41 (33.88%)	28 (23.14%)	121
Internal	34 (27.41%)	38 (30.64%)	52 (41.93%)	124
Parents of children supported	74 (61.66%)	6 (5.00%)	40 (33.33%)	120
Service Policy	36 (29.75%)	45 (37.19%)	40 (33.05%)	121
Service Management	50 (40.98%)	30 (24.59%)	42 (34.43%)	122
	Level of interest			
	Yes (%)	No (%)	Unsure (%)	***n* sample**
Interest in further training	98 (80.33%)	16 (13.11%)	8 (6.56%)	122

3.3.5.3 **Devices and uses of technology**

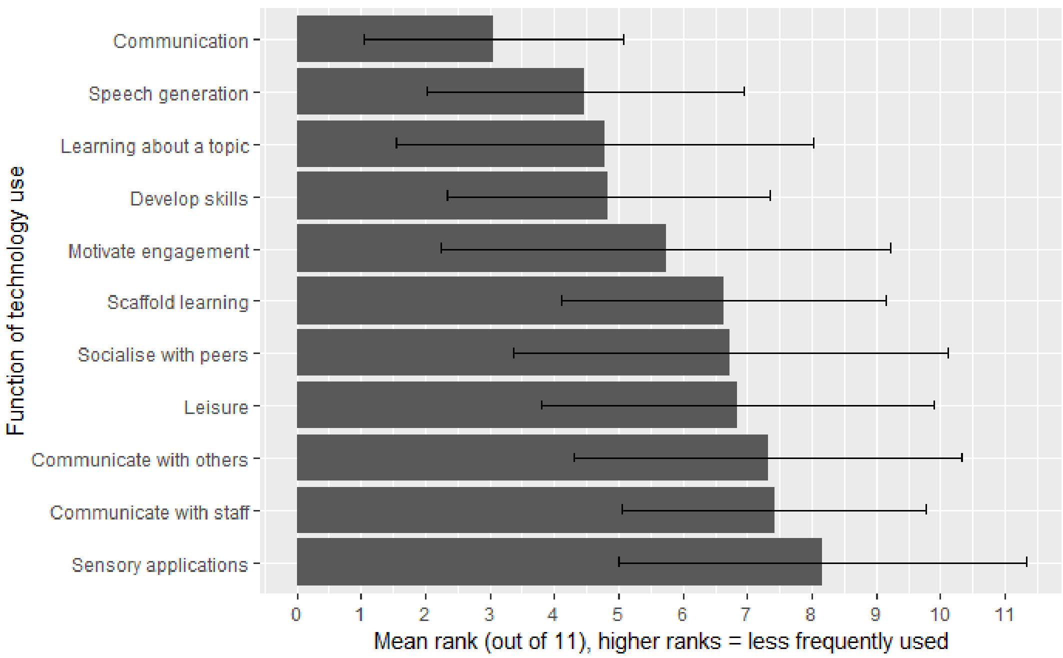
Table 3.4 shows the devices which were reportedly available to practitioners, and which devices were provided by the school, brought from home, or not available to use. The most widely used devices, and those which were regularly provided by the school or organisation, were tablet devices, computers, and interactive whiteboards. Technologies which were sometimes brought from home by the pupils included tablets, smartphones, and personal music players. Technologies which were less commonly available to practitioners included robotics, wearables, tangibles, and table-top devices. Table 3.4 also shows the breakdown of usage of classroom technologies by students, as reported by practitioners, where respondents indicate whether the device is used by the students independently, used by the students with staff support, or not used by the students but available. In both cases, percentages are calculated based on available survey data, as reported in the far-right column.

Table 3.4: Overview of technology used in the classroom

	The technology is provided by…			
Device	School/Service (%)	Student (%)	Not available (%)	***n* sample**
Tablet	72 (72.00%)	21 (21.00%)	7 (7.00%)	100
Computer	72 (80%)	8 (8.88%)	10 (11.11%)	90
Interactive Whiteboard	72 (82.75%)	0	15 (17.24%)	87
Educational website (e.g. BBC Bitesize™)	61 (77.21%)	3 (3.79%)	15 (18.98%)	79
YouTube™	59 (81.94%)	0	13 (18.05%)	72
Internet	59 (72.83%)	7 (8.64%)	15 (18.51%)	81
Television	55 (61.11%)	14 (15.55%)	21 (23.33%)	90
Radio	39 (49.36%)	8 (10.12%)	32 (40.50%)	79
Tabletop device	16 (20.25%)	1 (1.26%)	62 (78.48%)	79
Personal music player	16 (21.62%)	17 (22.97%)	41 (55.40%)	74
Tangible device	13 (16.66%)	2 (2.56%)	63 (80.76%)	78
Robot	12 (14.63%)	2 (2.43%)	68 (82.92%)	82
Mobile phone	5 (7.04%)	13 (18.30%)	53 (74.64%)	71
Wearable device	2 (2.50%)	7 (8.75%)	71 (66.75%)	80
Smartphone	1 (1.38%)	21 (29.16%)	50 (69.44%)	72
	Pupils use this technology…			
Device	Independently (%)	With help (%)	Never (%)	***n* sample**
Tablet	54 (62.79%)	52 (60.46%)	6 (6.97%)	86
Computer	50 (47.61%)	47 (44.76%)	8 (7.61%)	105
Interactive Whiteboard	28 (34.56%)	47 (58.02%)	6 (7.40%)	81
Educational website	36 (43.37%)	47 (56.62%)	0	83
YouTube	35 (38.88%)	48 (53.33%)	7 (7.77%)	90
Internet	42 (42.85%)	46 (46.93%)	10 (10.20%)	98
Television	20 (31.25%)	31 (48.43%)	14 (21.87%)	64
Radio	22 (35.48%)	30 (48.38%)	10 (16.12%)	62
Tabletop device	12 (50.00%)	7 (29.16%)	5 (20.83%)	24
Personal music player	22 (41.50%)	17 (32.07%)	14 (26.41%)	53
Tangible device	10 (38.46%)	10 (38.46%)	6 (23.07%)	26
Robot	4 (19.04%)	10 (47.61%)	7 (33.33%)	21
Mobile phone	10 (27.02%)	5 (13.51%)	22 (59.45%)	37
Wearable device	4 (28.57%)	2 (14.28%)	8 (57.14%)	14
Smartphone	16 (35.55%)	9 (20.00%)	20 (44.44%)	45

Rankings of reasons for using technology, by frequency, are shown in Figure 3.1. The most common purposes for using technology, according to practitioners, were communication, speech generation, and learning about a topic. The least common purposes for technology in the classroom were sensory applications, communication with staff, and communication with other people.

Figure 3.1: Rank of educational practitioners' uses of technology with autistic students



3.3.5.4 **Technology attitudes**

Of the 99 survey respondents who completed the question about the "general impact" of technology in the classroom, 37 (37.37%) said that technology had a very positive impact, 47 (47.47%) said mostly positive, 11 (11.11%) gave the neutral response option, 3 (3.03%) said that the impact of technology was somewhat negative, and 1 respondent (1.01%) said that technology mostly had a negative impact.

Responses to questions asking about technology attitudes are shown in Figure 3.2. Cronbach's alpha was .73 for questions about general technology attitudes (95% confidence interval: .71, .75), and for autism-specific questions about technology, Cronbach's alpha was .69 (95% confidence interval: .65, .72), indicating moderate to good scale reliability for both sets of questions (Bland & Altman, 1997; Cronbach, 1951). Following numerical conversion, the median score (out of 50, which indicated most positive attitudes) for general questions was 30 [interquartile range: 27, 32], and the median score for autism-specific technology questions was 27 [interquartile range: 25, 27]. A Wilcox Rank Sum Test indicated that the difference between these scores was significantly different from zero; $W = 3182$, $p < .01$. Figure 3.3 shows that practitioners have more negative overall attitudes towards technology use in autistic children, compared to attitudes about technology use in neurotypical children.

A Kruskal-Wallis test was used to assess whether the amount of training (number of training types) participants had received was associated with attitudes about technology. No significant effect of types of training received was found; $x^2(7) = 6.67$, $p = .463$.

Finally, a linear regression was used to identify predictors of technology-related attitudes in autism practitioners (see Table 3.5). Variables included in the regression were the age of the survey respondent, their gender, the amount of time they had reported working with autistic children, whether the pupils they worked had learning disabilities, and their view on whether technology had a positive impact in the classroom. The linear regression revealed no significant predictors of attitudes about autism and technology from the demographic data of survey respondents.

Figure 3.2: Responses to questions about technology attitudes in general- and autism-specific contexts

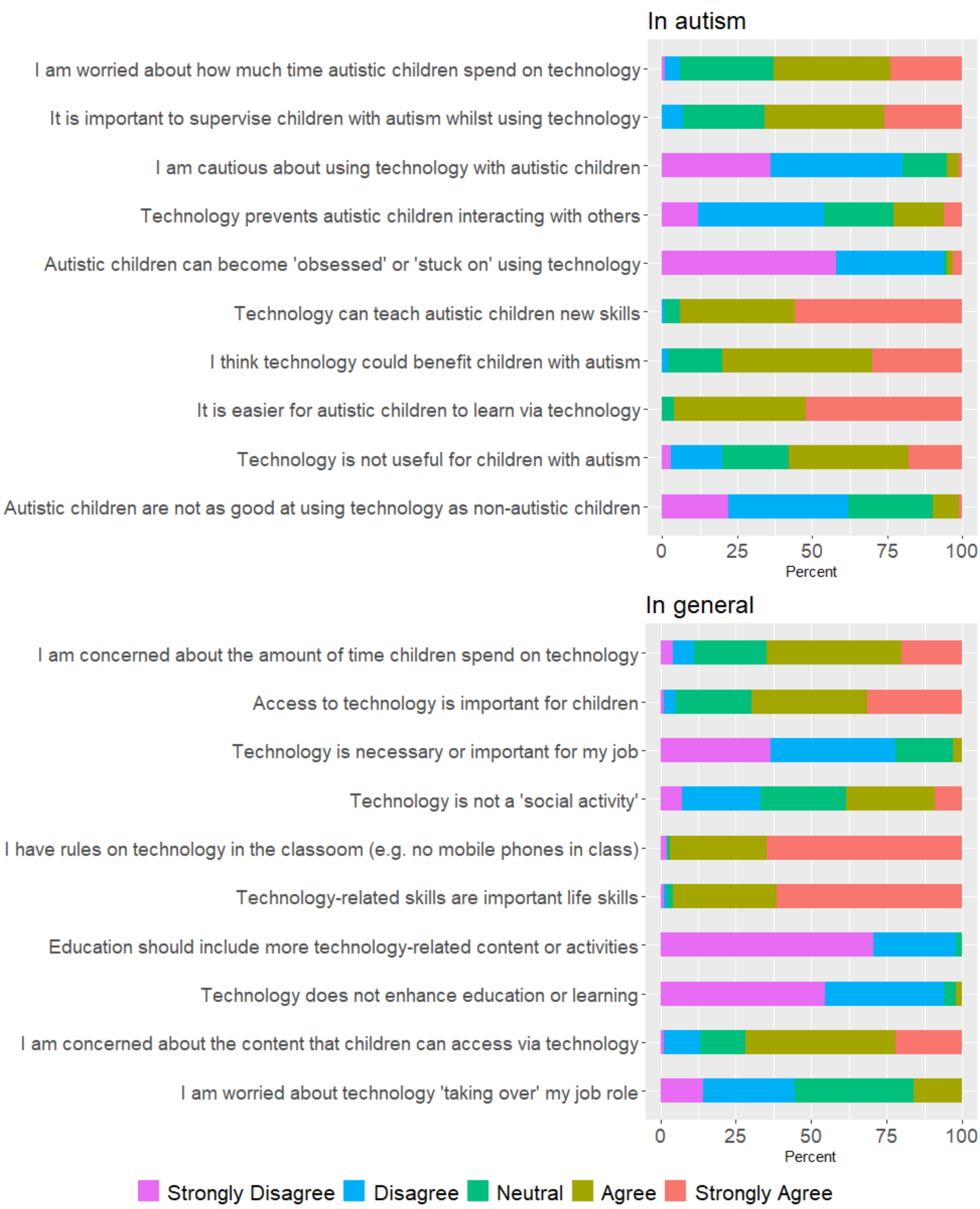


Figure 3.3: The severity of negative attitudes in practitioners to different groups of children

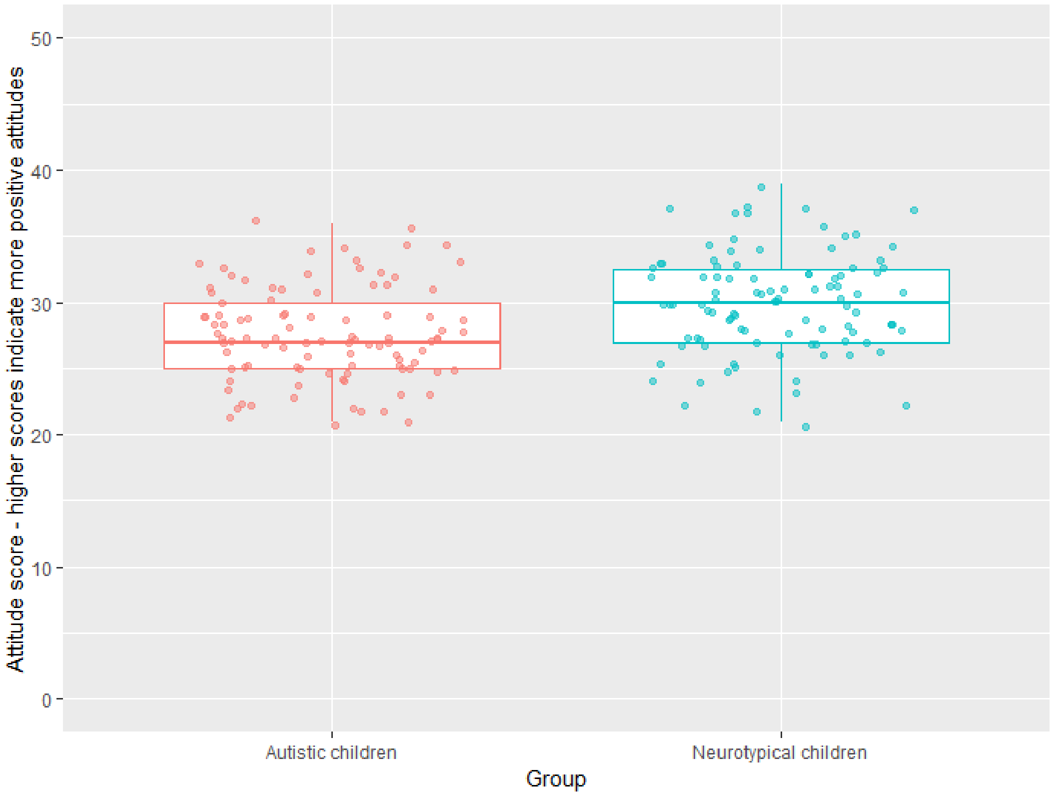


Table 3.5: Results from linear regression on predictors of autism and technology attitudes

Predictor	*b*	*b* [LL, UL]	sr^2	sr^2 [LL, UL]
Intercept	23.70**	[15.32, 32.07]		
Practitioner Age (years)	.01	[-.08, .10]	.00	[-.01, .01]
Practitioner Gender	-.52	[-2.58, 1.54]	.00	[-.02, .02]
Length of time working with autistic children (years)	-.04	[-.16, .08]	.00	[-.02, .03]
Pupils' learning profiles	2.24	[-.01, 4.49]	.04	[-.03, .11]
Perceived impact of technology	6.48	[-1.90, 15.86]	.02	[-.02, .03]
Model fit	r^2 = .150 [.00, .21]			

* indicates p < .05; ** indicates p < .01.
A significant *b*-weight indicates the semi-partial correlation is also significant. sr^2 represents the semi-partial correlation squared. Square brackets are used to enclose the lower limits (LL) and upper limits (UL) of a confidence interval.

3.4 Focus groups

The research questions for the focus group study were:

- What are the views of autism practitioners in special education settings on the influence of technology on social interaction and communication?
- Are there any potential mediating factors in the classroom, according to autism practitioners, which affect how technology shapes social interaction in autistic students?

3.4.1 **Participants**

Participants were members of staff at two different education services in the central belt of Scotland for children aged 5 – 18 years. One school was exclusively for autistic children, and the other school was for children with additional support needs, with a large roll of autistic students. Both services primarily catered for children who had high levels of support needs, and the majority of students in these services had a learning disability.

Focus group participants were recruited after the online survey was closed. In each case, the school management team invited their teaching staff team (including trainee teachers and teaching assistants) to participate in the research, and participants brought themselves along to a session scheduled by the lead researcher outside of school hours. In one focus group, all participants were class teachers (n = 5) and in the other focus group (n = 8), focus group participants included the school deputy head teacher, two teachers in training (pre-qualification), and a school health and clinical psychologist, with the remaining 5 participants in teaching roles. In total, 13 staff members participated in the focus groups. For reimbursement, all participants were given an Amazon gift voucher (valued at £5) for participating.

3.4.2 **Positionality**

In qualitative research, it is important to reflect on the role of a lead researcher or team in both identifying, shaping, gathering, and interpreting data, throughout the research process (Braun & Clarke, 2013; Coghlan & Brydon-Miller, 2014). In this case, my personal views on educational technology, my previous experience working as a practitioner working with autistic children, and my scientific background and interest may all have shaped both my role in collecting and interpreting the data, as well as moderation of the focus groups. In general, I have an understanding that the use of technology in education services, and with autistic children, can be complicated, both by intermittent and varying access to educational technologies and resources, as well as by practitioner attitudes (in my own, personal experience). In focus groups, this may have encouraged practitioners to share their own experiences, as I made it very clear throughout the research process that I wanted it to be driven by their testimonies, so that the subsequent studies in this thesis were deliverable, realistic, and relevant to practitioners on the ground. But on the other hand, as a (relatively) young person, who 1) personally plays video games, 2) could be considered "techy", by virtue of the former, and 3) has a critical viewpoint on the notion of "screen-time" (see section 1.2.2 on page 7), this may attract a less diverse range of opinions. Each of these factors may not only have affected how participants chose to share their experiences, but also in how the subsequent data was analysed and interpreted. This particular researcher's positionality therefore serves as perhaps both a strength and a potential weakness in the implementation of qualitative research in this area. As a moderator in the focus group sessions, I tried to mitigate this personal influence by encouraging a range of responses and perspectives to each focus group question, encouraging always more than one person to share their perspective, and whether the overall group agreed with what had been shared.

3.4.3 **Procedure & Materials**

Focus groups were moderated by the lead researcher, who also transcribed the focus groups from audio-recordings. Each focus group lasted around 45 minutes. All participants were informed at the beginning of the focus group about its purpose and aims – to examine whether and how technology influences social interaction in autistic children. A schedule of each focus group was drawn up and used as a guide during the sessions. Core questions were

1. What technologies do you use in the classroom with your students, and what do you use these technologies for?
2. How does technology impact the social behaviour of your students?
3. Do you think that new technologies, such as robots, tangibles and virtual reality have the potential to support social interaction?

For clarity, visual representations of these different technologies were shown to the participants (for an example, see Figure 3.4).

3.4.4 **Thematic analysis and early theme development**

Focus group discussions were audio-recorded using a Dictaphone and transcribed by the first author. Each participant was assigned a pseudonym during transcription. Transcription and analysis were conducted using NVivo software, and thematic analysis was used to identify and analyse patterns within the data. Both transcription and analysis followed the recommendations and method outlined by Braun and Clarke (2013), where analysis involved an inductive approach to coding and developing themes which were closely linked to the original data. The analysis of the data was conducted iteratively, with themes and patterns redefined and rearranged in multiple stages. Complete and open coding was used initially, where all possible and potential patterns and themes within the full dataset are explored (Braun & Clarke, 2006), and then codes were grouped into potential themes that identified patterns across the data.

The early stages of thematic analysis gathered quite ‘literal’ themes from the data, which were driven by the questions that the focus group asked. These themes were useful in the beginning stages of coding the data, but themes were revised to provide a more general overview of autistic children’s social interactions in digital environments. Early themes identified “constraints” on the use of technology with autistic students, including expectations from the curriculum and from the students themselves, and also identified logistical factors which prevented effective use of technology, such as a lack of staff training. Another constraint was staff’s concerns about the use of technology, which influenced the way that they let children use technology in the classroom and their lack of confidence in using newer technologies.

Staff were quick to raise limitations to the use of newer technologies in the classroom, such as a concern about the transfer of social learning from digital (e.g. robotic) to non-digital environments, and staff sharing that their students “wouldn’t be very interested” in these types of games. A further early theme which was identified was the reference to space – in terms of physical and social spaces that children interacted in, and the influence of digital technology in the curation of these spaces. For instance, children’s “social space” could be ‘expanded’ by digital technologies through the use of online communications and by engaging children based on their interests (linking to previously discussed idea of monotropic experiences and scaffolding, see section 1.4.1 on page 29, and section 8.3.5 on page 199).

Figure 3.4: Example visual references of technology discussions

Figure 3.4a: Smart table (large touch-screen tabletop device)

Figure 3.4b: Osmo™ (tangible technology: physical to screen interaction)

Figure 3.4c: Milo from RoboKind™: Socially intelligent robot

3.4.5 **Results**

Thematic analysis produced three recurrent themes in the data, capturing the perspectives of autism practitioners when using technology in school, with a specific focus on the impact of technology on social interaction. *Staff experience* captures the way that staff felt about using technology in their practice, including pressures and expectations from the curriculum, as well as their own knowledge and confidence using new technologies in the classroom. *Facilitators* captures the ways in which technology could positively influence social interaction in autistic children, by providing a shared interest for students, and structuring interactions in a way that encourages interaction. *Autism-specific concerns* refers to concerns around using technology specifically with autistic children, mapping onto the core areas of difficulty associated with autism. Table 3.6 summarises the structure and scope of these three themes and their sub-themes. Table 3.7 on page 79 provides illustrative verbatim quotes for each sub-theme of *Staff Experience, Facilitators and Autism-specific concerns* respectively.

Table 3.6: Overall theme structure and definitions from focus groups

<table>
<tr><th>Themes</th><th>Definitions</th></tr>
<tr><td rowspan="2">Staff experience</td><td>Expectations
Staff felt they were expected to use technology with their students, as part of the curriculum and in response to student's interests.</td></tr>
<tr><td>Confidence
Individual staff felt varying levels of confidence using technology with their students. This was related to staff training, opportunities, and previous experience using technology with autistic students.</td></tr>
<tr><td rowspan="2">Facilitators</td><td>Common ground
When technology or digital media was a shared interest between students, this encouraged interaction and brought students together. When children enjoyed using technology, sometimes they wanted to share that with others.</td></tr>
<tr><td>Structured interactions
Certain technologies could provide structure to shared interactions which benefitted some autistic children. These included the proximity afforded by technology, creating a closely shared space, and having specific turn-taking instructions.</td></tr>
<tr><td>Autism-specific concerns</td><td>Staff shared concerns about using technology related to the two domains of autism: social interaction and communication, and intense interests or repetitive behaviours.</td></tr>
</table>

3.4.5.1 **Staff experience**

Staff described how their confidence and expectations from the curriculum and school inspectorate influenced how and whether they chose to use technologies in the classroom. Staff felt more comfortable using technologies they were familiar with and knew how to troubleshoot and operate, and were more hesitant to use new technologies that they had not been trained to use. However, staff also acknowledged that they were encouraged to use technology in the classroom in order to meet requirements for school inspections and curriculum.

3.4.5.2 **Facilitators**

Staff shared how technology could positively influence or mediate social interactions with the autistic children and young people that they worked with. Two common patterns were that i) technology was a shared interest between students which fostered interaction and relationships, and ii) technology structured or presented collaboration in a way that suited the students' own interests and preferences. For example, staff described how devices such as tablets and table-top devices (see Table 3.7) encouraged children to work in close proximity, whilst other devices such as the smartboard allowed children to have more personal space. These features could influence interaction in a positive or a negative way depending on the child's preferred social interaction style. Similarly, apps and games differed in how collaboration was supported in the classroom, either by facilitating collaboration through the software itself (deliberate turn taking), or the teacher implementing collaboration beyond the technology (implemented turn taking). More generally, technology was something that seemed to 'bring children together' across different classrooms and areas within the school.

3.4.5.3 **Autism-specific concerns**

The concerns that staff raised about using technology with autistic children mapped onto the two core domains of difficulty: social interaction and communication ('social difficulties') and restricted and repetitive behaviour ('fixations'; see Table 3.7).

Table 3.7: Sub-themes and illustrative quotes from practitioner focus groups

Sub-theme	Illustrative quotes
Staff experience	
Expectations	"… but the curriculum as well, is a big part of that. And even what inspectors expect to see when they come in too, there's a little bit also about culture, inspectorate will evaluate schools based on how they're using technology" (Laura, Deputy Head)
Confidence	"It's probably a confidence thing in a way, I'm much more confident at using the smart board than I am with other things. Because I do feel sometimes… [the new technology is] not working [properly], or the volume's set down or whatever. Whereas I feel pretty confidence that if something goes wrong with the smartboard, I can fix it." (Anita, Class teacher)
	"It's all about the first things that were in the classes – smartboards – it's probably the thing we've been using the longest" (Claire, Class teacher)
Facilitators	
"Common ground"	"In my classroom technology acts as, kind of like a common ground, so for example all three of my kids play Minecraft, and they'll come in and they'll talk to each other about what they've done on Minecraft. So, I suppose [Minecraft] acts as a… commonality that they can talk to each other about it." (Andrew, Class teacher)
Structured interactions	"When we go to [the interactive sensory room] we do take turns, because the types of games that we're playing don't work when there's four or five people trying to join in, so we do take turns. But the other young people will be cheering on the person that's playing the game…" (Claire, Class teacher)
	"The Wii was a big hit! And it was a very sociable activity because it, you probably were competing against people." (Karen, Class teacher)
	"The difference between the smart table and the smart board, is that the smart-table is multi-person, they can be touching it at the same time. Whereas the smartboard is definitely turn-taking, isn't it? …It's managed differently because you would have everybody sitting, and then "it's your turn," whereas the smart table is more of a "free-for-all" you know, like people just get in about it" (Alison, Class teacher)
	"When we're at the whiteboard they do have space, and they're not usually next to the other person, they usually are kind of back or forward – separated a bit. But I'm wondering if it's smaller, they will have to be kinda closer to look…" (Laura, Deputy Head)
Autism-specific concerns	
Fixations	"The children can get quite fixated if they're using it as a leisure activity, and they don't want to let their iPad go… it can cause quite a lot of anxiety" (Karen, Class teacher)
	"We've gone back to putting the technology away when they're not using it, and you can see they're kind of itching to get it back" (Claire, Class teacher)
Social difficulties	"[the] concept of going home and talking to these… people [strangers] online. We've had to do some work with [students] about y'know, people around [online]. The safety of that – 'do you know who you're talking to?'" (Laura, Deputy Head)

Illustrative quotes have been edited to facilitate easier reading, as indicated by […].

Staff shared their concerns about children becoming 'fixated' on technology and having difficulty transitioning from technology-based activities to other activities, particularly when technology activities involved screens. Staff also discussed how social difficulties could lead to vulnerability whilst using technology, for example, on social media, similar to the rich-get-richer hypothesis which has been described previously. There was also a concern that some autistic children were so motivated by technologies they became less engaged with the social and classroom environment around them, and hence that technologies could offer a potential 'escape' from social interactions for some students. Practitioners reported that for some children this escapism through technology was necessary for re-engagement in the classroom later, but for other children it was challenging to transfer from digital to non-digital activities.

3.5 Discussion

This chapter aimed to explore how practitioners use technology when working with autistic students, and to gather practitioners' views about technology-facilitated interactions. The findings from the online survey show that technology is most commonly used to support technology-mediated learning and communication, but less commonly used to support peer interactions and technology-facilitated interactions. The survey also showed that practitioners had positive perceptions of technology use, and that while attitudes did vary this was not linked to particular demographic information or factors which were expected to predict technology attitudes. In focus groups, practitioners identified a number of factors which influenced autistic children's social interactions while using technology, and thematic analysis found that these were linked to children's interests and developmental profiles, and particular design affordances of technologies. The results of the survey and focus group study will now be discussed in terms of broader literature on autism, technology, education and social interaction, and future directions for the remaining thesis studies will be presented.

3.5.1 **The use of technology in autism education**

The survey findings on what and how technology is used within education settings reflects the applications which have been most studied in research literature (Bölte et al., 2010; Grynszpan et al., 2014; Zervogianni et al., 2020). That is, the most popular devices that practitioners reported were tablets, computers, and interactive whiteboards, and the majority of studies which have looked at autism and educational technology have focused on these devices (Grynszpan et al., 2014). Furthermore, practitioners most commonly reported using technology to teach children academic and communication skills, which reflect the two most common areas in which research aims to understand technology's applications to support autistic children (Bölte et al., 2010; Fletcher-Watson, 2014; Grynszpan et al., 2014). However, what is surprising is that more recently published research has tended to focus on newer technological innovations, such as tangibles, robotics, and virtual reality devices (Good et al., 2016), while in this survey practitioners rarely reported using these devices. There are a number of potential explanations for this, such as these devices not being widely available yet to practitioners, not being accessible to schools in terms of price or facilities, or practitioners not being confident in using these newer technologies (King et al., 2017), which was also reflected in the focus group data. In terms of future directions and how to move the evidence base for technologies forward, there are two contrasting implications. The first is that there needs to be continued evaluation of newer technologies such as tangibles and robotics, so that when these do become more widely available to services there is an evidence base upon which to implement them and train practitioners (Fletcher-Watson, 2014; Parsons et al., 2017; Zervogianni et al., 2020). But on the other hand, it is also important for research to directly inform current practices, which means conducting evaluations on technologies which are available to practitioners on the ground (King et al., 2017).

It does not seem a surprising finding that learning applications are the most frequently reported use of technology within education contexts, but what is interesting is that, in focus groups, practitioners were able to give many examples of the ways in which technology could support social interaction, outwith direct skills-based or teaching opportunities. In other words, when probed about “naturalistic” interactions when using technology, practitioners could identify and describe examples, even though according to the survey this is not the way that technology is most commonly used. It should be noted that the practitioners who completed the survey were not the same practitioners who participated in the focus groups, but it is still an interesting finding given that the survey data was from over 100 educational practitioners, and the focus group included a much smaller sample. This finding highlights the potential benefits of having teachers and practitioners reflect on their uses of technology and could contribute to more constructive and balanced discussions about the benefits and limitations of technology use within a classroom setting.

3.5.2 **Autism-specific technology concerns**

As discussed in chapter 1, the concerns that people have about technology use in autistic children map directly onto the behavioural characteristics of autism. The repetitive behaviours in autism have been linked to over-use of technology and particularly screen-based devices, and it is thought that the social difficulties associated with autism will be exacerbated through the use of digital technologies, and opportunities for social learning be displaced by autistic children using technology (Mazurek et al., 2012; Ramdoss, Lang, et al., 2011). The findings of both the survey and focus groups reinforce this connection between diagnostic criteria and concerns about technology (Ramdoss, Lang, et al., 2011). Previous work has shown that severity of autistic traits is associated with more reports of “problematic” technology use in parental surveys (Engelhardt & Mazurek, 2014), however, the current study has failed to find a link between demographics and technology use, consistent with more recent parental survey data (Laurie, Warreyn, et al., 2019). Moving forward, it actually seems disingenuous to pathologize or disregard negative attitudes to technology use, as these are genuine concerns which people have, and, to facilitate better translation into practice, research should be responsive to the community that it serves. Within a participatory research movement, it seems like more progression could be made by partnering with autistic people and with practitioners to understand the potential opportunities that technology could provide, and contribute to a constructive evidence-base for practitioners and autistic people (Parsons et al., 2019; Zervogianni et al., 2020).

3.5.3 **Practitioner attitudes to autistic children's use of technology**

Overall, according to Figure 3.2, practitioners generally had positive views towards using technology to support autistic students in school. They said that they did not feel cautious or worried about using technology, and that technology had the potential to provide beneficial learning experiences for autistic children. Despite what has been reported in other studies (Alarcon-Licona & Loke, 2017; King et al., 2014), the practitioners in this survey were largely not concerned about autistic children "getting stuck on" using technology. In the current study, concerns were reported about time that autistic children spent using technology, and there was a more varied opinion on whether technology was beneficial for learning, despite practitioners also saying that technology could provide learning opportunities. This potentially highlights a difference between what people think about technology, and how they use it in the classroom, which has been highlighted in other work showing mixed perspectives on the benefits of technology in education settings with autistic children (King et al., 2017).

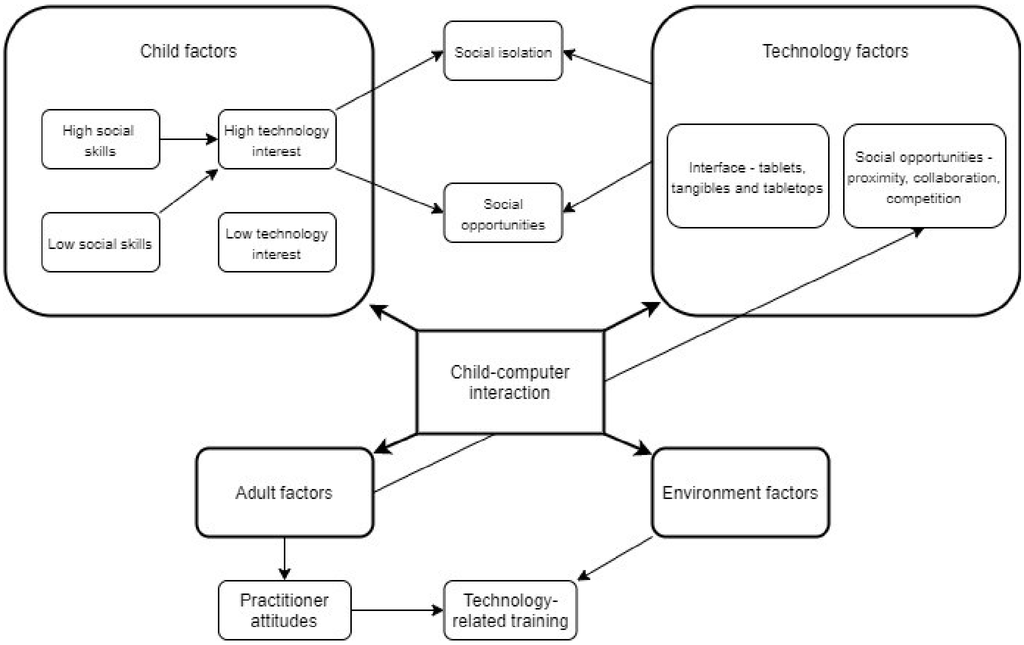
3.5.4 **Factors which influence autistic children's social interactions**

Looking back to the model of child-computer interaction initially proposed by Manches (2018), we can now add the following, autism-specific, considerations about how children interact with other people when using technologies, as illustrated in Figure

3.5. In the focus group study, practitioners highlighted that children's own interests and social skills could influence if and how they interacted with other people when they used technology. Practitioners also compared different technological interfaces and environments, such as large- and small-scale screen-based devices, and environments which foster friendly competition, and talked about how these particular features may provide social opportunities for the students they worked with (see Table 3.7 on page 79).

In particular, there seems to be relationships between the different 'factors' which may influence child-computer interaction. For instance, in previous work, practitioners suggested that they would feel more confident using technology if they had more training and resources, and that this might change their attitudes towards technology use. While this relationship was not found to be significant in the survey study (see Table 3.5), it still highlights that these different factors, i.e. practitioners personal attitudes about technology use and the training and support provided in services, might collectively shape perceptions of technology in education. A further relationship is found between child factors and technology factors, which is more complex and difficult to untangle. According to practitioners, autistic children who are highly engaged and interested in technology may use this to engage in social opportunities with peers, but other autistic children who are highly interested in technology may become less motivated to engage with others, and use that technology time to engage in solitary play activities. Similarly, the design and interface of particular technologies may either positively or negatively influence the way that children interact with other people, which may be mediated by children's own levels of social skill and technological motivation.

Figure 3.5: Practitioners perspectives on technology-facilitated interaction in autistic children



Bold lines indicate sections which were present in the initial model proposed by Manches (2018). New highlights, derived from the study with practitioners, are included in the thinner lines.

3.5.5 **Implications for the thesis**

This chapter aimed to explore how technology is used in educational practice to support autistic children, and to understand the school context in which future research in this thesis would take place. The first highlight, from the focus group findings, is further evidence that technology can facilitate meaningful social interaction in autistic children. A handful of previous studies have observed autistic children playing freely with digital toys and assessed a ‘naturalistic’ influence of technology on social behaviour (Farr & Yuill, 2012; Francis et al., 2019; Hourcade et al., 2013), and to create an evidence base from which to explore this further is a strength, for the rest of the work within this thesis. For instance, technologies which encouraged children to be in closer physical proximity were said, for some children, to create social opportunities. Practitioners could identify opportunities for turn-taking between children on certain technologies or digital activities, even when technology was designed to be played individually (i.e. single-player). Children’s own motivations and social development played a key role in the extent to which these “scaffolds” were effective, but these could be further tested and characterised by measuring the effect of these individual technology features. The focus group results provide further evidence that constraining collaboration in digital settings can encourage social interaction and potentially social learning, particularly for children who are highly interested in using technology. The extent to which collaboration is constrained across different technologies, and whether effects are different when collaboration is mediated by technology or by an adult, are potential future directions to explore (and will be, in chapters 6 and 7 of this thesis).

The second key finding is the role of children’s personal interest in technologies and how this influences their social interactions while using technology. On the one hand, some children who are highly engaged in technology may choose to share with others their positive experiences, for instance, developing friendships with other children through enjoying Minecraft, or sharing achievements when using technology. But other children, according to practitioners, may be highly motivated by technology but not engage in social interactions, and use technology as a “social break” from others, or be invested in their own personal experiences of technology. These individual differences are certainly worthwhile to explore, as they would potentially be useful for practitioners to better match technologies and support to the children they support, and also potentially lead to future avenues of personalised technology and designs (Zervogianni et al., 2020).

4 The effect of technological interface and classroom environment on autistic children's social play when using technology

4.1 Chapter acknowledgements

I am grateful to Rebecca Stewart for conducting the secondary coding of social play in this chapter.

4.2 Introduction

The previous chapter explored the use of technology in educational settings and gathered practitioners' perspectives on how technology can influence social interaction in autistic children. Practitioners generally have positive attitudes towards using technology in education settings, and shared examples of how technology can facilitate social interaction in autistic children, including through shared interests with peers and mediating joint engagement (see Table 3.7 on page 79). Focus groups with practitioners revealed insights into potential factors which mediate social interaction when autistic children use digital technologies, including children's interest in technology and their social interaction style (see Figure 3.5 on page 85). For instance, children who are highly interested in technology and have good social skills could use their interest to mediate and form friendships with students, whereas children who have low interest in technology would perhaps not interact in the same ways. The current study will further explore the influence of technological software, interface, and environment on autistic children's social interactions while using digital technology.

4.2.1 **Technological interfaces and social interaction**

There is a widespread concern that screen-based technologies, and 'screen time', prevent or inhibit social interaction in young children. It is believed that as children spend more time using screens, they will spend less time engaging in social interaction (Przybylski & Weinstein, 2019). While this belief is largely unsupported by the literature (see section 1.2.2 on page 7), it still remains a concern among parents and educators (Livingstone & Franklin, 2018; Przybylski et al., 2019). However, there is a large body of human-computer interaction research which has sought to design specific screen-based devices or software which promote social interaction in autistic (Brosnan et al., 2019; Ramdoss et al., 2012) and non-autistic children (Cole & Stanton, 2003; Mandryk et al., 2001; Parsons & Karakosta, 2019). For instance, devices such as smartphones and tablets, can encourage social interaction by virtue of children having to be closer together to share engagement with the small screen (see Table 3.7 on page 79).

Arguments have been made in favour of tangible objects in promoting social interaction, since these technologies can be physically manipulated and easily shared with others (Bekker et al., 2010, 2014). Tangibles often have an "active part", and this is thought to encourage autistic children to engage in more socially interactive play with peers (Farr, Yuill, & Raffle, 2010; Francis et al., 2019). Combining screen and tangible interfaces could potentially encourage more social interaction by merging the social benefits of screen-based and tangible toys, and by encouraging children to sit together but also allow for tangible interactions with physical objects (Horn et al., 2012). In comparing multiple technology hardware, this study will explore how different interfaces shape children's social interactions, and whether a particular interface promotes more social interaction in autistic children.

4.2.2 **Optimal digital environments for fostering social interaction and play**

According to practitioners, features of the technology and the child's own interests and skill profile can influence social interaction in digital settings. Autistic children are thought to have high levels of interest in technology, which can be leveraged to support interaction and communication in digital settings (Fletcher-Watson, 2014;

Hourcade et al., 2013). Furthermore, according to practitioners, specific environmental features such as encouraged collaboration and competition, as well as enforced proximity, can also promote social interaction in some autistic children, especially those who have high levels of interest in technology. This complex interaction is illustrated in Figure 3.5 on page 85, where practitioners noted how characteristics of the child engage with features of technologies and can produce different social outcomes from digital activities. It is therefore possible that there is an 'optimal' environment which encourages social interaction for some autistic children, for instance, engaging in children's interests but also scaffolding interaction in a motivating way for the child. Understanding how practitioners can provide social opportunities is an important priority for education research (Parsons & Kasari, 2013), and previous work has suggested that technology could be a promising way to do so (see Table 3.7 on page 79).

4.2.3 **Design-based research**

Design-based research is a methodological approach within the learning sciences to address "complex problems in authentic settings" (Cobb et al., 2003), combining research theory and practical implementation to understand how best to support learning (Anderson & Shattuck, 2012; Barab & Squire, 2004). Design-based research is iterative, collaborative, and seeks to understand how best to implement new technologies or materials in learning environments by cyclically theorizing, implementing, and measuring the impact of changing environments. Design-based approaches are common practice within participatory design of new technologies with autistic children (Fletcher-Watson, Pain, et al., 2016; Frauenberger et al., 2019; Porayska-Pomsta et al., 2012). Previous work has shown that collaboration with practitioners in the design of a new playground environment promoted social engagement and collaborative play in the autistic children they worked with (Castro et al., 2017). As a result of design-based methodologies, research becomes grounded within practice, and seeks to identify what practitioners can do within their own resources and settings to encourage collaborative play. Design-based approaches therefore address the 'artificiality' of lab-based experiments and studies of human-computer interaction, by exploring a number of simultaneous variables on social interaction, rather than "designing out"[1] potential factors and contexts which may foster collaboration.

4.2.4 **Research questions**

The current study aimed to explore how different technologies and environments influence autistic children's social play. It addresses the following research questions:

- How does the profile of the child influence social interaction within digital environments?
- Do different technologies, including interfaces and software, produce different social interactions in autistic children? Are some technologies, such as tangibles or tangible-screens, more encouraging of social interaction?
- How can practitioners facilitate social interaction while autistic children use technologies, and what strategies can they use in classroom settings to encourage social play with technology?

4.3 Methodology

4.3.1 **Participants**

Participants were four autistic children with learning disabilities who were recruited from a single class at a local school for children with additional support needs. This particular school is a school for children with a range of additional support needs, including children on the autism spectrum and children with other neurodevelopmental conditions. They were known to the researcher as a school who had expressed an interest research studies, and had previously taken part in research

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[1] Manches (2020), from personal communication with Prof. Shaaron Ainsworth, University of Nottingham.

at the University of Edinburgh, including the trial of the FindMe iPad application (Fletcher-Watson, Petrou, et al., 2016). The school were situated within a relatively deprived area of the city, with many students receiving free school meals, and from international backgrounds.

In the current study, the participants' class teacher completed a range of standardised assessments to gather information on each child's social and communication abilities (see Table 1). Descriptions of the children's interaction profile and technology preferences are provided below. All participants' names, throughout the current and the following chapters, are pseudonyms.

4.3.1.1 **Harry**

Harry is eleven years old and is a fluent speaker with a mild speech impediment. According to his teacher, Harry does not show a lot of interest in technology but enjoys listening to music on the class iPads. Harry spent most of his time in the research study playing with various Osmo games, but only appeared interested in doing so when a teacher or another staff member was present. Harry was usually observed interacting with members of staff and often sought them out to celebrate achievements, to ask for help, or to initiate play with them. Harry and Laura had the closest friendship of all participants and they would often choose to play together, but were both also highly socially motivated towards classroom staff.

4.3.1.2 **Jack**

Jack is eight years old and is non-verbal and currently receiving support to use a non-digital picture-based communication system. His teacher reported that Jack often enjoys playing with iPads, and particularly for making music and playing musical games. Jack spent the large majority of his time during the sessions playing with Code-A-Pillar on his own and seemed most engaged with the lights and the music that Code-A-Pillar made. Jack would very occasionally play around or near others and observe what they were doing, but for the most part seemed to be content in solitary play.

4.3.1.3 **Laura**

Laura is eight years old and is a fluent speaker with a moderate speech impediment. Her teacher said that Laura enjoys playing with the classroom iPads and listening to music on them and using the interactive whiteboard for storytelling. Laura spent most of her time playing with Osmo games and with the Toca Tea Party™ iPad app, but in general did not seem particularly interested in technology. She often requested to do other activities (e.g. play outside, arts and crafts), and often would leave technology sessions with Harry to do these activities. Laura would choose to play with Harry, particularly on Osmo, but would also happily play by herself or play with a member of staff.

4.3.1.4 **Oliver**

Oliver is ten years old, and currently uses gesture-based communication, although also receives support from an augmented and alternative communication app on an iPad. Oliver nearly always carries this device but was not observed using it during the research sessions. According to his teacher, Oliver enjoys taking photos and videos using a digital camera and iPads, and enjoys playing some iPad apps and games, and uses the computer to type and make sentences. Oliver often enjoyed and requested to play the Osmo games during the sessions, particularly Numbers and Words. Oliver rarely engaged in play with peers and was usually always accompanied and supported by an adult during play.

Table 4.1: Participants' total scores on social and adaptive measures

Participant (gender, age [years:months])	**SRS-total *t* scores**	**VABS ABC score**	**WSQ Category**
Harry (M), 11:5	71 (moderate)	59 (mild)	Active but odd
Jack (M), 8:10	89 (severe)	39 (moderate)	Aloof
Laura (F), 8:10	68 (moderate)	65 (mild)	Active but odd
Oliver (M), 10:1	84 (severe)	36 (moderate)	Aloof

SRS = Social Responsiveness Scale-2 Teacher version (Constantino et al., 2007). Ratings in brackets denote level of difficulty with social interaction and communication.
VABS = Vineland Adaptive Behaviour Scales III Teacher Version (Sparrow, 2011). Adaptive Behaviour Composite (ABC) scores represent adaptive functioning (relative to chronological age) where the normative mean is 100 (*SD* = 15). Lower scores indicate more difficulties with adaptive behaviours, and ratings in brackets denotes severity of difficulties in adaptive functioning.
WSQ = Wing's Subgroups Questionnaire (Castelloe & Dawson, 1993).Subgroup categorisation of autistic children based on social interaction profiles and behaviours.

4.3.2 **Technology**

The technology used in this study was selected in part from the results of the previous chapter, and through iterative discussions between the research team and the host class teacher. As a result of the previous chapters' findings, the research aims at this point had shifted to investigating the influence of different technological interfaces and software on autistic children's social interactions. A shortlist of different technologies which would allow for investigation of the effect of technological interface, particularly screen, tangible, and combined interfaces, were chosen within the research team, and the host class teacher made the final decision on which technologies they thought their class would be most interested in using. On the teachers' part, important considerations were that technologies mapped onto current curriculum targets for students (e.g. numeracy, literacy), and would be of interest to the children. The class teacher wanted to have the study include iPads, because these were devices children were most familiar with in class. The shortlist of technologies, and notes from the meetings with the class teacher, are included in Appendix 2: Technology shortlists for chapters 4 - 7, on page 209).

4.3.2.1 **Tablet: iPads**

iPad tablets (Apple Inc. ®, 2nd generation, with a 9.7" display, released in 2011) were loaded with pre-selected educational apps and games (see Appendix 2: Technology shortlists for chapters 4 - 7, on page 209). Initially, apps included a variety of mainstream designs selected from top-rated apps on the Apple Store™, and apps designed for autistic children selected from apps rated highly from community reports (including researchers and families) on www.beta-project.org/en/home/ and www.dart.ed.ac.uk. A list of these apps is available in Appendix 2: Technology shortlists for chapters 4 - 7, on page 209). After the first two sessions, the apps available on the iPads were reduced so that the most frequently used apps could be studied in more detail. These selected apps were chosen through teacher conversations and with intentional selection for different features of software to explore social interaction within a naturalistic and facilitated way (as detailed in Appendix 2). Selected iPads apps are described in Table 4.2.

4.3.2.2 **Tangible: Osmo**

Osmo™ (1st version, released in 2014) is a series of educational games which are played in an augmented (physical) space, created by a mirror over the iPad camera (see Table 4.3 and Figure 4.1 illustrations). The Osmo Genius Kit aims to promote Science, Technology, Engineering and Mathematics learning in children aged 5-12 years, and includes five games: Tangram, Words, Numbers, Masterpiece and Newton (see Table 4.2 and www.playosmo.com for more information). Each Osmo game either contains physical pieces which are then placed into an augmented play area in front of the iPad (i.e. Tangram, Words, Numbers), or requires the player to use a pen and paper within the augmented space to interact with the screen (i.e. Masterpiece, Newton).

4.3.2.3 **Robotic: Code-A-Pillar**

Code-A-Pillar™ by Fisher Price Think & Learn™ is a musical-construction robotic toy aimed at children aged 3-6 years old, which is designed to teach children the basics of coding (see Figure 4.1). The Code-A-Pillar is built by attaching the head ("active part") to different body pieces (via USB ports), with coloured symbols signifying a different command (e.g. forward, left turn, play music). Once constructed, commands are executed when the button on Code-A-Pillar's head is pressed, making Code-A-Pillar enact accordingly to the programmed commands. While moving, Code-A-Pillar plays music and the command that is currently being actioned (E.g. forward, play music) will light up. Code-A-Pillar's eyes also light up and change colour through the command sequence.

Table 4.2: Selected iPad apps and descriptions

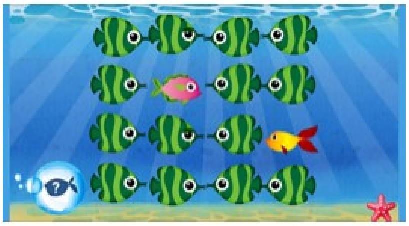
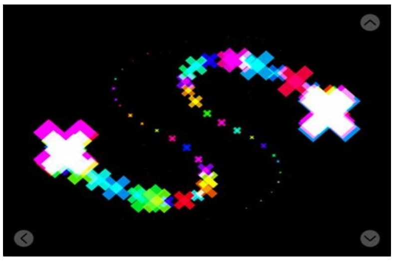
iPad apps		
App information	**Screenshot**	**Description**
Balloon Pop by Joe Scrivens, version 1.3 (release 2015), costs 99p.		A simple game, without written instructions, where the 'task' is to pop balloons by touching the screen. The description (on the Apple Store) claims that it can support individuals with attention or fine-motor difficulties.
Fish School HD by Duck Moose, version 2.1 (release 2016), free		A series of educational games with an aquatic theme. Games are designed to teach users numbers, letters, shapes, matching by exploring the underwater world.
ReacTickles Magic by the Centre for Applied Research in Inclusive Arts and Design (CARIAD), version 1.0 (release 2012), free		Users explore a "magical world" in app, through touch gestures, including specific lights, patterns, and displays. Has received a 'bronze' rating on BETA and positive reviews on DART website. Designed through participatory research with autistic children (Boyd et al., 2015).
Toca Tea Party by Toca Boca AB, version 1.0.5 (release 2013), costs £3.99.		A game where user(s) host a tea party, and have to 'eat cake', 'look after hosts' and 'wash the dishes' afterwards. Has received a 'bronze' rating on BETA and positive reviews on DART website.

Table 4.3: Selected Osmo apps and descriptions

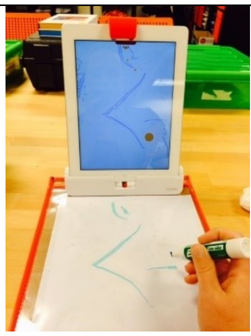
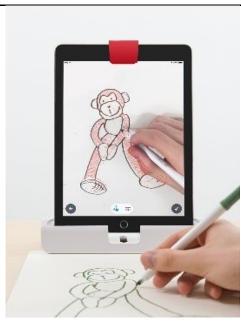
Osmo apps		
Tangram		Players arrange different shapes of tiles into patterns shown on the screen.
Words		Players use letter tiles to either spell out words, or ‘add’ missing letters (e.g. N in this example photo).
Numbers		Players use ‘domino’ tiles to match with the numbers on the screen and score points in a ‘fishing-style’ game.
Newton		Players physically draw (using pen and paper) a maze or circuit for an on-screen ball to reach its target
Masterpiece		Players physically draw on paper a copy from a picture shown on screen. The screen mirrors the players’ hand so they can use it as a kind of ‘tracing’ activity.

Figure 4.1: Examples of play on Osmo and Code-A-Pillar

A: Osmo B: Code-A-Pillar

4.3.3 **Procedure**

4.3.3.1 **Session structure**

The sessions took place in school during students' timetabled 'free play.' Children were allowed to play with the technologies described above, or to participate in an alternative activity as they wished. As mentioned above, Harry and Laura often chose to spend part of the sessions with the digital toys, and other parts of the session in other activities, particularly playing outside in the playground. In addition to student absences, this means that the available data for each child varies widely, both in terms of number of sessions attending and in the amount of observable footage available for each child on each technology. Since children were given completely free choice to attend and to participate, some chose to play on their 'preferred' technologies and others played with more of a variety of digital and non-digital toys. This is summarised in Figure 4.2.

Sessions were usually held twice a week, except for school in-service days (e.g. during week 5 only one observation took place, so this observation was merged within iteration 1). The researcher attended four unrecorded classroom observations before data collection, recording, and design iterations started, to create familiarity between the researcher and the child participants. These sessions were often during play where sometimes children played with the interactive whiteboard in class, used the school computers and tablets, or sometimes did non-digital activities. These familiarisation sessions were also an opportunity for the researcher to discuss with staff their experience of using technology in the classroom, and so that staff understood the procedure for design-based research. An outline of the session structure and design iterations is provided in Table 4.4.

Observations were split over two locations within the school environment, as per the teachers' request to prevent parts going missing and children having more physical and personal space to play. The Code-A-Pillars and the iPads were used in the classroom area, while the Osmo kits were set up on tables directly outside of the classroom in the school hallway area. In both locations, one or two static video cameras were placed in a corner, out of the children's direct way. In total, the study observed the use of four iPads, two Code-A-Pillars, and two Osmo kits.

4.3.3.2 **Participant consent**

Written consent was gathered from the participants' parents and the participating school staff via standardised research consent forms. The whole class (*n* = 9) were invited to participate. At this point, one child's parents wrote back and told the team they would rather not have their child participate in the research study due to their concerns about their child's technology use. The remaining parents of the classroom pupils did not reply to the research invitation, leading to *n* = 4 participating students. One additional participant consented but was excluded from the research analysis as they did not have a diagnosis of autism.

A bespoke consent procedure was developed in collaboration with the staff team to ensure that children's right to participate in the research was respected. The researcher and the staff team devised personal 'consent interviews' with each participating child, which explained the study to the child in their preferred communication medium. The skeleton of which these personalised plans were derived from is included in Appendix 3: Participant consent procedure, on page 213). At each session, children were informed that there would be video cameras present in the classroom, and asked permission for the researcher and the teacher to watch these videos. Children were told that they could play with the toys that the researcher had brought that day, or that they could go and play with something else if they wished. If they wanted to play with the toys, but not have video recorded, they were set up behind the line of camera, and their play was not analysed from video footage later. Information about each session and available data is summarised in Table 4.4 and Appendix 6.

Table 4.4: Overview of session structure and practitioner iterations

Week number	Observation number	Technologies used	Design iteration	Practitioner discussions	Description
1	0	Standard classroom	-	-	-
	0		-	-	-
2	0	Standard classroom	-	-	-
	0		-	-	-
3	1	iPads	Baseline	-	Children's typical play with familiar technologies
	2				
4	3	iPads, Osmo, Code-A-Pillar	1	1	Introduce new technologies (Osmo and Code-A-Pillar)
	4				
5	5				
6	6	iPads, Osmo, Code-A-Pillar	2	2	Move classroom desks closer together
	7				
7	8	iPads, Osmo, Code-A-Pillar	3	Debrief	Practitioners direct play with peers
	9				

4.3.3.3 **Design-based procedure**

Design-based research is an iterative and collaborative process, where future sessions are designed after observing initial and previous sessions. In this study, iterations are split into four phases: baseline, and three subsequent iterations as described in Table 4.4. The baseline and first iteration were planned by the research team, to gather general data on children's technology use and preferences, and to explore whether introducing new technologies would change children's social behaviours. The second and third iterations were decided on by discussions between the researcher and the staff team, who were participating in the study. These discussions took place immediately before the iteration was implemented.

At these discussions, the researcher asked practitioners to share their own insights and observations into children's social interactions and play behaviour during the previous session(s), and the researcher also discussed with staff their own observations on specific moments of interactions. The researcher's insights that were shared at these meetings were not based on analysis of video, but from notes gathered during the sessions. Together, the researcher and the staff team decided on a specific new thing that they could do to promote children's social play further. Questions asked at these sessions included:

- How did the children play with the technologies, and what did they enjoy the most?
- Was that a 'typical' day for that child, or did they do something new or unusual?
- Did you see any 'nice moments' of social interaction by the children?
- Is there anything you think you could do to encourage children to interact more?

On the second iteration, it was decided that the tables in the classroom could be moved closer together to create 'shared spaces' for children to use technology, and so they could more clearly see what others were doing and maybe want to join in. On the third iteration, it was decided that practitioners could explicitly direct children's play to peers, by explicitly scaffolding peer interactions (e.g. "shall we see what they are doing?" "why don't you both share or take turns?"). It was intended for each of these discussions to be audio recorded for further analysis, but due to technical difficulties only the first discussion was correctly recorded.

4.3.4 **Video sampling and coding**

The corpus of video footage collected during the project was filtered to a manageable level for using the pre-selected measure of social play, which will be described below. Analysis of the complete footage, using a different measure of social interaction, is reported in the following thesis chapter (chapter 5). Each video recording lasted on average 25-30 minutes, and the decision was made to “snip” parts of the footage for analysis of children’s play to make it more manageable for video analysis. The windows between 5-10 minutes and 15-20 minutes of each video were selected, to maximise the chances that children were ‘settled into’ the play session, and to seek a range of behaviours (i.e. not from the same continuous video sample). This may have potentially biased the subsequent analysis, by attempting to capture a segment of the session which was most relevant for the research question. Other parts of the session, such as the immediate beginning or end of a session, may have also provided important reference context, such as children either being excited about technology being set up, being reluctant to finish a session, or other moments of interaction. A full breakdown of the video snipping and the amounts of footage in which this analysis chapter is based off is described in Appendix 6 on page 217). The total footage analysed in this chapter included 31 video clips, each lasting 5 minutes, yielding 155 minutes (nearly 2.5 hours) of video footage.

All video coding was conducted using ELAN video annotation software (Max Plank Institute for Psycholinguistics, 2016). Each participants’ social play was rated using the Peer Play Scale developed by Howes (1988), and the version used in this study is included in Appendix 5: Peer Play Scale by Howes & Matheson (1992) on page 216. The Peer Play Scale includes eight levels of social play; non-play, adult interaction, solitary, parallel, parallel-aware, simple social, complementary & reciprocal, and social-pretend. Play was only coded when children were using or referring to the particular technologies of interest (e.g. with an iPad or Osmo) and was coded as `NA` when children were referring to other toys or activities.

Play was categorised using interval coding, where the video data was parsed into ten-second windows and one category of play, and other relevant variables (see Table 4.5 for a description of the ELAN tier structure), was assigned to each ten-second window. For a 5-minute video, this yielded a maximum of 30 observation windows per participant per video clip (6 windows per minute, x 5 minutes / video clip). When multiple participants were visible in the video, separate tiers were created and labelled using participant codes. Play was always coded at the level of the participant, so two or more children could be visible to the camera but engaged in either the same level of play (e.g. parallel or social play with each other), or in different levels of play (e.g. one child in parallel play with peer, but other child engaged in social play with adult). The category of play allocated to each ten second segment was chosen based on the whole ten second segment – either the category which was most visible during the segment (e.g. in more than half of the segment), or where multiple categories were present equally, the highest level of play observed was chosen for that segment. When children were playing with both adults and peers at the same time, the play with peer took precedent and was coded (e.g. parallel play with both and adult and a peer would have been coded as parallel with peer, parallel play with either an adult or a peer would have been coded as appropriate). When no relevant data was available, each tier was coded with an `NA` and these data were filtered from subsequent analysis.

Table 4.5: ELAN tier structure and definitions

Name	Description
Peer Play Scale category	The acronym for the level of play observed within the ten second window (e.g. Solitary play = ST, parallel play = PP, as described in Appendix 5).
Play partner	Included levels "none" (for ST and NP), "adult" and "peer". Adult was always coded for "adult interaction" level, where children were talking to adults but not engaged in playful behaviours, or where conversation was not relevant to digital play. Both "adult" and "peer" levels could be applied to all other categories of play except ST.
Technology	Categorised the technology child was using at the time, both in terms of interface and app (e.g. "iPad (Toca Tea Party)", "Osmo (Numbers)", Code-A-Pillar). When the app was not visible from the data footage, "unknown" was put in brackets next to the interface.

4.3.5 **Analysis methods**

From ELAN, data was exported into .csv format and then into RStudio for analysis (RStudio Team, 2016). Missing data, due to children being absent or not visible to the camera, were removed from the dataset. Due to the variance in available data for each child, both in terms of overall data and for data on each respective technology, analysis is undertaken on a case by case basis, and data reported in terms of absolute values (e.g. number of intervals and equivalent amounts of time, as well as in terms of percentage values, either for particular participants or technologies).

First, the frequency of observations for each play category, in each condition (i.e. interface / technology, and play partner), was tallied within the dataset. These observations were then converted into an equivalent time in minutes using the formula: $\frac{(n \times 10)}{60}$, where *n* is the frequency count for each code, *10 converts this into number of seconds, and division by 60 transposes this into minutes. The frequency unit, *n*, is used to calculate proportions of data based on total *n* within a given particular category, such as proportion of observations for different participants and for different technological interfaces. Due to the exploratory nature of the study, as well as the small and highly variable dataset, results are presented in tables and figures with both absolute and proportionate values where appropriate.

First, the total time and proportion of time that children spent engaged in each play state, on each interface, was calculated. The children all spent different amounts of time engaging with each technology, as well as each play state. Next, for the whole dataset, amount of time spent in each play state on each interface is presented in Table 4.6, and percentages calculated for both time spent in each play state, each interface, and play state by interface respectively. This provides opportunity to explore which types of play states were most frequently observed on each interface, as well as a sense of how this relates to the proportion of observations across play states and interfaces. Observations from each iPad and Osmo app are visualised, so that patterns can be identified across the different apps available. And finally, the frequency and time of play is calculated for each participant across sessions and iterations, to explore how the changing environment influenced children's social play.

4.3.5.1 **Second coding of social play**

A random sample of 8 video clips (comprising of 22% of the 5-minute video clips) were second coded by an independent rater, who was trained to use the Peer Play Scale and unfamiliar with the study aims and dataset. Training on the Peer Play Scale was done by the lead researcher, who conducted the full coding of the dataset using this measure. Videos were randomly selected from the database, but representation of all participants, technologies, and timepoints (i.e. iterations) were manually checked. To achieve reliability on the categories of play, the second coder was only asked to code the Peer Play Scale category, meaning that all play with adults in this instance was coded as "adult interaction", and scale reliability was assessed only on data which contained peer play. The clips were checked to ensure that peer play was appropriately represented in the video data. The mean percentage of agreement on the Peer Play Scale was 78.03% (at the level of 10-second windows), and a Cohen's Kappa of .78 indicated good agreement between both raters.

4.4 Results

4.4.1 **Participant variance in play and use of technologies**

The total time that children spent on each technological interface and in each state of social play is presented in Figure 4.2. Proportion for each play state was calculated at the level of participant and play partner, meaning that, for instance, proportions represent a participants' peer play on Code-A-Pillar, a participants' play with adults on Code-A-Pillar, and a participants' non-social play on Code-A-Pillar respectively. Figure 4.2 highlights that each child spent a different amount of time on each technological interface and in each state of play – i.e. most of Jack's play was solitary, and he spent most of the time playing with Code-A-Pillar. On the other hand, Laura and Harry spent most of their time engaged in social play at various levels, and also spent more time playing with Osmo than the other participants.

Figure 4.2: Total and proportion play on each interface by each participant

4.4.2 **Effect of technological interface and software on social play**

Table 4.6 shows the amount of social play observed, for each play category and each partner type, across each technological interface (e.g. across all observations and apps for iPad, Osmo, and Code-A-Pillar). Results have been reported as raw values (e.g. frequency of 10-second windows), equivalent length of time (in minutes), and as a percentage of the total available data on the particular interface.

Participants spent the most time in nearly every play state on the iPad, reflecting that the most observation data is available when children were using iPads (i.e. in terms of both number of sessions where footage is available, and in children's choices to play with iPads over the other technologies). In terms of peer play, the most frequently observed level was parallel peer play, and this was mostly seen on the iPad. Children also showed the most social play (6.8 minutes, 61.19% of total social play with peers), and complementary play with peers (1.1 minutes, 87.5% of total complementary play with peers) on the iPad, and the most parallel-aware play with peers (2.6 minutes, 59.25% of total parallel-aware play with peers) on the Code-A-Pillar interface. While the most common type of play observed in the whole dataset was simple social play with adults, Table 4.6 shows that most of this was observed when children used the Osmo interface.

Figure 4.3 shows the observed play on each iPad and Osmo app across all sessions, and further highlights that the majority of play on Osmo was children playing with adults, although the most social play with peers on Osmo apps were on the Numbers and Tangram apps. Across the iPad apps, the most play with peers (when the app is known) is on Toca Tea Party and is also where the most complementary and reciprocal play with peers observed within the dataset. Other apps where children were observed playing with peers included Fish School HD and Reactickles Magic.

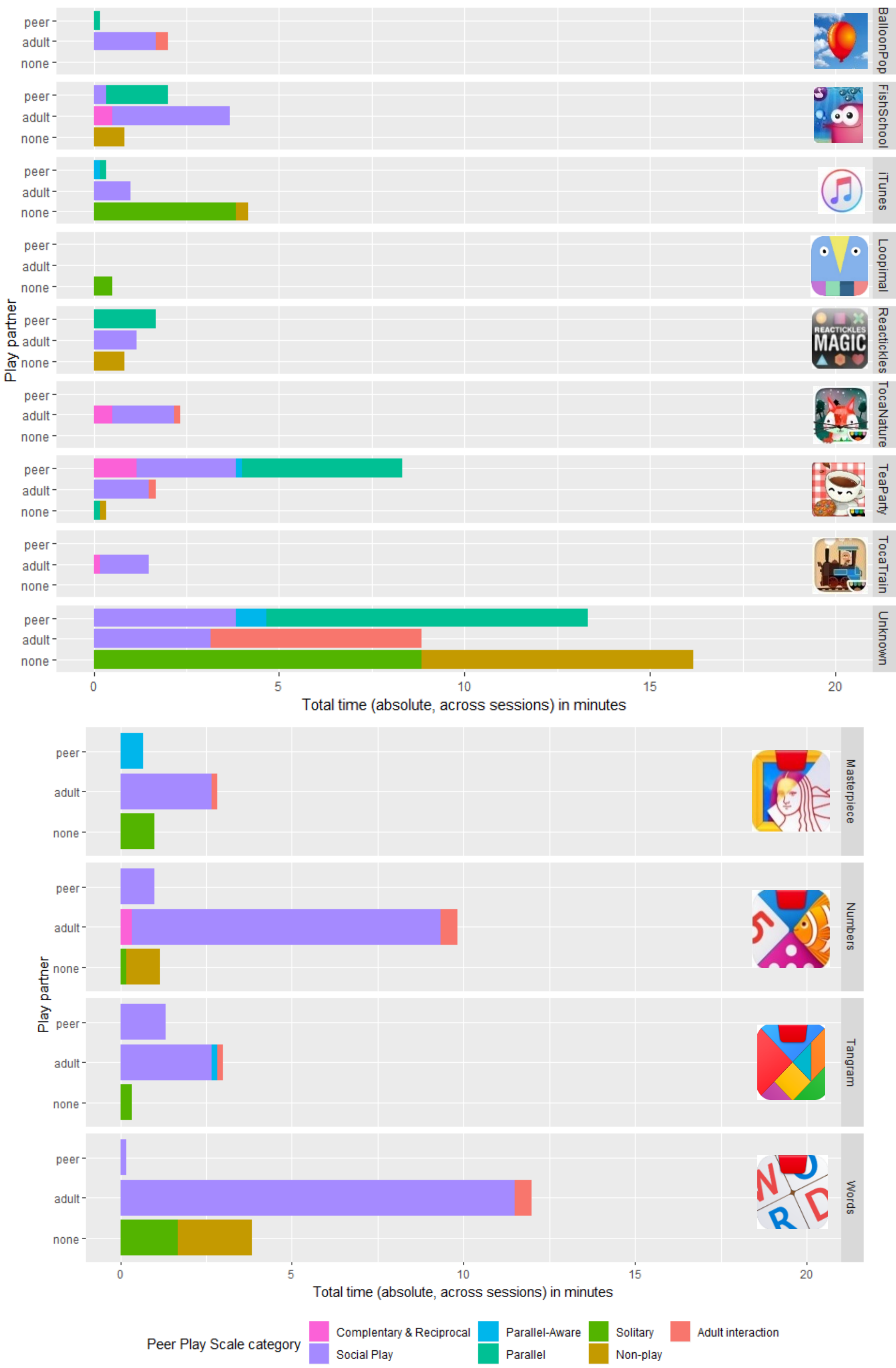
Table 4.6: Observations of play across different technological interfaces

Play category	iPad (*n, time, % of total interface time)*		Osmo (*n, time, % of total interface time)*		Code-A-Pillar (*n, time, % of total interface time)*		Play totals (*n, time, % of total time)*	
Non-play	57 (9.5 mins, 13.41%)		19 (3.1 mins, 8.52%)		29 (4.8 mins, 8.73%)		105 (17.5 mins, 10.82%)	
Adult interaction	38 (6.3 mins, 8.94%)		8 (1.3 mins, 3.58%)		3 (.5 mins, 0.90%)		49 (8.1 mins, 3.1%)	
Solitary	79 (13.1 mins, 18.58%)		19 (3.1 mins, 8.52%)		144 (24 mins, 43.37%)		242 (40.3 mins, 26.3%)	
	Peers	*Adults*	*Peers*	*Adults*	*Peers*	*Adults*	*Peers*	*Adults*
Parallel	100 (16.6 mins, 23.52%)	1 (0.1 mins, 0.23%)	0	0	19 (3.1 mins, 5.72%)	9 (1.5 mins, 2.71%)	119 (19.8 mins, 12.2%)	10 (1.6 mins, 1.03%)
Parallel-Aware	7 (1.1 mins, 1.64%)	0	4 (0.6 mins, 1.7%)	1 (0.1 mins, 0.44%)	16 (2.6 mins, 4.81%)	5 (0.8 mins, 1.5%)	27 (4.5 mins, 2.78%)	6 (1 min, 0.61%)
Simple social	41 (6.8 mins, 9.64%)	88 (14.6 mins, 20.7%)	15 (2.5 mins,6.72%)	155 (25.8 mins, 69.5%)	11 (1.9 mins, 3.41%)	80 (13.3 mins, 24.09%)	67 (11.1 mins, 9.90%)	323 (53.8 mins, 33.29%)
Complementary	7 (1.1 mins, 1.64%)	7 (1.1 mins, 1.64%)	0	2 (0.3 mins, 0.89%)	1 (0.1 mins, 0.30%)	5 (0.8 mins, 1.5%)	8 (1.3 mins, 0.82%)	14 (2.3 mins, 1.44%)
Interface Totals	425 (70.8 mins, 43.81%)		223 (37.1 mins, 22.9%))		322 (53.6 mins, 32.22%))		970 (161.6 mins)	

In this context, *n* refers to the frequency of observations of each respective level of play with each partner- i.e. the number of ten second windows in which this category of play was observed. The *n* was used to calculate the equivalent length of time, and percentages, based on the total amount of data available for each technological interface, as shown in the bottom row.

The data were coded additively with regards to video data containing information about one or more participants or interfaces. i.e. the total time (161.6 minutes) represents the total number of 10-second windows that have been coded, which is more than the ~155 minutes of video footage that was analysed.

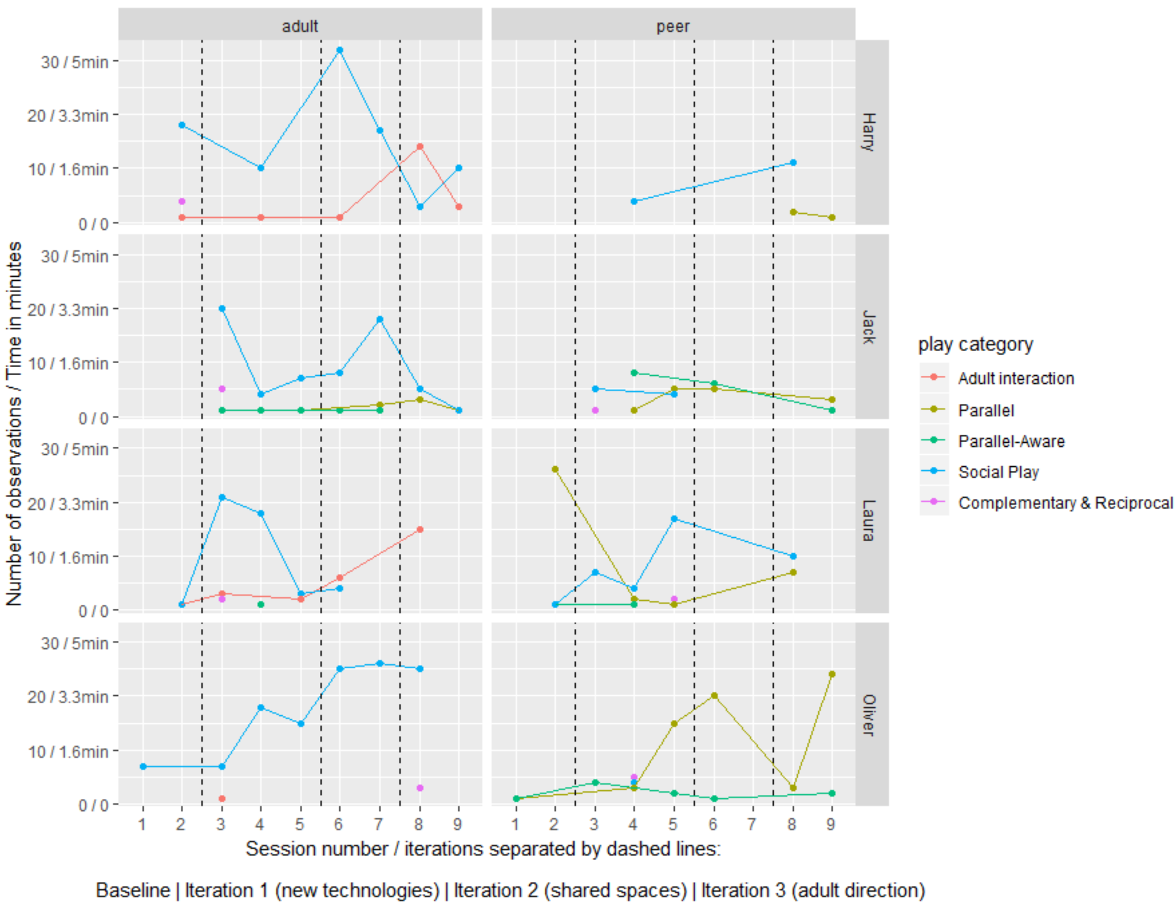
Figure 4.3: Total time observed for each play state across Osmo and iPad apps



4.4.3 Effect of design-based iterations and environments on social play

Iterative design-based research with autism practitioners was used to explore ways in which practitioners could use technology in their classroom to facilitate social play with peers. A summary of the design iterations and sessions is reported in Table 4.4. The key elements of each iteration were: 0) baseline observation, 1) introduce new technologies, 2) move desks to create more collaborative play spaces, and 3) practitioners scaffold peer play. The social play observations (in frequency and equivalent time) across sessions and iterations for each participant are shown in Figure 4.4. Overall, there does not appear to be any clear relationship between children's play behaviours and iteration stages, and there is lots of variation between the different participants in terms of their general play behaviours, as well as their play behaviours over time and iterations.

Figure 4.4: Total play observations across sessions and iterations



4.4.3.1 **Changes between baseline and iteration 1**

One hypothesis was that the introduction of new technologies to the classroom (Osmo and Code-A-Pillar) would increase children's social interactions, either through wanting to share new experiences, asking for help, or being more socially motivated in new environments. For the participants where this data is available, particularly Laura and Oliver, their social play with adults does increase between baseline and the first iteration. The frequency of play with peers in the data at this stage are much less, although there is some suggestion that Oliver interacted more with peers during Iteration 1 than baseline, but Laura interacted less with peers (but more with adults) between iteration 1 and baseline.

4.4.3.2 **Changes between iteration 1 and iteration 2**

The hypothesis for iteration 2 was that by creating a shared and collaborative space for peer play, children would be more "aware" of others (particularly peers) and have more opportunities to engage in interaction. The data to assess the impact of iteration 2 is extremely limited, although Oliver does increase parallel play with peers between iteration 1 and iteration 2. Jack has a low frequency of play with peers and this does not substantially change between iteration 1 and 2. In terms of adult interactions, all participants seem to engage in more interaction and play with adults between iteration 2 and 1. What this could indicate is that adults were more regularly present when children were clustered together in these shared spaces, hence explaining why adult interaction also increased between these sessions. Another explanation is that perhaps adults were mitigating issues or disputes (which sometimes did happen), although this was a very rare occurrence, and it is unlikely to completely explain increased adult engagement.

4.4.3.3 **Changes between iteration 2 and iteration 3**

The hypothesis for iteration 3 was that practitioners could increase children's play with peers by explicitly directing and scaffolding peer play, by either inviting other children to join in when play was between one child and one adult, for instance. The only participant for which there is data to assess this hypothesis is Oliver, who showed increasing amounts of parallel play with peers across iterations (except in session 8). The other children either did not have significant amounts of peer play in iteration 2 to see whether this changed during iteration 3 or had missing data from the final iteration.

4.5 Discussion

The current chapter has explored how different technologies and environments influence autistic children's social play. It found that there is large variance in autistic children's technology and play preferences, which result in individual profiles of social interaction within digital contexts. On comparing autistic children's social play on different technological interfaces, the most social play with peers was observed when children used the screen (iPad) and tangible interfaces (Code-A-Pillar), but the most social play with adults was observed when children used the screen-tangible interface (Osmo). While practitioners recommended a number of ways to facilitate social play in the classroom, including creating a shared space and redirecting children's play, these did not appear to have strong or consistent effects on children's social interactions. Across the sessions, novelty of new technologies appeared to cause the biggest increase in children's interactions.

4.5.1 **What makes a "socially interactive" technology?**

This study has shown that different technological hardware and software shape autistic children's social play, and that some appear to foster more social play than others. At the level of hardware, it was found that the most social play, overall and with peers, was observed when children used the iPads. Reasons for this may be because the participants were most familiar with iPads and relevant software, meaning that they found them more engaging and were more motivated to use and share them with others. Other reasons might be due to the physical interface, which is small and 'forces' children to engage in close proximity in order to play together, thereby potentially encouraging social interaction (Holt & Yuill, 2017; Inkpen et al., 1999; Mandryk et al., 2001). This was predicted by practitioners who worked in educational settings with autistic children, see Table 3.7 on page 79. On the other hand, practitioners also highlighted that some children preferred their own personal space, and therefore tangible objects may be easier for children to share with others. This has been suggested in literature on the design of tangibles for neurotypical children (Bekker et al., 2010, 2014), and in research which has shown that tangible technologies promote more social play in autistic children than non-digital counterparts (Farr, Yuill, & Raffle, 2010; Francis et al., 2019). This study finds that each technological interface promotes a different pattern of social play, which is likely to have been influenced by each child's social and technology interests, and the context in which they use the technology.

While children spent different times on each individual app, it was clear that one specific app, Toca Tea Party, promoted the most social play with peers (see Figure 4.3). Reasons for this may include the fact that it is a well-designed, commercially successful app, which some participants were already familiar with from playing at home. Another reason is potentially the *encouraged collaboration* which is fostered by Toca Tea Party. While designed as a single-player game where players host a tea party, the app always sets out three placemats for a tea party (see Table 4.2 for a screenshot to illustrate). The marketing materials suggests that children can play a tea party with stuffed animals (see https://tocaboca.com/app/toca-tea-party/), but this may also provide a 'cue' for children to share with people. On multiple occasions, practitioners chose to sit children at each 'placemat' in the app and scaffolded turn-taking by saying: "It's your turn, and now your turn…". Hence, the structure of the app could have reinforced this adult scaffolding and created a 'safe space' for children to share with others, because sharing would 'make sense' by having three placemats at the tea party table. This idea of technology being a 'safe space' from which autistic children can engage in collaboration has been suggested in previous literature, particularly in technology-mediated social interventions (Parsons, 2015; Ramdoss et al., 2012).

It is an intriguing finding that social play decreased for all children across sessions (see Figure 4.4 on page 111). What this might suggest is that novelty plays an important driving factor for children's social interactions, where they were more likely to either seek help to using technology, or more likely to celebrate achievements and 'successes' with new technologies. It might explain why studies show that autistic children are more engaged with technology in research studies, since these technologies are often newly developed, not commercially available, or unfamiliar to the children. However, this goes against a common assumption among parents and practitioners that autistic people get 'stuck' in repetitive behaviours around technology, and that novelty creates anxiety (Alcorn et al., 2014; King et al., 2017; Mazurek et al., 2012; Ramdoss, Lang, et al., 2011). The results of this study actually suggest the opposite – that novelty could create positive social experiences for autistic children and are perhaps not sustained over the longer term. To date, there are no studies which evaluate social interaction and digital technologies on a longer-term basis whether interaction is sustained across a school term (in this case), or for longer periods of time. This effect of novelty may be useful in practice – by slowly scaffolding or building on children's social opportunities or potential through novel experiences, either digital or otherwise.

Teachers reported mixed levels of technology-related interests within the child participants (see section 4.3.1), which in itself contradicts an oft-made stereotype that autistic people are stereotypically interested in with digital technologies (Baron-Cohen et al., 2009; Fletcher-Watson, 2014; Kagohara et al., 2013). It may be possible that there is a difference between autistic children with and without learning disabilities in this regard, since the interests and uses of technology by autistic children with learning disabilities have seldom been explored in the literature (Laurie, Warreyn, et al., 2019). Technologies which rely on fine-motor skills and language abilities, such as a large majority of apps, games, and interfaces used in this study, may simply be inaccessible or unengaging for this group (Fletcher-Watson, Pain, et al., 2016), and this may be reflected in the findings of this study. Nonetheless, what this current study shows is that individual children are engaged by different technologies, interfaces, and contexts, and all participants engaged in varying social interaction styles, across different technologies and contexts. Therefore, a large part of what makes technologies "socially engaging" is a match between children's interests and skills, perhaps more so than the features of technology itself, although these also seem to influence social engagement.

In summary, there are multiple and interacting factors which could make technology socially engaging for autistic children. These include features of the technology, such as the hardware and software, the contexts in which they are used, and perhaps ultimately, a good match with the interests of the children themselves. This provides important implications for choosing and implementing technologies in practice. For instance, practitioners could use children's shared interests in technology to provide social opportunities or create social experiences through new technologies.

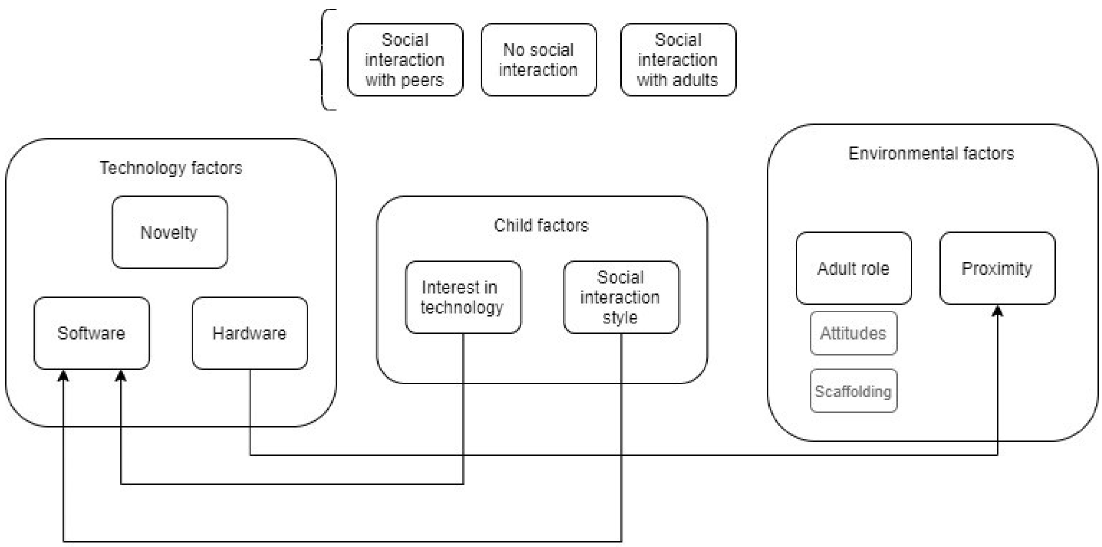
4.5.2 **Is there such a thing as the "most" socially interactive technology?**

In defining which technologies promote "the most" social play, absolute frequencies and proportions of time spent in social play were calculated and interpreted. Both ways of interpreting the data showed that the most social play with peers was observed while children used iPads and Code-A-Pillars, but the most social play with adults was observed while children used Osmo (see Table 4.6 on page 109). This thesis is focused on autistic children's play with peers, and hence this shaped how "the most socially interactive" technologies were defined and interpreted. However, that is not to say that there was no or few interactions while children used Osmo, and in fact, overall, the "most" simple social play category was observed while children used the Osmo interface. From these observations, it can be concluded that there is no such thing as technologies which are ‘good’ or ‘bad’ for social interaction, but rather that technologies promote different types of social interactions and playful contexts. It is therefore, of interest, to identify *when* and *how* technologies support social interaction in autistic children, rather than trying to search for a single type of technology which supports social interaction.

4.5.3 **Further interdependent factors on child-computer interaction**

Additional factors for consideration can now be added to the model of child-computer interaction, initially proposed by Manches (2018), and last updated in the previous chapter (see Figure 3.5 on page 85). This study has identified that different contexts and interfaces promote different styles of social play and interaction (see Table 4.6), and that there is considerable individual variance in autistic children with their interests in technology and their engagement within digital contexts (see Figure 4.4). This reinforces the views and experience of practitioners, which were reported in chapter 3 (see Table 3.7 on page 79), and produces additional interactions to the model (see Figure 4.5).

Figure 4.5: Insights from design-based research on autistic children’s interactions in digital classroom contexts



It has now been identified that factors related to the technology, the child, and the environment have potentially inter-dependent effects on children’s interactions with others when using digital technologies. Children's interest in technology, as well as social interaction style, including motivation and engaging with adults and peers, seemed to drive children's engagements above all other factors. Children's profiles shaped how they engaged with technology, how they responded to different classroom environments, and who they interacted with while using technology (e.g. see Figure 4.4 on page 111). In terms of environmental factors, the role of the adult was a key takeaway finding from this research study. Children reached out to them for help to use new technologies, were motivated to show them achievements, and practitioners felt that they could direct children's play to be more engaged with peers. In this way, adults could provide scaffolding of social interactions to children, for instance, by directing and modelling children's social interactive play (this will be discussed more in the next chapter). Practitioners recommended that children be in close proximity to one another to encourage social interaction, and this can be enforced through the technological interface, particularly through screens which encourage children to sit near to each other to share (see Table 3.7 on page 79).

4.5.4 **Conclusions**

This study reinforces that multiple factors shape autistic children's social interactions while using technology, including personal preferences and social interaction styles, aspects of the technological interface and software, and the environmental contexts in which interactions take place. By working collaboratively with practitioners, a number of ways in which technology could positively support interaction in autistic children with learning disabilities were revealed. Since children's preferences and social interaction styles had the biggest influence over their social interactions in digital settings, it would be interesting to reverse the research question and ask, what design and environmental features can be drawn from looking at moments when autistic children initiate and engage with others?

5 Exploring moments of child-led interactions when autistic children use different technologies to identify specific facilitators of social interaction

5.1 Chapter acknowledgements

A preliminary version of the data reported here was published in the proceedings of the *Interaction Design and Children* conference (Laurie, Manches, et al., 2019). Dr. Sue Fletcher-Watson conducted the second coding of event analysis.

5.2 Introduction

The aim of this thesis is to investigate the influence of technology on social interaction and play in autistic children. This can be broken down into two overall questions – the first being *whether* technology has an influence on social interaction, and the second being *how* technology influences social interaction in autistic children. This chapter reports on a micro-analysis of autistic children's deliberate social initiations and explores *how* these are facilitated in environments that contain digital technologies.

In chapter 3, practitioners shared a number of ways in which digital technologies encouraged social interaction and joint play in their students. One example, as reported in Table 3.7 on page 79, the school had been running a successful Minecraft™ club where pupils could come together and share "common goal[s]" with each other, and develop friendships through their shared interests. Other practitioners shared that aspects of the environment or interface could structure shared play – for instance, being in competitive play environments, or by using devices where children can see what others are doing. In summary, it seemed that technology could foster positive social interactions and relationships for autistic children, but that perhaps there was also a strong influence of the particular context in which the interaction was taking place, the particular interests of the child, or the specific features of the software or interface which influence interaction.

In chapter 4, a design-based research study was conducted with education practitioners to try and unpack more specifically some of these features and environments which encourage social interaction in autistic children within school settings. The study showed that autistic children engaged in different levels of social play on different interfaces and apps, and also that interfaces which were more novel or complex to use, such as Osmo, supported more interaction with adults rather than peers. Practitioners suggested that creating a shared space by moving the toys and classroom tables closer together, and directing children's interaction towards their peers through scaffolding, would increase pupil's socially interactive play (see Table 4.4 on page 100). While these results did not seem to have as large an effect on children's engagement (as shown in Figure 4.4 on page 111) what was interesting is that there seemed to be a large effect of novelty of technology, as shown by increased social play for all pupils after new devices were introduced.

The instrument chosen to measure and analyse children's play in the previous chapter was a standardised assessment of play and may not capture with enough precision or sensitivity the interactions which happen while children play with technology. A key component of play is that it is child-directed, and as discussed throughout chapters 3 and 4, these "moments" of interaction can be fleeting and hard to spot from observations (Wilson et al., 2019). The Howes' Peer Play scale does not directly look at these moments of intrinsic and child-led interactions, and any that did not flourish into exchanges that lasted for a significant amount of a ten second window would not be coded (Howes et al., 1988). Environments which contain autistic children, who may interact differently, and technologies, which are complex and dynamic, potentially need more fine-grained and sensitive approaches to understand the interpersonal interactions that take place (Fletcher-Watson, 2014; Manches, 2018). This chapter will look at the same dataset collected in chapter 4, but use a much more fine-grained approach to better understand precise factors which influence child-led interactions in these environments.

5.2.1 **Social overtures by autistic children in digital environments**

Autism is characterised by reduced quantity and quality of social overtures, which leads to less successful interactions and relationships with others (Bottema-Beutel, 2016; Locke et al., 2017). Social overtures are deliberate communicative behaviours, which are done with the intention of initiating interactions with others, or to maintain ongoing interactions (Lord et al., 2000). Overtures can involve verbal behaviours, such as asking questions or changing the conversation topic, and non-verbal behaviours such as pointing to objects of interest or reaching out to literally 'grab' someone's attention. Overtures can be defined by particular actions or their intentions, as shown further in the results section (see Table 5.3). In play settings, overtures are essential for establishing collaborative sequences of interactions, by either inviting other people to be involved in the play or to keep their interest and engagement ongoing (Freeman & Kasari, 2013).

ECHOES was a multi-disciplinary research project which developed an artificially intelligent learning environment to foster social communication skills, specifically joint attention, in young autistic children (Porayska-Pomsta et al., 2012, 2018). The main quantitative analysis of the ECHOES revealed no significant improvement in children's social interaction behaviours in a non-digital activity after using the ECHOES system, but teachers who worked closely with the child participants did report some qualitative improvements in children's behaviour (Porayska-Pomsta et al., 2018). When observing the ECHOES video footage, it was noticed that when the system had an error or made a mistake, sometimes children would initiate interaction with (i.e. make overtures towards) the research assistant, who was controlling the intelligent agent from a computer off to the side of the room. Children would gather the assistants' attention, or share comments and jokes about the ECHOES system, even in moments where it might be expected that children would be frustrated about the errors made (Alcorn et al., 2011). These observations were further tested by embedding “surprising” errors in tablet games, and it was observed that autistic children also made comments and jokes about the deliberate errors (Alcorn et al., 2014). The author concluded, from observations in a relatively controlled environment, that software elements of novelty and surprise had the potential to promote child-led interactions in autistic children.

The Lands of Fog is a virtual reality environment, designed to encourage social interaction and collaboration in pairs of autistic and non-autistic children. It contains a number of design features thought to elicit social interaction, including an immersive “fog” which conceals each player’s point of view from the whole map, thus providing opportunity to share and collaborate across players to better vantage the play area (Crowell et al., 2018). Children are asked to explore the virtual map and collect new ‘creatures’ using a butterfly net. These creatures interact with other creatures in the collaborative environment, thus providing novel interaction opportunities when the two players ‘meet’. In a small evaluation study, it was shown that the autistic children increased the number of social initiations (i.e. overtures) and responses made across sessions with the Lands of Fog (Mora Guiard et al., 2016). They also found that players played more closely together in the Lands of Fog environment as each session went on, potentially because of the ‘game rewards’ unlocked by having creatures interact with each other.

Micro-analysis of social events has the potential to gain deeper understanding about the cause and the context of these particular, person-led interactions, and could potentially contribute to designing future technologies which promote these specific events (Wilson et al., 2019). In order to make sense of a dynamic and complex environment, cognitive event analysis was proposed within the learning sciences, to specifically identify ‘key moments’ within particular environments and sequences, and to unpick these moments and identify potential antecedents or factors that lead to them (Steffensen, 2013; Vallée-Tourangeau et al., 2016). In this way, instead of looking at general patterns and comparisons, researchers can seek to understand moments of 'success' within the process of learning or interactions. Wilson (2019) defines "moments of interaction" as "an instance of social connection, communication, or understanding between two people… the culmination of micro instances of joint attention, turn-taking, and imitation." During participatory design sessions with young, non-verbal, autistic children, the author describes two key examples of "moments of interaction", where children's engagement with a design prototype led to a meaningful social exchange between child and researcher. The authors then reflect on these moments of interaction and consider the potential design ideas they can draw from these sessions and discuss how these small observations would be easily missed without the use of micro-analyses.

Overall, a few small case studies have revealed that analysing small, significant moments of interaction can contribute to how we best design and use technologies to support child-led interactions in autistic children (Alcorn et al., 2014; Wilson et al., 2019). By identifying and conducting rich analyses around moments where autistic children engage in child-directed, intrinsically motivated interactions, there is potential to link these moments to features of design and environment. This more clearly answers the overall thesis question; "*how* do technologies influence social interaction in autistic children?" The two overall aims of the current study are, to:

1. Explore if different software or interfaces promote different types or amounts of social overtures
2. Identify the contexts and facilitators of social overtures in environments that contain different technologies

5.3 Data collection and analysis

5.3.1 **Summary of chapter 4 methodology**

The data reported and analysed in this chapter comes from the same video data that was collected previously, in chapter 4, where full methodological detail including recruitment, sampling, and session structure are provided (see section 4.3 from page 90). The study was a design-based research project, with education practitioners, to explore the influence of technology interface and classroom environment on autistic children's social interactions and play. Four autistic children (see Table 4.1 on page 93 for results of social and adaptive behaviour measures) were observed in their classroom over the course of nine sessions, playing with different technologies (which had different software and interfaces). Interfaces included a screen-based device, iPad, a tangible-screen device, Osmo, and a tangible device, Code-A-Pillar. Children were observed in their classroom during free play time and staff were advised to support the children as they normally would. Staff supporting the children took part in design-based research consultations, where they worked with the researcher to come up with ways that they could change the environment to promote the students' social engagement. After introducing new technologies to the classroom, the practitioners suggested that moving the tables closer together and creating a shared space for play, and scaffolding children's peer-directed play. These iterations were implemented after every 2-3 sessions, as summarised in Table 4.4. on page 23 and in Appendix 6 on page 217.

5.3.2 **Social overture definition**

The definition of a social overture is taken from the Autism Diagnostic Observational Schedule II, a behavioural assessment designed to measure autistic traits through observation (Lord et al., 2000). Social overtures are "behaviour[s] initiated by the examinee [which are] directed to another person for the purpose of communicating social intent." Overtures can be "subtle" or "brief," and involve only one behaviour modality (e.g. looking, but not speaking), or can be "overt" and involve multiple communication modalities (e.g. looking *and* speaking). For instance, a "showing object" overture could be picking up an object and moving it in the direction of someone else, or it could be picking up the object, making eye contact with the person, saying "look at this!" and moving the object directly within the other person's line of sight. Example types of social overtures are included in Table 5.1).

Table 5.1: Definition of social overtures from the Autism Diagnostic Observation Schedule

Social overture type	**Description**
Initiate Joint Attention	Initiating shared attention on an object with another person, e.g. "look at this!"
Check-in	Looking at another person to make sure they're watching
Request	Any behaviour with intent to get help or direct another person (e.g. "put that piece there")
Celebration	Interacting with someone else specifically to share achievement (e.g. "I did it")
Showing object	Showing another person a specific technological part (e.g. Code-A-Pillar piece, iPad screen)
Maintain interaction	Maintain an ongoing interaction (e.g. by making a comment, pulling on someone's arm)

5.3.3 **Cognitive event analysis procedure**

Cognitive event analysis is a method for analysing particular moments within observational data, and developing an understanding of the mechanisms and implications of these particular moments (Steffensen, 2013). It uses a framework of describing a person's actions (with physical tools) and interactions (e.g. the understanding they have achieved from that action) in detail, and collecting patterns across different cases, of either events or participants. In the current study, the existing framework to looking at children's engagement with technology (Manches, 2018) was used to help guide note-taking and understanding of events, and provided a structure for the notes taken during event analysis. There are three stages to event analysis: 1) event identification, 2) event description and detail, and 3) event analysis.

Event analysis was conducted on the full dataset collected, which included over eight hours of video footage (see Appendix 6 on page 217).

5.3.3.1 **Event identification**

Social overtures made by children while using the technologies and toys of interest (i.e. iPad, Osmo, and Code-A-Pillar) were identified on the first watch of the videos, using ELAN video annotation software.

5.3.3.2 **Event description**

Once events were identified, a window which included the event and five seconds before and after the event was created, and rich detail of the event and particular artefacts of interest were described (for an illustrative example, see Figure 5.1 on page 127). The following tier structure was used in ELAN (see Table 5.2 for a broad description, and Figure 5.2 for an example), taking inspiration from the model outlined by Manches (2018), and acknowledging the role of the child, the technology, other people, and the wider environment in understanding children's interactions with technology.

5.3.3.3 **Event analysis**

All data, including labels and annotations from the ELAN files, were collated into a single .csv file for further analysis. Analysis involved a combination of linking the observations and descriptions to the pre-identified model of child-computer interaction (see Figure 1.1 on page 3) and also developing any patterns which did not quite fit that model. The next stage of analysis involved integrating contextual information about events, from their descriptions, and creating connections between the different nodes of the model to create *contingent* factors – in other words, when there was a joint influence of two or more factors on a particular event. Analysis was conducted iteratively, involving rewatching of particular events and examples, re-reading of notes and annotations, and revisiting the questions in Figure 5.1.

Figure 5.1: Questions and structure of the event analysis

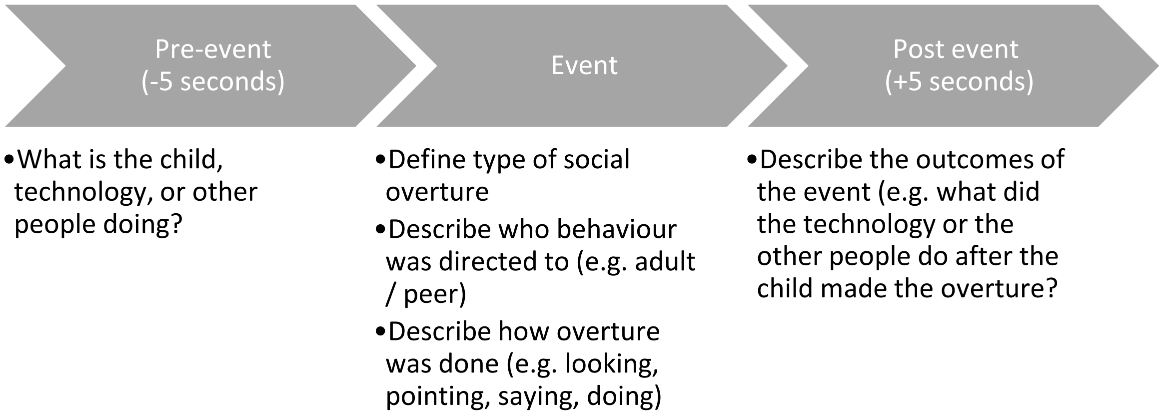
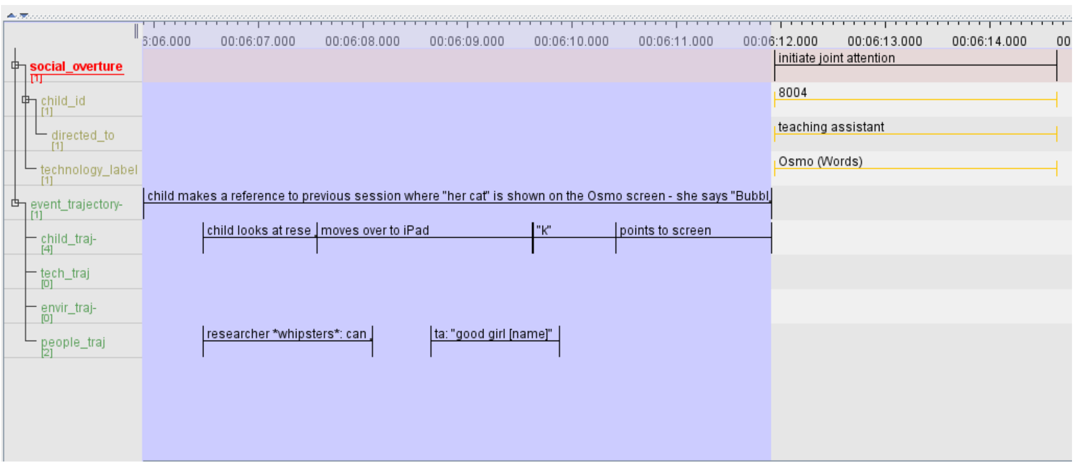


Table 5.2: ELAN Tier structure for event analysis

Tier description	
Event type	Categorical variable describing overture type
Child	Description of what the child is doing, where they are looking, where their hands are (e.g. moving pieces), including small actions like 'looks away for a brief second' also recorded.
Technology	Description of what the technology is 'doing', i.e. content shown on screen, any noises, animations, or artefacts created (e.g. makes music, pop-up bubble appears)
People	Description of what adults / peers are doing (e.g. where they are looking / what they are doing or saying)
Environment	Description of other features in the environment, such as what distant people are doing

Figure 5.2: Example of event analysis in ELAN



5.3.3.4 **Second coding**

The presence and type of social overtures was second-coded by an independent rater who was familiar with the Autism Diagnostic Observation Schedule but was not familiar with the video footage. Four events from the list of all events were randomly selected for independent rating. The second coder watched five short video clips (where one clip did not contain an overture) and was asked to identify if and when an overture occurred, and what type of overture it was. Full agreement was reached on the presence and type of overture in these five video clips between the researcher and the second coder.

5.4 Results

5.4.1 Illustrative examples of events

Here, I will provide three examples of events, which will illustrate the format and the level of detail in the data collected as a result of the previous analysis, and contextualise the results reported later. For an illustration of these events as per the tier structure, see Figure 5.3. Each of these themes and examples illustrates that there are multiple contextual and environmental factors that lead to a child making a social overture while using digital technologies.

5.4.1.1 **Example 1: Sharing successful tea parties**

Laura is sitting in the corner of the classroom playing with the Toca Tea Party app on the iPad. Another student is sitting next to her also playing their own game of Toca Tea Party, but they do not interact. Laura is familiar with the tea party game, having played it at home. She quickly works her way through the game, focusing on finishing all the cakes that are on the plates. When all the cakes are gone, she shouts “look!” towards a teaching assistant, who is sitting a few metres away. Laura holds up the iPad, showing the teaching assistant that all the cakes are finished. She says “I did it!” and points at the iPad screen, while making eye contact with the teacher. The teacher responds by saying “oh yes, you’ve done it, well done!”, before turning back to continue working with another student.

In this example, Laura was playing with Toca Tea Party on her own, and the teacher she initiates interaction with was also doing their own work with another student. When Laura felt she had made an achievement, by making all the cakes disappear, she seemed proud of this and wanted to share it with a teacher. She uses verbal communication and pointing to direct the teacher’s attention from their own work, and to show them the finished game. This is an example of *showing / passing object,* and also *initiating joint attention*. In response, there was a brief interaction between Laura and the teacher where she was praised for completing her goal. Afterwards, Laura continued to play the rest of the game independently.

5.4.1.2 **Example 2: Seeking help with Code-A-Pillar**

Jack and his teacher are playing with Code-A-Pillar. The teacher is attaching new pieces to the Code-A-Pillar, but Jack wants the Code-A-Pillar to play its music and not move, and Jack has learnt to make this happen by removing all the Code-A-Pillar pieces from its body. Jack has been playing with Code-A-Pillar in the same way for a few sessions now, after finding the way that he wants to play. After the teacher attaches a new piece to Code-A-Pillar, Jack wants to take it off to stop it from moving. The teacher watches him as he tries to take the piece off himself, but he is finding this difficult. Jack then turns to the teacher and hands them the Code-A-Pillar, in a request for them to take the piece off so that Code-A-Pillar cannot move. The teacher asks “do you want this piece off?” and Jack replies “yes” in sign language. The teacher then removes the piece from the Code-A-Pillar, and hands it back to Jack.

In this example, the teacher was trying to play with the Code-A-Pillar in a way that was not the same as how Jack wanted to play. Jack needed help to take the pieces off Code-A-Pillar, and his way of asking the teacher to do this was to hand the Code-A-Pillar to them. This is an example of *requesting.* The teacher then clarified with Jack what he wanted them to do, initiating a brief interaction between them. Once the pieces were off the Code-A-Pillar, Jack returned to playing independently and watching Code-A-Pillar "stutter" across the floor without its pieces.

5.4.1.3 **Example 3: Using Osmo to start a conversation**

Laura and her teacher are playing with Osmo Words together. Laura, so far, has not been very engaged or interested in playing with Osmo Words, but the teacher is encouraging her to practice her spelling for "one more" trial before she can go and play outside. A picture of a pig appears on the screen, asking Laura to place the missing letter tile "P" on the Osmo tray. Laura points at the pig, looks at the teacher, and says "pig… like on the farm!" Laura is referencing a recent class trip to a petting farm. The teacher says "yes, like those stinky pigs on [redacted] farm!" Laura then places the "P" tile in the right place and manages a few more Osmo trials before going outside to play.

While Laura had seemed unengaged while playing Osmo, this changed as soon as she saw the picture of the pig. It reminded her of a school trip to a petting farm, and having made that connection, was inspired to share this with the teacher. She uses both verbal and non-verbal (e.g. pointing) strategies to *initiate joint attention* with the teacher. This resulted in an interaction between Laura and her teacher and seemed to motivate Laura to engage with Osmo for a short while longer.

5.4.2 **Frequency of overtures on different technological interfaces**

It should be noted that children had different patterns of play throughout the dataset and played with each toy for different lengths of time. Oliver was observed in 4 (12%) overtures, which included 3 check-ins while using the iPad and 1 request overture on Osmo. Harry was observed in 11 (33%) of overtures, included 1 check-in while using the iPad and on Osmo, he made 6 initiate joint attention overtures, 2 requesting overtures, and 2 celebration overtures. Laura was observed in 16 (48%) of overtures, and also had the highest range of overture types. While using the iPad, Laura made

2 initiating joint attention overtures, 2 showing an object overtures, and 1 check-in. While using Osmo, Laura made 6 initiating joint attention overtures, 2 celebration overtures, 2 check-ins, and 1 maintenance of interaction. Jack was observed in 3 (9%) of overtures which included 2 requesting overtures on Code-A-Pillar, and 1 overture on the iPad to initiate joint attention. Frequency counts of total overture types across different technological interfaces are reported in Table 5.3.

Figure 5.3: Illustration of three events

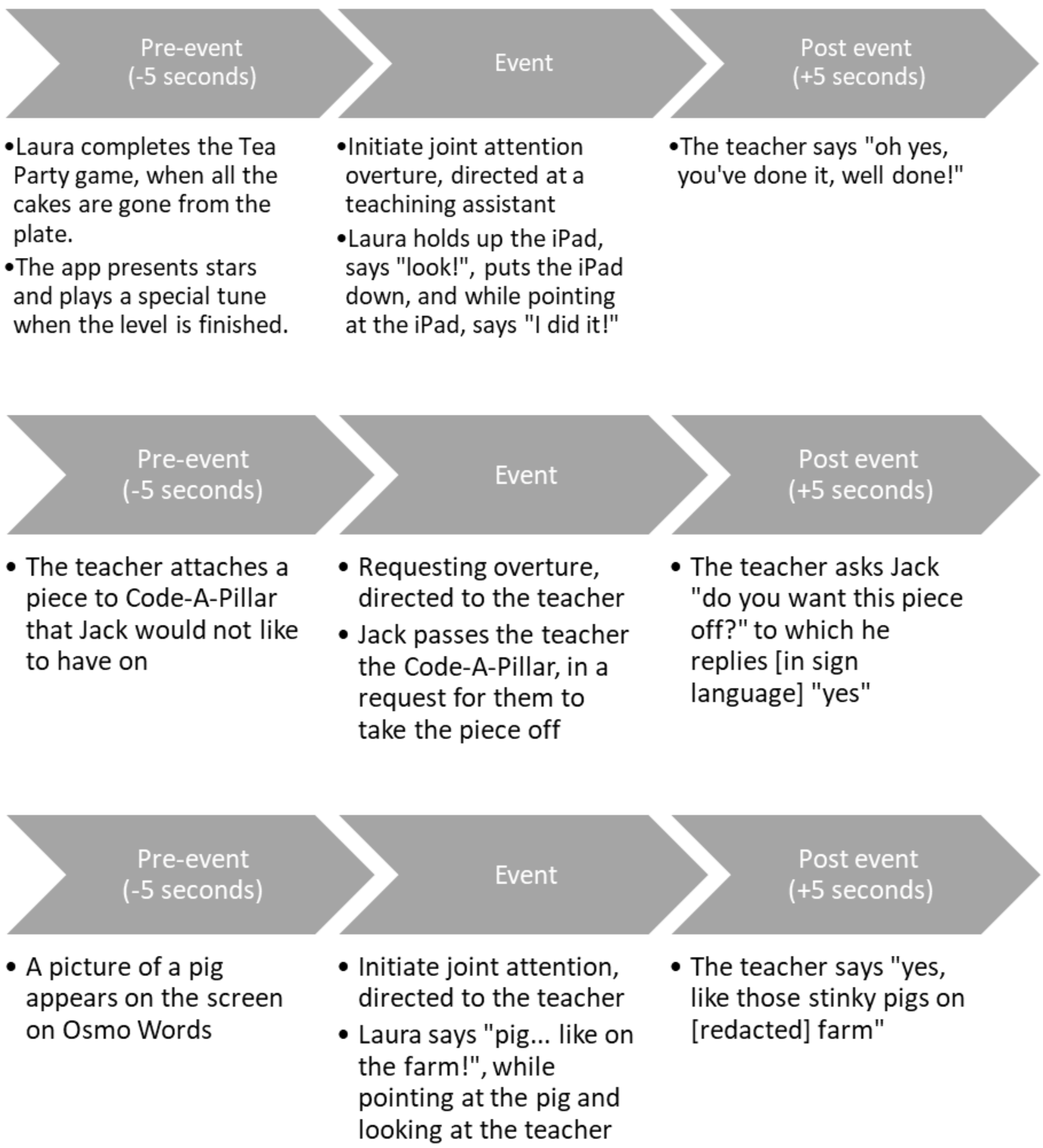


Table 5.3: Frequency of social overture types on different interfaces

Event type	**Frequency**	***on iPad***	***on Osmo***	***on Code-A-Pillar***
Initiate Joint Attention	15 (45.45%)	3 (20%)	11 (73.33%)	1 (6.66%)
Check-in	7 (21.22%)	5 (71.42%)	2 (28.57%)	0
Request	4 (12.12%)	0	2 (50%)	2 (50%)
Celebration	4 (12.12%)	0	4 (100%)	0
Showing object	2 (6.06%)	2 (100%)	0	0
Maintain interaction	1 (3.03%)	0	1 (100%)	0
Total events	33	10 (30.3%)	20 (60.6%)	3 (9.09%)

5.4.3 **Initial observations: event contexts and digital artefacts**

Qualitative analysis revealed a pattern of contexts in which children made social overtures. These contexts describe the purpose of the social overture made and link children's behaviour to a broader social context, including the actions of the technology and other people within the environment (see Table 5.4). These initial observations help shape the final results, which map onto the framework for understanding child-computer interaction. Further analysis focused more specifically on the features of technology which preceded and influenced children's overtures. Moving beyond technological interface, I also looked at specific features of software and apps which appeared to drive children's overtures (see Table 5.5).

5.4.4 **Final cognitive event analysis results**

The results of the qualitative analysis were framed within the model of child-computer interaction and are reported in Table 5.6.

Table 5.4: The contexts in which autistic children make overtures in digital environments

Context	**Description**	**Example**
Enjoyment	Children will share with others when they are pleased with their play – some will offer comments, such as “I like this” and others will look to adults/others to check if they are also watching or enjoying what is happening	Oliver listens to music on the iPad, and starts dancing around the classroom. He looks to his teacher and starts to smile and laugh, encouraging her to dance too.
Achievement	When children complete levels or tasks, particularly when these have been challenging for *either* child or adult to finish, children will celebrate these “wins.” Some will shout “hooray!” and the like, while others will proudly proclaim “I did it!”	Osmo makes a noise and a flash when the piece is placed correctly – Harry turns to his teacher, and loudly says “yay!”
Led by interests	Children will be more engaged or will make social overtures when the game their playing is related to their own hobbies or interests.	Laura initiates joint attention with the teacher when a picture of a cat appears in Osmo. Laura then tells the teacher about her own pet cat, Bubbles.
Needing help	Some children will explicitly make overtures in moments where they need help to progress further with their play.	Both Oliver and Laura directly ask for help several times while using Osmo.

Table 5.5: Digital artefacts and features which prompt social overtures

Digital artefacts	**Description**	**Example**
Collaborative prompts	The software will suggest or guide inter-personal interaction, by way of explicit instruction or as implied through the placement of cues.	The Toca Tea Party app lays out four plates on a table, hinting that children can come and sit at their “plate” and play together.
Indicators of achievement	The software will provide audio and visual clues on how to proceed further in the game, and also provide information about how much the player has achieved.	Osmo games use ‘floating examples’ to illustrate on the screen where pieces should go on the playmat. There is a ‘progression bar’ on the screen which shows how many points have been earned.
Proximity	Interfaces with screens force children to sit closer together in order to jointly engage (e.g. to look at the same screen or play with the same app). Code-A-Pillar allows children to sit further away from each other, but can still foster engagement (e.g. driving between two people across a room)	The Code-A-pillar, set up by Jack, accidentally bumps into the teacher and another child working in a different play space. Laura, who was watching Code-A-Pillar from a distance, points to the Code-A-Pillar and says “look, miss!” towards the teacher.

Table 5.6: Extended description and examples of child-technology interaction framework

Node of the child-technology interaction framework	Description / examples
Child	
Experience with technology	New technologies provide opportunity for children to reach out to adults for help, or to share new experiences. Children who are more familiar with technologies could be less likely to start such interactions.
Interest in technology	Children's engagement with each technology fluctuated during and across sessions. When children were more engaged, motivated, or driven to play with the technology, their social overtures increased.
Player type	Children who were driven to 'complete' games or tasks, or had a competitive streak, would share progression with adults. Whereas children who engaged in more solitary play would be more likely to make requests for adults to help them with their particular play activities.
Technology	
Scaffolding and feedback	Software can provide cues and instructions for children to play together – either implicitly or explicitly. Feedback provided to players can encourage sharing of achievements, or encourage other children to ask for help.
Unexpected behaviours	Particularly when a child is new to a specific technology, surprising elements of some games an evoke responses. For example, the participants who used Osmo had positive responses to the first time they successfully placed a tile on the Osmo tray and were inspired to share this with the teacher/teaching assistant.
Interface & physical space	In order to play together on screen-based devices, children are enforced to sit close to one another in close proximity. For some children, this seemed to help their social engagement – as supported in the quantitative data showing that these devices evoked more overtures. However, other children seemed to prefer having physical distance and having more control over when to make a move into joint play.
Adult	
Demonstrating digital play	Children would sometimes respond, and overture, to adults who showed children how to play a specific game, or the unexpected findings of the adult player. For example, watching an adult complete a game, turning around and cheering.
Making comments / asking questions	Similarly, adults who asked questions or directed children's engagement with the technology could foster responses and overtures from children. This can involve asking questions about what is happening/going to happen next, leading children to make a response and then overture to keep that conversation or engagement going.

Scaffolding interaction	Some teachers would explicitly encourage social interaction between two or more children, by either bringing groups of children together or setting out rules for turn-taking (e.g. "now it's your turn"). This type of scaffolding encouraged joint play, which led to children "checking in" on both the other play partner and the adult, or starting new conversations with the child who had just joined in.
Environment	
People watching	Some children were happy to sit and watch what others were doing in their own digital play – these children would sometimes share their observations with others, or step in to get involved themselves, making overtures to join in the play. Things that children seemed to respond to, sometimes, included other children playing by themselves (e.g. child goes over to join them), and children who were stuck or needed help (e.g. Code-A-Pillar drives across the room away from Jack).

5.5 Discussion

In this chapter, I have explored moments where children initiated interaction with other people while using technology, and provided rich descriptions of how factors related to the child, the technology, and other people facilitate these social overtures using the Manches (2018) framework for evaluating child-computer interaction. The first main finding is that more social overtures were observed when participants played with the iPad and Osmo interface compared to Code-A-Pillar (see Table 5.3 on page 132). Differences in the frequency and breadth of social overtures observed within the participants builds on the previous chapters' profiling of children's social and adaptive skills (see Table 4.1 on page 93). The second main finding is that there are many ways in which moments of interaction are influenced, through the child's own experience and interests, through features of the technology and the way the adult scaffolds the interaction, and through a combination of factors within these three elements (see Table 5.6 on page 134). Together, these results illustrate the importance of looking beyond the specific technology, and looking at factors of the child and their environment which all interact and lead to specific moments of intrinsic, meaningful, and child-led interactions.

5.5.1 **Implications for technology designers**

The results reported here provide insight into how future technologies could be designed to specifically encourage child-led interactions. It can be hard for designers to specifically 'design' for specific types of interaction, such as social overtures, as these particular behaviours can be largely unpredictable and may be influenced by other environmental factors or people, such as the adult (Bekker et al., 2014; de Valk et al., 2013). In some ways, the aim is to create player experiences which triage their attention between the game or technology itself and another person. This isn't traditionally what many technologies are designed to do, and the unpredictability of the user behaviour, in this case, the social overtures made by autistic children, means it is difficult to predict single technological features which always produce these results (Alcorn, 2016).

Technology has the potential to play a significant role in interpersonal interaction for autistic children, and there has been much work looking into how technology can provide social opportunities for this group (Farr, Yuill, & Raffle, 2010; Francis et al., 2019; Holt & Yuill, 2014; Hourcade et al., 2012). Identifying potential technological features which may provide social benefits has two applications – one, it provides suggestions for the design of future technologies which foster these intrinsic social interactions, and two, it could feed into criteria that practitioners can use for 'off-the-shelf' technologies to evaluate if and how well they might support social interaction, either for a particular child or in a particular classroom environment (Fletcher-Watson, 2014; Zervogianni et al., 2020). Another important reason to identify particular design features is that these can be isolated out and tested within a more rigorous and experimental fashion – for instance, comparing children's social play while using technology with a specific feature and the same technology without that feature. While it could be argued that these types of studies have limited ecological validity, due to the creation of technologies which either don't exist or wouldn't be available without the full set of features (Kim et al., 2018; Ramdoss, Lang, et al., 2011), these studies can potentially identify features which play a significant role in shaping user experience and outcome (Brosnan et al., 2019).

When the particular app or game provided ‘implicit scaffolding’ of shared interactions, such as the Toca Tea Party plates laid out at three places, or turn-taking to connect Code-A-Pillar pieces, children seemed more willing to engage in shared play and also were more likely to invite themselves to play with others. By ‘implicit scaffolding’, I mean that the game did not enforce collaboration in any way, but merely suggested and gave opportunity for players to engage in collaborative play. Several studies have looked at the effect of enforced collaboration on autistic children’s social engagement with others on digital activities, including storytelling on table-top devices (Battocchi et al., 2009; Bauminger-Zviely et al., 2013; Gal et al., 2016) and joint engagement on a card-sorting task (Holt & Yuill, 2014, 2017). What the current chapter shows is that the ‘enforcement’ is not strictly necessary, and that children may intrinsically choose to engage in shared play when offered the opportunity, without enforcement from the technology. For designers, this perhaps means providing different options for collaborative ‘levels’ which vary in the degree of enforcement on players, so that children can choose to play individually or not. This ‘implicit scaffolding’ could be built on by practitioners and adult facilitators and may be a more gradual way to get children engaged in social play.

There were a number of times within the dataset when children were observed responding positively to feedback provided by the app or game. In terms of general support for learning, autistic children are thought to respond well to feedback or learning materials presented visually, or through technology more generally (Fletcher-Watson, 2015; Neely et al., 2013). More specifically, the feedback provided by Osmo either helped children identify why they weren’t solving the puzzles (e.g. the piece had to be at a different angle) or gave children a sense of achievement. Osmo provides both visual and audio feedback, and also is responsive when players haven’t moved a piece or engaged in a few minutes (e.g. it ‘helps’ players who may be stuck in the game, by providing clues). The current study identifies further benefits of providing such feedback, specifically for autistic children: it can provide ‘concrete’ information for autistic children to share with others, especially for those children who use few words. Perhaps one future design idea could be feedback which more explicitly encourages sharing, like “show a friend / teacher” or “let someone else have a turn!” This could capitalise on children’s engagement with feedback and encourage them to share and collaborate with others.

Previous research has shown that unexpected and surprising elements in digital environments and technologies can result in autistic children initiating interaction with others (Alcorn et al., 2014; Porayska-Pomsta et al., 2018). This is actually quite a surprising finding, given that clinically, autism is associated with an intolerance of change, stress or anxiety about surprises, and a need for sameness and routine (Alcorn et al., 2011, 2014). In the current chapter, results show a similar pattern to previous work, where more social initiations are observed in the technologies that children are less familiar with in their classroom. This observation could be manipulated in future designs – for instance, by embedding deliberate errors and surprises in a game, and rewarding children’s engagement with them, as shown in Alcorn *et al.* (2014).

5.5.2 **Evaluation of technology and interaction**

In the preceding chapter, I used the amount and proportion of time that children spent engaged in social play, as defined using a standardised measure, to conclude that the iPad and Code-A-Pillar interfaces promoted more social play (see Table 4.6 on page 109). However, in this analysis of moments where children lead and initiate interaction with others, Osmo and the iPad had more overtures observed than Code-A-Pillar (see Table 5.3 on page 132). Therefore, the interpretation of which technologies provide the ‘best social opportunities’ will depend on how social interaction is measured (as also discussed in section 4.5.2 on page 116). Previously

I had argued that using standardised measures, such as the Howes Peer Play scale as used in chapter 4, was better as it could provide a fairer assessment of all children's abilities, typically developing or not (see section 2.3 on page 48). However, perhaps for children who are developing differently, these more bespoke measures give a greater insight into children's strengths and interests than what would be captured in a standard scheme, or even in standard practice, such as participatory design (Wilson et al., 2019). In summary, there are multiple ways to capture social interaction, and the measure chosen may have implications for how technologies influence on interaction is evaluated.

5.5.3 **Conclusions**

This micro-analysis has revealed features of both the technology and the surrounding environment which lead to moments of child-led social interactions while autistic children play with different technologies. It found that children chose to engage with others when they needed help, when they wanted to celebrate their achievements on new technologies, and under conditions of 'encouraged collaboration' by the technology and supporting adults. By this, I mean that adults and technology can successfully scaffold social interaction in autistic children, when this is relevant to the needs or interests of the particular child(ren) that are involved. In future work, features of particular technologies could be experimentally manipulated to test whether and how much they influence social interaction in autistic children.

6 The effect of enforced collaboration on autistic children’s social play on digital and non-digital toys

6.1 Chapter acknowledgements

Thank you to Rebecca Stewart who completed the secondary coding of the dataset.

6.2 Introduction

This thesis investigates the influence of digital technologies on autistic children’s social interactions in classroom settings, with the aim to explore whether and how different technologies shape social interaction and play. So far, through consultation with education practitioners and observational studies, it has been revealed that social interaction in digital contexts is influenced by the environment, the technological interface, and the social interaction style of the child. (see Table 3.6 on page 77). Additional factors include mediating features of software and interface which support social interaction in autistic children, and environmental contexts which lead to novel social engagement, such as the presence of new technologies and adult-scaffolded interactions.

This chapter will return to the question of *whether* technologies promote social play in autistic children, by comparing children’s interactions in digital and non-digital environments. Concerns about the impact of technologies on social interaction in autistic children have been shared by practitioners, within this thesis (chapter 3) and in wider literature (Alarcon-Licona & Loke, 2017; Alcorn et al., 2019; King et al., 2017), by parents of autistic children (Laurie, Warreyn, et al., 2019; Mazurek et al., 2012; Mazurek & Wenstrup, 2013) and in the research community (Parsons et al., 2017; Ramdoss, Lang, et al., 2011). Since previous work within this thesis (chapters 4 and 5) shows that technologies can influence social interaction and play, and this is of concern to multiple stakeholders, it is a logical step to then explore how technology itself may influence social interactions. Answering this question, with a focus on participants who have high support and communication needs, will address concerns about the impact of technology on social interaction more directly.

6.2.1 **Comparing digital and non-digital play**

Contrary to concern about social interaction on technology, a number of studies have suggested that digital media and toys may increase social engagement in autistic children, relative to non-digital counterparts. Hourcade *et al.* (2013) showed that autistic children engaged in more conversation, collaboration, and social engagement while using tablet apps, compared to non-digital equivalent activities (e.g. an app for painting compared to pen and paper painting). It has been shown that autistic children engage in more socially interactive play when using Topobo, a tangible block toy, compared to analogue LEGO bricks, and that there are higher probabilities of children progressing to more social states of play on Topobo relative to LEGO (Farr, Yuill, & Raffle, 2010; Francis et al., 2019). Even when the tangible features of a toy are simply switched on and off, and toys are therefore directly matched, autistic children engage in more social interaction when the tangible toys are active (Farr & Yuill, 2012). Farr *et al.* (2010, 2012) have suggested that tangibles offer more “pathways to social interaction”, through multi-media experiences (e.g. visual, audio), and by the active parts of tangible toys enforcing collaboration.

However, one outstanding question is whether the same results would be observed in autistic children who have different types of social interaction style, and varying interests in technology. There is a previously reported correlation between level of autistic traits and patterns of media use, that shows that some autistic children with perhaps higher support needs will use technology in less socially interactive ways than other children (Engelhardt & Mazurek, 2014; Mazurek et al., 2012). From the perspective of designers, this group are perhaps more difficult to engage with technologies (Fletcher-Watson, 2014), which may therefore affect how they interact with others. While the results of this thesis show that perhaps this is not true, and that technologies are also socially relevant and engaging for autistic children with learning disabilities (see chapters 4 and 5), this still doesn't answer whether technologies are *more* engaging than non-digital toys. The features that were identified as most important in previous thesis work, such as enforced collaboration and child's social interaction style, may apply across both digital and non-digital contexts, and may therefore not be specific to technology at all. In other words, previous chapters have shown that both factors related to the child (interest, social motivation) and technology (mediation of interaction, such as through proximity of software features), and this current chapter will test whether these aspects are specific to digital contexts or not.

6.2.2 **Enforced collaboration**

One way in which technology can facilitate social interaction and engagement in autistic children is through enforced collaboration, where players are only able to proceed through a game when they interact or engage with another, co-located, player (Ben-Sasson et al., 2013). This design feature has shown to be effective at encouraging collaborative story-telling on table-top devices (Gal et al., 2009, 2016), and promoting joint engagement between players on tablet and computer interfaces (Holt & Yuill, 2014, 2017). However, as shown in chapters 4 and 5, there are other ways in which collaboration can be enforced, independent of the technology design. For instance, adults could 'enforce collaboration' by directing children's turn-taking on shared devices, and moving the desks nearer to each other in the classroom encouraged social awareness and parallel play in children (see Figure 4.4 on page 111). One question is whether enforced collaboration is 'specific' to digital technologies, in which case, enforcing collaboration would be less effective on non-digital toys. But if enforced collaboration encourages social interaction across digital and non-digital toys, this potentially provides some recommendations for the design of new technologies, or how classroom activities, both digital and non-digital, could be implemented to encourage social interaction.

6.2.3 **Current study**

This study aims to explore social play while autistic children with learning disabilities use digital and non-digital toys, and to investigate whether enforced collaboration is effective in both digital and non-digital contexts. The research questions are:

- Do autistic children with learning disabilities engage in more social play while using digital toys compared to non-digital toys?
- Is enforced collaboration effective at encouraging social interaction across digital and non-digital contexts?

6.3 Methodology

6.3.1 **Participants**

Participants were seven autistic children who were recruited from two schools for students with additional support needs. One school provided specific educational services to children with a diagnosis of autism spectrum disorder and a range of support needs, and the other school provided support to children with a range of social, emotional, and behavioural needs. Each school had shown previous interest in technology research, since they both participated in the focus group study reported in chapter 3, and had worked with the DART team (www.dart.ed.ac.uk) on previous projects related to design of new apps to support autistic children, and to evaluate technology-based learning and support.

All seven participants completed an Autism Diagnostic Observation Schedule II (ADOS; Lord et al. (2000)), at a level appropriate to their chronological and developmental age (see Table 6.1). Six of the participants had a co-occurring learning disability, as reported by their class teacher. Participants had a mean age of 14 years and were all male. Profiles of participating children are described below, which were derived from informal discussions between the teaching team and the researcher, as well as the observations of children's play during the study. Each of the participants' class teachers were asked to complete the same standardised measures used in chapter 4 for characterising the sample (i.e. the Social Responsiveness Scale, the Vineland Adaptive Behaviour Scale, and the Wing's Subgroups Questionnaire), however, the teaching team were unable to complete these forms within the school term to allow for a valid assessment of children's social communication skills during the observational study.

Table 6.1: Participant demographics

Participant	Age (years)	ADOS score (module)	Number of toys per pair
Aaron	14	10 (1)	2 (free collaboration)
Brendon	16	10 (3)	1 (enforced collaboration)
Daryl	16	4 (3)	1 (enforced collaboration)
Francis	14	8 (1)	2 (free collaboration)
Mark	14	5 (1)	2 (free collaboration)
Tom	14	9 (1)	2 (free collaboration)
Tyler	15	9 (1)	1 (enforced collaboration)

6.3.1.1 **Aaron**

Aaron is 14 years old and spoke a handful of single words. According to Aaron's teacher, he was highly interested in technology and enjoyed playing with the interactive sensory room in his school and playing on the classroom iPads. Throughout the sessions, Aaron seemed to be engaged in both the digital and non-digital toys, although was curious and excitable about Code-A-Pillar when it was first introduced.

6.3.1.2 **Brendon**

Brendon is 16 years old, verbally fluent, and appeared highly socially motivated during his ADOS, and often interacted with staff and the researcher during the session. Brendon told the researcher that he enjoyed playing video games at home, but his teacher said that Brendon was not particularly motivated by technologies or computers in class.

6.3.1.3 **Daryl**

Daryl is verbally fluent and was 16 years old at the study time. Daryl appeared interested in using technology at school and had taken part in Minecraft club and a computer programming course. He did remark on one occasion during the sessions that Code-A-Pillar was “too easy” but was still happy to engage in the research sessions.

6.3.1.4 **Francis**

Francis is 14 years old and non-verbal and uses gesture-based communication with staff. Francis enjoyed ‘rough and tumble’ play during the sessions and enjoying picking up the pieces of each toy and throwing them around, sometimes engaging in back and forth throwing of bricks with a staff member. His teacher said that Francis loved to play with any kind of bricks or construction toy in this way and said that he would probably mostly enjoy playing with the bricks which were easier to pick up than the Code-A-Pillar pieces.

6.3.1.5 **Mark**

Mark is 14 years old and uses some spoken words and gesture-based communication with staff and peers. According to his teacher, Mark was less interested in using technology at school and mostly engaged in rough and tumble play, like Francis. Mark often left the sessions early to do other activities or did not stay for very long – particularly in the digital sessions.

6.3.1.6 **Tom**

Tom is 14 years old and uses some spoken words to communicate with others. According to his teacher, Tom was very interested in and keen to use technology in the classroom, and also enjoyed using the interactive sensory room in school. His teacher reckoned that Tom would probably prefer Code-A-Pillar, because of the music and the construction elements, and this was most seen in the first sessions when Tom was excited to see and play with Code-A-Pillar for the first time.

6.3.1.7 **Tyler**

Tyler is 15 years old and uses some spoken words to communicate. He did not seem particularly interested in either of the toys during the study, and often left sessions early or chose to do other activities. Tyler enjoyed using the laptop in the classroom, researching and making presentations on different topics, but did not seem particularly interested in either Code-A-Pillar or the BRIO magnetic train.

6.3.2 **Toys**

The toys used in this study were selected in part from the results of previous chapters, and also through iterative discussions between the research team to identify “the best match” to the digital toy.

6.3.2.1 **Selection of Code-A-Pillar (digital toy)**

In chapter 4, the interface which promoted the most (in absolute values and percentages) of social play with peers was iPad, and the app which promoted the most complementary play, the highest level of social play, was Toca Tea Party (see section 4.4.2 on page 108). The obvious non-digital toy to compare social play on this app to would be a pretend tea party set, but it was felt that the participants in this study would have difficulty engaging in pretend play (as would be expected from a pretend tea set), and would not be as interested in this type of toy, according to the teacher. The technology which promoted the next best levels of complementary play with peers was Code-A-Pillar, and hence Code-A-Pillar was chosen as the digital toy.

6.3.2.2 **Selection of BRIO magnetic train (matched non-digital toy)**

Having chosen Code-A-Pillar as the digital toy, a number of toys were shortlisted to be a non-digital equivalent, and to compare social play, and the information and details about these toys are included in Appendix 2: Technology shortlists for chapters 4 - 7, on page 209). In short, a number of mobile, buildable toys were chosen as potential candidate comparison toys, some with anthropomorphic features similar to Code-A-PIllar, and some with a vehicle theme. Some of these toys were not chosen because they contained lots of small parts, presenting a choking hazard or being difficult for children with fine motor difficulties to manipulate. The BRIO magnetic train™ was chosen as the best matched non-digital equivalent to Code-A-Pillar, because of its simplistic construction and the mapping of colours to particular item features (see Figure 6.1. and Table 6.2 for more information).

6.3.2.3 **Enforced collaboration**

The effect of enforced collaboration for both digital and non-digital play was manipulated on a between-participants basis. At one school, each pair of children arrived at a session with only one toy [to share], and at the other school each pair had two toys to share. The decision to conduct comparison this way was done for continuity for participants (e.g. it might have been upsetting for children to be ‘forced’ to share after not being expected to do so previously). The condition that each participant completed is reported in Table 6.1 on page 144.

Figure 6.1: Code-A-Pillar and BRIO magnetic train

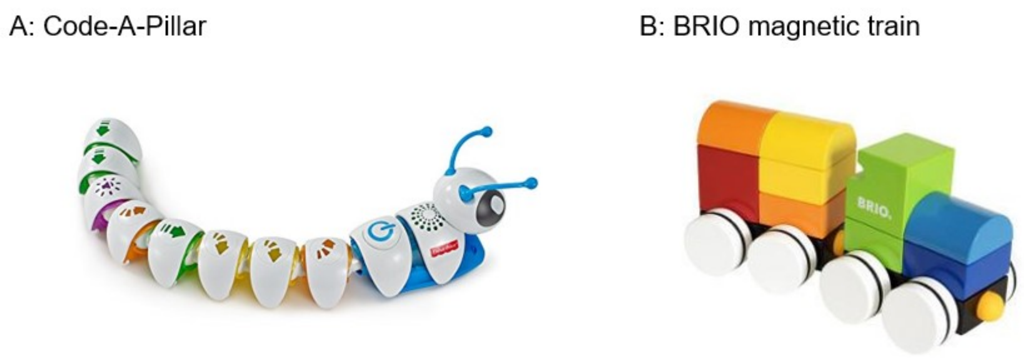


Table 6.2: Feature comparison of Code-A-Pillar and BRIO magnetic train

Toy	Code-A-Pillar (digital)	BRIO magnetic train (non-digital)
Manufacturer information (release date)	Fisher Price Think and Learn™ (2016)	BRIO™ (2004)
Materials	Plastic / batteries	Wood / magnets
Player interaction and goal	Connection by USB ports, activate toy with button on head, make Code-a-Pillar move to a target*	Connection by magnets
Motion	Self-propelling (independent from user)	Pushed on wheels by player
Individual kit information	*11 pieces:* 1 head piece; "active part" 3x forward (green) 2x right turn (yellow) 2x left turn (orange) 1x music (purple) 1x start point (green disc) 1x finish point (red disc)	*11 pieces:* 2x base with wheels; "active part" 4x small boxes (yellow, orange, green, blue) 1x large box piece (red) 3x cylindrical pieces (orange, yellow, blue) 1x large cube with cut-out (green)

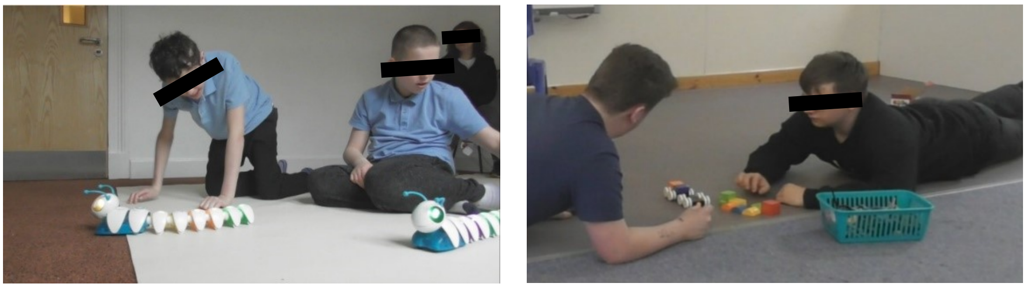
The Code-A-Pillar "target" was two discs which acted as start and finish points to guide Code-A-Pillar's direction. These were not used by the children in this way during the sessions – but they were available throughout. Some children engaged in disc-spinning, and this was not coded as Code-A-Pillar play unless it involved engagement with another part (e.g. watching Code-A-Pillar move and spinning a disc counted as Code-A-Pillar play). The BRIO train did not come with targets to direct the train motion.

6.3.3 **Procedure**

6.3.3.1 **Session structure**

Observations took place in school during students' timetabled 'free play.' Children were allowed to play with the designated toys in each session (see Appendix 6: Video footage meta-data and clip selection process, for studies reported in chapters 4 - 7 on page 217), or to participate in an alternative activity as they wished. As mentioned above, some children were less interested in technology and so meant that they left sessions early. The observed time in each technology was variable, and some students were absent on the arranged session day which meant that sessions had to be 'made up' at a later date.

Figure 6.2: Example of 'enforced' and 'free' collaboration, where pairs of children had either their own toy or one shared toy



Children always came to each session in pairs, and this was usually the same pair each time except when on occasion students were absent and others ‘filled in’ (see Appendix 6: Video footage meta-data and clip selection process, for studies reported in chapters 4 - 7 on page 217). At each session, the toy(s) were laid out in the middle of the floor and children entered the room after completing the consent procedure described above. When two toys were given, each toy was placed in a separate pile not more than one metre apart each time, and when one toy was given, this was piled into the middle of the room (see Figure 6.2). There were no explicit instructions given during the session, by teacher or by researcher, that children had to play together.

On one occasion in each school, participants were given five minutes to play with one toy, which was immediately followed by five minutes on the other toys (i.e. two sessions were recorded back to back, and each time the first toy was packed away before giving children the second toy). Each session was planned to last for five minutes (ten minutes total when this was two sessions back to back), although the actual session and recording time varied. Sometimes, sessions were shorter because children left early or sometimes sessions were longer because children were enjoying the session. In one school sessions were held once a week with all participating students (across the full term), and in the other school sessions were held twice a week across part of the school term, around 4-5 weeks. Prior to recording, the researcher attended each school once to observe some of the children in class and get to know them. The administration of the Autism Diagnostic Observation Schedule was done throughout the study to fit in with the school's schedule.

The sessions were recorded in the same location within each school – in one school this was in an empty classroom, and in the other it was a small room which contained the school's interactive sensory room unit. The equipment was removed prior to each session. In each location, one or two static video cameras were placed in a corner, out of the children's way. The staff who were supporting the children in each session remained in the room, and mostly sat on the side observing the children. Occasionally, they would be involved in play when children requested them to (i.e. "have a look at this!", or when children took their hand/looked at them to invite them to play).

6.3.3.2 **Consent procedure**

Consent was collected for each teacher, member of staff, and student involved in the study. Written consent was gathered from members of staff, and participants' parents, and verbal consent was collected from each participant at each session following the same procedure from chapter 4 (see section 4.3.3.2 on page 99, and Appendix 3: Participant consent procedure on page 213).

6.3.4 **Rating of social play**

The Peer Play Scale by Howes and Matheson (1992) was used to rate children's social play (see Appendix 5: Peer Play Scale by Howes & Matheson (1992) on page 216). The same coding procedure and structure was replicated from chapter 4, where for each 10-second window I coded the child's state of play, their play partner, and the toy they were using (see Table 4.5 on page 104). As previously, ELAN version 4.9.2 was used to code the video data (Max Plank Institute for Psycholinguistics, 2016).

6.3.5 **Analysis procedure**

From ELAN, data was exported into .csv format and then into RStudio for analysis (RStudio Team, 2016). Missing data, due to children moving out of the line of the camera or leaving a session early, were removed from the dataset. Due to the variance in available data for each child, analysis is undertaken on a case by case basis, and data reported in terms of absolute values (e.g. amounts of time, as well as in percentages values, either for particular participants, toys, or stages of play.

First, the frequency of observations for each play category, in each condition (i.e. digital / non-digital toy, enforced collaboration / free collaboration), was tallied within the dataset. These observations were then converted into equivalent time in minutes using the formula: $\frac{(\mathrm{n} \times 10)}{60}$, where *n* is the frequency count for each code, *10 converts this into number of seconds, and division by 60 transposes this into minutes. The frequency unit, *n*, is used to calculate proportions of data based on total *n* within a given particular category, such as proportion of observations for different participants and for different technological interfaces. Due to the exploratory nature of the study, as well as the small and highly variable dataset, results are presented in tables and figures with both absolute and proportionate values where appropriate.

To look at differences between digital and non-digital play, the percentage of points exceeding the median was calculated. This procedure is used in single-case designs to calculate individual effect sizes (Ma, 2006; Wendt & Miller, 2012). The number of intervals observed in simple social play for each observation of digital play was compared to the median number of intervals of simple social play across all observations of non-digital play. The proportion of digital simple social play observations which exceeded the median number of non-digital simple social play observations was converted into a percentage and is interpreted as an individual effect size for the effect of the digital condition on simple social play relative to non-digital play (baseline). Finally, the amount of social play is plotted across each session to assess whether play changes across the observation sessions.

6.3.5.1 **Second coding**

A random sample of 3 videos (comprising 20% of videos) was second coded by an independent rater who was trained to use the Peer Play Scale, but who was unfamiliar with the dataset – the same coder who conducted secondary coding for chapter 4. Videos were randomly selected from the database, but representation of participants and technologies was manually checked by the lead researcher. The percentage of agreement between the two coders was 81.33%. The intra-class correlation was .87 [.82, .90] based on absolute agreement, 2-way fixed effects model, and from the mean of 2 independent raters. Cohen's Unweighted Kappa was .72 [.63, .81].

6.4 Results

6.4.1 Individual comparison of digital and non-digital play

The total time that children spent using each toy and in each state of social play is presented in Figure 6.3. This figure highlights that each child was observed on each toy and play state for a different amount of time, i.e. that most of Brendon's observations were on Code-A-Pillar and most of his play was simple social play, and most of Mark's observations were on BRIO train and most of his play was parallel play with peers. Note that while social play is rated individually, children were observed in pairs as follows: Brendon and Daryl, Tyler and a non-participating peer, Francis and Mark, and Aaron and Tom (see Appendix 6: Video footage meta-data and clip selection process, for studies reported in chapters 4 - 7 on page 217 for full pairing information).

6.4.2 Effect of toy and enforced collaboration on social play

Table 6.3 shows the amount of social play observed, for each play category and each condition, across each toy. Results have been reported as raw values (e.g. frequency of 10-second windows), equivalent length of time (in minutes), and as a percentage of the total available data on each toy and condition cross-over: enforced non-digital, free non-digital, enforced digital, and free digital).

Across the dataset, children spent most of the time observed engaged in parallel play, followed by adult interaction and then non-play (see Figure 6.4). When collaboration was enforced, children spent most of the observed time in simple social play when using both BRIO (non-digital) and Code-A-Pillar (digital) toys. When collaboration was not enforced, children spent most of the time in adult interaction or parallel play when using BRIO, and parallel play when using the Code-A-Pillar toys. When complementary and reciprocal play was observed, this was only shown when collaboration was enforced (on both digital and non-digital toys). However, this may also be due to the different social profiles across groups of participants, as the most socially motivated or able children were in the same group where collaboration was enforced.

The percentage of points exceeding the median was used to measure the difference between children's simple social play on digital and non-digital toys (see Table 6.4 on page 157). The percentage of points exceeding the median is calculated by taking the median observations of simple social play in non-digital sessions and comparing this median to the *absolute* observations of simple social play on each digital session. The number of absolute observations which exceed the median observation is converted into a percentage, and represents an effect size (Ma, 2006). As can be seen in Table 6.4, each participant has a different percentage of points exceeding the median, further highlighting individual variance within the dataset. Of the seven participants, four had a strong effect size which showed they engaged in more simple social play while playing with Code-A-Pillar. The remaining three participants had small effect sizes or no evidence of a statistically significant difference between digital and non-digital play. Participants who experienced enforced collaboration all had large effect sizes, while the participants who experienced free collaboration all had smaller effect sizes.

Figure 6.3: Individual participants' social play on Code-A-Pillar and BRIO

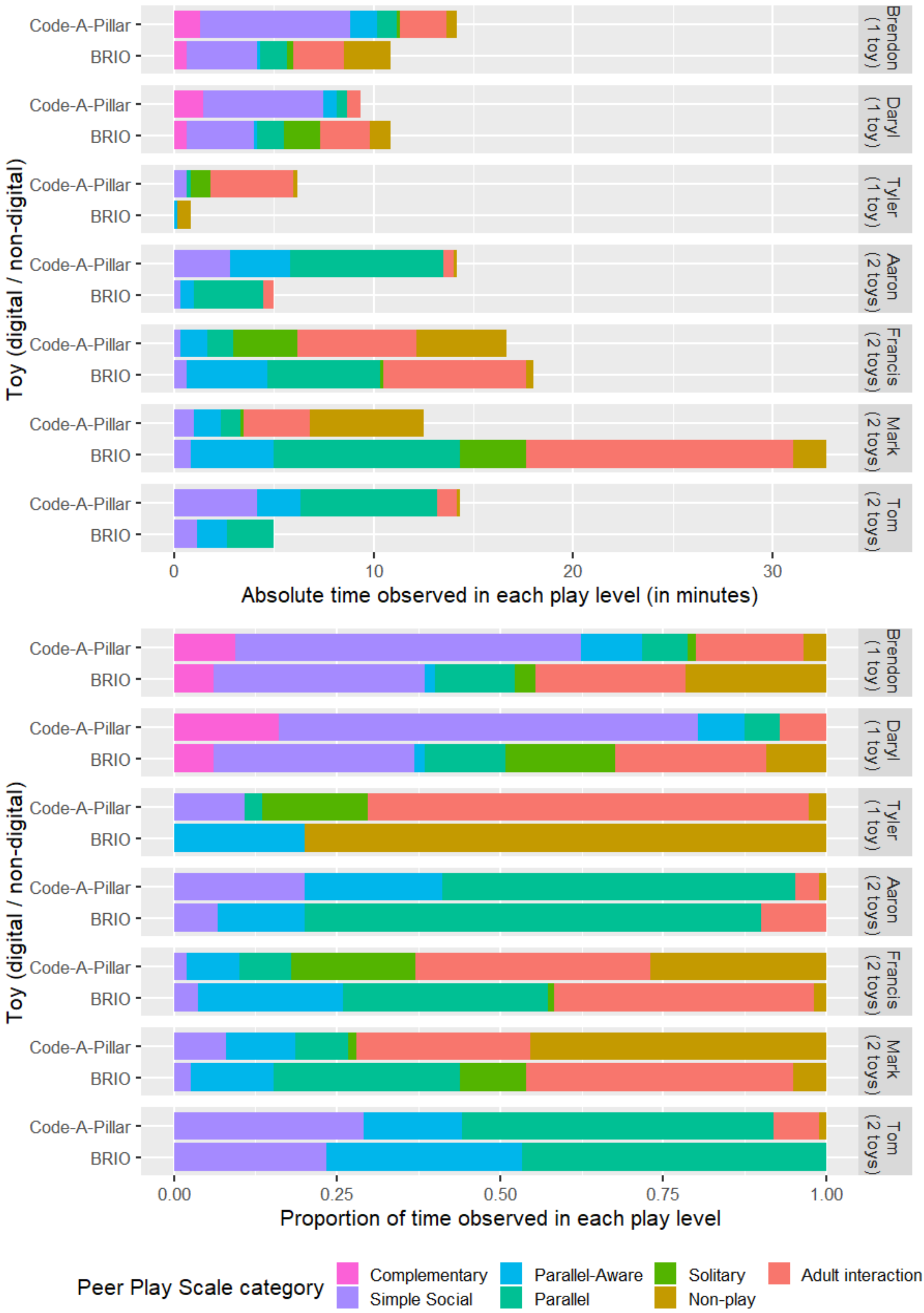


Table 6.3: Observations of play across digital and non-digital play in enforced and free- collaboration

Play category	**BRIO (*n, time, % of total condition time)***		**Code-A-Pillar (*n, time, % of total condition time)***		**Play totals (*n, time, % of total time)***
	Enforced	*Free*	*Enforced*	*Free*	
Non-play	24 (4mins, 17.7%)	12 (2mins, 3.3%)	4 (0.6mins, 2.2%)	63 (10.5mins, 18.2%)	103 (17.1mins, 10.06%)
Adult interaction	30 (5mins, 22.2%)	126 (21mins, 34.6%)	43 (7.1mins, 24.1%)	65 (10.8mins, 18.7%)	264 (41mins, 25.8%)
Solitary	13 (2.1mins, 9.62%)	21 (3.5mins, 5.7%)	7 (1.1mins, 3.9%)	20 (3.33mins, 5.7%)	61 (10.1mins, 5.9%)
Parallel	16 (2.6mins, 11.8%)	125 (20.8mins, 34.3%)	10 (1.6mins, 5.61%)	101 (16.8mins, 29.1%)	252 (42mins, 51.3%)
Parallel-Aware	3 (0.5mins, 2.2%)	62 (10.3mins, 17.1%)	12 (2mins, 1.12%)	47 (7.8mins, 13.58%)	124 (20.6mins, 12.1%)
Simple social	41 (6.8mins, 30.3%)	18 (3mins, 4.9%)	85 (14.1mins, 47.7%)	50 (8.3mins, 14.4%)	194 (32.3mins, 18.9%)
Complementary	8 (1.3mins, 5.92%)	0	17 (2.8mins, 9.5%)	0	25 (4.1mins, 2.44%)
Condition totals	*135 (22.5mins, 27.1%)*	*364 (60mins, 72.9%)*	*178 (29.6mins, 33.9%)*	*346 (57.6mins, 66.1%)*	
Toy totals	***499 (83.1mins)***		***524 (87.3mins)***		***1023 (170.5mins)***

Percentages have been calculated based on the total available data for each toy and each condition (e.g. 17.7% of the play observed in the non-digital, enforced, condition was non-play, 22.2% of play in this condition was adult interaction… etc).

Figure 6.4: Overall social play on each condition

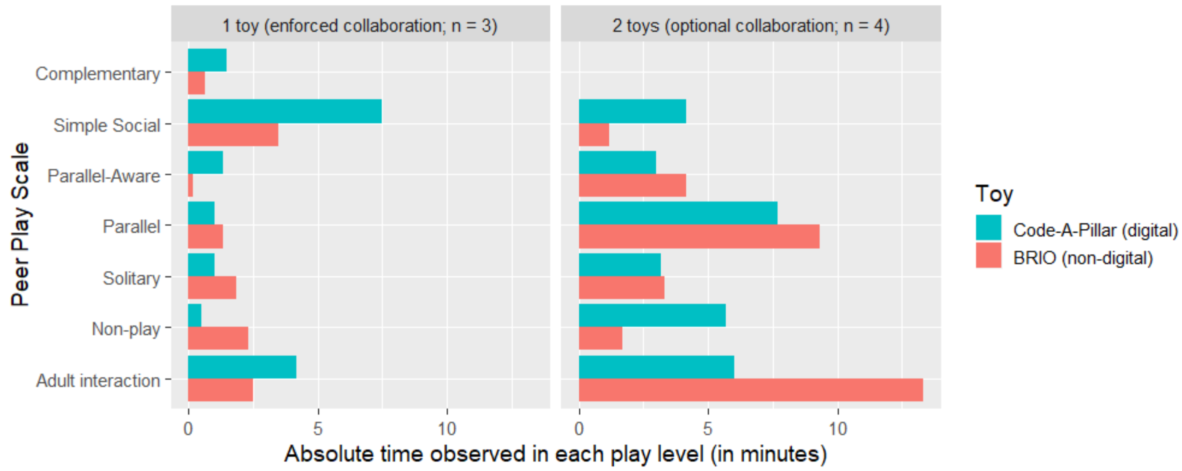


Table 6.4: Percentage of points exceeding the median

Participant ID	Condition	Median Simple Social play observed across **non-digital** sessions (*n* observed sessions)	Absolute observations of simple social play on each **digital** session (*n* observed sessions)	Percentage of Points Exceeding the Median (simple social play on digital > non-digital)	Effect size
Aaron	2 (free collaboration)	2 (1)	7, 10 (2)	100%	1
Brendon	1 (enforced collaboration)	21 (1)	38, 5, 2 (3)	33%	.33
Daryl	1 (enforced collaboration)	20 (1)	36 (1)	100%	1
Francis	2 (free collaboration)	4 (3)	2, 0 (2)	0%	0
Mark	2 (free collaboration)	5 (4)	6, 0 (2)	50%	.5
Tom	2 (free collaboration)	7 (1)	10, 15 (2)	100%	1
Tyler	1 (enforced collaboration)	0 (1)	4 (1)	100%	1

6.4.3 **Patterns of social play across sessions**

Figure 6.5 shows the observations of social play for each participant across sessions. All participants appear to have a steady decline in all levels of socially interactive play, as the sessions go on.

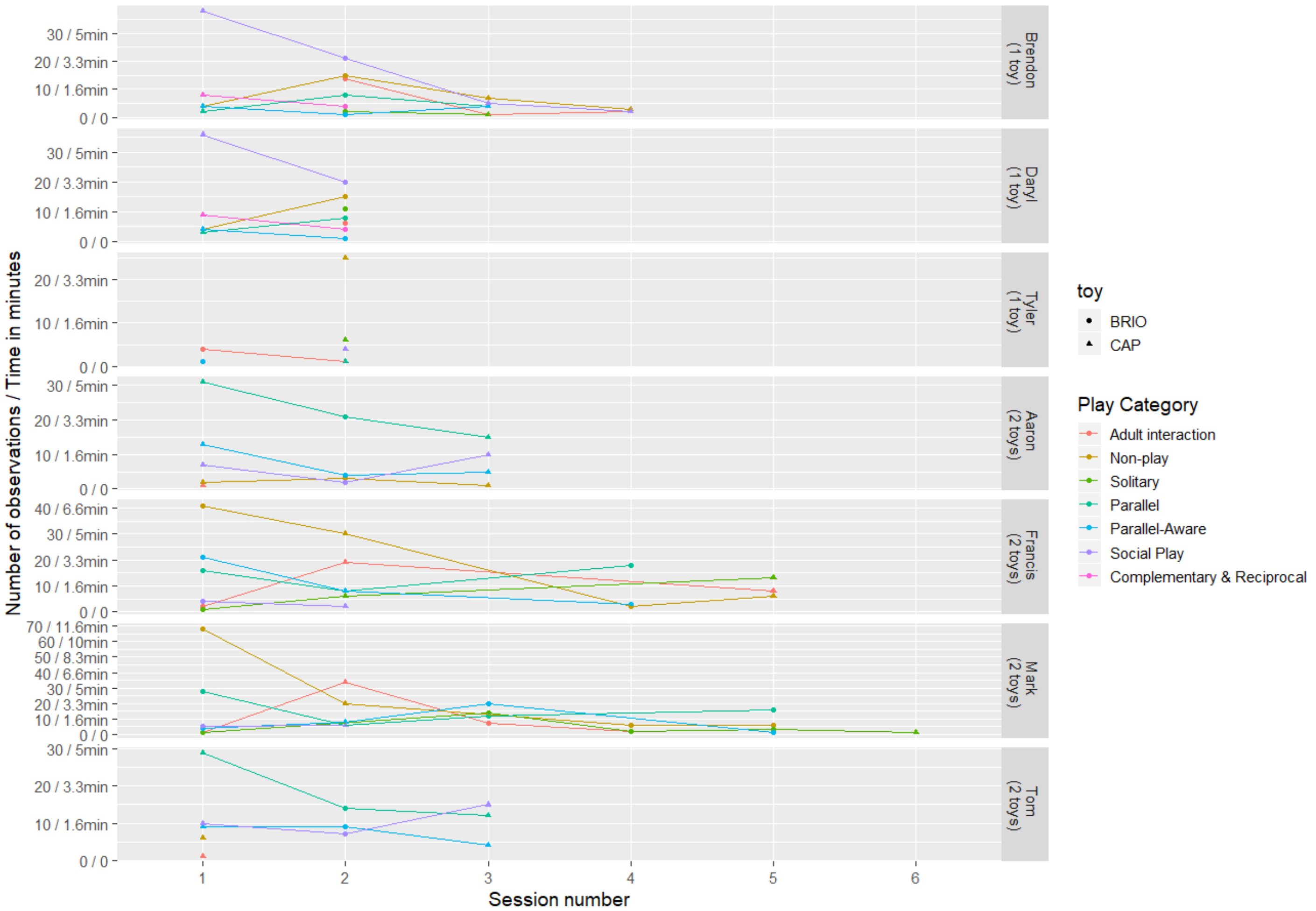
6.5 Discussion

The current chapter explored autistic children's social play whilst using matched digital and non-digital toys and investigated the effect of enforced collaboration in digital and non-digital settings. Although there were individual differences in overall patterns of play, the results showed that most of the participants engaged in higher levels of social play on the digital toy compared to the non-digital toy. The results also showed that children who were observed in the 'enforced collaboration' condition had more social play in both digital and non-digital contexts, than children who were observed in the 'free collaboration' condition.

6.5.1 **Alignment with previous literature**

A handful of studies have shown increased social play and interaction while autistic children use digital technologies, compared to matched non-digital toys (Farr, Yuill, & Raffle, 2010; Francis et al., 2019; Hourcade et al., 2013). These studies have observed play in free-play environments (Francis et al., 2019), and in conditions where adult moderators instruct children to engage in group play (Farr, Yuill, & Raffle, 2010; Hourcade et al., 2013). What this study adds is that there is individual variance in the patterns of social play across digital and non-digital settings in autistic children, and that children will engage in more social play when collaboration is enforced, across both digital and non-digital toys. This key finding highlights the role of child profile, their own interests and levels of social motivation, and the effect of toy-mediated or environmentally-enforced collaboration.

Figure 6.5: Total play observations across sessions for each participant



Note that session number refers to participants' session numbers, so some participants, like Mark, have concurrent observations of play on BRIO because he missed some of the sessions on Code-A-Pillar.

Other work on technology-mediated social interactions in autistic children has shown that enforcing collaboration in digital environments will increase social engagement (Ben-Sasson et al., 2013; Gal et al., 2016; Holt & Yuill, 2017). In line with the literature, the likelihoods of progressing to more socially interactive levels of play are increased when collaboration is enforced, in both digital and non-digital settings (see Appendix 8: D'Mello Likelihood Metric scores by each condition (collaboration and number of toys) on page 220), which was previously suggested by Farr *et al.* (2010). What this study adds to the literature is enforced collaboration can increase social play in non-digital settings too, thereby contributing to the overall design and implementation of toys to support social interaction in autistic children. While enforced collaboration is manipulatable through specific software or interface design (Ben-Sasson et al., 2013; Holt & Yuill, 2017), it can also be executed by encouraging children to share the same 'set' of a toy. How this applies to other technologies, such as touch-screens and digital interfaces, is unclear, since previous work has shown that there is less social interaction and engagement when children are forced to share one screen, compared to having separate control of a dual-controlled interface, where children have their own screen but can easily watch what another person is doing (Holt & Yuill, 2014). Future work could further explore the effect of enforced collaboration, at the level of software and hardware, to draw out where enforcing collaboration would be most effective.

6.5.2 **Theoretical implications: motivated vs. mediated social interactions**

In the beginning of this thesis, I proposed that the social motivation theory of autism could explain why autistic children were more likely to socially engage while using technology. The social motivation theory suggests that autistic people have reduced levels of overall social motivation, but will be more likely to engage in social interactions which are engaging to an individual (for instance, with familiar people or about special interests) (Chevallier et al., 2012, 2015; Elsabbagh, Gliga, et al., 2013; Jaswal & Akhtar, 2019). Although the theory has its limitations (see section 1.3.3 on page 25), the chapters in this thesis so far have generally supported the social motivation account. That is, that children's social interaction style and preferences tended to shape children's interactions in digital environments (see chapter 5), and those children with the most reported levels of social motivation were also engaging in more collaborative play with others while using technology (see chapter 4).

However, the findings of this chapter do not precisely fit with the social motivational account, in terms of explaining why interaction is increased around digital technologies. Social motivation theory would have been more strongly supported if both groups had engaged in more social engagement with the digital toy, independently of enforced collaboration. Here, it is shown that enforced collaboration increased levels of social play across contexts, thus suggesting that social interaction is strongly mediated by constraints on collaboration, and not something about the technology specifically. If they were driven by motivation alone, we would expect children to 'over-rule' the constraints of interaction and either engage or not engage in social interaction according to their preferences. Another limitation of the motivation theory to explain social interaction in digital contexts is, as with previous chapters of this thesis (see Figure 4.4 on figure 111), the finding that interaction consistently decreases across sessions (see Figure 6.5 on page 159), suggesting a strong role of novelty in shaping children's social engagements. While it is hard to delineate from the current analysis precisely why and which children were more motivated by digital technologies, these findings suggest that enforced collaboration, or rather, adult-mediation of context, had a strong influence on children's interactions, seemingly independent of pupil profiles or interest in technology. Future work could compare autistic children with high and low 'interests' in technology to see whether the changes in social play are related to reported motivations for technology, or due to other factors, such as adult- or technology-mediated interactions.

6.5.3 **The matching of digital and non-digital toys**

In line with similar work (Farr, Yuill, & Raffle, 2010), the digital and non-digital toys used in this study were matched on visual presentation and characteristics of player interaction. However, on reflection and after watching the footage, these toys still have a significant difference in the way in which collaboration was ‘enforced’, which may in part explain some of the findings, and provide new avenues for future research. As with similar tangible toys which have been discussed in research, each Code-A-Pillar has one “active part” which is thought to constrain and promote interaction in autistic children (Farr, Yuill, Harris, et al., 2010). The BRIO train, on the other hand, each have “two” active parts, if these are matched to the bricks with wheels, which allow the train to move (see Figure 6.1 on page 147). In this sense, two children could still successfully ‘play with’ BRIO train separately from one kit, because each child could have a separate “active part”, but on Code-A-Pillar this was not possible because the singular functional part was what allowed the toy to move and be played with. That said, there was still a large difference in presence of socially interactive play when collaboration was ‘enforced’ rather than ‘free’ on the BRIO train. However, future work should carefully control the constraints on collaboration and joint engagement, to investigate its influence more thoroughly on social interaction.

A further limitation on final conclusions from this chapter is the randomised assignment of school / participants to enforced collaboration condition, which may have introduced additional variables which could explain the final results. That is, that both the participants who completed a module 3 ADOS (see Table 6.1 on page 144), and had higher verbal communication skills, were assigned to the condition where collaboration is enforced. What this means is that participant profile, including overall social skills and related verbal and conversational skills, may explain increased levels of social play, rather than there being an effect of enforced collaboration. While previous chapters in this thesis show that the measure of social play used can capture social interaction in younger children with higher support needs than these participants in question, their baseline social skills being higher than the average of the group may still partly explain the observation of increased social play. However, as shown in Figure 6.3, there is still a notable increase in social play between digital and non-digital play for these participants, which is also observed in participants with different demographics and social profiles. Further work could explore the role of baseline social profile and social skills in digitally mediated play environments, to unpick whether changes in social play result from participant profile or changes in the environment (e.g. presence of digital technologies or enforced collaboration).

6.5.4 **Conclusions**

This study suggests that autistic children with learning disabilities engage in more social interaction while using digital technologies, compared to non-digital toys. It also suggests that enforcing collaboration, in digital and non-digital contexts, promotes socially interactive play. Moving forward, future work could explore the different ways in which collaboration can be enforced, and at particular gradients of enforcement (e.g. as what was inadvertently done in this study, when comparing Code-A-Pillar and BRIO magnetic train). With larger samples, future work could attempt to address how children’s overall interest in technologies interact with different levels of mediated collaboration, to see whether social motivations fully explain social engagement in digital and non-digital environments.

7 The effect of enforced collaboration on joint engagement when autistic children play with digital and non-digital toys

7.1 Chapter Acknowledgements

I am grateful to Dr. Jenny Gibson (Play in Education, Development and Learning (PEDAL) at the University of Cambridge) for sharing materials for calculating the D'Mello Likelihood Metric scores, and Dr. Bethan Dean (Centre for Reproductive Health, University of Edinburgh) for training and support on implementing the joint engagement coding scheme.

7.2 Introduction

This thesis has investigated the influence of technology on social interaction and play in autistic children. Chapter 3 reported on a survey and focus groups with autism practitioners about the impact of using technology in the classroom. Practitioners generally reported positive attitudes to using technology (see Figure 3.2 on page 70) and positive implications of technology for autistic children's social interactions (see Table 3.7 on page 79). However, practitioners also reported concerns about autistic children's repetitive behaviours while engaging with technology, and used phrases like "fixated" to describe some children's engagement with screen-based devices in the classroom. One survey respondent said: "*some screen-based technology is designed to keep you playing, and this can make it harder for some autistic children to disengage because of their attentional differences*."

The remainder of this thesis has sought to explore the influence of different toys, digital interfaces, and classroom environments on autistic children's social interaction and play. Chapter 4 reported on a design-based research study, conducted in collaboration with education practitioners, which found that autistic children showed the most social play while using Code-A-Pillar. No observable effects were found on autistic children's social play behaviours in different classroom environments, although there was a lot of variation between different participants' preferences for toys. Chapter 5 reported on a micro-analysis of specific moments where the children initiated interaction with others, and identified features of different apps such as suggested scaffolding collaboration, surprising digital events, and specific interfaces which prompted children to initiate interaction with other people. Chapter 6 explored the influence of enforcing collaboration on digital and non-digital toys on autistic children's social play. It was found that enforcing collaboration increased social play in both digital and non-digital conditions, but the effect was larger for the digital condition. While these results are promising in terms of social interaction, they do not test explicitly for the hypothesis of decreased social attention when children are using digital devices.

Joint engagement is coordinated attention between another person and a shared object of reference and is a known difficulty for many autistic children (Kasari et al., 2010). I will use a standardised scheme which has been applied in autism research to assess joint engagement, and categorise children's attention by object-oriented, person-oriented, or jointly engaged states (Adamson et al., 2008). This analysis thus provides an evaluation of whether digital toys capture autistic children's attention differently to non-digital toys, and whether attention in digital play is less socially oriented, or whether enforced collaboration has a significant effect on joint engagement.

7.2.1 **Joint attention and joint engagement in autism**

The terms "joint attention" and "joint engagement" are closely linked, and are often used interchangeably (Bottema-Beutel, 2016). One distinction is that joint attention refers to the initiation or response to shared attention bids with others, whilst joint engagement refers to *sustained* and shared attention between two or more people and a reference object (Locke et al., 2010). In the context of this thesis, joint engagement will be used to refer to a child's coordinated and sustained attention between another person and a shared physical reference, such as a toy (Bakeman & Adamson, 1984). Thus, joint engagement evaluates dyadic and coordinated interaction, whilst joint attention only assesses the behaviour of an individual, e.g. initiations or responses (Bottema-Beutel, 2016). In contrast to previously used measures of social play in this thesis, joint engagement therefore focuses more narrowly on children's 'actions' (including looking, attention), at a more fine-grained (temporally) level than the Howes' Peer Play Scale, which has been used previous in this thesis (e.g. in chapters 4 and 6).

Children with autism appear to develop joint attention skills differently, relative to children with developmental delay, other neurodevelopmental conditions, and neurotypical children (Adamson et al., 2008). For typically-developing infants, the ability to engage in joint attention usually develops within the first year of life (Mundy & Newell, 2007). The most complex forms of joint engagement are more frequently observed in children aged between two and three years. There is a large variability in autistic children's propensity to engage in joint engagement (Hurwitz & Watson, 2016). Early characteristics of autism before diagnosis typically refer to reduced frequency of joint attention behaviours, including fewer responses to others' bids of shared attention, fewer responses when the infants' name is called, and rarely initiating shared attention with others, such as pointing or showing objects to other people (Dawson et al., 2004). Mundy and Newall (2007) suggest that children with autism have more difficulty in initiating joint attention than responding to joint attention bids from others, and further work has suggested that autistic children will engage in joint attention behaviours, including initiating social interactions and pointing, when they are in environments which interest and motivate them (Jaswal & Akhtar, 2019; Meindl & Cannella-Malone, 2011; Mundy et al., 2007; Murray et al., 2005).

It is thought that teaching autistic children joint attention and engagement will lead to a cascade of skill development across other social communication areas (Charman, 2003). Thus, joint attention is a common target for autism interventions (Bottema-Beutel, 2016; Warreyn et al., 2014). Longitudinal studies with autistic children have shown that the frequency of responsiveness to others' joint attention bids in childhood is associated with a range of cognitive and social outcomes, including quality of social play in later childhood (Bruinsma et al., 2004; E. A. Jones & Carr, 2016), peer relationships at school (Freeman et al., 2015), expressive and receptive language in adolescence (McGovern & Sigman, 2005), and improved social functioning in adulthood (Gillespie-Lynch et al., 2012).

7.2.2 **Technology and social attention in autism**

With joint attention a "pivotal" skill for intervention (Charman, 2003), research has looked at the ways in which technology may mediate or teach joint attention skills to autistic children. Fletcher-Watson *et al.* (2016) developed an iPad app, FindMe™, designed to teach joint attention skills to preschool autistic children. The app specifically targeted 'precursors' to joint attention by encouraging children to assist a virtual character in collecting objects around a screen and rewarding children to following the character's pointing and gaze, which was developed through participatory design with autistic children (Fletcher-Watson, Pain, et al., 2016). FindMe was evaluated in a randomized control trial, which found no significant difference on social development between children who did or did not use the app. However, parents reported that their child enjoyed using the app to engage with their child (Fletcher-Watson, Petrou, et al., 2016), but the study did not collect observations of autistic children while using the FindMe App as part of the evaluation. The follow-up point, at which the primary outcome was assessed, was six months after the end of the intervention period, and therefore a long time for children to either gain or lose skills learned either from the FindMe intervention or from other educational support. While it cannot be concluded that technology is an effective teacher of joint attention skills, the study design also could not confirm whether technology had more immediate or interpersonal benefits on joint engagement while children were using the app.

Another example of a technology-mediated joint attention intervention is the ECHOES project, which developed a virtual environment to teach and reward joint attention skills in autistic children (Bernardini et al., 2014; Porayska-Pomsta et al., 2018). ECHOES encouraged children in a series of mini games to engage in joint attention with a virtual avatar. Autistic children were most successful when the ECHOES system engaged in "mutual gaze" with the child (Alcorn et al., 2011), in contrast to conditions where the system only used pointing or other single modality interactions. In contrast to FindMe discussed previously, ECHOES was an intelligent agent which tracked and responded to children's behaviour, as controlled by a co-present research assistant in a Wizard of Oz set up. A formal evaluation of ECHOES showed no evidence of transfer to play in a non-digital, collaborative task (Porayska-Pomsta et al., 2018). However, video analysis of autistic children engaging with the ECHOES system showed that novel and surprising events encouraged autistic children to initiate social interaction with the research assistant. These instances included autistic children turning around and making direct eye contact or interaction with another person, in response to these 'mistakes' made by the ECHOES system (Alcorn et al., 2011, 2014).

In addition to the studies within this thesis, previous work has shown that technology can be designed in a way which fosters collaboration, social awareness, and joint engagement (Bölte et al., 2010; Farr, Yuill, & Raffle, 2010; Holt & Yuill, 2017). A number of studies which have compared autistic children's social play on digital and non-digital toys have suggested that autistic children are more motivated to engage in social interaction when using digital toys (Farr, Yuill, & Raffle, 2010; Francis et al., 2019). A number of studies have highlighted that enforcing collaboration can elicit social awareness and joint engagement in autistic children (Battocchi et al., 2009; Gal et al., 2016; Holt & Yuill, 2014, 2017). Being able to see what others are doing, is thought to elicit social awareness in both non-autistic and autistic children, including those who have high support needs (Holt & Yuill, 2014, 2017; Yuill et al., 2014).

What this work suggests is that while there is limited evidence of the effectiveness for technology-mediated joint attention interventions for autism, technology may provide an environment where autistic children find it easier to engage in joint attention and engagement. Increased social play has been observed while autistic children use digital technologies compared to non-digital toys (Farr, Yuill, & Raffle, 2010), and increased joint attention has been observed when collaboration is enforced in digital conditions (Gal et al., 2016; Holt & Yuill, 2017). What is yet unexplored is whether social attention is different when autistic children play with matched digital and non-digital toys, and whether social attention is mediated by enforced collaboration in both digital and non-digital conditions.

7.3 Research questions

The current study presents a reanalysis of data reported in chapter 6, measuring children's social attention while playing with digital and non-digital toys, and when engaging in enforced and free collaboration. There was a three-month break between initial analysis of social play (reported in chapter 6) and the current analysis of joint engagement, so that the observations from the previous chapter were not influential on the coding in the current chapter. The specific research questions were:

- Is social attention different when autistic children engage with digital and non-digital toys?
- Is there an effect of enforced collaboration in digital and non-digital environments on autistic children's joint engagement?

7.4 Methodology

7.4.1 **Summary of chapter 6 methodology**

The data reported and analysed in this chapter comes from the same video data that was collected previously in chapter 6, where full methodological detail including recruitment, design, and session structure are provided (see section 6.3 on page 143).

This observational study compared autistic children's social play when using matched digital and non-digital toys, and when children engaged in either enforced or free collaboration (see Figure 6.2). Seven autistic children (see Table 6.1 on page 144 for participant profiles) were observed playing with Code-A-Pillar and BRIO magnetic train in pairs. Three children had to share one toy between each pair, and four children were given one toy each, to assess the effect of enforced collaboration in both digital and non-digital settings. Children were observed in a classroom during free play time. The full description of the video data collected for the project is included in Appendix 6: Video footage meta-data and clip selection process, for studies reported in chapters 4 - 7 on page 217.

7.4.2 **Rating of joint engagement**

Joint engagement was coded using the scheme described and developed in Bakeman and Adamson (1984). A copy of this instrument, and minor adaptations, are included and justified in Appendix 7: Joint engagement by Bakeman and Adamson (1984) and adaptations on page 219). The measure was adapted by adding a new category of 'adult interaction', to refer to any interaction that children had with adults (including when it was a conversation with adults). Rating of joint engagement was conducted in ELAN, where a similar tier structure was used as in previous chapters, where joint engagement was coded instead of social play (see Table 4.5 on page 104). In this study, the same procedure used for coding peer and adult interactions was used, but these were merged into a separate 'adult interaction' category described above as they were so rarely observed in the dataset. Coding was done temporally and continuously (i.e. without distinct windows), and as per Bakeman and Adamson (1984), children had to engage in a given state for at least three seconds for it to be coded. As with previous chapters, children's engagement states are coded independently for each child.

7.4.3 **Analysis procedure**

From ELAN, data was exported into .csv format and then into RStudio for analysis (RStudio Team, 2016). As per previous chapters, missing data were removed from the dataset, when children were out of sight of the camera or when children left a session early. Due to the variance in available data for each child, analysis is undertaken on a case by case basis, and data reported in terms of absolute values (e.g. amount of time), as well as in percentage values, either for particular participants, toys, or states of joint engagement

First, the duration of time spent in each engagement state that participants were observed in while using each toy is calculated. The children all spent different amounts of time engaging with each toy, as well as in each engagement state. Next, for the whole dataset, the amount of time spent in each engagement state, on each toy, and in each collaboration condition, was tallied and is presented in Figure 7.1, and percentages calculated for time spent in each engagement state.

The likelihood of progression between different engagement states was calculated, to look at differences between digital and non-digital joint engagement, and the effect of enforced collaboration. D'Mello Likelihood Metrics have been used in previous studies to examine the likelihood of autistic children progressing to more 'socially complex' forms of play while using digital and non-digital toys (Farr, Yuill, & Raffle, 2010; Farr & Yuill, 2012; Francis et al., 2019). D'Mello Likelihood Metrics were calculated for progression between one state of joint engagement to another, for each combination of states (e.g. from unengaged to solitary, and from solitary to unengaged, and so on…). The equation for calculating D'Mello Likelihood Metric scores was taken from D'Mello, Taylor and Grasser (2007):

$$L = \frac{\Pr(N \mid C) - \Pr(C)}{(1 - \Pr(\mathrm{N}))}$$

L stands for the Likelihood, Pr stands for probability, C is the current state of engagement and N is the subsequent state of engagement. The D'Mello Likelihood Score is statistically equivalent to Cohen's Kappa (D'Mello et al., 2007; D'Mello & Graesser, 2012) and ranges between 1 and -1, where 1 is 100% likelihood to progress from C to N, .5 indicates a 50% likelihood of progressing from C to N, and negative values indicate the degree to which an event is unlikely. Scores exceeding a threshold of .10 (i.e. 10% change of progression from C (current) to N (next)) are considered statistically significant (Francis et al., 2019).

7.5 Results

7.5.1 **Participant variance in joint engagement on digital and non-digital toys**

The total time that children spent using each toy, in each state of joint engagement, is presented in Figure 7.1. Figure 7.1 highlights that each child was observed on each toy and engagement state for a different amount of time.

7.5.2 **Effect of toy and collaboration condition on children's joint engagement**

Figure 7.1 shows the duration and proportion of time that children spent in each joint engagement state, on each toy and in each collaboration condition. When collaboration was enforced, children were observed in more coordinated joint engagement on both BRIO and Code-A-Pillar (see Figure 7.3). When collaboration was free, children were observed in more object-oriented play, on both BRIO and Code-A-Pillar. For comparison purposes, Figure 7.2 is a reprint of the results from chapter 6, which shows the influence of digital and non-digital toys, and enforced and free collaboration, on participants' social play. Table 7.1 shows the amount of each joint engagement state observed across all participants, for each engagement state, toy, and condition of enforced collaboration. Results have been reported as raw values (e.g. total duration summed), and as a percentage of the total available data on each toy and condition cross-over: enforced non-digital, free non-digital, enforced digital, and free digital).

Figure 7.1: Individual participants' joint engagement on Code-A-Pillar and BRIO (repeat from chapter 6)

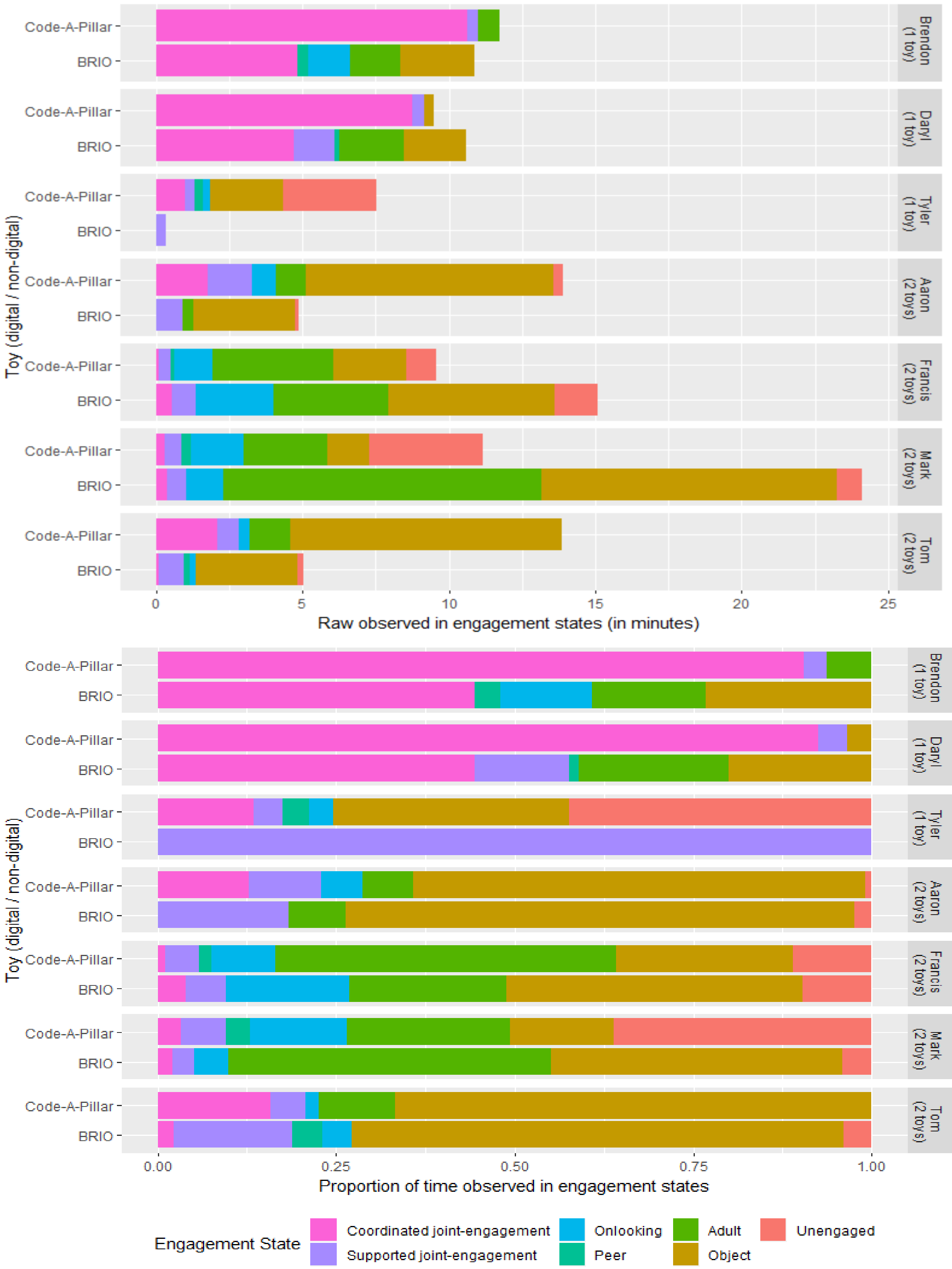


Figure 7.2: Individual participants' social play on Code-A-Pillar and BRIO

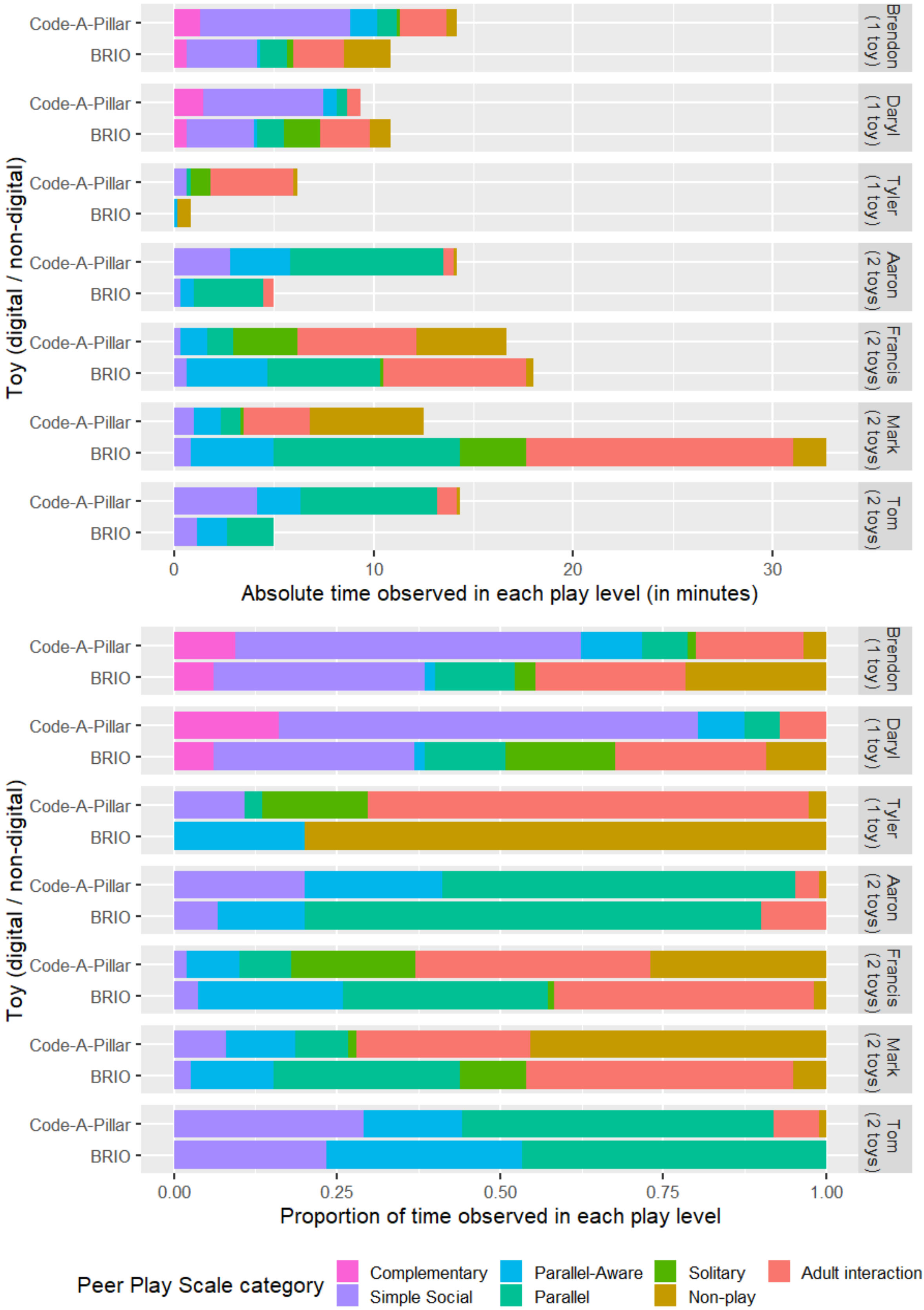


Figure 7.3: Group level duration and proportion of time in each collaboration condition on each toy

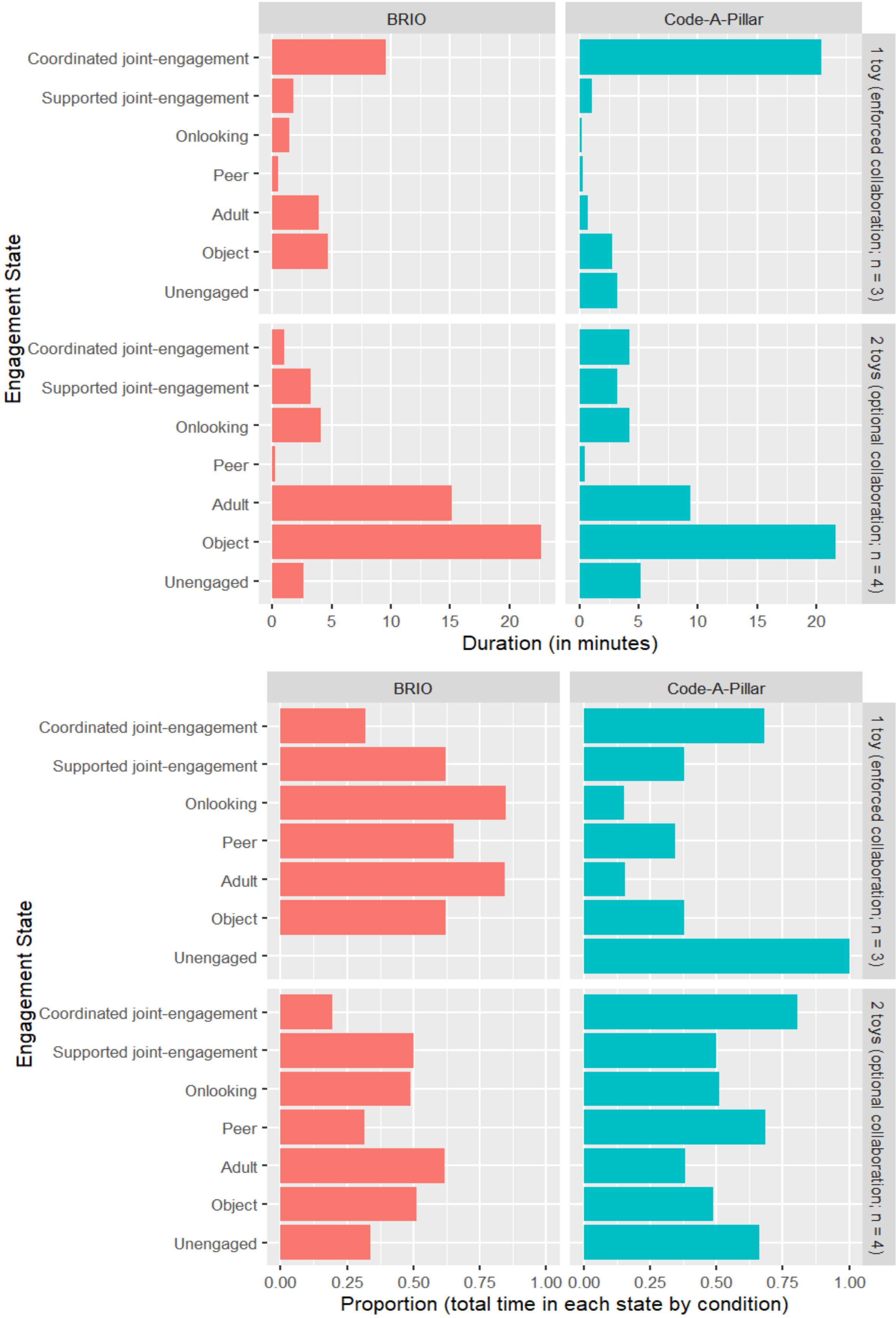


Table 7.1: Observations of joint engagement on digital and non-digital toys, in enforced and free collaboration conditions

Play category	**BRIO (*time, % of total condition time)***		**Code-A-Pillar (*time, % of total condition time)***		**Play totals (*time, % of total time)***
	Enforced (n = 3)	*Free (n = 4)*	*Enforced (n = 3)*	*Free (n = 4)*	*n = 7*
Unengaged	0	2.6mins (5.9%)	3.1mins (10.8%)	5.2mins (10.72%)	11mins (7.42%)
Object	4.6mins (21.1%)	22.7mins (26.23%)	2.8mins (9.75%)	21.6mins (44.53%)	51.8mins (34.97%)
Onlooking	1.4mins (6.42%)	4.1mins (8.3%)	0.25mins (0.87%)	4.26mins (8.78%)	10mins (6.75%)
Person (peer)	0.5mins (2.29%)	0.2mins (.4%)	0.28mins (0.97%)	0.46mins (0.94%)	1.5mins (1.01%)
Person (adult)	3.9mins (17.8%)	15.1mins (30.7%)	0.7mins (2.4%)	9.4mins (19.38%)	29.3mins (19.78%)
Supported joint engagement	1.7mins (7.79%)	3.2mins (6.51%)	1.06mins (3.69%)	3.23mins (6.65%)	9.3mins (6.27%)
Coordinated joint engagement	9.5mins (43.57%)	1.03mins (2.09%)	20.4mins (70.08%)	4.25mins (8.76%)	35.2mins (23.76%)
Condition totals	*21.8mins (30.74%)*	*49.1mins (69.25%)*	*28.7mins (37.17%)*	*48.5mins (62.82%)*	
Toy totals	**70.9mins**		**77.2mins**		***148.1mins***

The D’Mello Likelihood Metric calculates the probability of children progressing from one state to another, and this was used to look at changes in joint engagement state by toy and enforced collaboration condition. Table 7.2 shows the D’Mello metrics for non-digital play, and Table 7.3 shows the D’Mello metrics for digital play. In each table, boxes on the top-right indicate progressions to more complex or social forms of engagement (e.g. from unengaged to peer, from supported to coordinated joint engagement), and boxes on the bottom-left indicate progressions to less complex or social forms of engagement (e.g. from peer to unengaged, from coordinated to supported joint engagement). Shaded numbers indicate those which exceed the threshold of statistical significance, of +10% increase, in likelihood scores. For instance, in the non-digital condition (Table 7.2), there is a 38.9% likelihood that participants will progress from unengaged state to object engaged (row 2, column 2) and there is a 18.5% likelihood or progressing from object engagement to adult engagement (row 3, column 3). The D’Mello Likelihood metrics for each toy and enforced collaboration condition are reported in Appendix 8: D’Mello Likelihood Metric scores by each condition (collaboration and number of toys) on page 220). In summary, these show more significant positive progressions between engagement states when collaboration is enforced, in both digital and non-digital contexts.

Figure 7.4 visualises the statistically significant thresholds for both digital and non-digital conditions. There are more “pathways” (as referred to by Farr *et al.* (2010)) to both supported and coordinated joint engagement states when children used the digital toy, as illustrated in Figure 7.4 which shows the unique progressions to Code-A-Pillar. In both conditions, there is a bidirectional loop between object engagement and adult interaction, and more pathways to object engagement when children used the digital toy. Figure 7.5 is a reproduction of the same Code-A-Pillar figure, but showing only the independent Code-A-Pillar pathways to joint engagement, illustrating that Code-A-Pillar increased progression to more complex states of joint engagement.

Table 7.2: D'Mello Likelihood Metric for play on BRIO magnetic train

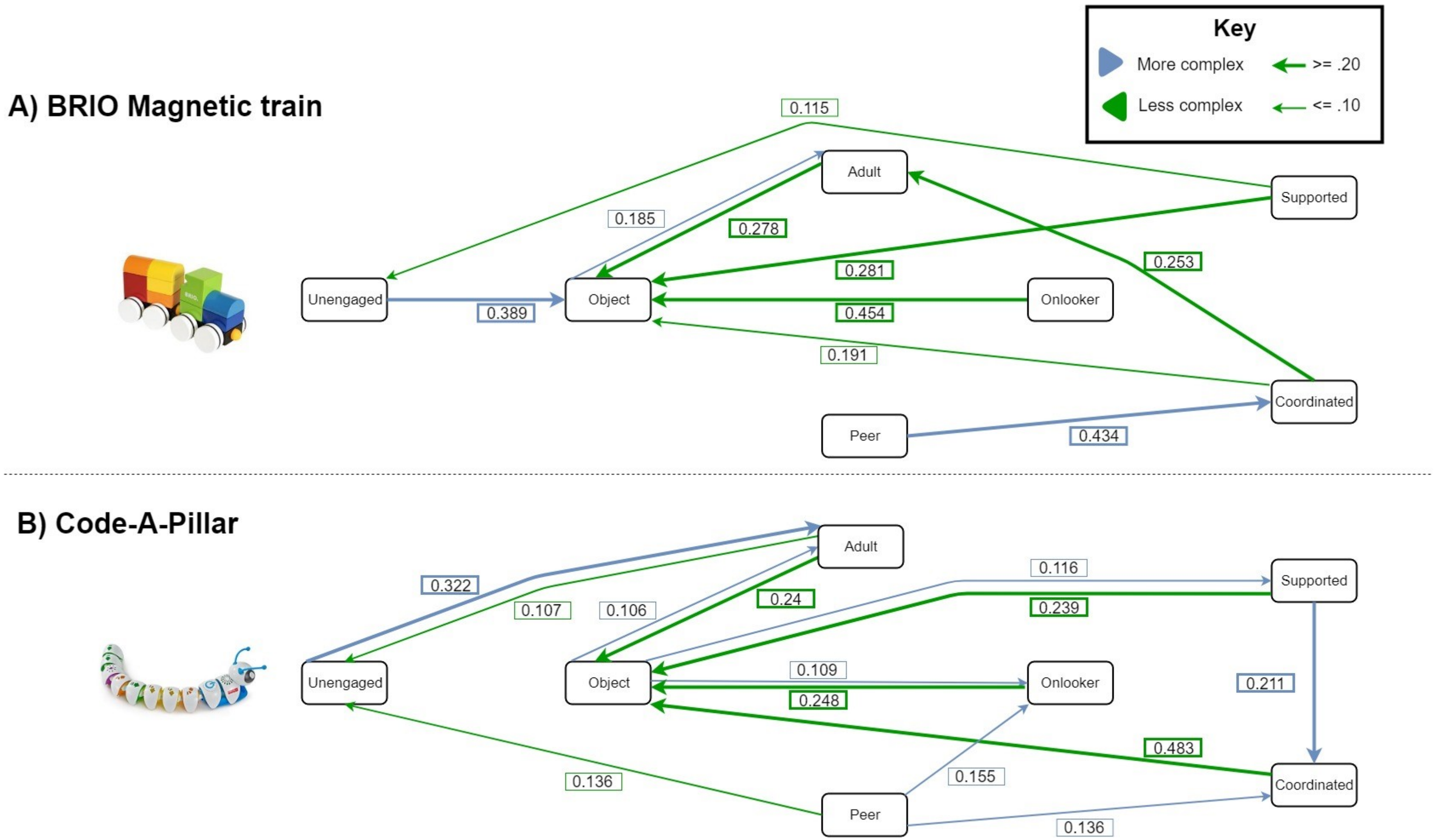
Next								
Previous	State	Unengaged	Object	Adult	Onlooking	Peer	Supported	Coordinated
	Unengaged	-	0.389	-0.016	-0.006	-0.022	-0.106	-0.057
	Object	0.054	-	0.185	0.099	-0.006	0.076	0.003
	Adult	-0.015	0.278	-	0.033	0.035	0.017	-0.038
	Onlooking	-0.074	0.454	-0.043	-	0.015	-0.066	-0.011
	Peer	-0.074	-0.146	-0.111	-0.015	-	-0.106	0.434
	Supported	0.115	0.281	-0.270	-0.024	-0.022	-	0.067
	Coordinated	-0.074	0.191	0.253	-0.160	-0.022	0.024	-

The D'Mello Likelihood Metrics represent likelihood of progressing from one state (in the row) to the next state (in the column). Likelihoods above the diagonal represent transitions from a less socially complex state to a more socially complex state, while likelihoods below the diagonal represent transitions from more complex to less complex. Numbers which are underlined and shaded indicate +.10% likelihood of progression.

Table 7.3: D'Mello Likelihood Metric for play on Code-A-Pillar

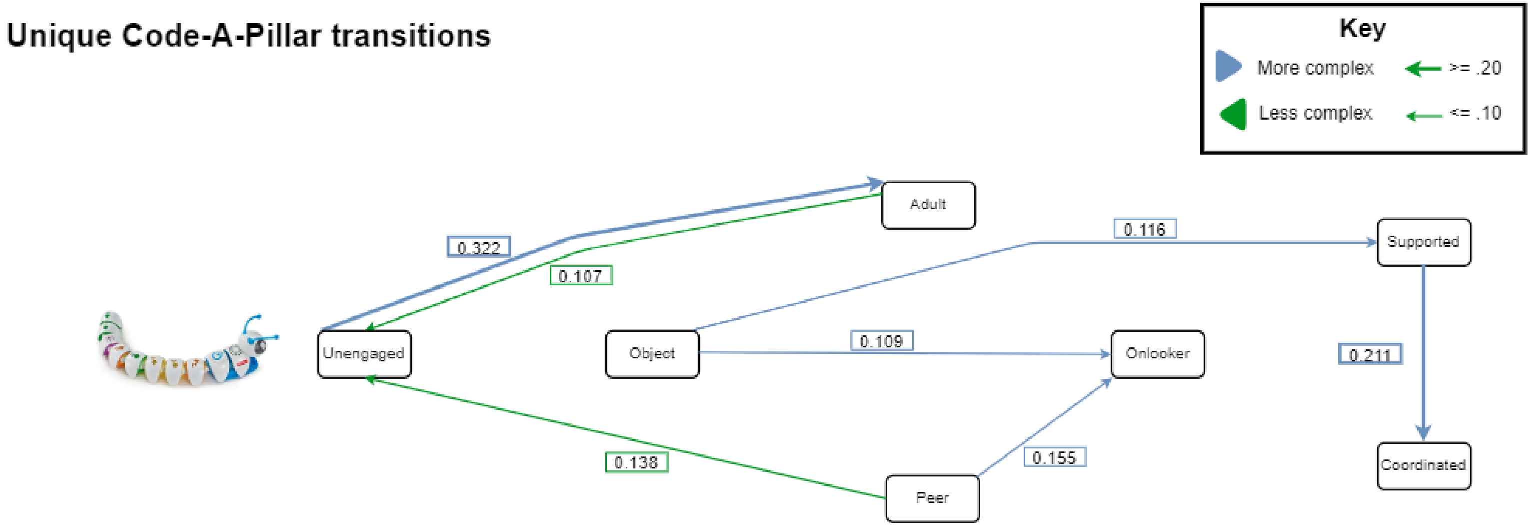
Next								
Previous	State	Unengaged	Object	Adult	Onlooking	Peer	Supported	Coordinated
	Unengaged	-	-0.169	0.322	0.046	0.019	-0.012	-0.064
	Object	-0.004	-	0.106	0.109	-0.004	0.116	0.033
	Adult	0.107	0.240	-	0.014	-0.020	-0.042	-0.008
	Onlooking	0.078	0.248	-0.058	-	0.021	-0.097	-0.014
	Peer	0.136	-0.447	0.056	0.155	-	-0.097	0.136
	Supported	-0.092	0.239	-0.060	-0.127	-0.020	-	0.211
	Coordinated	-0.029	0.483	-0.079	-0.127	0.016	-0.018	-

Figure 7.4: Likelihood scores for transitions between engagement states



Only significant (>10%) progression likelihoods are plotted. Bold lines indicate progressions which exceed +20% likelihoods. Colours indicate progressions to more complex engagement states (blue) and less complex engagement states (green)

Figure 7.5: Unique transitions between engagement states for Code-A-Pillar



Only significant (>10%) progression likelihoods which are unique to Code-A-Pillar plotted. Bold lines indicate progressions which exceed +20% likelihoods. Colours indicate progressions to more complex engagement states (blue) and less complex engagement states (green

7.6 Discussion

7.6.1 **Summary of results**

This chapter aimed to build on the findings from chapter 6, by exploring whether digital toys and enforced collaboration influenced joint engagement in autistic children. There is a concern that technology might capture autistic children's attention and displace engagement in social interaction with other people (Ramdoss, Lang, et al., 2011). This study aimed to address this concern specifically by analysing social attention in autistic children while using matched digital and non-digital toys in pairs, and to investigate the influence of enforced collaboration on joint engagement on both digital and non-digital toys.

Social attention and social play conceptually overlap at a behavioural level, so it is not surprising that a similar pattern of results to chapter 6 was observed here (see Figure 7.1 and Figure 7.2). That is, that more social play and coordinated joint engagement were observed when autistic children used a tangible digital toy compared to a matched non-digital toy, and when collaboration was enforced vs. when it was free. However, the measurement of joint engagement showed that children will often switch between states, which was not captured in the measurement of social play used in chapter 6, and that the likelihood of children progressing to more complex states of social play was also increased in both digital and enforced conditions. In summary, not only do autistic children engage in more social interaction while using digital toys and when collaboration is enforced, but they are also more likely to progress to more complex forms of social interaction under these conditions. Therefore, there is no evidence here that playing with digital toys is associated with lower levels of social engagement, and on the contrary, more opportunities for engaging in social interaction are observed in the digital condition compared to the non-digital condition.

7.6.2 **Relation to other work**

Previous work has shown that autistic children will engage in more social play and interaction when using digital toys, and when interacting in conditions which enforce collaboration. Francis *et al.* (2019) showed that autistic children would engage in increased social play when using Topobo, a tangible toy, and a non-digital counterpart, LEGO bricks. Similar results were shown in Farr *et al.* (2010), who theorised that Topobo enforced collaboration through limited use of an “active part”, meaning that children had to cooperate with others in order to engage fully in the game. Enforced collaboration has previously been explored through the eloquent design of software, which restrict children’s progression through a game until they engage and collaborate with other players. Enforced collaboration has been shown to increase joint attention and other awareness in young autistic children with learning disabilities on computer and tablet technologies (Holt & Yuill, 2014, 2017), and encourage social play while children engage in group games on a tabletop interface (Battocchi et al., 2009; Gal et al., 2016). The current study took a different approach to enforcing collaboration, by manipulating the number of devices given to pairs of children. This is a rather crude method for enforcing collaboration, only effective to a degree as discussed previously (see section 6.5.3 on page 161), but means that children’s collaboration is specifically child-led, rather than directly scaffolded by the non-digital toy. In other words, children *could* choose to go and play on their own in any way they wanted, and it is clear that children did this when they each had a toy (see Figure 7.1).

7.6.3 **Limitations and future implications**

The implications from this work on the social motivation theory of autism, and its relevance to technology-facilitated interactions, have been previously discussed in section 6.5.2 on page 160. With a larger sample, future work could unpick whether specific children who have high interests in technology engage in more social interaction in digital settings, with or without enforced collaboration. There is still an open question on whether the same effects of enforced collaboration would be derived from software-driven constraints, i.e. on apps and screen-devices. Previous work has successfully shown that software which enforces collaboration has a positive impact on autistic children's social engagement with peers (Bauminger-Zviely et al., 2013; Gal et al., 2016; Holt & Yuill, 2017; Piper et al., 2006).

An additional limitation in measuring joint engagement was that it was difficult to define when children were engaging in 'shared object play', since each toy in this study was compiled of multiple 'objects'. In other words, two children could each build a separate toy from the same pile of bricks, which would be classified as joint engagement since each brick came from the same pile, even if children are not actually interacting with each other. This note is reminiscent of previous debates in this thesis on how to define "the most socially engaging" activity (sections 4.5.2 on page 116, and 5.5.2 on page 138). In interpreting the data during coding, a consideration of "areas of engagement / interest" was taken as more absolute (e.g. the pile of bricks) rather than exactly matching whether each brick came from the same 'set'. Future work could perhaps rule this out by examining different coloured sets of the same train, to precisely code whether engagement was 'conjoined' with the same set, but on the other hand, spatial proximity seems an appropriate metric in considering social awareness and joint engagement (Chorney et al., 2015; Holt & Yuill, 2014). Future work could specifically examine proximity as a metric for joint engagement and observe whether children who start off in close proximity stay in joint engagement than children who play with separate piles of toys at bigger distances. This would perhaps shed light on a motivational dimension of play – since children would have to actively move to then become engaged with the other player, rather than simply 'becoming engaged' by proxy of having two piles of toys placed fairly near each other.

7.7 Conclusions

In summary, it was found that autistic children engage in increased levels of joint engagement when using digital technologies than non-digital toys, and joint engagement also increased when collaboration was enforced in both digital and non-digital contexts. This finding highlights the role of the environmental set up in shaping autistic children's social interactions, and further shows that technology, and toys, themselves can shape children's interactions, perhaps in conjunction with or over and above, their own interest in technology. That is, that both children's social interaction style *and* socially facilitating environments can have unique effects on autistic children's social engagement. This highlights that future work to design new technologies or environments which foster interaction remains a useful avenue, in order to identify features which can be best-matched to individual participants or contexts. Overall, there is now further evidence for no (clinically) significant differences between interactions on digital and non-digital toys, even in children with profound levels of social difficulties, and that digital technologies can provide social opportunities for autistic children.

8 Discussion

This thesis has explored the influence of digital technologies on social interaction and play in autistic children. Three studies, and six analytic approaches, have yielded qualitative and quantitative data which can help us address *whether* interaction is different in digital contexts, and *how* technology can provide social opportunities for autistic children. These studies combine insights from educational practitioners and classroom observations to explore ways in which technologies could potentially be used in schools to provide meaningful social experiences for autistic children. The findings build on existing work which has shown that autistic children engage in more social interaction while using digital technologies and consider how this might be achieved within classroom and special education settings. This thesis takes a less 'techno-centric' approach than previous literature, and explores how profiles of the children themselves, how the role of the adult and environment, as well as features of the technology can shape autistic children's social interactions in digital settings. This produces more direct relevance to practice than previous research in the area.

8.1 Summary of findings

Chapters 1 and 2 outlined the context and rationale for exploring the influence of technology on social play and interaction in autistic children. It was shown that in non-autistic children, technology is likely to have very small or negligible effects on social development. However, features of technology, such as the interface, design, and explicit scaffolding, can encourage social interaction. Autism is characterised by differences in social interaction and development, and many autistic people have interest in and are motivated by digital technologies. A large body of work has explored how technology can be used to teach social skills to autistic children, but so far research had rarely explored how technologies could be used in classroom settings to support social interaction and play between peers of autistic children. A summary of each chapter's methodology and key findings are presented in Table 8.1.

Table 8.1: Summary of key findings in this thesis

Chapter	Key findings
Chapter 3 Perspectives from practitioners on the use of technology by autistic children in education settings	• Explored how educational practitioners use technology with autistic students in school, and whether they think technology influences students' social interaction • Found that practitioners mostly used technology for academic learning and mediating social interactions, and less often for facilitating social play • Identified factors within the classroom context which influenced engagement with technologies, including child's own interests, social context of technology use, and certain features of technology such as technological interface
Chapter 4 The effect of technological interface and classroom environment on autistic children's social play when using technology	• Observed autistic children playing with different technological interfaces and software (apps), and collaborated with practitioners to develop an environment which facilitated social play • Found that different interfaces and apps led to different levels of social play, and with different people (i.e. with adults and with peers).
Chapter 5 Exploring moments of child-led interactions when autistic children use different technologies to identify specific facilitators of social interaction	• Identified moments where autistic children initiated interaction with others, and explored features of the technology and environment which led to these moments • Identified factors related to the technology, environment, and the role of the adults that led to children initiating interaction with others. These included specific app features, children's interests, and scaffolding by adults.
Chapter 6 The effect of enforced collaboration on autistic children's social play on digital and non-digital toys	• Observed autistic children playing with digital and non-digital toys in pairs, and tested whether enforcing collaboration also influenced children's social play • Found that autistic children engage in more social play when using digital toys compared to non-digital toys, and that social play increased in both conditions when collaboration was enforced
Chapter 7 The effect of enforced collaboration on joint engagement when autistic children play with digital and non-digital toys	• Measured whether joint engagement (i.e. social attention) was different when autistic children played with digital and non-digital toys, and when collaboration was enforced • Found that children engaged in higher levels of joint engagement with digital toys, and in both digital and non-digital contexts when collaboration was enforced

Chapter 3 explored how educational practitioners used technology in classrooms with autistic students, to ensure that the proceeding studies were embedded in current practices. In an online survey about their use of technology, practitioners said that they more frequently used technology to teach social skills to autistic students, rather than to facilitate peer interactions. Respondents also said that technologies such as smart boards, tablets, and computers were used more widely than more recent technological developments which are often more prominent in human-computer interaction research, such as tangibles and robotics (Good et al., 2016). These results were followed up by focus groups, where practitioners highlighted that different features of interfaces, such as smartphones, tablets and large table-top devices, made children more aware of social partners and could sometimes encourage or inhibit interactions depending on children's social interaction style and technological preferences. According to practitioners, children who were interested in technology would be more likely to socially benefit from it, than others who were less interested in technology.

Chapters 4 and 5 reported on a design-based research study, in collaboration with educational practitioners, to explore the influence of different technologies and classroom environments on children's social interactions and play. The main finding was that children interacted differently with both technologies and with other people, and that different apps and technological interfaces produced unique patterns of social interactions. Children engaged in more social play with peers while using the iPad and Code-A-Pillar technologies, and more social play with adults while using Osmo. Children seemed to rely on adults to help them use technologies they were less familiar with, such as Osmo and Code-A-Pillar, and different features of each app and toy were identified which led to children engaging in socially interactive play and initiating interactions with others, and novel technologies seemed to inspire more socially interactive play.

Chapters 6 and 7 compared social play and joint engagement in pairs of children while they played with digital and non-digital toys and explored the effect of enforced collaboration. The results showed that children engaged in more social play and joint engagement when using digital toys. Enforcing collaboration led to more interactive play and joint engagement in both digital and non-digital conditions. This suggests that technology itself has a strong influence on autistic children's social interactions.

Together, the studies within this thesis highlight that there are many ways in which autistic children engage with other people while using digital technologies, and many opportunities to foster these interactions in classroom settings. This includes designing technologies and environments which mediate proximity and turn-taking, as well as providing novel digital experiences which motivate children to interact with others. The role of enforced collaboration has been demonstrated, in both digital and non-digital contexts. In conclusion, technologies do influence social interaction in autistic children, but so do children's social interaction styles and preferences, the wider classroom environment including adult roles, and so do particular technological interfaces and software. In terms of *how* technology mediates interaction, it can provide a socially inclusive space where children can jointly engage in devices and activities which interest them, provide an engaging environment where others can scaffold interaction (i.e. practitioners), or the technology itself can mediate child-led interactions through children's interests.

8.2 Limitations

The studies reported in this thesis present a realistic, but not generalisable, picture of how technology is and could be used to support autistic children's peer play in education settings. The methodological decisions within this thesis were chosen to capitalise on a small sample size of participants, and to explore the factors which shape children's engagement with technologies and with other people. The small sample size is one upfront limitation which limits the extent to which results generalise to other children, to other settings, and to other technologies. However, and as discussed previously in chapter 2 (see page 51), practitioners often work with small groups of children or service users and have limited resources (e.g. access to technologies), and the main goal of this thesis was to explore how such practitioners could use available technologies with the range of children they work with to support social interaction. The contribution of this thesis should therefore be considered within the limitations of what these studies can say about the influence of technology and social interaction and play in autistic children.

8.2.1 **Off the shelf technologies**

The use of commercially available technologies prevented the opportunity to explore the effect of specific features, such as app behaviours and interface alone, on children's social interactions. In studies 4 and 5, a range of off-the-shelf technologies were used, including screen devices, tangible-screen, and tangible toys. Each technology, and associated app, varied from another and therefore, potentially that multiple and cumulative features had an influence on children' social interactions. This limits the direct comparisons that can be made between these different technologies. Chapter 5 attempted to address this limitation by looking specifically at moments of child-led interactions and identifying individual features of technology from children's engagement and behaviour. In traditional human-computer sciences and design research, the next steps would be to further isolate these features into new apps or devices, and more explicitly test the effects of separate features. This "design-driven" form of research could potentially help to understand how "strong" a particular feature's influence is on children's social interactions, therefore creating more targeted recommendations for designers and practitioners. An example could be testing an app that has a particular guided tutorial on collaborative play, and testing the same app without that tutorial, and seeing if the presence of the tutorial effects children's collaborative play. However, this type of study has its own limitations, such as not being representative of the types of technologies which autistic children, their practitioners, and their families are regularly using (Kim et al., 2018; Ramdoss, Lang, et al., 2011; Zervogianni et al., 2020).

A limitation of using such “off the shelf” technologies was illustrated when evaluating the effects of enforcing collaboration in digital and non-digital contexts. As discussed in section 6.5.3 on page 161), the digital and non-digital toys did not truly enforce collaboration equally. With more direct manipulation of enforced collaboration (e.g. by removing one of the wheel parts from the BRIO train set), it might be that children then engage in similar levels of collaborative play in both conditions where collaboration is enforced. This limitation illustrates the potential for, even implicit, design features to strongly shape social interaction, and perhaps one way in which practitioners could introduce collaborative play in the classroom or scaffold children to engage in more social play.

8.2.2 **The perspectives of autistic children**

As discussed in section 1.3.2, the definition of play is “fuzzy” and measurement relies on observer interpretation (i.e. coding, measurement), rather than the perspective of children. In choosing a definition and procedure for measuring play from a psychological perspective, the viewpoint of the child and their meaning from the “playful experiences” (as they have been coded as), is missing (Scheepmaker et al., 2018). In human-computer interaction, the child’s perspective often plays a central role in technology evaluation, and this perspective may have given valuable insight into the intrinsic motivations for social behaviour, and thus prove useful to evaluate the “social potential” of a given technology. For autistic children, this insight has often been overlooked in design research, where technologies often strive to change children’s behaviour based on assessment and judgement from others, without giving agency to autistic children (Spiel et al., 2019). While the studies within this thesis were not direct interventions, they did (somewhat) provide environments which scaffolded and mediated social interactions, within children’s own interests and motivations, and it would have been interesting to explore how children were aware of this or to hear their views on what they choose to share with others in digital environments. In a similar fashion to the consent procedures (see Appendix 3: Participant consent procedure), a feedback form could have been implemented to gather children's views, and may be useful in further research on evaluating technology and play in autistic children.

8.2.3 **Participant information and recruitment**

Recruitment for the studies reported in this thesis relied on self-selecting participants who willingly filled in online surveys, participated in focus groups, and hosted research in their school and classroom about technology. Generally, it can be assumed that the adult participants in this thesis, i.e. the teachers and practitioners, had positive perceptions of technology and perhaps had the resources to either access or engage in research which was held during term time. It therefore might be expected that results would have been different in those who did not have such positive views about technology in schools. It would have perhaps been beneficial to assess the practitioner participants' attitudes to technology in chapters 4 – 7, to perhaps elucidate whether practitioner's scaffolding of technology use and social interaction in their students was shaped by or related to their technology attitudes.

A further limitation in this thesis is the limited participant characteristics available in chapters 6 and 7. The participating schools were given the same measures used in the previous study but were not able to complete the assessments within an appropriate timeframe for them to provide valid matching to observation data. This additional participant data could have been useful to explain the variance observed in children's play, especially regarding levels of social motivation to further examine its effect on digital play. However, missing data is a natural consequence of conducting research "in the real world," and the level of detail and analysis conducted on the video data creates a number of avenues for future research.

8.3 Thesis implications

This thesis sits at an intersection of developmental psychology and child-computer interaction, and provides relevant information for practitioners, technology designers, and researchers. The main message from this thesis is that there are many ways in which technologies can provide meaningful social opportunities to autistic children, and in moving away from a technocentric focus, practitioners could leverage technology to provide these experiences within classroom settings.

8.3.1 Key implication

The key implication is that social interaction by autistic children in digital environments is shaped by and depends on a number of environmental and personal features, that are both contingent on and independent of the technology itself (see Figure 3.5 on page 85, and Figure 4.5 on page 117). Throughout this thesis, studies have highlighted the dual influence of children's own social interaction style and technology interests, on the ways in which technology mediates interaction, and shows that if matched well, autistic children will engage in more social interaction when using technology. For instance, effects of enforced collaboration and particular technological interface were found to shape the way that autistic children interact with each other while using technology (see chapters 6 and 7). However, children's own preferences for and engagement with technology also drove social interactions within digital contexts and seemed to account for some of the participant variance observed throughout the observational studies (i.e. in chapters 4 and 5). The main take-home message is that concerns about technology should move away from a techno-centric focus, and practitioners instead should explore how they can use current resources and technologies to foster social opportunities with their students.

8.3.2 Research-based practice, and practice-based research

One priority area in autism research is to ensure that results are beneficial and applicable to practice – in supporting and caring for autistic people, particularly in services including education (Dingfelder & Mandell, 2011). The gap between research and practice in autism research is large, in part due to the focus on biological research, and misalignment between research topics and the priorities of autistic people, their families, and services (Fletcher-Watson et al., 2019; Pellicano et al., 2013). There is a further gap, between the technologies for autistic people which have an evidence base and are evaluated in research studies, and those which are available to and used by autistic people and their families (Kim et al., 2018; Laurie, Warreyn, et al., 2019; Parsons et al., 2017, 2019). It is now considered good practice for researchers, after having completed their research, to think about the implications for practitioners and services, for instance, by writing post-hoc practitioner notes in journal articles or by creating accessible summaries of research for wider dissemination. These are undoubtedly useful exercises and may benefit some practitioners who are able to find these resources, but it misses a mark where research itself can be embedded within practice and informed by staff and autistic people (Long et al., 2017; Long & Clarkson, 2017). In the research area of autism and technology, one solution is to evaluate the designs and products which are available to autistic people and their families (Ramdoss et al., 2012; Zervogianni et al., 2020).

Design-based research offers a potential middle-ground, where researchers and practitioners collaborate on the research aims, implementation, and evaluation (Barab & Squire, 2004). The benefits of design-based research are that research is centred on current practices, informed by experts 'on the ground', and contributes to an evidence base which has direct relevance to those practitioners (Anderson & Shattuck, 2012) and ultimately, to the populations served by those practitioners – in this case, autistic children. As illustrated in chapters 4 and 5, practitioners were invaluable in providing information which helped contextualise observations (e.g. whether observations reflected children's typical behaviours in chapter 4). Throughout the research process, practitioners emphasised the importance of child-led experiences and opportunities of technology, which drove the selection of methods within these thesis chapters and provided useful insights for qualitative analysis. In recognising the importance of autism research which is based on rigorous theory and morally ethical participation of the autistic community (Fletcher-Watson et al., 2019), there is a wide-casting range of benefits to conducting practitioner-led research, to leverage staff practice, training, and insights, and to benefit service users who are often advocated for by others, including parents and staff (Long et al., 2017). In the face of wider discussions about the rigor and the ethics of research in both psychological science (John et al., 2012) and human-computer interaction circles (Spiel et al., 2019), practitioner-based research could pave the way for making sure that research is accessible, beneficial, and has a positive impact within education, social care, and policy contexts.

Where should research on autism, technology, and social interaction and play go next? Creating a formal evidence base in autism and technology has challenged researchers for decades, not least because of the heterogeneous profiles of autistic individuals and the technologies they use (Zervogianni et al., 2020). This thesis adds to that the different “pathways” to social interaction for autistic children in digital environments, both in terms of mediating and facilitating social play and the contexts which provide social opportunities. Iteratively, throughout this thesis, other factors have been added to the initial model of child-computer interaction, and increasingly it has been demonstrated that these separate influences have the potential to be independent but are more likely interlinked within classroom and real-world settings.

First, it is important to address practitioner concerns about technology and social interaction, since these may shape how people use technology in the real-world (Luckin et al., 2012; Manches, 2018), and as shown in chapter 3 (see Table 3.7 on page 79). Addressing concerns about social interaction on technologies could be achieved by recruiting a large sample of autistic children and observing them play with, say, an iPad app and a matched, non-digital, equivalent. Theoretically, this type of study could provide a more rigorous comparison between different profiles of children, who have different levels of social skills and preferences for technology, to highlight more robustly these effects on social interaction, both in digital and non-digital contexts. However, chapters 6 and 7 have demonstrated that identifying a “perfect non-digital match” for digital toys is challenging. Furthermore, this line of research may be considered ‘out-dated’, since technologies are ever increasingly used in practice now and it is no longer seemingly a choice on *whether* to use technology, but rather *how* to use technology effectively.

Secondly, it is also important that researchers work with the relevant communities to identify their needs, goals, and resources within a given context, in order to answer this question about *how* technologies can be used effectively (Parsons et al., 2019; Yuill et al., 2015). Further design-based research with different classrooms may provide very different results on how technologies can create socially motivating environments for autistic people, and ultimately identify further important factors to consider when using technology with autistic children. But ultimately, design-based research is a way for practitioners within specific settings to create their own evidence-base given their resources and the students they work with. Previous work suggests that in allowing practitioners to conduct research, we can instil a sense of confidence and deeper connection with the individuals who are supported, as well as more evidence-based practice being utilised (Long et al., 2017). Collaboration when it comes to choosing and using technologies within education settings already happens (i.e. see Table 3.3 on page 66, which shows that many practitioners take advice from their colleagues about technology implementation), and so extending this further and combining with academic insights would be interesting to explore. Given the variance surrounding the nature of social interaction, autism, and technology collectively and individually, this type of small-scale, bespoke, and practice-driven research seems more likely to have bigger impact ‘on the ground.’

8.3.3 **The importance of measurement in social and digital evaluations**

Designing technologies which promote socially interactive (e.g. human to human) and open-ended collaborative play is extremely challenging from the perspective of technology designers (Bekker et al., 2010). Children’s behaviour is largely unpredictable, and designers have to manage designs which create experiences for children to engage in social interaction, but also accept that sometimes children’s interactions will be completely unrelated or unaffected by the design (de Valk et al., 2013). Examples include children perhaps playing multi-player games by themselves (e.g. one child acting as “both” players), or children responding to features in a technology which were not predicted to evoke such reactions (as the software errors in the ECHOES environment (Alcorn et al., 2014)). Children’s play is intrinsic and personal, and therefore providing ‘too much’ scaffolding means the explorative and unrestricted principle of play may be lost (de Valk et al., 2013). Therefore, research evaluations which focus on design features may need to be balanced with child-centred approaches to understanding play with digital toys (Scheepmaker et al., 2018).

By child-centred approaches to design, I mean learning lessons from observations and children’s perspectives about the things that they value about a particular toy design, and the ways in which interaction might unintentionally be inspired by particular technological features. Different methodological approaches taken in chapters 4 and 5 respectively led to different conclusions about what the most “socially beneficially” technology is. In other areas of human-computer interaction, the child’s perspective is a central part of the evaluation processes (Druin, 2001; Good & Robertson, 2006), and would perhaps have elucidated further the experiences of autistic children with technologies (Spiel et al., 2017). In the specific contexts of working with autistic children and within education settings, there needs to be a balance between recognising the value of children’s and educators’ input. Children with communication differences, such as autism, may not accurately or effectively share their experiences in a way that is understood correctly by someone else, particularly by a non-autistic practitioner (Milton, 2012). Furthermore, the things that a child may report is fun, engagement, and helps learning may not lead to better scores on a test or learning as measured by a teacher – an often mentioned argument for managing technology use in education (Blackwell et al., 2013). Therefore, seeking a balance between the perspectives and values of inputs from children and teachers is therefore a challenge in evaluating technology in a learning context.

8.3.4 **Social motivation and autism**

The social motivation theory of autism posits that the social features of autism arise from reduced interest in other people and a lack of motivation to engage in early social interactions which then shape future social learning (Chevallier et al., 2012). The interpretation of behaviours as 'motivated' or not, and the extent to which this is a core feature of autism, has been widely debated (see Jaswal and Akhtar (2019) and commentary responses). While evidence for this theory is mixed (see section 1.3.3 on page 25), it had the potential to explain why autistic children are more likely to engage in social interactions in digital contexts. The results in chapters 6 and 7 show that interaction is increased while children play with digital toys, compared to non-digital toys and the participant case studies throughout these thesis chapters highlight the influence of children's own personal interests in technology, and how these interests shape engagement and interactions in digital environments. For instance, in chapter 5 children initiated social interactions with others when they enjoyed what they were doing or were motivated by computerised rewards to share with others. Each study within this thesis supports the hypothesis that motivation has an influence on autistic children's social interactions.

A recurring theme throughout this thesis is that children's personal attributes are influential, but so are specific features of technology and the mediating role of the adult and classroom environment. For instance, the link found between features of the app or software and children's responses in chapters 4 and 5 highlight that specific interfaces and features of technology could provide the 'foundations' for social interaction, through implicit scaffolding and encouragement of social engagement. Similarly, the observational studies within this thesis (chapters 4 – 7) demonstrate that adults play a key role in influencing children's interactions and will often encourage and scaffold children into collaborative play when they use digital technologies. What this shows is that both internal factors like motivation, and external factors in the environment, such as the technology and the adult, both influence the child's engagement and interactions. Separating these mechanisms and testing their unique influence would be an interesting question, but ultimately challenging to disentangle confounding effects in environments with technology and children (Luckin et al., 2012; Manches, 2018). It may be that no general formula or pattern exists which could be applied to each level or individual (e.g. this child, that technology, that classroom, etc). It is this interaction between these different factors which makes it hard to measure and evaluate children's social behaviours and the reason(s) why they may occur, and why naturalistic observations are a strength in this research area.

Despite growing evidence that a social motivation deficit may not be a core feature of autism (Jaswal & Akhtar, 2019), the model may still hold practical value for encouraging child-directed learning and recognising that behaviours may be inconsistent across contexts. Social motivation could potentially explain an individual's response to intervention, rather than explain core differences in social interaction (Dawson et al., 1998). Some autistic children, including some of the participants within these studies, do have high levels of social motivation, as measured through standardised assessments and observed within the sessions, and are willing to engage in interaction, though perhaps have other difficulties in communication or social understanding, and may find certain environments, including digital ones, more inspiring to interact in. Knowing which environments children find engaging has implications for how interventions are selected and evaluated, and how support can be personalised. It is for that reason that I still see potential in social motivation theories of autism, not as an explanatory cause of autistic features, but through identifying environments which engage more ‘hard to reach’ individuals.

8.3.5 **Understanding autism through human-computer interaction**

Autistic people are thought to have high interest and engagement with digital technologies, and explanations for this have driven theoretical developments in autism research, such as the empathizing-systemizing theory (Baron-Cohen, 2009). This theory suggests that autistic people tend to like predictable and replicable environments, which once characterised interactions with technology. However, technology and media now offer a much more diverse experience for the senses (e.g. moving away from visual information shown on a screen) and an often-unpredictable environment. In research studies, these specific features, such as unpredictability and multi-modal interactions, have actually shown to increase children’s social interactions with others, rather than deter them as would be predicted by a theoretical account such as the empathising-systemizing theory (Alcorn et al., 2014; Laurie, Manches, et al., 2019). Since technology is now such an integral part of our everyday lives, and particularly so for children and young people, it offers great potential to understand human nature in both typically and atypically developing populations (Hourcade et al., 2012; Rajendran, 2013).

Autistic children’s engagement with technology could contribute evidence towards and inform the development of specific theoretical models of autism. More generally, as established in this thesis, some autistic children engage in more social interaction within digital environments, and so digital environments potentially serve as a means to assess someone’s social competencies more accurately or fairly. For instance, digital environments may provide an easier, more accommodating, or more engaging environment for which to share social interactions with others (Hourcade et al., 2012, 2013). The skills of autistic children are known to be at risk for under-estimation, particularly in verbal and social domains, due to a “spiky profiles” of ability (Courchesne et al., 2015). This is partly reflected in the case studies within this thesis, where each child’s developmental profile as measured by teachers showed moderate to severe social difficulties, but nearly all were observed engaging in social play when presented with digital technologies (for instance, see Figure 4.2 on page 103). On reflection, Vygotsky’s principle of a proximal zones for development, where children could be scaffolded to reach their full potential of interaction and learning (Crawford, 1996), seems to fit with the general findings of this thesis. That is, that with support from adults and through engaging and rewarding technological designs, the autistic children who participated in these thesis studies demonstrated their social potential in the classroom, and these observations are apparent by both the results of this thesis and from teacher discussions during the course of the research (e.g. the practitioner discussions reported in chapter 4; see Table 4.4 on page 100).

8.4 Future directions

Having already noted the limitations and contributions of this work, this section now turns to highlight and further discuss specific areas that future studies on technology and social play in autistic children can examine. These include moving away from “technocentric” technology research, highlighting the contribution of factors related to children, adults, technology and environment, and ways that future studies could recruit larger samples and more robustly observe the link between these factors and children’s play in digital contexts.

8.4.1 **The context of technology use**

This thesis has focused on understanding how technology influences autistic children’s social interactions in digital contexts, and in doing so, has also explored other factors which may influence play in these settings, such as technological interfaces and different classroom environments. One next step would be to integrate new insight gained from this thesis into future work which explores how technology can be used in the classroom to support children's peer play, with both autistic, and potentially non-autistic children. For instance, the model of child-computer interaction developed by Manches (2018) could be a useful resource for teachers, allowing them to choose toys which match children's skill level and interests, and to become aware of their own practices in scaffolding children's interactions. This could help practitioners and researchers critically evaluate the benefits and limitations of particular technology features or contexts on children's interactions, leading to a more balanced view of using technology in education settings, and potentially allow children who are developing differently to access social opportunities with peers through the use of technology.

8.4.2 **Evaluating enforced collaboration**

In chapters 6 and 7, it was observed that enforcing collaboration produced more social play in autistic children in both digital and non-digital conditions. While this study enforced collaboration by giving children either one or two toys per pair, other work has tested the effect of enforced collaboration by restricting children's game progression in either story-telling (Battocchi et al., 2009; Gal et al., 2016) or picture-matching tasks (Holt & Yuill, 2017). Enforced collaboration is one way in which social interaction is scaffolded in digital play, and what would be interesting to explore is whether children "learn" to interact with others as a result of engaging with games which do enforce collaboration. There is some evidence for this from research on table-top technologies, where play is also supervised by an adult or a research team in a school or a play-centre (Bauminger-Zviely et al., 2013; Gal et al., 2009), but the technologies evaluated within these studies explicitly teach social skills, rather than observe whether children choose to engage or not with others. For instance, are children who experience enforced collaboration then more likely to engage in more social play in settings where collaboration is optional? Another application might be to look at different ways in which collaboration is enforced – perhaps on a sort of scale in terms of progressive constraints – to see if children respond and change their behaviour differently to different cues for collaboration. Understanding how collaboration can effectively be encouraged in the classroom would support the implementation of group learning activities and would perhaps be useful to encourage inclusion of autistic or other neurodivergent children within classrooms.

8.4.3 Scaling up from case studies

In this thesis, it has been suggested that children's interest in technologies and social motivation can influence how much social play is affected by technology. This finding could be more rigorously tested by a study which recruits a larger sample, and measures whether children's degree of technological interest and social motivation is predictive of behaviour change between digital and non-digital contexts. It might be found that particular subsets of children, e.g. those with very high interests in technology and social motivation, have larger differences in their digital and non-digital play behaviours than children who are less interested by technology or have lower levels of social motivation. Understanding the nature of this relationship could potentially drive new theoretical developments, which could then feed into the creation or evaluation of new technologies for supporting neurodivergent students in the classroom.

8.5 Final conclusions

This thesis has gathered evidence from practitioners and video observations of children, showing that technology can provide positive social opportunities for autistic children, including those with intellectual disability and who communicate non-verbally. It has explored the influence of different factors, including the social interaction style and technological interests of the child, the role of the practitioner in scaffolding interaction, the classroom environment, and different features of technologies, on children's social play and interaction while using digital technologies. The studies within this thesis provide novel insights into how technologies could be used in classroom settings to give social opportunities to autistic children. By exploring the social benefits of technology for autistic children, new theoretical models of autism and child-computer interaction could be explored, and more constructive narratives around autism and technology be developed in practice. This work paves the way for more inclusive and collaborative approaches to learning and peer relationships in autistic children through the use of digital technology.

9 Appendices

Appendix 1: Practitioner survey on educational technology

About me

My name is Maggi, and I'm a PhD Student at the University of Edinburgh. I'm interested in the role of technology in social interaction, play, and development in children with a diagnosis of Autism Spectrum Disorder (ASD, or "autism" for short). You can find out more information about my project here,

If you have any questions about this survey, or my research in general, please email me or get in touch via post at the address at the bottom of this page.

About this survey

I want to find out what technology is currently used in autism-specific education, and the perceptions of educational staff (this includes teachers, practitioners, and other professionals within autism education) on using these technologies. In other words, I basically want to find out 1) what technologies are used, 2) how they are used, and 3) what you think about technology in autism education.

The Moray House School of Education at the University of Edinburgh granted ethical approval for this survey. The survey mostly contains closed-ended questions (tick-boxes and selecting a response from a list), but you have the opportunity to add more information at the end of each section if you wish.

The survey will ask for your basic information (nothing identifiable, only age, gender and job role), questions about any technology-related training you've had at work, about the children you work with and their use of technology, and attitudes towards technology in education (both generally and specialist). You do not have to answer any questions you don't want to, and all responses are kept anonymous within the research team.

At the end of the survey, you can opt-in to a prize draw for a gift voucher (of your choice from Amazon or iTunes), there is 1x£50 and 2x£25 vouchers available. You can also opt-in to find out more and participate in the next phase of the study (an interview or group session about the topic of technology and autism education), and you can choose to receive a summarised version of the results of this survey, if you wish.

Please do not hesitate to contact me if you have any questions before completing the survey, I can be reached via

[principle and alternative contact information redacted]

#	Question	Data format	Categorical options
-	Please confirm your consent by checking your agreement with the following statements	Compulsory checklist	I have read all of the above information I won't be asked to give personal details about myself or my employer I can skip questions I don't want to answer I can exit the survey at any time I am happy to proceed to the survey
General participant information			
1	What is your age (in years)	Free text	
2	What is the gender to which you identify	Categorical	Female, Male, not listed
3	What is your highest level of qualification	Categorical	High school, vocational, undergraduate degree, postgraduate degree, doctoral degree, professional training or Other (free text)
4	What is your job role	Free text	
5	Approximately how long have you been in your current role	Free text	
6	Approximately how long have you worked with autistic children	Free text	
7	Approximately how long have you worked in similar job roles	Free text	
8	In what country do you work in?	Free text	
Technology training and guidance			
9	Have you received any training about using technology with the	Categorical	All options had choices: Formal, informal not received. Options were commercial training, external source, internal source, organisation or school policy, guidance

	children at work? Was it formal or informal?		from school management, guidance from teachers, and guidance from parents of students, and other (free text).
10	Are there any details about the training that we might find useful to know?	Free text	
11	If you have received training, would you rate it as useful for your practice/work?	Categorical	Very useful, somewhat useful, neutral, or somewhat unuseful
12	Would you like to receive more training or guidance on the use of technology in specialist education?	Categorical	Yes, no, unsure.
13	If you answered yes, briefly describe the kind of guidance you would like	Free text	
14	Is there anywhere else you get guidance on tech use from?	Free text	
The following questions will ask you about what kind of technologies you use personally, outside of work or in general			
15	Please select all the devices you use on a (fairly regular basis)	Checklist	Standard mobile phone, smartphone, personal computer or laptop, tablet, e-reader, wearable activity tracker, other (free text)
16	Do you use any of these 'social technologies' for communicating with others?	Checklist	Text or electronic messenger, social media, skype or video calling, email, playing video games with others, other (free text)
17	Please rate your agreement to the following statements about your digital skills in general	Likert (options were strongly disagree, disagree, neutral, agree, and strongly agree)	Statements were "I feel confident using technology", "I would describe myself as 'tech savvy'", "I am able to solve basic tech problems", and "I prefer using the digital option vs. pen and paper option"
About your pupil(s)			
18	What is the age range of the pupil(s) you work with	Categorical	Preschool (2 – 4 years), Early primary school (5 – 8 years), Late primary school (9 – 12 years), early high school (13 – 15 years), late high school (16 – 18 years)

19	At what level is your pupil or class? Select all that apply	Categorical	Non-verbal, 1-2 words, babbling, short phrases, full sentences, fluent
20	Do any of the pupils you work with have learning disabilities in addition to autism? Tick all that apply	Categorical	Yes the majority, yes the minority, no
Snapshot of the use of technology in education			
	Technology options: TV DVD or video, standard mobile phone, smartphone, iPad or tablet, computer or laptop, YouTube, educational website, other internet sites, radio or music player, portable music player, interactive whiteboard, tabletop device, tangible technologies, wearable activity tracker, robotic technologies, other (free text)		
21	For each technology, please indicate who provides the technology	Categorical	Provided by school, brought from home,
22	For each technology, please indicate how the pupils use the technology	Categorical	Pupil's use independently, pupil's use with help, pupil's do not use
23	Please indicate technology which is not available	Binary	
24	Is there anything else you would like to tell us about the technology you use that isn't covered above?	Free text	
25	For what purpose is technology used in your classroom? Rank in order of 10 = tech used least, to 1 = tech used most	Numerical rank	Learning about a topic, learning a new skill, communication, speech generation, leisure, socialising with other pupils, socialising with staff, socialising with others (e.g. family), scaffolding from a non-digital activity, motivate pupil learning or engagement, sensory stimulation
26	Are there any other purposes that the children use technology for, which aren't covered above? Please describe	Free text	
27	What is the general impact of technology in your classroom, or on your pupil(s)	Categorical	Very positive, somewhat positive, neutral, somewhat negative, very negative

28	From your work and/or observations in using technology in the classroom with autistic children, could you list example(s) of - positives from using technology - negatives from using technology	Free text boxes	
Attitudes to technology			
29	Rate your agreement to these statements regarding all children's use of technology in education	Likert (options were strongly disagree, disagree, neutral, agree, and strongly agree)	"Technology shouldn't be part of education", "Using technology with children makes me anxious or stressed", "I worry that children will break expensive technology", "I'm concerned about the time that children spend on technology", "I'm concerned about the content that children can access on technology", "Technology related skills are an important part of education", "Technology does not help children to learn", "It's important to supervise children whilst they use technology", "Rules on technology in the classroom are needed", "Using technology can make children socially isolated"
30	Rate your agreement to these statements regarding technology in autism-specific education	Likert (options were strongly disagree, disagree, neutral, agree, and strongly agree)	"Technology plays an important role in autism education", "It's important for autistic children to be supervised whilst they use technology", "I'm worried about the content that autistic children can access on technology", "I'm anxious about using technology with autistic children", "Autistic children can spend too much time using technology", "Learning how to use technology is not important for autistic children", "Children with autism are more likely to break technology", "Technology can help autistic children learn", "It's important to have rules for technology & children with autism", "Technology limits social interaction in children with autism"
31	Is there anything else you would like to tell us about your thoughts on technology and autism education	Free text	

Appendix 2: Technology shortlists for chapters 4 - 7

Chapter 4: Design-based shortlist

Toy and manufacturer	Description	Recommended age range	Recommended retail price	Social considerations	Educational considerations
CREATOR Robo explorer by LEGO	Build a robot with LEGO (3 design options)	7 – 12 years	£20.00	Collaboration	Problem solving, cause and effect, communication
Teksta Robot Puppy	Robot which respondents to voice, gestures, and iPad app	5+ years	£39.99	Gestures	Cause and effect, communication
Osmo Creative Set	Transform drawings onto the screen, solve problems and puzzle games	6 – 12 years	£49.99 (iPad required, includes 2 games)	Gestures / collaboration	STEM curriculum, problem solving, cause and effect
Osmo Genius Kit	Play with shapes, words, and numbers off-screen, which interacts with iPad	6 – 12 years	£99.00 (iPad required, includes 3 games)	Turn-taking / collaboration	Problem solving, numeracy, literacy, cause and effect
Code-A-Pillar by Fisher Price	A coding game where caterpillar moves once constructed	3 – 6 years	£55.00	Turn-taking / collaboration	Programming, cause and effect, logic and problem solving, mathematics
MiPosaur and Track Ball by WowWee	A robot which responds to voice, gestures and iPad app. Can feed, make it chase a ball, and interact	8+ years	£99.00	Gestures, turn-taking / collaboration	Problem solving, cause and effect, communication
LEGO BOOST Creative Toolbox	Construct a robot (5 design options) and use iPad to control it	7 – 12 years	£149.00	Turn-taking / collaboration	Programming, cause and effect, logic and problem solving

* These technologies (shaded) were selected by the teacher. Other technologies not chosen either due to small parts (i.e. choking hazard / likely to get lost in classroom), and students not being as interested in animals / dinosaurs.

Chapter 4: Initial iPad apps used in the study

Name	Developer	Price	Category
My First Keyboard	aacorn	Free	General education
Sparkle: Toothbrush Playtime	Agnitus	Free	General education
Happy Geese	Appically	Free	Autism-specific, casual game
Wordbubbles	Apprope	Free	Casual game
Seabeard	Backflip Studios	Free	Casual game
*Cbeebies Playtime** *Cbeebies Storytime**	BBC Media Applications Technologies Limited	Free Free	General education (reading)
MyReef 3D Aquarium 2 Lite	Bitbros Inc.	Free	Casual game (sensory)
Feed The Monkey Line Up	Busythings Ltd	Free	Casual game
Petting Zoo	C. Niemann	£2.49	General education (reading, literacy)
Reactickles Magic	Cariad Interactive	Free	Casual game (sensory, autism-specific)
Hat Monkey	Chris Haughton	£0.99	Casual game
Fish School HD Itsy Bitsy Spider HD Wheels on the Bus HD	Duck Moose	Free Free Free	General education (literacy, numeracy)
Peppa Pig: Paintbox* World of Peppa Pig*	Entertainment One	Free Free	Casual games / general education (literacy)
Todo Telling Time	Enuma, Inc.	£3.99	General education (numeracy)
Snakes and Ladders	eQuadriga	Free	Casual game / multi-player
Fluid 2 Fluid	Fabien Sandlard	Free Free	Casual game (sensory)
Grandma's Garden	Fairlady Media	£3.49	Casual game / general education (story-telling)
Skiing Yeti Mountain	Featherweight Games Pty Limited	Free Free Free	Casual game
Hippo Seasons	Hippotrix	Free	General education (seasons)
Temple Run	Imangi Studios, LLC	Free	Casual game
FindMe Pro	Interface 3	£2.99	Autism-specific, gamified intervention (Fletcher-Watson, Pain, et al., 2016, 2016)
Balloon Pop Random Touch	Joe Scrivens	£0.99	Casual came / designed for the developer's child with additional support needs
Cursive Writing Wizard – Joined Up Handwriting for Kids	L'escapadou	£4.99	General education (hand-writing)
Fingerpaint Magic	Meritum Soft d.o.o	Free	Casual game
3 Little Pigs Snow White	Nosy Crow	£4.99	Educational app (literacy and story-telling)
Dr. Suess's ABC – Read & Learn	Oceanhouse Media		Educational app (literacy and story-telling)
Endless 123 Endless Alphabet	Originator Inc.	Free Free	Educational app (literacy and numeracy)
Mr Men: Mishaps & Mayhem	P2 Entertainment Ltd	£2.99	Casual game
Splitter Critters	RAC7 Games	£2.99	Casual game

Angry Birds	Rovio Entertainment	Free	Casual game
Sago Mini Ocean Swimmer	Sago Mini	Free	Casual game
Aiko and Egor Animation Autism	Sea Beneath, Inc.	Free Free	Autism-specific
Miracle Modus	Seebs, LLC	Free	Casual game (sensory)
Sensory Magma	Sensory App House Ltd	Free	Casual game (sensory)
Tap & Sing	Storybots	Free	Casual game (music-making)
Farm Sounds	Tantrum Apps	Free	Casual game
Splingo's Language Universe	The Speech and Language Store LLP	£2.50	Autism-specific, educational app (literacy and language)
Tiggly Addventure: Number Line Math Learning Game Tiggly Cardtoons: 25 Interactive Counting Stories Tiggly Chef Addition: Preschool Math Learning Game	Tiggly	Free Free Free Free Free Free Free Free Free	Educational game (numeracy)
Drawing Together!	Tipitap Inc.	£2.50	Casual game
Toca Band Toca Blocks Toca Boo Toca Builders Toca Cars Toca Dance Toca Elements Toca Fairy Tales Toca House Toca Life: Vacation Toca Nature Toca Robot Lab Toca Tailor ***Toca Tea Party**** Toca Town	Toca Boca AB	Free Free Free Free Free Free Free Free Free Free Free Free Free Free	Casual games
Drawnimal Loopimal	Yatatoy	£1.50 £1.50	Casual game (music-making)
Pudding Monsters Cut The Rope	Zeptolab UK Limited	Free Free	Casual game

Italics indicate apps which children had used previously. **Bold** indicates apps which were used in sessions 3 – 9. Prices checked at time of writing [Spring 2020].

Chapter 6: Code-A-Pillar equivalent shortlist

Toy and manufacturer	**Description**	**Age range**	**Retail price**	**Similarities**	**Differences**
Code-A-Pillar by Fisher Price	*Programmable construction toy which moves independently once built. Has flashing coloured lights, plays music, and has light up eyes.*	3 – 6 years	£55.00		
My First Animal Brick Box by LEGO DUPLO	A constructible LEGO train where animals can be built (e.g. elephant, lion, giraffe)	1.5 – 3 years	£24.99	Can connect main train pieces, moves along on wheels (i.e. player pushes instead of programmed), animal theme	Construction of both large and small parts, LEGO built rather than 'plug in' Code-A-Pillar style
Wooden Build Up Train by Bigjigs	A constructible train toy with a pull-along string	Babies / toddlers	£21.49	Can connect main train pieces (like the Code-A-Pillar body), train can move (i.e. pushed)	Not an animal, both large and small buildable pieces (e.g. build body but also build passengers and decorations
Wooden magnetic train by BRIO	A constructible train toy which moves on wheels	1+ years	£23.99	One design, connect main pieces only, can move (i.e. pushed), similar colour mapping (e.g. red = big box, like green = forward on Code-A-Pillar)	Not an animal theme
Zoomin' Rides Building set by Kid K'NEX	A series of small, constructible 'creatures' that can move on wheels, some creatures resemble vehicles like helicopters or cars	3 – 5 years	£22.99	Can connect main creature pieces and small pieces, animal theme, some vehicles can move (i.e. pushed)	Variety of different construction toys instead of one specific one, whole toy constructed rather than only core parts,

Appendix 3: Participant consent procedure

Script for obtaining verbal consent from pupils with autism
Notes:

This is an example of the script and may be reviewed and slightly amended by the expert staff team who work with that child. The children may be offered pictorial or written responses to give back to the researcher (e.g. a smiley/sad face, written words “yes/no”).

Each child will be asked the following questions individually but a staff member may have to be present to support the child. In this case, the words from the child will be taken.

If a child does not provide consent to each step, but expresses upset at being left out of the games, the interview will be repeated.

The teacher will make the formal introduction to researcher and pupils to the class as a group, so at this point, the children should already be familiar with the researcher.
The table below is to record the consent at each level from the child. The staff member supporting the child or their teacher should be present and sign the box after the session

	The child has given consent to…				Date: Session:
Child Name	Play with technology	Researcher present	Video record	Keep recording	Staff signature

Session 1: Baseline/pilot

1. *Consenting to play with the digital games (before session)*
Researcher: Hi, my name is *Maggi* and I'm from Edinburgh. Do you enjoy playing with digital technology, like computers games or tablets?
[if child says yes] Great! I have brought some games with me today, would you like to play with them?
[if child says no] I think you'll enjoy playing the games that I brought with me today. Would you like to have a try?
[if child says no again] Would you like to go back to your classroom with your [staff member]?

If yes → the child will miss this session.

If no → the child will be asked what they want to do. The practitioner & the child will continue from here.

Researcher: The games that I have brought with me can be played on your own or together. You can choose if you want to play with a member of staff or another pupil.
2. *Consenting to the researcher being present*
Researcher: I am very interested in learning about how you play with these games. I would like to be able to sit in the classroom and take notes. Is this okay?
[if child says yes] Great! I'll put myself in this corner out of the way.
[if child says no] I would really like to sit in and just watch. Can I sit in the corner over there out the way?
[if child says no again] Would you like to play over here, so I cannot see what you're doing? [move child to behind the researcher & camera so notes cannot be taken about them]
3. *After the session*
Thank you everyone, you all did so well! It was really hard for me to keep up with writing notes, do you mind next time if I bring my video camera so I can video you while you play?
[next time bring the video camera and ask again to get permission to film]

Sessions 2:8

Repeat 1 & 2 to get consent for playing with games and researcher being present
3. *Consenting to the session being recorded*
Last time I came and I took notes with my pen and paper, but it was so tricky for me to keep up because you were all playing so well! I brought my camera this time so I can video you all playing, would that be okay?
[if child says yes] Great! I'll get this set up.
[if child says no] If I set my camera up, but you play over here so it can't see you, is that okay?

If yes → the child will be set up behind the camera

If no → I can either have my back to you or you can go with [staff name] and play in another room.

4. Consenting to the video being used for the research purposes (after the session has finished)
Well done everyone, you all did such a good job again! I was still trying to write notes but again it was very difficult to keep up with all your playing!
Is it okay if I keep the video and watch it again later?
[if child says yes] Great! I'll take the video home now and make my notes up to scratch
[if child says no] I will take the video, but not take more notes on what you did today.
5. Consenting to the video being shared with school/teacher
Would the teacher be able to look at this video to learn more about how you play?
[if child says yes] Great! I'm sure [teacher name] will really enjoy learning more about your play.
[if child says no] That's okay, only I will watch the video.

Appendix 4: Teacher technology form

Demographics Sheet

Please fill in the following questions to the best of your knowledge. If you are unsure, please specify/state in the relevant box. All information provided will remain anonymous and not be traced to the individual.

Pupil's first name:

Gender:

Date of birth:

How long has the pupil been at [redacted] (years/months):

To your knowledge, does the child have a diagnosis of autism, Asperger's Syndrome, or Autism Spectrum Disorder?

- ▫ Yes
- ▫ No
- ▫ Waiting for a diagnosis
- ▫ Not sure

Do they have an intellectual or learning disability?

- ▫ Yes
- ▫ No
- ▫ I think so
- ▫ Not sure

What is their verbal ability?

- ▫ Fluent speaker
- ▫ Some complex phrase speech (can use full sentences)
- ▫ Some simple phrase speech (i.e. "I want…")
- ▫ One-word speech
- ▫ Non-verb

Do they have any other diagnosis or difficulties that you think we should know about? Please detail below.

These questions are optional, and you can leave them blank if they are not applicable. They don't require a lot of detail – only a sentence or so.

Are you aware of the child receiving any behavioural intervention, speech and language, or other support? If yes, please briefly describe.

What does the child usually use technology for in the classroom (e.g. playing the iPad for leisure, doing research on the computer, using the sensory room, etc.)?

Does the child enjoy using technology, or are they particularly good at using technology (e.g. they enjoy watching YouTube videos on the iPad, they can use the iPad independently)?

Is there anything else about the child you think that we should know (e.g. sensory sensitivities, likes/dislikes or digital activities?)

Appendix 5: Peer Play Scale by Howes & Matheson (1992)

CHILDREN OBSERVATION FORM

The Peer Play Scale (Howes & Matheson, 1992)

7 Peer Play Categories

Solitary Play (ST)
Parallel Play (PP)
Parallel Aware Play (PA)
Simple Social Play (SS)
Complementary and Reciprocal Play (CR)
Social Pretend Play (SP)
Interaction with Adult (IA)

Operational Definition:

Solitary Play (ST)	Playing alone, with no eye gaze or mutual interest in objects with any peer (i.e., reading a book alone or moving a toy car back and forth for a period of time).
Parallel Play (PP)	Engaging in the same activity but not acknowledging each other (i.e., 2 children both playing blocks in same area but not paying attention to each other; no eye contact)
Parallel Aware Play (PA)	Involving similar activities and engaging eye contact; children are aware and imitate of each other's play (i.e., 2 children both playing blocks in same area and are paying attention to each other; imitation of each other's play)
Simple Social Play (SS)	Engaging in the same or similar activity and talking, smile, offering, and receiving toys or, or otherwise engaging in social interaction- a turn taking structure (i.e., taking turns pointing to pictures in a book, taking turns pour sand into a bucket, taking about some leaves they have found, digging sand with talking about their own interest)
Complementary and Reciprocal Play (CR)	Engaging in social game with a turn-taking structure and role reversal (i.e., run and chase, hide and seek, throw and catch a ball, tickling each other, peek-a-boo)
Social Pretend Play (SP)	Engaging in fantasy play- acting or using objects in an "as if" manner, engaging in scripted pretend play, enacting complementary roles such as mother and baby (i.e., Child A picks up the tea cup, child B asks "Would you like some tea?", child B pours pretend tea from the tea pot; "I'm the doctor." The car hit you but don't die; "Let's pretend it's snowing and we're out in the cold")
(g) Interaction with adults (IA)	Ask, talk and smile to adult, or read book with adult (i.e., child ask teacher to get a wagon or ball, teacher ask the child to share a toy each other or child play with teacher's hair.
Nonplay	Lacking characteristics of the social-cognitive play categories identified above (i.e., watching or listening to others while they are making a Leo structure

Appendix 6: Video footage meta-data and clip selection process, for studies reported in chapters 4 - 7

Chapters 4 & 5: Design-based research with practitioners

Iteration / session number	Participants	Camera*	Total footage	Trimmed footage (chapter 4)
Baseline observations: iPads and classroom only				
1	Oliver	Class*	00:34:01	2 x 00:05:00
		Class*	00:08:52	1 x 00:05:00
2	Harry, Laura	Class*	00:34:16	2 x 00:05:00
		Class*	00:35:00	2 x 00:05:00
Baseline total (% sampled):			01:52:09	00:35:00 (31.2%)
Iteration 1: Introduction of Osmo in corridor and Code-A-Pillars in classroom				
3	Oliver, Laura, Jack	Class	00:41:32	2 x 00:05:00
		Corridor	00:30:00	2 x 00:05:00
4	Oliver, Laura, Jack	Class	00:44:04	2 x 00:05:00
		Corridor	00:30:00	2 x 00:05:00
5	Oliver, Laura, Jack	Class	00:44:00	2 x 00:05:00
		NA	NA	NA
Iteration 1 total (% sampled):			03:09:36	00:50:00 (26.3%)
Iteration 2: Moved classroom desks to create a shared space for play				
6	Oliver, Harry, Laura, Jack	Class	00:39:29	2 x 00:05:00
		Corridor	00:30:00	2 x 00:05:00
7	Oliver, Laura, Jack	Class	00:35:19	2 x 00:05:00
		Corridor	00:29:10	2 x 00:05:00
Iteration 2 total (% sampled)			02:13:58	00:40:00 (29.85%)
Iteration 3: Practitioners deliberately directed children's collaborative play with peers				
8	Oliver, Harry, Laura, Jack	Class	00:44:01	2 x 00:05:00
		Corridor	00:30:00	2 x 00:05:00
9	Oliver, Harry, Jack	Class	00:36:08	2 x 00:05:00
		Corridor	NA	NA
Iteration 3 total (% sampled)			01:50:09	00:30:00 (27.23%)
Study total (% sampled)			09:05:52	02:35:00 (28.39%)

All lengths of footage are reported in hh:mm:ss format, which specifies the hours:minutes:second of the recording length. NA specifies missing data. The camera placed in the classroom ('class') recorded the area with iPads and Code-A-Pillars. The camera placed in the corridor recorded the area with Osmo. Asterisks specify where more than one camera has been used for the same area and timepoint (e.g. each camera might have a different view of different participants).

Chapters 6 & 7: Comparison of digital and non-digital play in child pairs

School 1			
Session number	Participants	Toy information	Video length
1	Mark, Francis	BRIO, 2 toys	00:17:59
2	Mark, Francis	Code-A-Pillar, 2 toys	00:09:14
3	Aaron, Tom	BRIO, 2 toys	00:05:02
4	Mark, Francis	Code-A-Pillar, 2 toys	00:12:27
5	Mark, Francis	BRIO, 2 toys	00:05:44
6	Aaron, Tom	Code-A-Pillar, 2 toys	00:05:17
7	Mark, teaching assistant	Code-A-Pillar, 2 toys	00:06:12
8	Mark, Francis	BRIO, 2 toys	00:04:52
9	Mark, Francis	Code-A-Pillar, 2 toys	00:05:30
School 2			
Session number	Participant pseudonyms	Toy information	Video length
1	Daryl, Brendon	Code-A-Pillar, 1 toy	00:09:28
2	Daryl, Brendon	BRIO, 1 toy	00:10:51
3	Tyler, peer*	Code-A-Pillar, 1 toy	00:05:12
4	Tyler, peer*	BRIO, 1 toy	00:06:00
5	Brendon, peer*	Code-A-Pillar, 1 toy	00:07:44
6	Tyler, teaching assistant	BRIO, 1 toy	00:05:03
7	Brendon, peer*	BRIO, 1 toy	00:01:20
8	Brendon, peer*	Code-A-Pillar, 1 toy	00:05:53
9	Tyler, peer*	Code-A-Pillar, 1 toy	00:06:23

* peer denotes a non-participating pupil who attended the session. Only the interaction with the consenting and participating child is reported. Shaded sessions denote those which were removed from dataset due to other child being absent / leaving early.

Summaries of video footage and group condition are provided below:

Condition	Toy information	Total video lengths (% total data)
Digital: Code-A-Pillar	1 toy / pair	00:34:40 (29.14%)
	2 toys / pair	00:32:28 (27.29%)
Non-digital: BRIO	1 toy / pair	00:18:11 (15.28%)
	2 toys / pair	00:33:37 (28.26%)
Total analysed footage		01:58:56

Appendix 7: Joint engagement by Bakeman and Adamson (1984) and adaptations

Original joint engagement (Bakeman & Adamson, 1984)	Adapted joint engagement (current study)	Description with notes on adapting to the current study
Unengaged	Unengaged	Child is neither engaged with the object(s) of interest - BRIO train, Code-A-Pillar, or relevant parts of the toys
Object	Object	Child is engaged with object only
Onlooking	Onlooking (peer)	Child is watching what a peer is doing, but not actively involved in the peer's activity
Person (mother OR peer)	Person (peer)	Child is having interpersonal interaction with a peer without relevance to the objects of interest. For instance, having a conversation about an unrelated topic.
	Person (adult)	Child's main attention is on the adult, including when this is in reference to the objects of interest (i.e. supported / coordinate joint engagement *with an adult* is coded here).
Supported joint engagement	Supported joint engagement (peer)	Child is attending to an object / selection of parts that another child is also attending to, but there is no awareness or direct interaction between the two children. This is *dyadic* joint attention.
Coordinated joint engagement	Coordinated joint engagement (peer)	Child is attending to an object / selection of parts that another child is also attending to, but there is awareness or direct interaction between the two children. This is *triadic* joint attention.

Appendix 8: D'Mello Likelihood Metric scores by each condition (collaboration and number of toys)

The D'Mello Likelihood Metrics represent likelihood of progressing from one state (in the row) to the next state (in the column). Numbers which are shaded indicate +.10% likelihood of progression.

The following two tables (A and B) show the D'Mello scores for digital play, on Code-A-Pillar, whilst participants had one or two toys per pair respectively (enforced vs. non-enforced collaboration). Overall, increased likelihoods for positive play transitions (e.g. moving towards a more socially complex level of play) are observed when children have one toy per pair, compared to when children had two toys per pair.

Table A: D'Mello scores for digital play, one toy per pair (enforced collaboration)

Next								
	State	Unengaged	Object	Adult	Onlooking	Peer	Supported	Coordinated
	Unengaged	-	-0.25	-0.111	-0.053	-0.053	0.444	0.167
	Object	-0.111	-	-0.11111	-0.053	-0.053	0.259	0.444
	Adult	-0.111	-0.250	-	0.474	-0.053	-0.111	0.167
	Onlooking	1.000	-0.25	-0.111	-	-0.053	-0.111	-0.667
	Peer	-0.111	-0.250	-0.111	-0.053	-	-0.111	1
	Supported	-0.11111	-0.25	-0.111	-0.053	-0.053	-	1.000
Previous	Coordinated	0.028	0.375	0.166667	-0.053	0.079	-0.111	-

Table B: D'Mello scores for digital play, two toys per pair (free collaboration)

Next								
	State	Unengaged	Object	Adult	Onlooking	Peer	Supported	Coordinated
	Unengaged	-	-0.16533	0.361	0.053	0.026	-0.050	-0.069
	Object	0.000	-	0.112053	0.114	0.001	0.109	0.036
	Adult	0.117	0.264	-	-0.016	-0.017	-0.038	0.002
	Onlooking	0.036	0.264	-0.065	-	0.026	-0.095	0.024
	Peer	0.229	-0.472	0.148	0.243	-	-0.095	-0.11515
	Supported	-0.08491	0.356	-0.038	-0.136	-0.017	-	0.094
Previous	Coordinated	-0.042	0.5584	-0.15	-0.136	-0.017	0.014	-

The following two tables (C and D) show the D'Mello scores for non-digital play, on BRIO magnetic train, whilst participants had one or two toys per pair respectively (enforced vs. non-enforced collaboration). Similar to the findings reported above for digital play, increased likelihoods for positive play transitions (e.g. moving towards a more socially complex level of play) are observed when children have one toy per pair, compared to when children had two toys per pair.

Table C: D'Mello scores for non-digital play, one toy per pair (enforced collaboration)

Next								
Previous	State	Unengaged	Object	Adult	Onlooking	Peer	Supported	Coordinated
	Unengaged	-	0	0	0	0	0	0
	Object	0.039	-	-0.12121	-0.028	-0.088	0.185	0.439
	Adult	-0.057	-0.096	-	-0.028	0.347	0.103	-0.233
	Onlooking	-0.057	-0.37037	-0.121	-	0.275	-0.121	0.486
	Peer	-0.057	-0.370	0.253	0.315	-	-0.121	-0.02778
	Supported	0.207143	-0.02778	-0.121	-0.028	-0.088	-	0.229
	Coordinated	-0.057	0.626263	0.184573	-0.028	-0.088	-0.121	-

Table D: D'Mello scores for non-digital play, two toys per pair (free collaboration)

Next								
Previous	State	Unengaged	Object	Adult	Onlooking	Peer	Supported	Coordinated
	Unengaged	-	0.367742	-0.050	-0.036	-0.007	-0.105	0.027
	Object	0.060	-	0.226563	0.125	0.011	0.053	-0.024
	Adult	0.009	0.337	-	-0.002	-0.007	0.002	0.025
	Onlooking	-0.097	0.557419	-0.050	-	-0.007	-0.061	-0.001
	Peer	-0.097	1.000	-0.313	-0.195	-	-0.105	-0.04255
	Supported	0.071757	0.39206	-0.313	-0.011	-0.007	-	0.038
	Coordinated	-0.097	-0.58065	0.5625	-0.195	-0.007	0.263	-

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