Symbolic Understanding, Language Learning and Engagement in Autism Spectrum Condition – The Role of Interactivity.

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Declaration

This thesis is my own work and no portion of the work referred to in this thesis has been submitted in support of an application to another degree or qualification at this or any other institute of learning.

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Abstract

Children with Autism Spectrum Condition (ASC) often experience difficulties engaging with educational tasks (Mayes & Calhoun, 2007) which may impact upon subsequent learning outcomes (Rogers et al., 2011). Technologies that provide opportunities for interaction, such as iPads, are proposed to aid children's learning and engagement (El Zein et al., 2016; Kucirkova et al., 2014). Interactive iPad applications may also reduce the need for adult involvement through providing real-time feedback and digital voiceover narration (Radesky et al., 2015; Schugar et al., 2013). This may complement the preferred learning style of children with ASC, who often experience low social engagement and wide-ranging social impairments (Pelphrey et al., 2011). However, research to date has not yet investigated the influence of interactivity on the learning and engagement of children with ASC, nor investigated the relationship between engagement and learning in this population. Moreover, there is a lack of consensus regarding whether children with ASC benefit from adult involvement during learning (Adamson et al., 2009; Chevallier et al., 2012). This thesis aims to address the gaps in the literature through four experimental studies. Performance on all tasks was compared to an ability-matched TD control group.

The first two studies investigated symbolic understanding. Study 1 examined whether the iconicity of symbols (through animation and interactivity) would influence symbolic understanding. Participants viewed coloured pictorial symbols of a novel object (given a novel name) on an iPad in one of three conditions: static 2D images and either automatically or manually rotating images (providing a three-dimensional context). They were then tested on their symbolic understanding and word learning. Despite no difference in symbol learning or label retention between groups or conditions, the findings suggest that interactive iPad tasks may increase engagement (visual attention) in both typical and atypical populations and greater visual attention may benefit symbol learning and label retention specifically for children with ASC.

Study 2 investigated whether providing a label, alongside the function of an object, benefitted symbolic understanding. Participants were shown a picture of an object and given

either a novel label alongside a description of the object's function or a description of the object's function without a label. Children then interacted with an array of stimuli (pictures and interactive objects) in a mapping test and in a generalisation test for each trial. The results suggest that labelling did not improve symbolic understanding for either group. As children with ASC performed as well as their TD peers in this study, it is possible that a spontaneous measure of symbolic understanding (such as free-play) may reveal competencies in word-picture-referent mapping in ASC.

Whereas Study 1 investigated the influence of interactivity on symbol and label learning from a specially designed, single purpose iPad application, Study 3 examined novel label learning and engagement within an interactive e-book, a setting more similar to every-day learning (Bus, 2001; McLeod & McDade, 2011). There was no evidence that learning new vocabulary from storybooks differed between paper-based and electronic mediums of presentation, and engagement was not found to predict performance for either group. However, TD children demonstrated better retention of the new vocabulary items in general, after a two-week delay.

Study 4 investigated narrative comprehension and engagement with e-books vs paper-books. This study also manipulated the level of adult involvement by including two e-book conditions – one in which the experimenter narrated the story and one in which the story was narrated through an in-app digital voiceover. There were no significant group or condition differences in narrative comprehension, and both groups demonstrated a similar level of narrative comprehension across the conditions. However, on-task engagement (visual attention) was linked to narrative comprehension in TD children in general.

Taken together, these findings suggest that interactivity does not directly influence the learning of children with ASC regarding three areas of language ability found to be weak in this population, neither positively nor negatively. However, interactivity was found to increase engagement – specifically visual attention – in both groups. For children with ASC, visual attention benefitted symbol and label learning from a single purpose application (Study 1), whereas in typical development visual attention benefitted narrative comprehension from an

e-book (Study 4). Adult involvement (through labelling and narration) was not found to influence learning in either group. Throughout this thesis, these findings are discussed in terms of theoretical and educational implications, with suggestions for future research.

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1. Literature Review

1.1. Introduction and Outline

This thesis presents a series of studies investigating the influence of task engagement on the learning of children with Autism Spectrum Condition (ASC). Task engagement is here defined as an individual directing their focus towards a task and maintaining attention for the duration of the activity (McWilliam, Scarborough, & Kim, 2003). Difficulties maintaining focus during educational tasks are frequently reported for children with ASC (Mayes & Calhoun, 1999; Mayes & Calhoun, 2007) which may impact upon subsequent learning outcomes (Rogers, Hwang, Toplak, Weiss, & Tannock, 2011). Therefore, it is vital to discover new and effective means to foster task engagement in this population. However, there is little research that attempts to define engagement into measurable categories (Moody, Justice, & Cabell, 2010; Richter & Courage, 2017; Roskos, Burstein, & You, 2012) or examine the relationship *between* engagement and learning – with no research to date investigating their relationship in children with ASC.

Much interest surrounds the use of interactive learning materials to increase task interest and engagement in children with ASC (Boone & Higgins, 2007). Touchscreen iPad applications allow for a level of interactive and multimedia learning not previously possible through traditional paper-based mediums; with features that include sound effects, animation, and physical manipulation of on-screen stimuli (Takacs, Swart, & Bus, 2015). Children with ASC demonstrate fewer disruptive behaviours and less task refusal when using iPads, suggesting greater ‘engagement’ with touchscreen mediums of presentation (El Zein et al., 2016; Fletcher-Watson et al., 2015; Lee et al., 2015; O'Malley, Lewis, Donehower, & Stone, 2014). However, research to date has not yet investigated the influence of interactivity on the learning of children with ASC.

Presenting a task via an interactive iPad application also reduces the need for adult involvement, as iPad applications can provide in-app narration of text and real-time feedback to support the child through the task (Radesky, Schumacher, & Zuckerman, 2015; Schugar, Smith, & J. Schugar, 2013). This may complement the preferred learning style of children with ASC who often possess low social engagement, allowing for a solitary learning experience (Chevallier, Kohls, Trojani, Brodkin, & Schultz, 2012). However, previous research suggests that adult involvement is essential to facilitate learning in typical and atypical development, both from iPads and paper-based mediums (Cubelic & Larwin, 2014; Falloon & Khoo, 2014; Highfield & Goodwin, 2013). Adult involvement allows for joint engagement (Adamson, Bakeman, Deckner, & Romski, 2009) - the adult can guide the child to relevant learning of stimuli by providing additional information, such as labels (Flack, Field, & Horst, 2018; McLeod & McDade, 2011; Robbins & Ehri, 1994). Moreover, shared reading has been found to benefit word learning and narrative comprehension (Hindman et al., 2008; Mucchetti, 2013; Sénéchal & LeFevre, 2002), potentially through increasing attention and providing opportunities for the student to ask questions (Falloon & Khoo, 2014). Therefore, whether adult involvement influences learning for children with ASC is in debate and will be explored in this thesis.

The first aim of the thesis is to determine whether interactive iPad applications benefit the learning of children with ASC, specifically regarding three areas of language ability found to be weak in this population - symbolic understanding (Hartley & Allen, 2015b; Preissler, 2008; Preissler & Carey, 2004), label learning (Luyster, Kadlec, Carter, & Tager-Flusberg, 2008; Manolitsi & Botting, 2011; Weismer, Lord, & Esler, 2010) and narrative comprehension (Banney, Harper-Hill, & Arnott, 2015; Diehl, Bennetto, & Young, 2006). The second aim is to explore how children with ASC engage with interactive iPad applications, as research to date has investigated this only in typical development (Richter & Courage, 2017). As no research to date has examined the influence of engagement on learning outcomes in children with ASC, the third aim is to explore task engagement as a possible mechanism through which interactivity may influence learning. Finally, as children with ASC often experience low social engagement and a preference for solitary learning (Chevallier et al., 2012), the fourth aim is to examine whether children with ASC benefit from adult involvement during interactive tasks, such as object exploration and listening to a story via an e-book.

This literature review begins with an overview of ASC symptomatology and prevalence, followed by an outline of the three areas of language ability investigated within this thesis – symbolic understanding, receptive vocabulary, and narrative comprehension. Next, iPad use within the classroom will be evaluated as a learning tool for children with ASC – focussing on potential benefits (increased task engagement and attention) and pitfalls (increased cognitive load and reduced adult involvement). Overall, this review will highlight gaps within the literature that will be explored within the four experiments of the thesis.

1.2. Autism Spectrum Condition

Autism Spectrum Condition (ASC) is a lifelong disorder that affects around 1% of the population, beginning early in development (Lai, Lombardo & Baron-Cohen, 2014). It is characterised by diverse symptoms of varying severity, including language and communication difficulties (Kjelgaard & Tager-Flusberg, 2001). ASC is more prevalent in males than females (Baron-Cohen, Lombardo, Auyeung, Ashwin, Chakrabarti, & Knickmeyer, 2011) at a ratio of 4:1 (Preissler, 2006). A single unifying cause for ASC has not been identified, however evidence suggests that there is a genetic link to the condition (Bailey et al., 1995) and chromosomal abnormalities have been identified as a possible risk factor for increased susceptibility (Abrahams & Geschwind, 2008). Individuals with ASC often have greater brain volume in infancy and differences in brain structure specific to certain regions – such as those responsible for communication and social behaviours (Hyde, Samson, Evans, & Mottron, 2009).

Despite some commonalities in brain pathology between individuals with ASC (Stanfield, McIntosh, Spencer, Philip, Gaur, & Lawrie, 2008), the condition is heterogeneous in nature, meaning that some individuals may experience vastly different symptoms and levels of functioning than others (Geschwind & Levitt, 2007; Hall, Huerta, McAuliffe, & Farber, 2012; Pelphrey, Shultz, Hudac, & Vander Wyk, 2011). Some children with ASC have difficulties learning new nouns and labels (Manolitsi & Botting, 2011; Weismer, Lord, & Esler, 2010), and specific difficulties generalising new labels learned for a particular symbol to a real-world object – a type of symbolic understanding (Hartley & Allen, 2014b; Preissler, 2008). Aside from symbolic understanding, children with ASC often demonstrate impaired understanding of narrative texts (Diehl et al., 2006). The following sections will provide an overview of these three areas of language ability: symbolic understanding, receptive vocabulary, and narrative comprehension.

1.3. Symbolic Understanding

Symbolic understanding of word-picture referent relations emerges at around 18-24 months in typical development (Ganea, Allen, Butler, Carey & DeLoache, 2009; Preissler & Carey, 2004), coinciding with the development of dual representation (DeLoache et al. 1998; Preissler & Carey, 2004). Dual representation is an understanding that a picture is both an object itself whilst simultaneously representing an object in the environment (DeLoache, 1987, 1991, 1995). Prior to the development of symbolic understanding and dual representation, infants often demonstrate associative learning of symbols, restricting a label given to a pictorial symbol to the actual picture and failing to generalise to the real-world referent (Ganea et al., 2009). Indeed, young infants often physically interact with pictures as though they were the real-world object, such as mouthing a picture of an apple (DeLoache et al., 1998).

Preissler and Carey (2004) investigated symbolic understanding in 18-24-month-old infants using a label mapping task. The infants were shown a pictorial symbol (black and white line drawing) of an unfamiliar object and taught a new label, e.g. 'whisk.' In a subsequent 'mapping test', they were shown the same symbol alongside the actual object and were asked to show the experimenter the 'whisk.' No participants demonstrated purely associative responding; all participants selected either the real object or a combination of the real object and the symbol. This study suggests that from the age of 18 months, infants understand the referential nature of symbols.

Deloache and Burns (1994) directly investigated dual representation in TD children aged 24 and 30-months-old. Both groups were shown a picture of a room that revealed the location of a hidden object. Across five experiments only 30-month-old children could reliably use the picture as a guide to find the object (demonstrating dual representation) while 24-

month-old children consistently failed at the picture-search task. However, in a final experiment, when the child was asked to use the picture as a guide to place an object, rather than search for an object, both age groups were successful. The findings suggest that 24-month-old children can successfully use pictures as a guide to action, however this is more restricted than 30-month-old children. In a later study, Suddendorf (2003) found that the first trial success rate of 24-month-old infants was above chance, indicating that 24-month-olds can initially demonstrate dual representation. However, this is later impeded by perseveration – choosing the same location again even when the object was hidden in a different place. Despite this, when an object was presented in a different room for each of the four trials, 24-month-olds demonstrated above chance levels of object retrieval. This suggests that, under certain conditions, 24-month-olds can successfully use pictures to guide their actions.

After the initial emergence of symbolic understanding, the skill gradually increases in robustness (Ganea et al., 2009; Hartley & Allen 2015b). Ganea et al. (2009) describe early symbolic understanding as a ‘fragile’ skill, in which children can generalise a symbol to an object of the same colour but fail to generalise to a differently coloured category member. However, at around 24-months-old, infants develop a shape-bias in object categorisation (Samuelson & Smith, 1999), allowing for the symbolic generalisation of a picture to differently coloured referents of the same shape - demonstrating ‘robust’ symbolic understanding.

Children with ASC often do not follow this developmental trajectory and continue to demonstrate associative responding into later childhood (Preissler, 2008). Preissler (2008) investigated the symbolic understanding of 22 low-functioning children with ASC using the same label mapping task as Preissler and Carey (2004). In contrast to the findings of Preissler and Carey, in which TD infants demonstrated consistent symbolic responding, 55% of children with ASC selected the picture as opposed to the real-world object in the ‘mapping test.’ Moreover, Hartley and Allen (2014a) investigated how children with ASC generalise symbols to real-world referents based on shape and colour. Children with ASC and TD children were taught a novel label for a picture of an unfamiliar target object. They were then shown an array of pictures and objects that matched the target object on either colour or shape. Participants were tasked with sorting the array into two different containers depending on whether each stimulus was another example of the target object. Whereas TD children almost always matched on shape, demonstrating a shape-bias, children with ASC matched items based on shape *and* colour.

Taken together, studies suggest that children with ASC are more natural associative responders and do not possess a shape-bias in the same way as TD children (Field, Allen, & Lewis, 2016b; Tek, Jaffery, Fein, & Naigles, 2008). This may be a hinderance to the language learning of children with ASC and limit the extent to which they can use visual communication systems (Bondy & Frost, 1994; DeLoache, 2004). Therefore, it is crucial to investigate factors that enhance the learning of word-picture-object relations in ASC. Although relatively scarce, research suggests that differential learning mechanisms are in place for children with ASC and TD children (Hartley & Allen, 2014b; 2015a, 2015b; Preissler, 2008). The pattern of findings suggest that children with ASC rely on perceptual similarity (iconicity) to foster symbolic understanding (Hartley & Allen, 2014b; Hartley & Allen, 2015a; Hartley & Allen, 2015b). Although TD infants also benefit from highly iconic symbols, older TD children can understand the symbolic nature of pictures if a verbal cue, such as a label, is provided (Hartley & Allen, 2015b; Preissler & Bloom, 2007). The following sub-sections will outline the influence of iconicity and labelling on the symbolic understanding of children with ASC and TD children.

1.3.1. Iconicity

Iconicity is the extent to which a symbol visually resembles the referent it depicts (Sirota, Kostovičová, & Juanchich, 2014). Fuller, Lloyd and Stratton (1997) define the iconicity of a symbol in terms of ‘transparency.’ According to this definition, symbols with the least pictorial realism (such as printed words or abstract line drawings) are defined as ‘opaque’, coloured drawings or cartoons are defined as ‘translucent’ and coloured photographs are defined as ‘transparent.’ Research suggests that children with ASC demonstrate greater symbolic understanding when exposed to more realistic or ‘transparent’ symbols compared to more abstract or ‘opaque’ symbols (Hartley & Allen, 2015a), whereas TD children aged over 2.5 years demonstrate consistently accurate symbolic understanding regardless of pictorial iconicity (Hartley & Allen, 2014b; Hartley & Allen, 2015b). Hartley and Allen (2014b) investigated whether children with ASC and a TD control group could take the intention of an artist into account when matching abstract symbols to real-world referents. Participants were first told that they were going to see some pictures drawn by a child with a broken arm. These abstract pictures were given a label, such as ‘mouse’. Participants were then shown a 3D version of the actual target referent or a scale object version of the abstract image. They were asked to indicate what the child was trying to draw. This was repeated one week later with realistic pictures as opposed to abstract pictures. Results showed that children with ASC only took artist intention into account in 27% of trials, whereas TD children did so in 85% of trials. Both groups accurately selected the correct referent when pictures resembled the real-world object. It was concluded that children with ASC rely on a high level of perceptual similarity between picture and referent to facilitate successful word-picture-referent mapping.

Furthermore, Hartley and Allen (2015a) showed children with ASC and a TD control group a range of symbols that were not labelled. These varied in visual iconicity, with abstract images (opaque), black and white line drawings (translucent) and coloured photographs (transparent). The symbols revealed the location of a hidden item which was concealed under one of four objects. After the children had viewed the symbols, they were asked to find the hidden item and their responses were recorded. Although participants performed well across all conditions, iconicity significantly improved search task success for both groups, with higher accuracy in the coloured photograph condition compared to the line drawings and abstract images. The researchers concluded that children with and without ASC benefit from greater pictorial iconicity when using unlabelled symbols to locate items in the environment.

The influence of iconicity on symbol learning in ASC was further investigated by Hartley and Allen (2015b). Children with ASC and a TD control group viewed a range of symbols that varied in iconicity (ranging from black and white line drawings to coloured photographs). Each symbol was accompanied with a novel label, such as ‘zepper.’ Participants were then shown an array consisting of the symbol and object referent in a ‘mapping test’; and the symbol and a differently coloured object referent in a ‘generalisation test’ and were asked to show the experimenter the named item. Whereas TD children consistently demonstrated symbolic understanding by selecting the object in both mapping and generalisation tests regardless of condition, the symbolic responding of children with ASC increased with pictorial iconicity, with the most object selections in the coloured photograph condition. Taken together, these studies suggest that children with ASC benefit from a high level of pictorial iconicity when learning labelled or unlabelled symbols. However, when symbols are labelled, TD children aged over 2.5 years do not benefit from increased iconicity.

1.3.2. Labelling

Labelling is thought to scaffold symbolic understanding in typical development (Callaghan, 2000; Callaghan, 2008; Preissler & Bloom, 2007). TD infants are predisposed to attend to social cues, such as language and gaze, known as a ‘basic affiliative need’ (Rochat & Callaghan, 2005). Furthermore, Callaghan (2008) states that the caregiver provides joint attention towards symbols from an early age through infant directed speech, conveying the communicative and social importance of symbols. Caregivers draw attention to the meaning of a symbol through language and labelling, thus scaffolding the learning of a new skill (symbol learning) with a familiar skill (language). Callaghan (2000) investigated how linguistic scaffolding affects the picture comprehension of TD children using a simple mapping task. The 30-month-old children were unable to use pictures as symbols if they were not presented with a verbal label. However, although the 36-month-old children performed consistently above chance with and without a verbal label, they performed slightly better when a verbal label was provided. It was concluded that, between the ages of 30 and 36-months-old, symbolic understanding is a fragile skill that is supported by verbal cues.

Research suggests that labelling aids object categorisation for young children (Booth & Waxman, 2002; Waxman & Booth, 2003). Booth and Waxman (2002) found that after 18 months of age, generalisation to another category member was enhanced by labelling the original exemplar. In the same study, Booth and Waxman (2002) extended this finding to 14-month-old infants, provided the infants were given an indication as to the function of the object. Waxman and Booth (2003) found that infants as young as 11-months-old demonstrated greater object categorisation when a word was provided alongside the initial exemplar, however participants performed equally well when the word provided was a noun (label) or an adjective. The researchers concluded that infants initially expect that several different classes of words (nouns and adjectives) emphasise similarities towards different categories of objects and that this expectation is refined through experience (Xu & Carey, 2000).

Preissler and Bloom (2007) investigated the influence of labelling on dual representation in typical development. The researchers showed 2-year-old children a symbol of an unfamiliar object, paired with either a novel label ("this is a dax") or accompanied with the verbal prompt "look at this!". In a subsequent 'mapping test', participants were given an array consisting of the target object and target picture, alongside a distractor object and distractor picture. They were asked to select another example of the stimulus they had previously seen. Participants demonstrated referential responding (selecting the target object) 90% of the time when the symbol was labelled, compared to 30% when the symbol was unlabelled. The researchers concluded that labelling scaffolds symbol learning by 2 years of age in TD children.

Hartley and Allen (2015b) conducted a second experiment examining the influence of labelling on symbolic understanding and extended Preissler and Bloom (2007) to include children with ASC in addition to 3-year-old TD infants. The researchers used the same methodology as Preissler and Bloom (2007), and again found that TD infants demonstrated greater referential responding when the symbol was labelled compared to when it was unlabelled. However, this was not the case with the ASC group, who exhibited no difference in referential responding between conditions. It was concluded that, for children with ASC, labelling does not scaffold symbol learning. A potential explanation for this finding is that children with ASC often experience wide-ranging language and social impairments (Kjelgaard & Tager-Flusberg, 2001; Pelphrey, Shultz, Hudac, & Vander Wyk, 2011) potentially reducing the ‘basic affiliative need’ for social cues (Rochat & Callaghan, 2005) and leading to low social motivation and engagement (Chevallier et al., 2012). Children with ASC may be less receptive to social information in the form of joint attention and language, reducing the efficacy of labelling to facilitate symbolic understanding in this population.

A recent study by Hartley, Trainer and Allen (2019) suggested that language ability may influence the pictorial understanding of children with ASC in addition to typical development. The researchers compared the picture comprehension and picture production abilities of children with ASC and TD children matched on both receptive and expressive language ability. Picture comprehension was measured using a simple mapping task (similar to Callaghan, 2000) and picture production was measured using a task in which children were asked to draw novel objects. When matched on language ability, performance did not differ between children with ASC and TD children. For both groups, picture comprehension was found to be supported by language ability while picture production was not. Overall language ability (receptive and expressive) was found to predict picture comprehension for both children with ASC and TD children.

Overall, research to date suggests that differential learning mechanisms are in place in typical and atypical development. Children with ASC rely on perceptual similarity and high pictorial iconicity to foster symbolic understanding, a non-social cue (Hartley & Allen, 2014b; Hartley & Allen, 2015a; Hartley & Allen, 2015b). In contrast, TD children can understand the symbolic nature of pictures regardless of perceptual similarity if a verbal cue, such as a label, is provided (Hartley & Allen, 2015b; Preissler & Bloom, 2007). Despite this, current language ability may influence symbolic understanding in typical and atypical development (Hartley, Trainer & Allen, 2019).

1.4. Receptive Vocabulary

Receptive vocabulary, the comprehension of individual words (Burger & Chong, 2011; Dunn & Dunn, 2009), is a crucial skill which underlies successful communication - both oral (through speech) and visual (through symbols and sign language) (Anglin, Miller, & Wakefield, 1993). Receptive vocabulary is also a significant predictor of narrative comprehension, as without the knowledge of individual words a reader/listener cannot extract the overall meaning from a story (Lepola et al., 2016; Nation, Clarke, Wright, & William, 2006; Sénéchal, Ouellette, & Rodney, 2006).

Children with ASC often have specific receptive vocabulary impairments (Luyster et al., 2008; Manolitsi & Botting, 2011; Weismer et al., 2010). A recent meta-analysis of 74 studies found impaired receptive vocabulary ability in ASC, approximately 1.5 standard deviations below TD children (Kwok, Brown, Smyth, & Cardy, 2015). However, overall language development is heterogenous in children with ASC, suggesting that there is not an all-encompassing deficit in word learning in this population (Arunachalam & Luyster, 2016; Hartley et al., 2020). Instead, individuals with ASC may be delayed in their language development and may be impaired in some of the mechanisms that underly successful word learning in typical development (Arunachalam & Luyster, 2016; Hartley, Bird, & Monaghan, 2020), while demonstrating no significant impairment in others (De Marchena, Eigsti, Worek, Ono, & Snedeker, 2011, Hartley, Bird, & Monaghan, 2019; Hartley et al., 2020; Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007; Swensen, Kelley, Fein, & Naigles, 2007).

Children can use cognitive heuristics to successfully work out new word meanings – such as noun-bias and mutual exclusivity (Gentner, 1982; Markman, 1990). Noun-bias is the tendency to map a new label to an object as opposed to an action (Gentner, 1982), and mutual exclusivity is the understanding that new words must apply to unfamiliar objects (Markman, 1990). Some children with ASC, like TD children, have been found to successfully use these cognitive heuristics identify the meanings of new words (De Marchena et al., 2011, Hartley et al., 2019; Hartley et al., 2020; Parish-Morris et al., 2007; Swensen et al., 2007). Moreover, some children with ASC can make use of information across multiple trials/situations to determine the meaning of a new word, known as cross-situational learning (Hartley et al., 2020; Venker, 2019), although children with poorer language ability find this more difficult (McGregor et al., 2013).

Responsiveness to social cues is related both concurrently and longitudinally to language ability and vocabulary size in both typical development and children with ASC (Farrant & Zubrick, 2012; Kasari, Gulsrud, Freeman, Paparella, & Hellemann, 2012; Newman, Ratner, Jusczyk, Jusczyk, & Dow, 2006; Parish-Morris et al., 2007; Paul et al., 2007; Scott et al., 2013; Watson et al., 2010). Through joint attention, adults can guide and support the identification of referents and new word meanings (Baron-Cohen, & Baldwin, & Crowson, 1997; Gliga et al., 2012). However, children with ASC often have difficulty with social orientation and exhibit a reduced sensitivity towards speech-sounds (Adamson et al., 2009; Adamson et al., 2010; Adamson et al., 2019; Chevallier et al., 2012; Neuhaus, Webb, & Bernier, 2019; Watson, Roberts, Baranek, Mandulak, & Dalton, 2012; Whitehouse & Bishop, 2009). Therefore, it is possible that individual differences in social responsiveness may impact upon the vocabulary and language acquisition of children with ASC (Hartley et al., 2019; Hartley et al., 2020), potentially impeding the learning of new word meanings from social situations (Gliga et al., 2012).

Fast mapping, the ability to immediately link a new word and match it to its intended referent, is often mistaken for word learning (Munro, Baker, McGregor, Docking, & Arciuli, 2012). The ability to fast map new words immediately after exposure often does not lead to the successful encoding and consolidation of the word (and its meaning) into long term retention - which requires the integration of new word information with existing knowledge and vocabulary (Arunachalam & Luyster, 2016; Dumay, & Gaskell, 2007). Word learning is a slow and effortful process, often requiring multiple instances of exposure to facilitate retention after a delay (Axelsson & Horst, 2014; Gupta, 2005). Fast mapped words are often forgotten less than 5 minutes after initial exposure and are not translated into long term memory (Horst & Samuelson, 2008).

Children with ASC are often less sensitive to relationships between word meanings (Norbury, 2005) and have difficulty forming integrated and robust semantic networks (Schafer, Williams, & Smith, 2013), requiring a greater number of representations of new word information over time to overcome this this difficulty (Arunachalam & Luyster, 2016; Haebig et al., 2017). While some studies have found that children with ASC or at risk of ASC have poorer retention of new word information than their TD peers (Bedford et al., 2013; Norbury, Griffiths, & Nation, 2010), others have found that children with ASC do not significantly differ in terms of retention (Hartley et al., 2019; Hartley et al., 2020). It is possible that, while word learning mechanisms are not qualitatively different in this population (Hartley et al., 2019; Hartley et al., 2020), children with ASC are less efficient at processing language input (Arunachalam & Luyster, 2016; Venker, Bean, & Kover, 2018). Consolidating new word information into long term retention relies on the successful co-ordination of a range of cognitive abilities, including attention, memory and non-verbal IQ (Omaki & Lidz, 2015). Therefore, word learning in ASC may be impacted by individual differences in these areas (Arunachalam & Luyster, 2016; Arunachalam & Luyster, 2018; Venker et al., 2018), as children with ASC often experience reduced sustained attention and impaired working memory (American Psychiatric Association, 2013; Bryson et al., 2004; Kercood, Grskovic, Banda, & Begeske, 2014; Liss, Saulnier, Fein, & Kinsbourne, 2006; Zwaigenbaum et al., 2005). Attentional difficulties in children with ASC can lead to difficulty co-ordinating visual attention in response to auditory cues, potentially resulting in auditory-visual misalignment which is found to disrupt word learning in this population (Baron-Cohen, Baldwin, & Crowson, 1997). Attentional differences in children with ASC will be discussed in more detail in section 1.6.

In summary, children with ASC often experience impairments in receptive vocabulary (Luyster et al., 2008; Manolitsi & Botting, 2011; Weismer et al., 2010). Some children with ASC have been found to perform as well as their TD peers when using cognitive heuristics to identify the referents of new words (De Marchena et al., 2011, Hartley et al., 2019; Hartley et al., 2020; Parish-Morris et al., 2007; Swensen et al., 2007), while experiencing difficulty using social cues to facilitate the identification of new word meaning (Arunachalam & Luyster, 2016). It is possible that children with ASC do not have qualitatively different word learning mechanisms compared to TD children (Hartley et al., 2020). Instead, certain mechanisms that underly successful vocabulary acquisition may be delayed or disrupted – such as social orientation (Adamson et al., 2009; Adamson et al., 2010; Adamson et al., 2019; Chevallier et al., 2012; Neuhaus,et al., 2019; Watson et al., 2012; Whitehouse & Bishop, 2009) attention (Bryson et al., 2004; Liss et al., 2006; Zwaigenbaum et al., 2005) and working memory (Kercood et al., 2014). Children with ASC may require more instances of new word repetition over a multiple time points to translate immediate fast mapping of new words into long term retention (Arunachalam & Luyster, 2016; Haebig et al., 2017; Hartley et al., 2020). It appears that, under certain conditions, children with ASC can retain new word information after a delay as well as their TD peers (Hartley et al., 2019; Hartley et al., 2020). However, it is unclear how children with ASC would retain new word information in natural environments in which new words are presented more rapidly within a constrained time period (Hartley et al., 2020). As receptive vocabulary is a significant predictor of future academic success (Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015), and reading and narrative comprehension (Lepola et al., 2016; Sénéchal, Ouellette, & Rodney, 2006), it is crucial to discover new and effective means to facilitate vocabulary acquisition in children with ASC.

1.5. Narrative Comprehension

Narrative comprehension concerns the understanding of narrative texts in which events are causally related to one another (Stein & Trabasso, 1982). Narratives can be presented as written text, spoken words, and static or animated cartoons (Cain, 2010). Successful narrative comprehension requires the co-ordination of language knowledge bases and skills, such as vocabulary and the generation of inferences, to make sense of the relations between events in a story and the character’s motivations and responses to those events (Perfetti, Landi, & Oakhill, 2005; Silva & Cain, 2015). The reader/listener must combine the knowledge of individual facts with their own experiences and the causal linking of events within the text to create a holistic mental representation of meaning (Kendeou, Lynch, Van Den Broek, Espin, White, & Kremer, 2005). Before learning to read, young children can successfully comprehend spoken and pictorial narratives (Daneman & Blennerhassett, 1984; Kendeou et al., 2005; Paris & Paris, 2003), and narrative comprehension is a significant predictor of concurrent and longitudinal reading comprehension in typical development (Cain, Oakhill, & Bryant, 2004; Oakhill & Cain, 2012).

Children with ASC have clear difficulties with narrative comprehension, particularly regarding the sequencing of temporal information into a coherent narrative (Banney et al., 2015; Diehl et al., 2006; Loveland, McEvoy, Tunali, & Kelley, 1990; Mäkinen et al., 2014) and the generation of inferences to make causal links between events in a story (Norbury & Bishop, 2002; Nuske & Bavin, 2011; Young et al., 2005). As executive function has been found to predict listening and reading comprehension in typical development (Follmer, 2018; Rudner et al., 2018), poor executive functioning in some children with ASC may be a potential explanation for narrative comprehension difficulties in this population. Children with ASC often demonstrate impairments in certain subdomains of executive function, including inhibitory control (Christ, Holt, White, & Green, 2007), attention shifting (Richard & Lajiness-O'Neill, 2015; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001), working memory (Kercood et al., 2014) and planning and organisation (Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008). Children with poor inhibitory control and attentional shifting may become preoccupied by environmental distractors and irrelevant stimuli of interest (Bryson et al., 2004; Liss, Saulnier, Fein, & Kinsbourne, 2006; Zwaigenbaum et al., 2005) and experience difficulty reorienting their attention towards a task or story (Renner, Klinger, & Klinger, 2006; Townsend, Harris, & Courchesne 1996; Werner, Dawson, Osterling, & Dinno, 2000), consequently disrupting the intake of relevant information. Moreover, impairments in working memory and planning may disrupt the storage of key facts and lead to difficulty organising story information into a complete and coherent narrative (Engel & Ehri, 2020; Florit, Roch, Altoe, & Levorato, 2009).

Another potential explanation is that children with ASC often demonstrate weak central coherence, the tendency to prioritise the processing of local detail over the gestalt (Frith, 1989). This could potentially impair narrative comprehension by creating a processing bias towards local information (such as individual facts) at the expense of the overall global context of the story (Nuske & Bavin, 2011), also known as context blindness (Vermeulen, 2015). Thus, an individual with weak central coherence may fail to create an integrated mental representation of a narrative (Norbury & Bishop, 2002), a potential explanation for weak narrative comprehension (Banney et al., 2015; Diehl et al., 2006; Loveland et al., 1990; Mäkinen et al., 2014; Rumpf, Kamp-Becker, Becker, & Kauschke, 2012) and poor inference-making in ASC (Norbury & Bishop, 2002; Nuske & Bavin, 2011; Young, Diehl, Morris, Hyman, & Bennetto, 2005). This contrasts with the processing style of TD children, who can utilise both local processing (for individual facts) and global processing (for inference-making) depending on their reading goals (Booth, 2006).

The relevance of weak central coherence to narrative comprehension can be understood in relation to the Construction Integration Model (Kintsch, 1988). Comprehension of a narrative requires the successful amalgamation of information across sentences to identify causal links between events and create a coherent and complete mental representation of meaning (Zwaan, & Radvansky, 1998). This is typically referred to as a situation model. Creating a coherent situation model requires temporal sequencing of events within the narrative alongside inference-making abilities, such as the integration of text information with the participant's own knowledge. Weak central coherence may disrupt the creation of a coherent situation model by impeding inference-making abilities and sequencing of events in a narrative, consequently leading to reduced narrative comprehension (Norbury & Bishop, 2002; Nuske & Bavin, 2011).

In line with the weak central coherence theory (Frith, 1989), studies have found a clear disparity in performance between TD children and those with ASC, when narrative comprehension was assessed through story recall and sentence completion tasks (Banney et al., 2015; Booth & Happé, 2010; Diehl et al., 2006; Loveland et al., 1990; Mäkinen et al., 2014; Rumpf et al., 2012). Loveland et al. (1990) performed a puppet show to 16 children with ASC and asked them to re-tell the story to the experimenter and answer comprehension questions. While children with ASC were able to accurately answer the questions, they had difficulty re-telling a coherent story, often failing to interconnect events to create a meaningful plot. Similarly, Diehl et al. (2006) asked 17 children with ASC and 17 TD participants to re-tell a story in their own words after listening to an audio narration. They were then asked a series of comprehension questions regarding the story. No differences in story length, complexity or recall of important events were found between groups. However, narrative coherence (how much the story made sense) was found to be diminished in participants with ASC. Booth and Happé (2010) used a sentence completion task to compare the processing style of children and young adults with ASC and TD participants of a similar age. Fourteen sentences were presented that required one word to be added to complete the sentence. The researchers examined whether the sentences were completed with words that made sense in the global context of the sentence or only made sense at a local level (in relation to the previous word alone). Participants with ASC demonstrated significantly more local sentence completions than the TD group. It was suggested that this is evidence of weak central coherence in children with ASC. Moreover, a study by Rumpf et al. (2012) examined participant narration of a wordless picture book by 11 children with ASC and a TD control group. Children with ASC produced narratives that were less coherent and relevant to the plot compared to TD controls, with greater focus on smaller details (such as individual facts) compared to the global context of the story. Taken together, these studies suggest that children with ASC have difficulty sequencing facts into a coherent representation of a narrative.

Children with ASC also demonstrate a deficit in inference-making abilities (Norbury & Bishop, 2002; Nuske & Bavin, 2011; Young et al., 2005), a significant predictor of narrative comprehension (Lepola, Lynch, Laakkonen, Silvén, & Niemi, 2012). Norbury and Bishop

(2002) read 5 stories to 6-to-10-year old children with ASC and a TD control group. The participants were then asked literal and inferential comprehension questions regarding the story. The control group scored significantly higher on the comprehension questions compared to the children with ASC, particularly on the questions regarding inference-making. Children with ASC often made inferences which were not relevant to the overall context of the story. In a study by Young et al. (2005), 17 children with ASC and a TD control group listened to a story while looking at a picture book. Children then answered comprehension questions regarding the narrative. In line with Norbury and Bishop (2002), while both groups demonstrated similar performance on fact-based questions, TD children scored significantly higher on questions requiring inference generation. This finding was replicated in a recent study by Nuske and Bavin (2011), who compared the narrative comprehension of 4- to 7-year-old children with ASC and a TD control group. The participants were each read six short stories and asked literal and inferential questions regarding the narratives. Despite similar performance on the literal questions, the TD control group outperformed the children with ASC on inferential questions requiring the integration of their own knowledge with events in the story. Collectively, these studies suggest that narrative comprehension difficulties in ASC do not manifest as a failure to recall key facts from a story, but rather as a difficulty combining one's own knowledge and experiences with story information to fully understand the relations between events and character thoughts and motivations (Norbury & Bishop, 2002; Nuske & Bavin, 2011). Such findings provide evidence for the weak central coherence theory (Frith, 1989), suggesting that children with ASC prioritise local detail within a narrative at the expense of the global story context.

In summary, executive dysfunction (Christ et al., 2007; Kercood et al., 2014; Richard & Lajiness-O'Neill, 2015; Rinehart et al., 2001; Sinzig et al., 2008) and weak central coherence (Frith, 1989) have been presented as a possible explanation for such narrative comprehension difficulties in this population, the latter potentially disrupting the creation of a coherent situation model (Kintsch, 1988). As narrative comprehension is a strong predictor of both concurrent and longitudinal reading comprehension (Cain et al., 2004; Oakhill &

Cain, 2012) and given the high incidence of reading comprehension difficulties in children with ASC (Nation et al., 2006), it is essential to investigate ways to better facilitate the acquisition of narrative comprehension skills in this population.

1.6. Focus on Task

Aside from specific language and learning difficulties, children with ASC often experience difficulties maintaining focus and attention on a task (Mayes & Calhoun, 1999; Mayes & Calhoun, 2007), as previously mentioned in sections 1.4 and 1.5. Attention is here defined as the ability to focus and actively engage with a task, with low distractibility and behavioural problems (Language and Reading Research Consortium (LARRC), Jiang, & Farquharson, 2018; Miller et al., 2014). Mayes and Calhoun (1999) found that 93% of 143 children with ASC had attention problems, demonstrating impaired concentration unless the task was specifically relevant to the individual interests of the child. Moreover, Mayes and Calhoun (2007) found that children with ASC often had similar levels of attention dysfunction on visual and auditory measures of attention to children with attention-deficit hyperactivity disorder (ADHD), with symptoms overlapping extensively.

Behavioural inattention is a significant predictor of academic achievement (Rogers et al., 2011) with longitudinal implications into later childhood and adolescence (Rennie, Beebe-Frankenberger, & Swanson, 2014). A potential explanation is that individuals with weak attention cannot successfully allocate attention to relevant information, leading to reduced academic performance (Pennington & Ozonoff, 1996). Children with ASC often experience difficulties in orienting their visual attention towards relevant stimuli (Renner, Klinger, & Klinger, 2006; Townsend, Harris, & Courchesne 1996; Werner, Dawson, Osterling, & Dinno, 2000), and exhibit abnormal sustained attention, becoming fixated on an item/topic of particular interest at the expense of other stimuli that are potentially more conducive to learning (Bryson et al., 2004; Liss, Saulnier, Fein, & Kinsbourne, 2006; Zwaigenbaum et al., 2005). However, Liss et al. (2006) found that children with ASC who displayed this pattern of selective attention often exhibited excellent learning and memory for their preferred topic of interest.

Due to the long-term academic implications of attention dysfunction (Rennie et al., 2014; Rogers et al., 2011), it is essential to discover new ways to facilitate engagement and task focus in children with ASC. As children with ASC often exhibit excellent learning and memory for topics of interest (Liss et al., 2006), this over-selective attention style could be utilised for improved learning outcomes by increasing the interest and customisability of learning materials (Patten & Watson, 2011). Indeed, the growing presence of technology within the classroom presents new and novel opportunities to tailor learning experiences to the heterogenous needs and interests of each individual child with ASC and subsequently enhance task focus and attention (Boone & Higgins, 2007).

1.7. iPads in the Classroom

The Apple iPad has become increasingly popular for use in educational settings as a learning aid for students (Geer, White, Zeegers, Au & Barnes, 2016). The portable and robust nature of iPads, combined with the media capabilities and applications on offer (Banister, 2010) make it an appealing tool for teachers in primary (Henderson & Yeow, 2012), secondary (Gitsaki & Robby, 2015), and university education (Nguyen, Barton & Nguyen, 2015). Moreover, much interest surrounds their use to aid the learning process of children with special educational needs (Cardon, 2012; Kagohara et al., 2013). The introduction of digital technologies to the classroom provides an opportunity for the unique needs of those with cognitive disabilities to be catered for, allowing for the creation of effective, personalised interventions (Boone & Higgins, 2007).

Parents and clinicians share a positive view of iPads as a learning aid for those with developmental disorders (Clark et al., 2015). A study by Clark et al. (2015) examined the opinions of parents and clinicians regarding iPad use in children with ASC. The researchers found that parents held a positive view of iPads and that this view translated into frequent and consistent use of iPads in the home environment. Despite holding a favourable view of iPads, clinicians reported narrow and infrequent usage of iPads and only as a component of intervention strategies. Clark et al. concluded that clinicians are more likely to wait for the efficacy of iPads to be scientifically verified before incorporating them into intervention strategies, whereas parents may be more willing to give applications a try without an evidence-base to support proposed benefits. Further research demonstrates an inconsistency between perceived and actual efficacy of the iPad as a learning tool for children with ASC. Allen, Jeans, Ball and Guarino (2015) found that caregivers of children with ASC who used an iPad as an intervention tool had a significantly lower opinion on the efficacy of iPads than non-users, with 20% of users stating that the iPad did not help at all.

Indeed, there is a lack of consensus within the existing literature in terms of the efficacy of iPads as a learning tool for students with ASC (Fletcher-Watson et al., 2015; Lorah, Parnell, Whitby, & Hantula, 2015; Lorah, Tincani, Dodge, Gilroy, Hickey, & Hantula, 2013; Sigafoos et al., 2013). Lorah et al. (2013) investigated whether a speech-generated therapy administered via an iPad would be more successful at teaching verbal skills to 5 children with ASC compared to the Picture Exchange Communication System (PECS). PECS enables children with verbal difficulties to independently communicate with teachers and caregivers using pictorial symbols. Results showed that 4 out of 5 children preferred the iPad method over the traditional PECS method and demonstrated a greater improvement with the iPad. Furthermore, Sigafoos et al. (2013) evaluated the efficacy of an iPad speech-generating device to improve communication and requesting in 2 children with ASC. The researchers found that not only was an iPad speech-generating device successfully used throughout the experiment to request the continuation of play, requesting was maintained after the experiment ended. Additionally, requesting became generalised to other actions and objects. Lorah et al. (2015) subsequently built upon these findings through a review of 17 studies into iPad-based communication interventions. Results showed that children using iPads and tablets for speech generation exhibited more rapid improvement in vocabulary and often preferred to use them than the traditional picture card method of PECS.

These findings were contrasted by Fletcher-Watson et al. (2015) who administered a social communication intervention to 56 young children with ASC and monitored progress. Despite favourable parental ratings of the intervention, no improvements in social communication were elicited. The researchers concluded that such iPad-based interventions may not elicit real-world benefits to social communication skills. Further research suggests that simply presenting stimuli on an iPad, compared to paper, is not enough to enhance the learning of children with ASC (Allen et al., 2015). Allen et al. (2015) investigated whether the medium of presentation (iPads vs traditional paper-books) influenced the learning of new symbols in children with ASC and a TD control group. Children were taught new words for four novel objects presented on an iPad or within a paper-book and then tested on their symbolic understanding and generalisation to other category members. The researchers found no difference in learning when symbols were presented on an iPad compared to a paper-book, suggesting that the iPad as a medium of presentation is no more effective than presenting information on paper, when all other variables remain constant.

Researchers suggest that iPad applications must adhere to certain design and implementation guidelines to function as effective learning tools for children with ASC, such as including customisable features (McNaughton & Light, 2013; Gevarter et al., 2014), maintaining adult involvement (El Zein et al., 2016) and a ensuring a firm foundation in current research (Boyd, Barnett, & More, 2015). Furthermore, it is essential to control the level of interactivity in iPad applications (De Jong & Bus, 2002). The following section will provide an overview of interactive and multimedia learning within iPads and evaluate the efficacy of interactive applications to facilitate the learning and engagement of children with ASC.

1.7.1. Interactivity and Multimedia Learning

Digital technologies, such as the iPad, allow for a level of interactivity not previously achievable with traditional paper-based learning materials – allowing for sound effects, animation and physical manipulation of on-screen stimuli (Takacs et al., 2015). Touchscreen interactivity may allow information to be processed as an active experience (Russo-Johnson, Troseth, Duncan, & Mesghina, 2017), as opposed to passively listening to information in a classroom (Kucirkova, 2014). This may change the way information is processed and stored, complementing the preferred learning style of those in infancy and early childhood (Highfield & Goodwin, 2013).

Indeed, presenting information through multiple modalities (such as sound, vision and touch) may increase child interest and sustained attention (Mineo, Ziegler, Gill, & Salkin, 2009). According to the cognitive theory of multimedia learning (Mayer, 1997) the presentation of information simultaneously to different modalities (such as visual and verbal) improves meaningful learning by allowing for the construction and co-ordination of multiple representations of the same information. Mayer (1997) reviewed a total of 24 studies investigating the influence of multimedia learning and found that the co-ordinated presentation of visual and verbal information significantly improved creative problem solving, especially for those with low prior knowledge of the subject area.

Mayer and Moreno (1998) state that, although the simultaneous presentation of information to multiple modalities can be conducive to learning, care should be taken to avoid overwhelming the individual with miscellaneous information. Known as the Coherence Principle, research has found that adding extraneous detail to task instructions inhibits performance and creative problem solving by up to 50% (Harp & Mayer, 1997). Irrelevant information is particularly detrimental for individuals learning a new skill (Mayer & Moreno, 1998) and young children with limited cognitive resources (Kirkorian, 2018). This is because processing redundant information alongside relevant information increases cognitive load, adding strain to working memory and impeding the consolidation of information into long-term memory (Sweller, 2005).

Multimedia and interactive learning materials have the potential to be both beneficial and detrimental to learning based on their design. If relevant and carefully designed, interactive and multimedia features may increase user-engagement and guide visual attention towards relevant features, improving learning (Radesky, Schumacher & Zuckerman, 2015; Xie et al., 2018). If irrelevant, they may increase cognitive load more-so than non-interactive materials, impeding learning (De Jong & Bus, 2002; Krcmar & Cingel, 2014). Takacs et al. (2015) conducted a meta-analysis of over 2000 children (both TD and those with language and learning difficulties) aged between 3 and 10 years old across 43 studies, investigating the influence of multimedia and interactive features within iPad e-books on narrative comprehension. Although the researchers found a small positive effect for learning using e-books, multimedia and interactive features influenced learning in different ways. Multimedia features, such as sound effects and animations, were found to improve narrative comprehension, yielding greater performance than both orally presented narratives and narratives accompanied by static pictures. However, when interactive features (such as hotspots and games) were added, learning was impeded. The researchers concluded that interactive features may distract children from relevant information, leading to cognitive overload (Sweller, 2005). However, multimedia features that are contingent with the plot of the story were found to enhance learning for children with and without language and learning difficulties.

The inclusion of only relevant interactive and multimedia features is particularly important to facilitate the understanding of children with ASC, due to the executive dysfunction (deficits in inhibition and attention shifting) and weak central coherence demonstrated by this population (Christ et al., 2007; Frith, 1989; Omar & Bidin, 2015; Richard & Lajiness-O'Neill, 2015; Rinehart et al., 2001). As previously explained, weak central coherence leads to a processing bias towards local detail over the gestalt (Frith, 1989). This is a problem for the narrative comprehension of children with ASC, as they often focus on small details out of context, rather than organising information into a coherent mental representation of meaning (Norbury & Bishop, 2002; Nuske & Bavin, 2011). Multimedia and interactive features that highlight the central plot of the story could improve the global processing of children with ASC by drawing attention away from irrelevant features and towards the relevant information (Omar & Bidin, 2015). Such features may also foster increased engagement and attention in a population with known attentional difficulties (Mayes & Calhoun, 1999; Mayes & Calhoun, 2007; Mineo et al., 2009). However, the influence of multimedia features and interactivity on the learning and engagement of children with ASC is yet to be investigated.

1.7.2. Task Engagement

iPad applications have been widely credited with increasing task engagement in both typical and atypical development (Kucirkova, Messer, Sheehy & Panadero, 2014; Moody et al., 2010). Task engagement is here defined as an individual directing their focus towards a task and maintaining attention for the duration of the activity (McWilliam, Scarborough, & Kim, 2003). However, much evidence regarding iPad engagement relies on reports of favourable user-perception (Kucirkova et al., 2014; Richter & Courage, 2017) and less disruptive behaviour during iPad use (El Zein et al., 2016; O'Malley et al., 2014). Very little research has attempted to define task engagement into measurable categories (Moody et al., 2010; Richter & Courage, 2017; Roskos et al., 2012). Three such studies, investigating learning and engagement with e-books in typical development, will be explained here.

Moody et al. (2010) explored the task engagement of 25 pre-schoolers when read a story on an e-book or a traditional paper-book. Children were video recorded whilst listening to the story to allow for the coding of task engagement. Moody et al. coded engagement by measuring persistence (pointing to pictures and turning pages), enthusiasm (showing excitement towards the task) and compliance (staying seated and following directions). Instances of communication, such as labelling and task-relevant speech, were also coded as an additional measure of engagement. Whereas children showed greater levels of task persistence when using an e-book, communication was higher for the traditional paper-book. The researchers theorised that communication may be impeded when listening to the e-book story as children are distracted by the interactive features.

Roskos et al. (2012) built upon the findings of Moody et al. (2010) to create a typology for measuring engagement with e-books. A sample of pre-schoolers were video recorded during a shared e-book reading activity and their behaviour during the task was coded and sorted into engagement categories. The researchers created a framework for engagement coding, including control behaviours (such as working the device), multi-sensory behaviours (including looking time and touching the screen), and communication (such as the use of language and non-verbal utterances). The researchers concluded that such a framework was a reliable measure of a child's task engagement with e-books.

Richter and Courage (2017) combined the engagement categories suggested by Moody et al. (2010) and Roskos et al. (2012) to compare task engagement and narrative comprehension between e-books and paper-books in a sample of 79 pre-schoolers. Engagement was measured through visual attention (looking time at the book/screen, adult, and off-book/screen), communication (such as labelling and speech relevant to the story), and 'persistence, enthusiasm and compliance.' Children were then tested on their narrative comprehension though answering 9 comprehension questions. Although children exhibited high visual attention across both conditions, with 89.5% of time visually engaged with the task, results showed greater on-task looking time for the e-book compared to the traditional book. Children in the e-book condition also demonstrated greater persistence, enthusiasm, and compliance. Low levels of communication were reported across both conditions, with 26.9% of children remaining completely silent during the task. The authors noted that this may be due to the young age of the participants. Despite higher engagement in the e-book condition, narrative comprehension did not differ between conditions. It was concluded that e-books may be beneficial for motivating and engaging children.

However, it is noteworthy that no studies have examined the link *between* engagement and learning outcomes. Despite favourable user and teacher perceptions of iPad learning (Clark et al., 2015; Kucirkova et al., 2014; Richter & Courage, 2017) and some evidence of the efficacy of iPads as a learning tool for students with ASC (Lorah et al., 2013; Lorah et al., 2015; Sigafoos et al., 2013), we do not know whether engagement is the mechanism through which interactive learning mediums, such as the iPad, may influence learning. As research to date has focussed only on task engagement with e-books, we do not know whether children will engage differently with other iPad applications teaching different skills – such as symbol learning. Moreover, as research to date only examines task engagement in TD pre-schoolers, we do not know whether children with ASC will engage with iPads differently to TD children.

1.7.3. Adult Involvement

Interactive iPad applications may foster a solitary learning style in children, allowing adult involvement to be replaced with on-screen feedback and digital voiceover narration of text (Radesky et al., 2015; Schugar et al., 2013). The self-contained nature of learning from iPads may complement the learning preferences of children with ASC, who often experience low social engagement (Chevallier et al., 2012). As previously explained, children with ASC often experience wide-ranging social impairments (Kjelgaard & Tager-Flusberg, 2001; Pelphrey et al., 2011) potentially reducing the 'basic affiliative need' for social cues (Rochat & Callaghan, 2005). Consequently, children with ASC may be less receptive to social information in the form of joint attention and language and may benefit less from adult involvement. This contrasts with TD children, who are predisposed to attend to social cues, such as language and gaze (Rochat & Callaghan, 2005).

Although children with ASC often have difficulties with social engagement and are less receptive to social information (Chevallier et al., 2012; Kjelgaard & Tager-Flusberg, 2001; Pelphrey et al., 2011), supported joint attention (in which both the child and the adult attend simultaneously to the same stimulus) is relatively unimpaired in ASC (Adamson et al., 2009). Instead, children with ASC have difficulties with co-ordinated joint attention, in which both the child and the adult attend simultaneously to the same stimulus *and* the child actively acknowledges the presence of the adult (Adamson et al., 2009). Even in the absence of co-ordinated joint attention, children can still benefit from supported joint attention (Tomasello & Farrar, 1986; Yoder, Kaiser, Alpert, & Fischer, 1993). Labelling of unfamiliar stimuli (by the adult) during periods of supported joint attention has been found to improve the word learning of typically and atypically developing children (Tomasello & Farrar, 1986; Yoder et al., 1993). Even though children with ASC may demonstrate less sophisticated joint attention towards an adult than their TD peers (Adamson et al., 2009), jointly attending to a task accompanied by adult prompting and labelling may be sufficient to improve learning in this population (Tomasello & Farrar, 1986; Yoder et al., 1993).

Further evidence suggests that adult involvement within a task can improve learning outcomes (Cubelic & Larwin, 2014; Falloon & Khoo, 2014; Highfield & Goodwin, 2013; McLeod & McDade, 2011; Robbins & Ehri, 1994). The shared reading of storybooks has been found to benefit the vocabulary learning of young TD children and children with ASC (Flack et al., 2018; McLeod & McDade, 2011; Robbins & Ehri, 1994), facilitating greater narrative comprehension through joint attention and providing opportunities for questioning and commenting on key aspects of the story (Hindman et al., 2008; Mucchetti, 2013; Sénéchal & LeFevre, 2002). However, a common feature of iPad applications and e-books is the availability of in-app voiceover narration of text as an alternative to adult narration (Schugar et al., 2013), which may take the place of the adult and replace shared reading. Due to the scarcity of research in this area, it is unclear whether such features may be beneficial or detrimental to learning.

As suggested, it is possible that solitary, non-social learning will benefit the preferred learning style of children with ASC (Radesky et al., 2015; Schugar et al., 2013). In contrast, removing opportunities for supported joint attention, adult guidance and labelling may lead to poorer learning outcomes (Adamson et al., 2009; Cubelic & Larwin, 2014; Falloon & Khoo, 2014; McLeod & McDade, 2011; Tomasello & Farrar, 1986; Yoder et al., 1993). To fully investigate the relationship between engagement and learning in children with ASC, and to inform appropriate iPad use for this population, both task engagement *and* adult involvement will be examined in this thesis.

1.8. Summary

In summary, it is clear that ASC is a complex and heterogeneous condition encompassing a range of language and learning impairments of varying degrees of severity, including difficulties in symbolic understanding (Hartley & Allen, 2015a; Hartley & Allen, 2015b; Preissler, 2008), receptive vocabulary (Luyster et al., 2008; Manolitsi & Botting, 2011; Weismer et al., 2010) and narrative comprehension (Norbury & Bishop, 2002; Nuske & Bavin, 2011). The prevalence of impaired task focus within this population (Mayes & Calhoun, 1999; Mayes & Calhoun, 2007) has led to the increased popularity of digital technologies, such as the iPad, to motivate and engage children with ASC (Boone & Higgins, 2007). Despite a positive user-perception of iPads and children often preferring their use over paper-based mediums (Kucirkova et al., 2014; Richter & Courage, 2017), there is a lack of consensus within the existing literature on the efficacy of iPads as a learning tool for students with ASC (Fletcher-Watson et al., 2015; Lorah et al., 2013; Lorah et al., 2015; Sigafoos et al., 2013).

Sound effects, animation and touchscreen exploration are readily available within most iPad applications (Takacs et al., 2015), however little research has investigated how children with ASC learn from interactive and multimedia iPad applications and compared this to traditional paper-based mediums. iPad popularity in specialist education is driven by the perceived benefits to child engagement (Boone & Higgins, 2007). However, the little research that attempts to classify engagement into measurable categories focusses only on typical development, and only on one type of iPad application – the e-book (Moody et al., 2010; Roskos et al., 2012; Richter & Courage, 2017). Therefore, how children with ASC engage with e-books and other iPad applications compared to TD children is yet to be determined. Moreover, no research to date examines the relationship *between* engagement and learning outcomes. Therefore, we do not know whether engagement with interactive iPad applications influences the learning of children with ASC.

Finally, interactive iPad applications may foster a solitary learning style (Radesky et al., 2015), removing the need for adult involvement by providing on-screen feedback and digital voiceover narration of text (Schugar et al., 2013). Research to date suggests that although children with ASC often experience low social engagement (Chevallier et al., 2012; Kjelgaard & Tager-Flusberg, 2001; Pelphrey et al., 2011), supported joint attention and adult labelling may still be beneficial to learning outcomes (Adamson et al. 2009; Tomasello & Farrar, 1986; Yoder et al., 1993). Despite the potential of interactive iPad applications to increase task engagement (Kucirkova, et al., 2014; Moody et al., 2010; Richter & Courage, 2017), it is important to also investigate how adult involvement within a task may influence the learning of children with ASC (Cubelic & Larwin, 2014; Falloon & Khoo, 2014; Highfield & Goodwin, 2013; McLeod & McDade, 2011; Robbins & Ehri, 1994).

Together, the experiments presented in this thesis investigate the influence of engagement on the learning of children with ASC regarding three areas of language ability found to be weak in this population – symbolic understanding, label learning and narrative comprehension. Specifically, whether engagement is a possible mechanism through which interactive iPad applications may influence learning. To guide the appropriate use of interactive iPad applications within this population, this thesis also investigates whether adult involvement in a task benefits the learning outcomes of children with ASC. Performance on all tasks is compared to an ability-matched TD control group.

The first two studies investigate the symbolic understanding of children with ASC and a TD control group. Study 1 examines whether the iconicity of symbols will influence symbolic understanding and engagement, and crucially, whether task engagement will relate to robust symbolic responding. Study 2 investigates whether providing a label, alongside the function of an object, benefits symbolic understanding, as measured through free-play in an object exploration task.

Whereas Study 1 investigates the relationship between engagement and learning using a specially designed, single purpose interactive iPad application, Study 3 examines the relationship between novel label learning and engagement within an interactive e-book, a setting more similar to every-day learning (Bus, 2001; McLeod & McDade, 2011). Finally, Study 4 investigates narrative comprehension and engagement with interactive e-books vs paper-books in ASC and a TD control group. This study also manipulates the level of adult involvement in the story by including two e-book conditions – one in which the experimenter narrates the story and one in which the story is narrated through an in-app digital voiceover. Overall, the aim of this thesis is to investigate whether engagement benefits the learning of children with ASC using interactive learning materials, and whether adult involvement is beneficial to learning in this population.

Symbolic understanding and word-picture-referent mapping from iPads in autism spectrum condition: the roles of iconicity and engagement

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Abstract

We investigated symbolic understanding, word-picture-referent mapping, and engagement in children with Autism Spectrum Condition (ASC) and ability-matched typically developing (TD) children. Participants viewed coloured pictorial symbols of a novel object (given a novel name) on an iPad in one of three conditions: static 2D images and either automatically or manually rotating images (providing a three-dimensional context). We found no significant difference in word-picture-referent mapping between groups and conditions, however, children who manually rotated the picture had greater on-screen looking time compared to other conditions. Greater visual attention related to more successful word-picture-referent mapping only for the children with ASC. Interactive iPad tasks may increase visual attention in both typical and atypical populations and greater visual attention may benefit word-picture-referent mapping in ASC.

Keywords: symbolic understanding, word-picture-referent mapping, autism, iPad, engagement

Symbolic Understanding and Word-Picture-Referent Mapping from iPads in Autism Spectrum Condition: The Roles of Iconicity and Engagement.

Communication problems are one of the main reported weaknesses associated with Autism Spectrum Condition (ASC) (Alzrayer, Banda, & Koul, 2014; American Psychiatric Association, 2013; Caruana et al., 2017; Paul, Chawarska, Klin, & Volkmar, 2017). For children across the spectrum, receptive and expressive language development can be significantly delayed (Anderson, 2007; Wodka, Mathy, & Kalb, 2013). Children with ASC often communicate using pictorial symbols as an alternative to speech (Bondy & Frost, 1994; Kasari & Patterson, 2012; Lord & Jones, 2013) and demonstrate a relative strength in visuo-spatial processing compared to language (Kumar, 2013), yet knowledge regarding how children with ASC understand pictures on a symbolic level is relatively scarce. Critically, existing research suggests differential learning mechanisms are in place for children with ASC and TD children (Hartley & Allen, 2014b; 2015a, 2015b; Preissler, 2008).

Symbolic understanding of word-picture-referent relations emerges at around 18-24 months in typically developing (TD) children (Ganea, Allen, Butler, Carey & DeLoache, 2009; Preissler & Carey, 2004). Word-picture-referent relations is here defined as the knowledge that a label refers to both the pictorial symbol and the real-world referent it depicts (Hartley & Allen, 2014b, Hartley & Allen, 2015a; Hartley & Allen, 2015b). Children in their second year of life can successfully fast map new nouns to their intended referents immediately after label exposure (Munro et al., 2012) and retain the new noun over short time periods after a single instance of labelling (Spiegel & Halberda, 2011). At 24 months, children demonstrate a shape-bias in object categorisation (Samuelson & Smith, 1999), generalising the mapping of a new noun from the original referent to a differently coloured referent of the same shape (Hartley & Allen, 2014a). However, children with ASC often have specific difficulties understanding that words and pictures symbolically refer to objects (Hartley & Allen, 2014b; Preissler, 2008). Instead, they show associative mapping of word-picture-referent relations, restricting a label to the symbol itself and failing to generalise to a real-world referent or differently coloured exemplars. This is in contrast to the referential mapping exhibited by TD children, who readily generalise a label given to a picture to its corresponding object (Preissler & Carey, 2004). The differences in word-picture-referent mapping mechanisms between children with ASC and TD children could have a significant impact on word acquisition and the flexible use of language for children with ASC.

Increasing the iconicity of pictorial symbols has been found to be an effective way of improving the referential understanding of children with ASC (Hartley & Allen, 2015a). Iconicity is the extent to which an image visually resembles its referent (Sirota, Kostovičová & Juanchich, 2014). Images can vary in visual iconicity, with printed words defined as opaque, black and white images defined as translucent, and coloured photographs defined as transparent (Fuller, Lloyd & Stratton, 1997). Ganea, Pickard and DeLoache (2008) investigated whether the visual iconicity of an image in a printed picture book influenced the extent to which TD 15-18 month-old infants generalised the label of a picture to a real-world referent. Infants more often generalised the label to the real-world referent when the pictures were realistic and transparent (colour photographs) than when they were less realistic and translucent (cartoons). This was especially apparent for the 15-month-old infants. The researchers concluded that increasing the iconicity of pictures is beneficial in picture books because it enhances symbolic understanding, especially for younger infants.

As stated above, evidence suggests that children with ASC may interpret symbols, specifically pictures, in a different way to TD children (Hartley & Allen, 2015b; Preissler, 2008). Hartley and Allen (2014b) compared children with ASC (M_{age} = 9.7 years) and TD 2 to 5-year-olds in their ability to match abstract and iconic pictures with their intended referents. Children with ASC relied highly on visual resemblance and matched pictures to their referents more often with iconic than abstract images. In contrast, the TD children successfully matched both types of pictures with their intended referents. Their findings suggest that low-functioning children with ASC rely on resemblance, and do not take the intention of the artist into account, whereas TD children can understand the intention of the artist even in the absence of high visual resemblance. Thus, it appears that, unlike TD children, children with ASC rely on a high level of iconicity when matching a picture to a referent.

As another test of iconicity, Hartley and Allen (2015b) presented children with ASC (M_{age} = 9.7 years) and TD 2 to 5-year-olds matched on receptive vocabulary score with pictures of novel objects that varied in iconicity from grey and coloured line drawings to black and white and coloured photographs. For each trial, a novel word was paired with a novel picture. In a 'mapping' test, participants were asked to select the named item from a choice of the picture shown in the training phase and the previously unseen referent object. In a subsequent 'generalisation' test, the object was replaced with a differently coloured version of the same object and participants were again asked to indicate the referent. The TD children selected the object in the mapping and generalisation tests in the majority of trials, regardless of condition. In contrast, children with ASC often selected the picture they had been shown, suggesting that they had formed an association between the word and the picture and failed to generalise the word to the object. However, children were more likely to choose the object in both the mapping and generalisation tests as iconicity increased, with the fewest object selections for the black and white line drawings and the most for the colour photographs. This indicates that iconicity supports symbolic understanding.

As noted, symbols are essential to support the flexible use of language for those with communication difficulties, such as children with ASC. In recent years, the Apple iPad has become increasingly popular as a learning aid for students (Geer, White, Zeegers, Au & Barnes, 2016; Neumann, 2018), with a wide variety of educational applications available (Alzrayer et al., 2014). The portable and robust nature of iPads and tablets, combined with the media capabilities and applications on offer (Banister, 2010) make it an appealing alternative to paper-based learning for teachers in both specialist (Cardon, 2012; Kagohara et al., 2013; King, Brady, & Voreis, 2017) and mainstream education (Gitsaki & Robby, 2015). iPad-based learning has been found to increase student engagement and reduce problem behaviour in both typically and atypically developing populations (El Zein et al., 2016; Kucirkova, Messer, Sheehy & Panadero, 2014). Moreover, touchscreen interactivity allows for more information to be conveyed to the child through touch and motion and for information to be processed as an active experience, which may change how the information is encoded and stored (Russo-Johnson, Troseth, Duncan & Mesghina, 2017).

The educational value of interactive touchscreen learning is very much in debate (Kirkorian, 2018). Interactivity may increase the cognitive load of young children more-so than non-interactive material, impeding learning. However, it may also increase user-engagement and guide visual attention towards relevant features, improving learning. Indeed, studies to date report both positive (Highfield & Goodwin, 2013; Schwartz & Plass, 2014; Xie et al., 2018) and negative (Radesky, Schumacher & Zuckerman, 2015; Russo-Johnson et al., 2017) influences of interactivity on learning. Highfield and Goodwin (2013) stated that interactive iPad learning (through touch, repetition and exploration) complements the preferred learning style of those in infancy and early childhood. One claim is that iPads foster more active involvement for young children, rather than passively listening to information in the classroom (Kucirkova, 2014). Relevant here is work examining interactive e-books and applications as a learning aid for young pupils. On-screen interactivity increases language learning and reading skills in young children; one possible mechanism is that touchscreens provide real-time feedback to children and appropriately timed responses which are more engaging and similar to real-life interactions (Radesky et al., 2015). A recent meta-analysis of 36 studies found that young children learn a wide range of materials better from touchscreen devices than non-touch screen media (Xie et al., 2018).

However, there is evidence that the interactivity offered by e-books may be a potential hindrance to learning (Krcmar & Cingel, 2014). Krcmar and Cingel found that pre-schoolers showed greater learning from traditional books compared to e-books, with more relevant discourse between parents and children when sharing traditional print books. Moreover, Russo-Johnson et al., (2017) found no difference in young children’s word learning when images were viewed passively compared to an interactive condition.

Despite mixed results, iPads and touchscreen technology have been widely credited with increasing the engagement of learners in both mainstream and specialist education, with many reporting a user-preference towards iPads at the expense of traditional paper-based alternatives (Richter & Courage, 2017). However, very little research has defined engagement into measurable categories and, critically, examined the relationship *between* engagement and learning outcomes. One exception is a study by Richter and Courage (2017) that compared preschooler engagement in an e-book and a traditional book in terms of various categories including visual attention (looking time at the book/screen, adult and off-book/screen), communication (such as labelling and speech relevant to the story), and 'persistence, enthusiasm and compliance.' Measures of these different types of engagement during a storybook task were examined in relation to comprehension of the book. Results showed greater on-task looking time for the e-book compared to the traditional book and higher persistence, enthusiasm and compliance. Low levels of communication were reported across both conditions, which the authors note may be due to the young age of the participants. Despite higher engagement in the e-book condition, storybook comprehension did not differ between conditions. The researchers concluded that interactive iPad applications may be beneficial for engaging and motivating learners, however they may not influence learning.

Despite much interest surrounding the use of the iPad as an educational tool for children with ASC (Cardon, 2012; Chmiliar, 2017; Kagohara et al., 2013; Whitehouse et al., 2017), most research has focussed on TD populations and the effects of interactivity on symbolic understanding is yet to be investigated in both typical and atypical development. The overall efficacy of word-picture-referent mapping via iPads is very much in debate and remains an open and essential question (Allen, Hartley & Cain, 2016).

Presenting stimuli on a screen has the potential to enhance the iconicity of an image beyond traditional picture books, by providing the three-dimensional context of a real-world object. As a higher level of iconicity has been found to increase symbolic understanding (Allen, et al., 2016; Hartley & Allen, 2015b), providing three-dimensional context to images may lead to more successful word mapping. Moreover, the iPad touchscreen allows for interactivity and manual exploration of pictorial symbols. When participants touch and interact with images on an iPad screen, they may process the information more deeply or actively (Russo-Johnson et al., 2017), which may benefit the mapping of new symbols. The interactivity provided by the touch and motion may lead to greater engagement (such as visual attention and communication) in the task compared to non-interactive conditions (Radesky et al., 2015; Richter & Courage, 2017), which may positively impact subsequent word mapping.

The current study contrasts the word-picture-referent mapping and symbolic understanding of children with ASC and TD controls from images displayed on an iPad. Children completed a training phase in which pictorial symbols of unfamiliar objects were presented on an iPad paired with an unfamiliar spoken label. A critical contrast was whether the image was displayed as a static 2D image (similar to a printed photograph) or as a 3D image. For the 3D images, participants could view either the image rotating (automatic condition) or could rotate the images themselves by touching the screen (interactive condition). Children were then immediately tested on their word-picture-referent mapping. Studies have demonstrated that children can perform accurately on immediate mapping tests despite having poor retention after a delay (Horst & Samuelson, 2008). Therefore, children were tested again after two-weeks in a subsequent retention test. Children were also video recorded during the training phase to examine the relationship between engagement and successful symbolic mapping. Engagement categories were adapted from the coding scheme proposed by Richter and Courage (2017) and included visual attention (screen looking, adult looking and off-screen (environment) looking) and communication (labelling and relevant speech) as measures of engagement.[1.]

The first aim was to determine whether symbolic responding and label generalisation will differ by group (ASC vs TD) and condition (3D images vs 2D images). The second aim

[1] As 'persistence, enthusiasm and compliance' was measured through looking visual attention and communication, and so overlapped with the above engagement measures, this was removed as a distinct category.

was to determine if engagement (visual attention and communication) varies by group and/or condition. The third aim was to examine whether higher engagement is contingent with both immediate symbolic mapping and retention after a delay.

It is hypothesised that the 3D conditions (automatic and interactive) will yield more symbolic responding and label generalisation in the ASC group compared to the 2D condition due to increased iconicity provided by the rotation (three-dimensional context), with greater label retention after a delay. Following the findings of previous research (Hartley & Allen, 2015b) it is hypothesised that symbolic responding and label retention in the TD group will not differ between conditions. As interactivity has been found to complement the preferred learning style of children (Highfield & Goodwin, 2013), it is hypothesised that both populations in the interactive condition will exhibit greater on-task engagement for both engagement measures (visual attention and communication) compared to the 2D and automatic conditions. Finally, based on previous research we expect greater engagement to be contingent symbolic understanding and label retention after a delay (Kucirkova, 2014; Radesky et al., 2015, Xie et al., 2018).

Method

Participants

Ninety-six participants (34 female) were recruited for this study. There were 48 children with ASC (13 female) whose ages ranged from 4 years 11 months to 14 years 7 months (M_{age} = 9 years 0 months, SD_{age} = 23.12 months). They were recruited from five schools from North Wales and the north west of England and had been assessed by a qualified psychologist using standardised measures (ADOS, ADI-R), subsequently receiving a clinical diagnosis of autism. We further screened for the presence of symptoms using the current version of the Social Communication Questionnaire (SCQ; Rutter, Bailey & Lord, 2003) completed by the class teacher (M_{score} = 19.33; SD_{score}= 6.18; range = 10-32).[2.] A

[2] 38 participants scored 15 or above, the suggested cut-off for ASC. 6 participants scored between 12-14, and 4 participants scored below 12. As all of our participants had a clinical diagnosis of autism, and given the caution regarding false negatives obtained with the SCQ (Rutter, Bailey, & Lord, 2003), and suggestion that lower cut-

further questionnaire was administered to class teachers to examine the use of The Picture Exchange Communication System and iPads/tablets in the classroom. The Picture Exchange Communication System was used as a language support by 38.1% of children (although PECS was not used during the task), and 88.1% used iPads/tablets at school (see Table 1 for frequency of iPad use for TD and ASC participants). Forty-eight TD children (21 female) also participated in the study, with ages ranging from 1 year 8 months to 6 years 9 months (M_{age} = 3 years 5 months, SD_{age} = 14.23 months). They were recruited from two nursery schools and one primary school in the North Wales area and 35.4% used iPads/tablets at school. As shown in Table 1, children with ASC were more frequent users of iPads or touchscreen devices (once a week or more) in school, $\chi^2(1, N = 90) = 25.90$, $p < .001$. As the experiment is a test of label mapping and retention, ASC and TD participants were matched for comparable levels of receptive vocabulary prior to the experimental tasks (see Table 2 for receptive vocabulary and non-verbal ability raw scores to enable comparison between groups). Due to behavioural difficulties (fussiness and inability to focus on the task), 5 children with ASC could not complete the training phase and were subsequently excluded from the study. Additional participants were recruited to ensure a total of 48 ASC children. All 48 TD children successfully completed the training phase and were included in the study.

offs are sometimes appropriate (Eaves, Wingert, Ho, & Mickelson, 2006; Norris & Lecavalier, 2010) we included all participants in the analysis.

Table 1

The percentages (and frequencies) of iPad/tablet use in school/nursery for participants with ASC and TD participants.

Question: Do children have experience with iPads or touchscreen devices in the nursery/in school?		
	ASC	TD
Every day	28.6% (12)	8.3% (4)
3-4 times a week	9.5% (4)	0% (0)
1-2 times a week	50.0% (21)	27.1% (13)
Not anymore but has in the past	11.9% (5)	0% (0)
Never	0% (0)	64.6% (31)

Table 2

The, mean (M), standard deviation (SD), range and number (N) of raw scores of participants for the British Picture Vocabulary Scale third edition (BPVS3 – Receptive Vocabulary), Raven's Coloured Progressive Matrices (CPM – Non-Verbal IQ), the Wechsler Preschool and Primary Scale of Intelligence third edition (WPPSI 3 – Non-Verbal IQ) and chronological age.

	ASC				TD				
	M	*SD*	Range	*N*	*M*	*SD*	Range	*N*	*p*
BPVS3	47.85	28.15	3-109	48	42.92	27.81	5-104	48	.39
CPM	19.27	8.61	7-31	22	23.25	7.41	17-33	4	
WPPSI 3	10.15	7.74	1-28	26	12.57	7.24	1-26	44	
Age	108.40	23.12	59-175	48	41.21	14.23	20-81	48	

Receptive vocabulary was measured using the British Picture Vocabulary Scale-3 (BPVS-3; Dunn & Dunn, 2009). We report the raw scores as, for some participants, raw scores were too low to calculate a standardised score. The mean receptive vocabulary raw score for the BPVS-3 was 47.85 (range = 3-109) in the ASC group and 42.92 (range = 5-104) for the TD group, a non-significant difference, $t(94) = -0.86$, $p = .39$, $d = 0.18$. The standardised scores for the TD group were all within an age-appropriate range. To further characterise the sample (although not for matching purposes), the Raven's Coloured Progressive Matrices (CPM; Raven, 2003) or the Block Design task of the Wechsler Preschool and Primary Scale of Intelligence – third edition (WPPSI-3; Wechsler, 2002) were administered to participants as a measure of non-verbal ability. Twenty-two children with ASC (45.83%) and 4 children with TD (8.33%) over the age of 6, the minimum age suggested as appropriate for the test, completed the CPM. Twenty-six children with ASC (54.17%) who could not complete the CPM due to difficulty and 44 TD children (91.67%) below the age of 6 were assessed instead with the WPPSI-3. Although expressive vocabulary was not measured in this study, no non-verbal children were included in the study as confirmed by the class teacher.

Materials

A 32GB iPad Air 2 was used to present visual stimuli to participants in the training phase. Six unfamiliar objects were used in the study – consisting of a mixture of rubber dog toys and unusual household objects. Of the six unfamiliar objects, two were named target objects, two were unnamed distractor objects, and two were not shown on the iPad and were used only as distractor objects in the retention test. Although the two target objects were both dog toys, they differed in size, shape, colour and texture. No children expressed familiarity with the unfamiliar objects. Eight familiar objects were also shown on the iPad as distractor images, with four shown in each training phase. All familiar objects were selected from the Oxford CDI to ensure familiarity for children over 11 months of age. Stimuli were presented via an application developed for this study by a computer scientist at Lancaster University. This application facilitated presentation of real-world stimuli scanned into Object files (OBJ files) via a HP Sprout Pro 3D object scanning device. The application allowed for the images to be presented in each of the three conditions: 2D static presentation of images; automatic 360^{o} rotation of the 3D image; and manual touchscreen 3D rotation, which was controlled by the participant. Images were presented for a duration of 6 seconds each, regardless of condition.

Experimental Design

A between-subjects design with three conditions (2D, 3D automatic rotation and 3D interactive rotation) was used, with 16 participants from each group (ASC and TD) in each condition. Participants were assigned to conditions based on their BPVS scores, ensuring that there was a range of abilities in each condition and that there was no significant difference in receptive vocabulary score between conditions for the TD group, $F(2,45) = 0.06$, $p = .95$, $\eta^2 = .003$, and the ASC group, $F(2,45) = 0.27$, $p = .76$, $\eta^2 = .01$ (see Table 3).

Table 3

The, mean (M), standard deviation (SD), range and number (N) of raw scores of participants for the BPVS3 (receptive vocabulary measure) and chronological age across conditions for each group.

	BPVS3								
	ASC				TD				
	M	*SD*	Range	*N*	*M*	*SD*	Range	*N*	*p*
2D	43.69	31.60	3-109	16	44.56	28.86	5-104	16	.62
Automatic	48.94	30.80	4-104	16	41.19	29.98	8-98	16	.70
Interactive	50.94	23.44	22-99	16	43.00	26.19	8-92	16	.48
	Chronological Age								
2D	111.94	33.86	59-175		41.69	14.20	20-80	16	<.001
Automatic	106.81	14.77	76-133		39.25	14.48	20-81	16	<.001
Interactive	106.44	17.04	77-137		42.69	14.72	25-76	16	<.001

Counterbalancing was used to control for order effects. This included which target object (“Blicket” or “Toma”) was presented first in the mapping and generalisation tests, which target object was labelled “Blicket” and which was labelled “Toma”, the order of the stimuli in the mapping and generalisation tests, whether pictures or objects were shown first in the retention test and the order of stimuli presentation in the retention test.

Procedure

Testing took place individually over three separate days. The first two days of testing were consecutive, followed by a two-week gap before a test of retention. On the first day, participants were administered receptive vocabulary and cognitive measures. On the second day, participants were taken individually to the testing room, seated at a table adjacent to the experimenter and told that they were going to play a game on the iPad. A Samsung camcorder on a tripod was used to film the training phase and allowed for the coding of engagement. The camcorder was pointed towards the participant to allow for a clear view of the face and tabletop. Participants completed two trials each comprising a training phase and the mapping and generalisation tests, thus in total there were two separate training phases, mapping tests and generalisation tests. The trials were separated by a 5-minute break.

Training Phase

To begin the training phase, the experimenter selected either the 2D, 3D automatic or 3D interactive condition on the iPad, as appropriate to the condition assigned to that child. The target image was presented four times within a sequence that consisted of an unfamiliar distractor image (also repeated four times) and four individual familiar images (shown once each), with the images presented in a fixed order (to ensure order was controlled across conditions), with the participants viewing a total of 12 images in the training phase, with each training phase lasting 72 seconds. The fixed order consisted of the target image first, followed by the distractor image and then the familiar image. The target image was labelled aloud by the experimenter on each instance of presentation with the unfamiliar label “this is a Blicket/Toma.” This label was repeated twice on each instance, as per previous research (Allen, Hartley, & Cain, 2015), giving a total of eight label repetitions per trial to maximise exposure to the novel label in a short time frame. This is because studies suggest that, despite a high level of accuracy with immediate fast mapping of new words (Swingley, 2010), successful label retention requires multiple instances of repetition (Axelsson & Horst, 2014). Moreover, children with ASC may require multiple instances of labelling to learn a novel word due to difficulties in consolidating new word information (Haebig, Saffran, & Ellis Weismer, 2017). The distractor object was accompanied with the verbal prompt “look at this.” The familiar objects were not labelled in the training phase and were not present in the mapping and generalisation tests. Figure 1 shows the two sets of images, for the two trials.

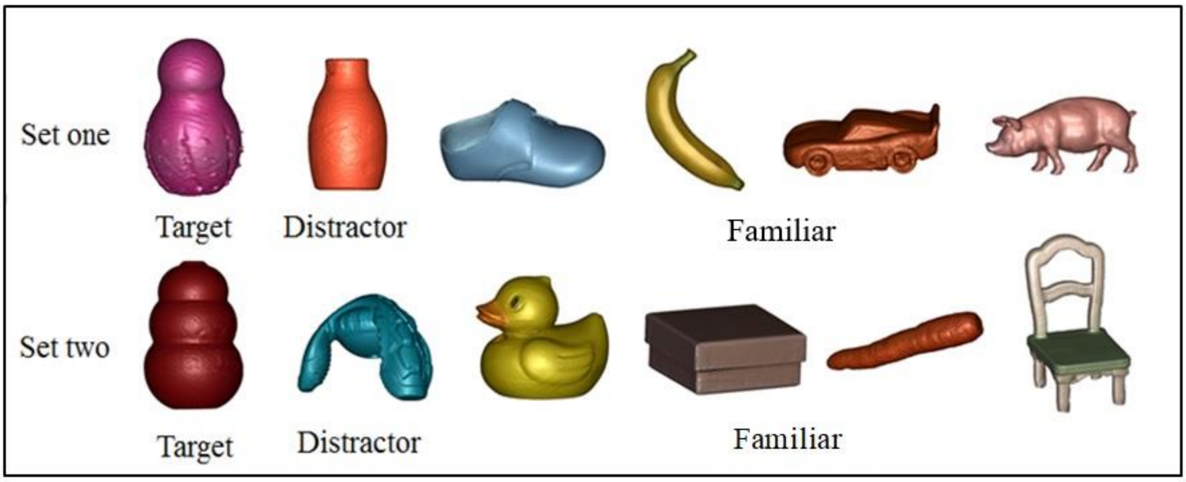

Figure 1. The two sets of stimuli presented to participants on the iPad in the training phase.

Mapping Test

Following the training phase, participants completed a mapping test, designed to assess their symbolic understanding. They were shown an array of stimuli in a row in front of them, consisting of an A5 printed screenshot of the target object, an A5 printed screenshot of the distractor object, the target object in the original colour and the distractor object (see example in Figure 2). Participants were then asked to identify the named object, with the experimenter requesting “show me a Blicket/Toma.” If the child had not understood the referential function of the image in the training phase, it was expected that they would only select the target image, thereby restricting the label to the picture itself. If the child had understood the referential nature of the image in the training phase, it was expected that they would select the target object or both the target image and target object, generalising the label from the picture to its real-world referent and taken as a measure of symbolic understanding (see Allen et al., 2015).

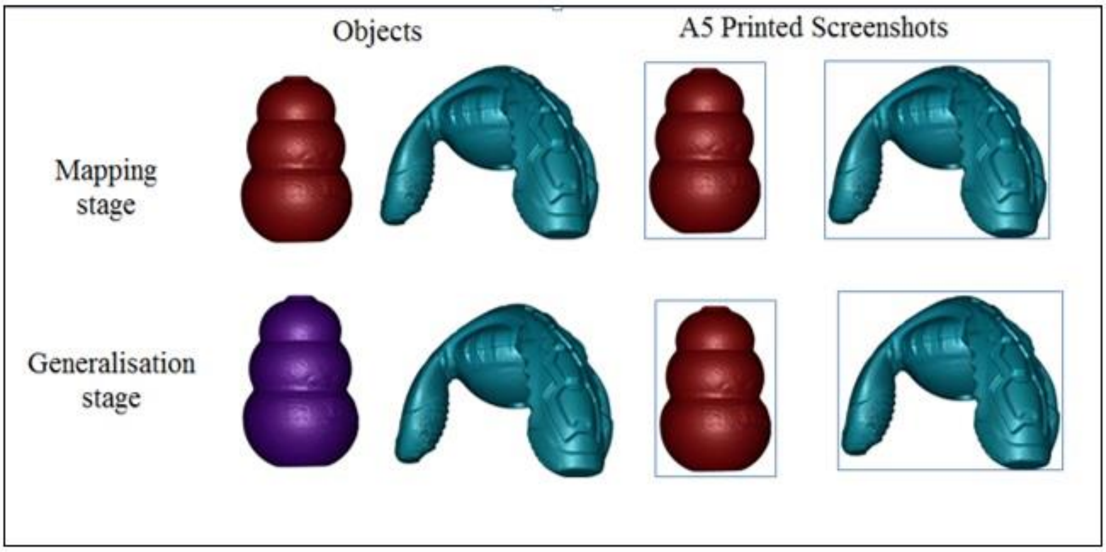

Figure 2. Example of array for mapping and generalisation tests for one target object.

Generalisation Test

After the mapping test, participants completed the generalisation test in which they were shown an array of stimuli in a row consisting of the same stimuli as the mapping test but with a differently coloured version of the same target object. Participants were asked again to "show me a Blicket/Toma." Children who had not formed a referential understanding of the image and had selected the target picture alone in the mapping test were expected to do so again in the generalisation test. As some children with ASC have specific difficulties generalising a novel label from the original exemplar to a differently coloured version, it was expected that some children in the ASC sample would select the target picture alone in the generalisation test despite selecting the object in the mapping test. In each stage of the experiment, positive reinforcement was given only to reinforce good behaviour and attention and was not directed towards task performance.

Retention Test

Participants were tested approximately two weeks later (M_{days} = 16.31, SD_{days} = 2.62) to examine word-picture-referent mapping after a delay. Participants were shown an array of stimuli in front of them, consisting of a total of three A5 pictures, one of the first target object, a novel distractor from the immediate recall test and a new novel distractor, shown in a counterbalanced order. They were asked “show me the Blicket/Toma.” This was then repeated with the actual objects instead of pictures and participants were again asked “show me the Blicket/Toma.” Both tasks were then repeated for the second target object.

Data Coding

Training Phase

All videos of the training phase were analysed for participant engagement by two independent coders, who analysed each entire video. Participant engagement was divided into two categories with individual sub-categories (see Table 4). As per Richter and Courage (2017), visual attention (towards the screen, adult or environment) was coded based on looking duration (in seconds). Communication (relevant speech and labelling) was coded on each instance. The duration of looks towards each sub-category was measured using the time data displayed on the video, and the total time for each sub-category was summed once coding was completed. For communication, each instance of relevant speech and labelling was coded and again an overall total was created for each sub-category. It is important to note that the video-coders did not define individual participants as “engaged” or “disengaged” based on their engagement scores. Instead, more visual attention and instances of communication in certain categories provided an indication of degree of engagement with the task (total looking time at the screen, relevant speech and labelling), while others provided an indication of the extent of social engagement (adult-oriented looking time) and task disengagement (off-screen (environment) looking time).

An intra-class correlational analysis with fixed effects and absolute agreement was conducted between the primary and secondary video-coder for each sub-category separately and all ratings were found to be greater than .97 (see Table 4 for reliability ratings for each sub-category). This represents high agreement according to Cicchetti (1994) where scores on or above .75 are classified as ‘excellent’. Therefore, the primary video-coder’s scores were used for analysis. Engagement scores were averaged across trials to create one total score for each participant.

Table 4

The description and maximum possible scores and inter-rater reliability of the 2 engagement categories and their sub-categories.

Engagement Category	Sub-Category	Description	Maximum Score	Inter-rater reliability
Visual attention	Total Screen Looking Time	Total amount of time the participant looks the screen. Greater total screen looking time would here indicate greater task engagement.	72 seconds	.97
	Adult-Oriented Looking Time	Total amount of time the participant looks at the adult. Greater adult-oriented looking time would here indicate greater social engagement.	72 seconds	.97
	Off-Screen (Environment) Looking Time	Total amount of time the participant looks away from the screen (excluding looking time at the adult). Greater off-screen (environment) looking time would here indicate greater disengagement with the task.	72 seconds	.97

Communication	Relevant Speech	Total instances of speech (word, phrase or sentence – each defined as one instance) relevant to the task or the images on the screen (excluding labelling the target image). More instances of relevant speech would here indicate greater task engagement. E.g. “Oh look, another one!” E.g. “Duck!”	No maximum.	.98
	Labelling	Whether or not the participant labels the target image for each individual instance of presentation. More instances of labelling would here indicate greater task engagement.	4 instances of labelling – whether or not they label each of the 4 target images per trial	.98

Mapping and Generalisation Tests

Item selection was coded by the researcher during the experiment (as per Allen, Hartley, & Cain, 2015; Hartley & Allen, 2015b). Item selection was defined as the child clearly pointing to particular items in the array or handing items to the experimenter in response to the question "Show me a Blicket/Toma." Only explicit responses were coded (pointing, giving or sliding the item towards the experimenter) as per Preissler (2008).

Consistent Symbol Mapping Across Trials

We were interested to see whether participants showed consistent responding across trials (see Joseph et al., 2019); in this way we could classify children as consistent symbolic responders or not across both mapping and generalisation trials. We defined consistent symbolic responding as a selection of the target object with or without the target picture in mapping tests (trial 1 and 2), and also across generalisation tests (trial 1 and 2). All other combinations of responses (associative responding, selecting distractor items, and symbolic responding on 1 trial only) were categorised as "not consistent." Binary logistic regressions were conducted for "consistent" and "not consistent" responses for mapping tests and generalisation tests separately. We then coded responses across mapping and generalisation tests to determine how robust children's responses were: Participants were categorised as "robust symbolic" when they demonstrated symbolic responding (selecting the target object with or without the target picture) across all tests (mapping and generalisation) for both trials. All other combinations of responses (associative responding, selecting distractor items and inconsistent symbolic responding) were categorised as "not robust."

Results

We first analysed results of the mapping and generalisation tests separately, then looked at how individuals performed across both mapping and generalisation tests together. We then assessed whether children retained the new labels after a two-week delay. Finally, we evaluated levels of engagement during the training phase, and determined whether this related to performance.

Mapping Tests Combined

Table 5 shows individual responses in the mapping tests. To check for consistency of responses, we combined the two trials. 68.8% of ASC participants and 60.4% of TD participants demonstrated consistent symbolic responding across both mapping tests. A binary logistic regression found no significant association between consistency of symbolic responding and group and condition, $\chi^2(3) = 1.10$, $p = .77$. There was no significant interaction between group and condition, $\chi^2(2) = 0.09$, $p = .96$.

Table 5

The number and percentage of participant responses for mapping tests 1 and 2.

Trial 1 Mapping Test							
	ASC				TD		
Response	2D	Automatic	Interactive	Response	2D	Automatic	Interactive
Picture	1 (6.3%)	1 (6.3%)	0 (0.0%)	Picture	1 (6.3%)	0 (0.0%)	2 (12.5%)
Object	13 (81.3%)	12 (75.0%)	5 (31.3%)	Object	8 (50.0%)	14 (87.5%)	7 (43.8%)
Both	1 (6.3%)	1 (6.3%)	7 (43.8%)	Both	5 (31.3%)	2 (12.5%)	4 (25.0%)
Distractor	1 (6.3%)	2 (12.5%)	4 (25.0%)	Distractor	2 (12.5%)	0 (0.0%)	3 (18.8%)
Trial 2 Mapping Test							
	ASC				TD		
Response	2D	Automatic	Interactive	Response	2D	Automatic	Interactive
Picture	0 (0.0%)	1 (6.3%)	0 (0.0%)	Picture	1 (6.3%)	4 (25.0%)	1 (6.3%)
Object	8 (50.0%)	11 (68.8%)	8 (50.0%)	Object	7 (43.8%)	9 (56.3%)	7 (43.8%)
Both	3 (18.8%)	2 (12.5%)	6 (37.5%)	Both	4 (25.0%)	1 (6.3%)	4 (25.0%)
Distractor	5 (31.3%)	2 (12.5%)	2 (12.5%)	Distractor	4 (25.0%)	2 (15.4%)	4 (25.0%)

Generalisation Tests Combined

60.4% of ASC participants and 58.3% of TD participants demonstrated consistent symbolic responding across both generalisation trials. A binary logistic regression found no significant association between consistency of symbolic responding and group and condition, $\chi^2(3) = 1.85$, $p = .60$. There was no significant interaction between group and condition, $\chi^2(2) = 2.25$, $p = .33$ (see Table 6 for all responses in the generalisation tests).

Table 6

The number and percentage of participant responses for generalisation tests 1 and 2.

Trial 1 Generalisation Test

ASC				TD			
Response	2D	Automatic	Interactive	Response	2D	Automatic	Interactive
Picture	3 (18.8%)	1 (6.3%)	0 (0.0%)	Picture	3 (18.8%)	2 (12.5%)	2 (12.5%)
Object	9 (56.3%)	11 (68.8%)	5 (31.3%)	Object	4 (25.0%)	11 (68.8%)	8 (50.0%)
Both	2 (12.5%)	0 (0.0%)	6 (37.5%)	Both	5 (31.3%)	3 (18.8%)	4 (25.0%)
Distractor	2 (12.5%)	4 (25.0%)	5 (31.3%)	Distractor	4 (25.0%)	0 (0.0%)	2 (12.5%)

Trial 2 Generalisation Test

ASC				TD			
Response	2D	Automatic	Interactive	Response	2D	Automatic	Interactive
Picture	0 (0.0%)	1 (6.3%)	0 (0.0%)	Picture	1 (6.3%)	1 (6.3%)	2 (12.5%)
Object	10 (62.5%)	12 (75.0%)	9 (56.3%)	Object	9 (56.3%)	8 (50.0%)	8 (50.0%)
Both	1 (6.3%)	1 (6.3%)	5 (31.3%)	Both	4 (25.0%)	4 (25.0%)	3 (18.8%)
Distractor	5 (31.3%)	2 (12.5%)	2 (12.5%)	Distractor	2 (12.5%)	3 (18.8%)	3 (18.8%)

Robust Symbol Mapping Across Trials

Here, we investigated response patterns across mapping and generalisation tests when taken together by examining whether or not participants were “robust symbolic” responders. 54.2% of ASC participants and 47.9% of TD participants were robust across both trials. A binary logistic regression found no significant association between robust symbolic responding and group and condition, $\chi^2(3) = 2.73$, $p = .44$. There was no significant interaction between group and condition, $\chi^2(2) = 1.47$, $p = .48$ (see Table 7 for all scores).

Table 7

The number (and percentages) of robust symbolic responding (robust and not robust) across all test trials and the mean (and standard deviation) of labels correctly assigned to their target pictures/objects in the retention test.

	ASC			TD		
	2D	Automatic	Interactive	2D	Automatic	Interactive
Robust	7 (43.8%)	10 (62.5%)	9 (56.3%)	6 (37.5%)	9 (56.3%)	8 (50.0%)
Not Robust	9 (56.3%)	6 (37.5%)	7 (43.8%)	10 (62.5%)	7 (43.8%)	8 (50.0%)
Number of labels	2.20 (1.74)	2.77 (1.42)	2.07 (1.44)	3.00 (1.46)	2.75 (1.44)	1.80 (1.82)

Retention Test

Due to school absences, only 90 out of 96 participants (93.75%) completed the retention test. Five children with ASC (10.4%) and one TD child (2.1%) did not complete the retention test. Out of a total of four possible instances of labelling in the retention test– trial 1 (picture and object) and trial 2 (picture and object) – participants correctly assigned a mean of 2.43 labels (SD = 1.58) to their target images/objects (see Table 7). No significant difference in retention was found for group, $F(1,84) = 0.27$, $p = .61$, $\eta^2 = .003$, or condition, $F(2,84) = 2.34$, $p = .10$, $\eta^2 = .05$ and no significant interaction was found between group and condition, $F(2,84) = 0.97$, $p = .38$, $\eta^2 = .02$.

Participant Engagement Coding

Time data were analysed for the visual attention measures and frequency data were analysed for communication. Individual participant data from both trials were averaged to create a combined total score for each measure (see Table 8 for all engagement scores).

Table 8

Mean (and standard deviation) of engagement scores averaged across trials 1 and 2. All looking times are calculated in seconds. Speech is calculated in instances.

	ASC			TD		
	2D	Automatic	Interactive	2D	Automatic	Interactive
Visual Attention						
Total screen looking	55.53* (14.55)	58.11* (9.98)	68.25* (5.76)	52.80* (12.85)	59.11* (10.63)	65.00* (8.30)
Adult-oriented looking	3.41* (2.78)	5.00 (5.79)	0.75* (1.02)	11.30* (10.07)	6.39 (4.64)	3.63* (6.44)
Off-screen (environment) looking	13.06* (14.58)	8.89 (11.54)	3.00* (5.56)	7.90* (8.04)	6.50 (6.95)	3.37* (4.29)
Communication						
Relevant speech	4.19* (3.90)	4.57* (4.96)	2.00* (2.48)	6.83* (3.34)	5.57* (4.60)	3.37* (3.14)
Labelling	1.22* (1.15)	1.29 (1.42)	0.81* (0.89)	2.20* (1.41)	1.07 (1.30)	0.40* (0.83)

Visual Attention

Looking time proportions between the screen, adult and off-screen (environment) indicated a high level of engagement in the task for both groups. Children with ASC spent 84.4% of time looking at the screen compared to 4.1% looking towards the adult and 11.5% looking off-screen (environment). TD children spent 81.9% of time looking at the screen compared to 9.9% looking towards the adult and 8.1% looking off-screen.

Total screen looking time was analysed using a two-way ANOVA with group and condition as factors. No difference was found between groups, $F(1,84) = 0.54$, $p = .47$, $\eta^2 = .01$. A main effect of condition was found, $F(2,84) = 10.66$, $p < .001$, $\eta^2 = .20$. Tukey post-hoc analysis showed significantly higher total screen looking time in the interactive condition (M = 66.68 seconds) compared to the 2D condition (M = 54.21 seconds) and the automatic condition (M = 58.61 seconds). No significant interaction was found between group and condition, $F(2,84) = 0.34$, $p = .72$, $\eta^2 = .01$.

Off-screen looking time was split into adult-oriented looking time and off-screen (environment) looking time. As these measures are mutually exclusive, only adult-oriented looking time is reported here. These data were analysed using a two-way ANOVA with group and condition as factors. A main effect of group was found, $F(1,84) = 10.89$, $p = .001$, $\eta^2 = .12$. The TD group looked significantly longer at the adult (*M* = 7.13 seconds) compared to the ASC group (*M* = 2.97 seconds). A main effect of condition was also found, $F(2,84) = 6.33$, $p = .003$, $\eta^2 = .13$. Tukey post-hoc analysis showed significantly greater adult-oriented looking time in the 2D condition (*M* = 7.23 seconds) compared to the interactive condition (*M* = 2.15 seconds). No significant interaction was found between group and condition, $F(2,84) = 2.57$, $p = .08$, $\eta^2 = .06$.

Communication

On average, children with ASC produced 3.54 instances of relevant speech per trial and TD children produced 5.25 instances of relevant speech per trial (see Table 8). Relevant speech was analysed using a two-way ANOVA with group and condition as factors. A main effect of group was found, $F(1,84) = 4.35$, $p = .04$, $\eta^2 = .05$. The TD group produced significantly more instances of relevant speech (*M* = 5.25 instances) than the ASC group (*M* = 3.54 instances). A main effect of condition was also found, $F(2,84) = 4.93$, $p = .01$, $\eta^2 = .11$. Tukey post-hoc analysis found significantly more instances of relevant speech in the 2D condition (*M* = 5.47 instances) and the automatic condition (*M* = 5.07 instances) compared to the interactive condition (*M* = 2.66 instances). No significant interaction was found between group and condition, $F(2,84) = 0.39$, $p = .68$, $\eta^2 = .01$.

On average, children with ASC produced 1.10 out of 4 possible instances of labelling and TD children produced 1.23 out of 4 possible instances of labelling of the target image per trial (see Table 8). Labelling was analysed using a two-way ANOVA with group and condition as factors. No significant group difference was found, $F(1,84) = 0.22$, $p = .64$, $\eta^2 = .003$. A main effect of condition was found, $F(2,84) = 6.73$, $p = .002$, $\eta^2 = .14$. Tukey post-hoc analysis found significantly more instances of labelling in the 2D condition (*M* = 1.69 instances) compared to the interactive condition (*M* = 0.61 instances). No significant interaction was found between group and condition, $F(2,84) = 3.11$, $p = .05$, $\eta^2 = .07$.

Engagement and Performance

In this section, we examine whether there is a relation between engagement (screen looking time) and symbolic responding and label retention (both immediate and in the retention test) for the ASC and TD groups respectively. Although group differences did not emerge in our earlier analyses, the literature and our earlier predictions suggested that different factors might underlie performance (Field, Allen, & Lewis, 2016a).

Robust Symbolic Responding

An independent samples t-test was conducted to examine whether engagement and immediate robust symbolic responding differed between groups. For the ASC group, a significant difference in engagement was found between robust and non-robust symbolic responders, $t(44) = -2.49$, $p = .02$, $d = 0.76$. Robust symbolic responders had greater screen looking time ($M = 64.72$ seconds) than non-robust symbolic responders ($M = 56.00$ seconds). No significant difference was found for the TD group, $t(42) = -1.42$, $p = .16$, $d = 0.43$. We also wanted to check whether robust symbolic performance was related to PECS usage for the ASC group. We found a significant negative correlation between PECS use and robust symbolic performance, $r = -.39$, $p = .01$.

Retention Test

An independent samples t-test was conducted to examine whether performance on the retention test (time 2) differed between robust and non-robust responders at time 1. For the ASC group, a significant difference in retention was found between robust and non-robust symbolic responders, $t(41) = -2.18$, $p = .04$, $d = 0.66$. Robust symbolic responders scored higher on the retention test ($M = 2.78$) than the non-robust symbolic responders ($M = 1.80$). No significant difference was found for the TD group, $t(45) = -1.22$, $p = .23$, $d = 0.36$.

A correlation was conducted to examine the relationship between screen-looking time and performance on the retention test for both groups. No significant relationship was found for the ASC group, $r = -.01$, $n = 42$, $p = .94$, or the TD group, $r = .01$, $n = 44$, $p = .98$.

Discussion

This study investigated whether symbolic responding and label retention differ between children with ASC and TD children when given a new label for novel “three-dimensional” image (either automatically rotating or interactive) compared to 2D static images on an iPad screen. Contrary to predictions, we did not find any group or condition differences: both groups demonstrated a similar level of symbolic understanding and label retention across the three different presentation conditions. We found similar levels of on-screen attention to the task in both groups, but different patterns of task performance emerged. We discuss these findings in turn.

As expected, we found no difference in symbolic responding and label retention amongst conditions for the TD group. However, contrary to our hypothesis, we also found no difference in performance between conditions for children with ASC. These results suggest that enhancing iconicity through motion and interactivity does not increase symbolic understanding over and above static, non-interactive, coloured stimuli. One possible explanation for the absence of an effect is that motion and interactivity may impede dual representation (Uttal et al., 1998). Dual representation is the understanding that a symbol can be both an object in its own right while also representing something else in the environment, such as an image being both a picture and also a symbol for a real-world referent (DeLoache, 1987, 1991, 1995). Increasing the interest and attractiveness of a symbol can make it difficult for children to think of a symbol both referentially and as a concrete object (DeLoache, 2004; Uttal et al., 1998), potentially masking any potential gains that might be achieved by increasing perceptual iconicity.

Collectively, the results show variation in performance for both the ASC and TD samples, with only half of the cohort reliably symbolic. Two explanations may account for such variation. One possibility concerns our relatively strict coding: children needed to demonstrate symbolic understanding on all four trials to be considered ‘robust’. This is different from past research that consisted of single trials and forced choice responses between the picture and object in the absence of distractors (Hartley & Allen, 2015b;

Preissler, 2008). Thus, our study provided more opportunity for error, but also provides a more stringent test of symbolic understanding. A second explanation is that the acquisition of symbolic understanding is not a qualitative step-change in a Piagetian sense (Fischer & Silvern, 1985; Piaget, 1936), but something that develops over time and varies with input and experience. Children may also be testing out various strategies (Alibali, 1999), in which they switch to more accurate and efficient methods of learning (Siegler, 2006).

Despite the variation in overall robust symbolic responding, very few ‘associative’ responses were made, even in the 2D condition for either population. It is possible that there is a threshold over and above which any enhancement to iconicity will not benefit performance. Perhaps colour photographs, already considered to be ‘transparent’ symbols, are enough to promote symbolic understanding (see also Hartley & Allen, 2014b). Indeed, our baseline level of iconicity was colour photographs, in contrast to previous research which has included symbols with lower iconicity such as black and white line drawings and cartoons. This may explain why we found only an average of 3.1% associative responses across trials, compared to prior studies using a similar design (55% in Preissler (2008) and an average of 62.9% in Hartley and Allen (2015b)). Hartley and Allen (2015b) found a large difference between black and white line drawings and coloured photographs, with associative responding decreasing by 25% when colour photographs were used. We thus appear to have provided optimal conditions for word-picture-referent mapping in the current study and it is encouraging that under such conditions our ASC group were just as successful as their TD peers.

As predicted, and in line with Richter and Courage (2017), the interactive condition increased the visual attention (e.g. on screen looking) of both groups. However, instances of communication (relevant speech and labelling) decreased for both groups in the interactive condition compared to the 2D condition. These results suggest that interactive stimuli increase engagement in terms of looking behaviour but may decrease social communication. It is possible that on-screen interactivity can either be beneficial or detrimental to engagement depending on the specific needs of the learner. To facilitate focus on a task, an interactive application may serve to increase attention and prevent external distraction which could inhibit learning (Oakes, Ross-Sheehy, & Kannass, 2004). However, iPad applications may not be the optimal method to foster social communication and engagement between the teacher and the learner, a skill that is typically diminished in children with ASC (Wodka, et al., 2013). Although the adult provided a degree of mediation through co-viewing in all conditions, it is possible that interactive features may reduce the opportunities for active adult mediation – such as responding to participant comments and questions – as children are distracted with their individual touchscreen exploration (Nathanson, 2001). Instances of relevant speech in the ASC group dropped by 50% in the interactive condition. Moreover, adult oriented looking time reduced by 85% between the automatic condition and the interactive condition. This suggests that physical manipulation of stimuli reduces spontaneous communication and social interaction compared to passively viewing stimuli in this population. Previous research has found that touchscreen interventions for social communication do not transfer into real-world communication skills (Fletcher-Watson et al., 2016), despite high engagement in the task. It is possible that the self-contained nature of learning through this medium (Allen et al., 2016) and the increased cognitive load provided by interactive touchscreen features (Kirkorian, 2018; Richter & Courage, 2017) may diminish the need to share salient information with the adult and may be a particular hinderance to the facilitation of social interaction in individuals with ASC. Non-interactive presentation of learning material may be optimal for increasing social communication in this population.

A different pattern of looking time was observed for the ASC group compared to the TD group. Despite similar proportions of on-screen looking time, the ASC group predictably looked less at the adult (Constantino et al., 2017; Jones, Carr, & Klin, 2008; Kasari & Patterson, 2012). Moreover, as expected, the TD group was found to have significantly higher levels of relevant speech than the ASC group, in line with previous research (Anderson, 2007; Dawson et al., 2004; Wodka, et al., 2013).

Finally, consistent with our hypothesis that engagement would be associated with performance, it was found that robust symbolic responders engaged in significantly more on-screen looking time than non-robust symbolic responders in the ASC group alone. This may be due to increased attention to relevant stimuli, preventing distractions which could impede task performance (Oakes et al., 2004), which is particularly important for children with poorer executive functioning (Richter & Courage, 2017), such as those with ASC (Finnegan & Mazin, 2016). However, it is important to note that, while based on prior coding schemes (Richter & Courage), attention is multi-faceted and defining what is on-task behaviour is complex (Knudsen, 2007). For example, although children may demonstrate a high level of visual attention towards the screen, we do not know precisely what they are attending to with observation alone. Future research could use eye-tracking to more accurately define whether participants are attending to on-task (target stimuli) or off-task (background) information.

Interestingly, screen looking time was not related to task performance on the follow-up test of label retention two weeks later. Instead, robust symbolic responders at time 1 had significantly greater retention for the ASC group only, with no significant difference found for the TD group. It appears that whether children treat pictorial symbols as referential (i.e. symbolic) has an impact on their subsequent retention of a new label. Future research should investigate whether this specifically affects encoding or retrieval processes (Bowler et al., 2004; Ben-Shalom, 2003).

Limitations

In addition to the limitations discussed above, we detail here the four most pertinent for future research. First, a potential explanation for the comparable levels of symbolic understanding between ASC and TD groups in this study may be that our ASC group had a lower mean SCQ score by 8.17 points compared to previous research (Allen et al., 2015). This suggests that the current sample consists of higher-functioning ASC participants than past studies; it is possible that minimally verbal children with ASC are more natural associative learners (Preissler, 2008) and that the heterogeneity of the condition and language profile (Allen & Yau, 2019) implicates different routes of learning word-picture-object relations across individuals with ASC. To investigate this further, future research should compare ASC participants with range of abilities, such as lower-functioning/minimally verbal children with ASC with higher-functioning/verbal ASC participants using the same methodology.

Second, children were matched on their receptive vocabulary score and, as per previous research, were not matched on chronological age (Field, Allen, & Lewis, 2016a; Maljaars, Noens, Scholte, & van Berckelaer-Onnes 2012; Tager-Flusberg, 1985; Tek, Jaffery, Fein, & Naigles 2008). Children with ASC are a heterogenous population in which overall receptive language ability and functioning can vary significantly despite chronological age (Weismer, Lord, & Esler, 2010). Thus, to match for chronological age would most likely have resulted in a control sample with higher verbal skills that fell into a narrower range of performance. However, we acknowledge that age is a good proxy for increasing vocabulary ability in TD populations (Dunn & Dunn, 2009) and may influence performance. It is also important to note that, as the BPVS3 provides an age-equivalent score from 45 months and over, some of our participants could not be provided with an age-equivalent score as they were either too young (in the TD group) or scored too low (in the ASC group). However, as it was crucial for children to be matched on their receptive vocabulary, as this is a task of label mapping and retention, children were matched on raw scores in this study.

Third, although our study goes beyond the single trial methodology of previous research, two trials still cannot be generalised to symbol learning at large. Future research should increase the number of trials to increase the generalisability of findings to real-world symbol learning. Finally, word-symbol-referent mapping studies to date have focussed on the teaching of new noun labels (Allen, Hartley & Cain, 2015; Hartley & Allen, 2015b; Preissler & Carey, 2004; Preissler, 2008). However, in order to be representative of word acquisition as a whole, the symbolic mapping of other word-types (such as adjectives and verbs) should be examined in future work in this area.

Conclusion

Overall, this study suggests that children with ASC are just as able as vocabulary-matched peers to treat pictures symbolically and retain new labels at the same rate after a delay. Increasing the iconicity of pictures to a ‘transparent’ (Fuller et al., 1997) level through two-dimensional colour photographs may be sufficient to elicit the maximum benefit to symbolic understanding in ASC, evidenced by our lack of condition difference when rotation and interactivity were added to the task. However, interactivity has been found to increase engagement in terms of visual on-task attention for both groups, at the possible expense of communication. This finding may have important implications for learning through the medium of iPads/tablets, suggesting that iPads/tablets can be successful to elicit some skills (such as greater visual attention) and unsuccessful at eliciting others (such as social communication). These findings suggest that practitioners need to clarify their purpose – how and why – they use electronic education due to the different pattern of findings for word learning and engagement. Taken together, our results suggest that there is a link between engagement and task performance for individuals with ASC, and that different routes to symbolic understanding may be implicated in typical and atypical development.

The influence of labelling on symbolic understanding and dual representation in autism spectrum condition

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Abstract

Background and aims: Children with autism spectrum condition (ASC) often have specific difficulties understanding that pictorial symbols refer to real-world objects in the environment. We investigated the influence of labelling on the symbolic understanding and dual representation of children with ASC.

Methods: Children with ASC and typically developing (TD) children were shown four coloured photographs of objects that had different functions across four separate trials. The participants were given either a novel label alongside a description of the object's function or a description of the object's function without a label. Children were then given 30 seconds to interact with an array of stimuli (pictures and objects) in a mapping test and in a generalisation test for each trial. This exploration phase allowed for spontaneous word-picture-referent mapping through free-play, providing an implicit measure of symbolic understanding.

Results: We found no significant difference in word-picture-referent mapping between groups and conditions. Both groups more often performed the described action on the target object in the exploration phase regardless of condition.

Conclusions and implications: Our results suggest that a spontaneous measure of symbolic understanding (such as free-play) may reveal competencies in word-picture-referent mapping in ASC.

The Influence of Labelling on Symbolic Understanding and Dual Representation in Autism Spectrum Condition

Children with Autism Spectrum Condition (ASC) often experience specific difficulties in symbolic understanding of pictures – the knowledge that a picture represents and refers to a real-world referent (Hartley & Allen, 2014b; Preissler, 2008). Symbolic understanding is crucial for successful language development and social functioning, as symbols are used abundantly in society to convey information (DeLoache, 2004). Despite this, knowledge regarding how children with ASC understand and learn new symbols is relatively scarce.

Symbolic understanding emerges at around 18-24 months in early typical development (Ganea et al., 2009), coinciding with the development of dual representation (DeLoache et al. 1998; Preissler & Carey, 2004). Dual representation is the understanding that a symbol is both an object itself and a representation of a real-world referent (DeLoache, 1987, 1991, 1995). Before the development of dual representation, young children often manually interact with pictorial symbols as though they were the objects they depict, such as licking a picture of an ice-cream (DeLoache et al., 1998). However, after the age of 30 months, typically developing (TD) children reliably understand the referential nature of pictures, as demonstrated by their consistent success at picture-search tasks, such as locating a hidden toy using a pictorial symbol as a guide (DeLoache & Burns, 1994; Suddendorf, 2003).

In contrast to TD infants, who develop symbolic understanding early in development, older children with ASC often demonstrate a different route of symbol learning (Hartley & Allen, 2014b; Preissler, 2008). Preissler administered a word-mapping task to low-functioning children with ASC. Low-functioning is here defined as a child with an IQ under 70 and half of participants were entirely non-verbal. Participants were taught a new label matched with a novel picture (e.g. this is a *whisk*), over successive trials. Once it was confirmed that the participants learned the word-picture pairing, they were then administered a “mapping test” in which the novel picture was paired with the referent object and the participant was asked to select the labelled item (e.g. show me a *whisk*). In contrast to TD peers who included the real object in their choice, children with ASC more often demonstrated associative responding, restricting the label to the pictorial symbol itself and failing to generalise to the real-world object. This pre-disposition towards associative responding in low-functioning children with ASC may implicate a different route of symbol acquisition and processing that could affect language development (Hartley & Allen, 2014b; 2015a, 2015b).

Language is thought to scaffold symbol learning in typical development (Callaghan, 2008; Preissler & Bloom, 2007). Moreover, young children have been found to generalise an exemplar to other category members when the item is labelled (Booth & Waxman, 2002; Waxman & Booth, 2003) and when they are given a verbal description of the item’s function, such as “it was made for cutting playdough” (Field, Lewis, & Allen, 2016b). In one study investigating dual representation in typical development, Preissler and Bloom (2007) showed two-year-old children a pictorial symbol of an unfamiliar object which was either paired with a novel label (“this is a dax”) or accompanied with the verbal prompt “look at this!”. Participants were then shown an array of the target object and target picture, along with a distractor object and distractor picture, and were asked to show the experimenter another example of the stimulus they had seen. When the symbol was labelled, participants chose the corresponding object – demonstrating referential responding - 90% of the time, compared to 30% when the symbol was unlabelled. It was concluded that labelling a pictorial symbol highlights the referential nature of an image in early typical development.

In a similar experiment, Hartley and Allen (2015b) found a marked difference between TD and ASC participants. In line with Preissler and Bloom (2007), TD children more often demonstrated referential responding when the target was labelled compared to when it was not. Crucially, this was not the case for participants with ASC, who exhibited no significant difference in referential responding between the labelled and unlabelled conditions. It was suggested that, unlike children in early typical development, language does not scaffold symbolic understanding in ASC, potentially due to the language impairments often experienced by this population (Anderson et al., 2007; Wodka, Mathy, &

Kalb, 2013). However, in terms of function, Field et al., (2016b) found that both young TD children and children with ASC demonstrated a 'function bias', more often generalising a novel label of an exemplar to objects with the same function compared to objects of the same shape. It may be the case that adding additional information, such as function, reveals label generalisation competencies in ASC that are not found when generalising a label based on shape or colour.

It is possible that children with ASC have difficulty using labelling to scaffold symbol learning due to impairments in joint engagement (Adamson, Bakeman, Deckner, & Romski, 2009; Adamson, Deckner, & Bakeman, 2010; Adamson, Bakeman, Suma, & Robins, 2019; Chevallier et al., 2012). Adamson et al. (2009) conducted a longitudinal study in which joint engagement between 30-month-old toddlers with ASC and their caregivers was coded during several play sessions and compared to language outcomes. Toddlers with ASC had specific difficulties with co-ordinated joint engagement (in which the child acknowledged the presence of the adult) and often disengaged when the caregiver was commenting on play. Symbol-infused joint engagement (in which the child attended to symbols during play) was related to an increase in receptive and expressive vocabulary during the study. This suggests that there is a relationship between symbolic understanding and language in ASC, however young children with ASC may be less receptive to caregiver attempts to comment and label items during play.

To date, the influence of labelling on symbolic understanding in ASC has only been measured using a highly controlled task with explicit rules and instruction (Hartley & Allen, 2015b). Whereas some children with ASC may find highly structured tasks, such as discrete trial training (DTT) useful for teaching new skills (Callenmark, Kjellin, Rönnqvist, & Bölte, 2014; Lovaas, 1987; Paul & Cohen, 1985; Schreibman, 2005) a more naturalistic approach, such as free-play, may allow for the design of more inclusive and interactive tasks (Schreibman et al., 2015). Active participation in a task may suit the preferred learning style of typically and atypically developing children (Yurovsky, Boyer, Smith, & Yu, 2013), allowing children to test their own predictions through exploration and trial and error (Saffran, Aslin, &

Newport, 1996). When learning using naturalistic approaches and activities, children with ASC demonstrate increased generalisation of new skills to different tasks and settings (Carr & Kologinsky, 1983; McGee, Krantz, Mason, & McClannahan, 1983). Naturalistic Developmental Behavioural Interventions (NDBI's), such as aided language modelling, have been found to improve symbolic understanding in pre-schoolers with ASC (Drager et al. 2006; Schreibman et al., 2015). The current study aims to investigate dual representation and subsequent symbolic understanding in ASC through an exploration task, allowing for spontaneous word-picture-referent mapping through free-play and removing the forced-choice element of previous mapping tasks (Hartley & Allen, 2015b)

In this study, children with ASC and TD children, matched on receptive language ability, were shown four coloured photographs of objects that had different functions across four separate trials in a 'training phase'. In both conditions, participants were provided with a description of the object's function. The critical contrast was whether the images were labelled or unlabelled, to measure the influence of labelling on word-picture-referent mapping for both groups. Participant responses were recorded during the training phase and in a subsequent 'exploration phase', in which children were given an array of target and distractor items to play with.

We were interested in whether children imitated the action on the photograph in the training phase and whether children imitated the action on the target object or restricted this action to the target picture in the exploration phase– both immediately and throughout the trial. If a child did not understand the dual nature of symbols, we expected them to imitate the action on the target picture in both the training and exploration phase, showing associative symbolic understanding and failing to generalise to a real-world referent. If a child did understand the dual nature of symbols, we expected them to imitate the action on the target object, generalising the action from the picture to the real-world referent. The generalisation test allowed us to determine whether children restricted the action and knowledge of the object's function to a particular stimulus or generalised this knowledge to a class/category of entities (Hartley & Allen, 2014a).

Prior to the development of dual representation, children often manually interact with a picture as though it was the object referent (DeLoache et al., 1998). Therefore, to measure dual representation in this study, we coded whether a participant performed the action on the target picture in the training phase (training phase action), the first item in the array a participant performed the action upon in the mapping and generalisation tests (first action) and the proportion of time spent performing the action on the target object in the mapping and generalisation tests compared to the target picture and distractor items (time spent performing action). Measuring the proportion of time spent performing the action on each item in the array allowed for a continuous measure of interest throughout each trial in addition to coding the first item. A greater proportion of time spent performing the action on the target object compared to the target picture would here be indicative of greater interest in the object. We also examined the relationship between symbolic responding and participant characteristics (chronological age and receptive language score), as the development of symbolic understanding has been found to relate to both age and receptive language ability (Ganea et al., 2009; Hartley & Allen, 2015a).

First, as children with ASC have been found to have specific difficulties with symbolic understanding and demonstrate a tendency towards associative learning (Hartley & Allen, 2014b; Preissler, 2008) it was expected that children with ASC would show more associative responding (performing the action upon the target picture) in the training phase and in the exploration phase. Second, as labelling has been found to scaffold symbol learning in TD populations (Callaghan, 2008; Preissler & Bloom, 2007) and not for children with ASC (Hartley & Allen, 2015b), it was expected that TD children would demonstrate less associative responding and more successful mapping of the action to the target object if the symbol was labelled compared to when it was unlabelled, whereas children with ASC would show no difference between conditions. This study therefore adds to the scant literature on dual representation in ASC and informs theories of categorisation and symbol learning.

Method

Participants

Sixty-four participants (23 female) participated. There were 32 children with ASC (10 female) whose ages ranged from 6 years 5 months to 14 years 7 months (M_{age} = 9 years 2.5 months, SD_{age} = 24.23 months)[1]. They were recruited from six schools in the North West of England and North Wales and had been assessed by a qualified psychologist using standardised measures (ADOS, ADI-R), subsequently receiving a diagnosis of autism. Teachers completed the Current Social Communication Questionnaire to provide a measure of characteristics consistent with autism (M_{score} = 17.47; SD_{score} = 5.80; range = 10-29)[2]. Thirty-two TD children (13 female) participated in the study, with ages ranging from 1 year 8 months to 6 years 9 months (M_{age} = 3 years 7 months, SD_{age} = 17.91 months); this broad range was purposely selected to pairwise match with the ASC group on receptive language ability and allow us to examine the role of chronological age. Four additional children with ASC and two children with TD could not complete the entire task due to fussiness or inattention and were excluded from the study.

Participants were matched for comparable levels of receptive language (see Table 1) using the British Picture Vocabulary Scale-3 (BPVS-3; Dunn & Dunn, 2009). We report the raw scores as, for some participants, raw scores were too low to calculate the standardised score. The mean receptive language score was 54.38 (range = 11-109) in the ASC group and 46.47 (range = 5-109) in the TD group, a non-significant difference, $t(62) = -1.03$, $p = .31$, $d = 0.26$. The standardised scores for the TD group were all within an age appropriate range. To further characterise the sample, although not for matching purposes, the Raven's

[1] As this is a task measures the influence of labelling, it was important that both groups had equivalent vocabulary skills. Therefore, ASC and TD participants were matched on receptive language ability and were not matched on chronological age. This study is consistent with previous research in this area that have comparable age ranges and mean ages for both groups (Allen, Hartley, & Cain, 2015; Field, Allen, & Lewis, 2016a; Hartley & Allen, 2014b; Hartley & Allen, 2015b; Maljaars, Noens, Scholte, & van Berckelaer-Onnes 2012; Tager-Flusberg, 1985; Tek, Jaffery, Fein, & Naigles 2008).

[2] 20 participants scored 15 or above, the suggested cut-off for ASC. Five participants scored between 12-14, and 5 participants scored below 12. As all of our participants had a clinical diagnosis of autism, and given the caution regarding false negatives obtained with the SCQ (Rutter, Bailey, & Lord, 2003), and suggestion that lower cut-offs are sometimes appropriate (Eaves, Wingert, Ho, & Mickelson, 2006; Norris & Lecavalier, 2010) we included all participants in the analysis.

Coloured Progressive Matrices (CPM; Raven, 2003) or the Block Design task of the Wechsler Preschool and Primary Scale of Intelligence – third edition (WPPSI-3; Wechsler, 2002) were administered to participants as a measure of non-verbal ability. Nineteen children with ASC (59.4%) and 4 children with TD (12.5%) over the age of 6, the minimum age suggested as appropriate for the test, completed the CPM. Thirteen children with ASC (40.6%) who found the CPM too difficult and could not complete the assessment, and 27 children with TD (84.4%) who were under the age of 6 instead completed the WPPSI-3.

Table 1

The, mean (M), standard deviation (SD), range and number (N) of raw scores of participants for the British Picture Vocabulary Scale third edition (BPVS3 – Receptive Language Ability), Raven's Coloured Progressive Matrices (CPM – Non-Verbal IQ), and the Wechsler Preschool and Primary Scale of Intelligence third edition (WPPSI 3 – Non-Verbal IQ) and chronological age (in months).

	ASC				TD			
	M	*SD*	Range	*N*	*M*	*SD*	Range	*N*
BPVS3	54.38	27.58	11-109	32	46.47	33.77	5-109	32
CPM	17.37	8.62	7-31	19	24.60	7.09	17-33	5
WPPSI 3	15.23	3.65	9-22	13	13.48	7.51	1-26	27
Age	110.5	24.23	77-175	32	43	17.91	20-81	32

Materials

The experimental stimuli consisted of 12 cardboard boxes that were painted and decorated. Four boxes were target objects that each had a hidden function (lights up, light changes colour, plays a sound effect, makes sound if shaken) and were each a separate colour (see Figure 1 for target and distractor objects). Another four boxes were identical to the previous objects in shape, size and function; however, they were painted a different colour in order to test for generalisation. The final four boxes were used as distractor objects. The distractor objects were painted and decorated in a similar way to the target objects;

however, they had no hidden function. Each distractor object was paired with a similarly sized target object and it was ensured that each distractor object was a different colour from the target object. Eight A5 photographs of the target objects in the original colour (four photographs) and the distractor objects (four photographs) were presented alongside the target and distractor objects in the exploration phase.

Figure 1. The four target objects (in the original colour) and their associated distractor objects below.

Experimental Design

A between-subjects design with two conditions (label and description vs description only) was used, with 16 participants from each group (ASC and TD) in each condition. Participants were assigned to conditions based their receptive language scores, ensuring that there were a similar range of abilities in each condition and that there was no significant difference in receptive language score between conditions for the ASC group, $t(30) = 0.95$, $p = .35$, $d = 0.33$ and the TD group, $t(30) = 0.40$, $p = .64$, $d = 0.14$.

Counterbalancing controlled for order effects. This included the order the target boxes were presented across the four trials, the label given to each target box (pim, dax, modi and zepper) and the order that the array of stimuli (pictures and objects) were presented on the tray in the exploration phase.

Procedure

Testing took place over two separate days approximately one week apart. On the first day, participants were administered receptive language and non-verbal IQ measures. On the second day, participants were taken individually to the testing room, seated at a table adjacent to the experimenter and told they were going to be shown some different things to play with. Participants completed four separate trials, each with a different target item. Each individual training phase was followed immediately by the exploration phase, containing a mapping and generalisation test for that item. After the first two trials, participants were given a two-minute break to do some colouring while the experimenter set up the stimuli for the final two trials. A Samsung camcorder on a tripod was positioned to record interaction with the items and allowed for the coding of participant responses.

Training Phase.

In the training phase, participants were shown an A5 coloured photograph of the target item. In the label and description condition, the image was given a novel label and a description of the object's function, such as "this is a dax and it lights up when you press the white button." In the description only condition, the image was given only a description of the objects function, such as "look at this, this lights up with you press the white button." The label and description/description alone were repeated twice as per previous research (Allen, Hartley, & Cain, 2015), as children with ASC often experience difficulties processing and consolidating new word knowledge (Haebig, Saffran, & Ellis Weismer, 2017).

Exploration Phase.

The exploration phase allowed participants to play with an array of the target object, target picture, distractor object and distractor picture. This was split into a mapping test and a generalisation test.

Mapping test. Immediately after the training phase, the participant was given the target picture, target object, a distractor object and a picture of the distractor object on a tray. If the participant did not spontaneously play with the stimuli, the experimenter could give up to three verbal prompts of "you can have a play if you like." ($M_{prompts}$ = 0.38 per child across the entire experiment). As two items required participants to pick up stimuli from the tray to shake and turn upside down, the experimenter could provide one verbal prompt of “you can pick things up if you like” if the participant was reluctant to do so ($M_{prompts}$ = 0.05 per child across the entire experiment). The experimenter allowed the participants to explore the stimuli freely and the first 30 seconds of exploration was coded by the experimenter.

Generalisation test. This followed the mapping test and was the same except the target object was replaced by a differently coloured version of the same object. The distractor object remained the same colour as in the mapping test. The participants were told “I’ll go and get some more things” and then given the new array. Participants were again given up to three verbal prompts of “you can have a play if you like” if they did not spontaneously play with the stimuli. The experimenter allowed the participants to explore the stimuli freely and the first 30 seconds of exploration was coded by the experimenter.

Data coding

Responses were coded from the video recordings post-experiment. The first 30 seconds of play/exploration was coded for each mapping and generalisation test, which began immediately after the experimenter put the tray on the table (see Table 2).

Table 2

The description of the three response coding categories alongside an example and instructions how to code for each category.

Description	Example	How to code
	Training Phase Action	
Does the participant perform the described action on the picture in the training phase?	Shaking the picture immediately after the experimenter tells them the item makes a noise if you shake it.	Yes or no for each target item and then a total calculated out of 4.
	First Action	
Which item in the array does the participant perform the described action on first for each mapping and generalisation test?	Participant shook the distractor item first	Code according to item
	Time Spent Performing Action	
How long does the participant spend performing the described action on each item in the array for each mapping and generalisation test?	Participant spends 15 seconds on the target picture and 15 seconds on the target object	Record time spent performing action on each item (out of 30 seconds)

Results

In this section, we first analysed symbolic responding across the training phase and exploration phase (mapping test and generalisation test) for all four trials using the three measures outlined in Table 2. We then analysed whether participant characteristics (chronological age and receptive language score) were correlates of symbolic responding in this study.

Training Phase

Whether the participant performed the action on the picture in the training phase for each of the 4 trials was calculated to create a score out of 4 (see Table 3). This was analysed using a two-way ANOVA with group and condition as factors. No difference was found between groups, $F(1,60) = 0.07$, $p = .79$, $\eta^2 = .001$. Although there were more interactions with the picture in the training phase in the description only condition ($M = 1.66$) compared to the label and description condition ($M = 1.06$), the main effect of condition did not reach significance, $F(1,60) = 2.89$, $p = .09$, $\eta^2 = .05$. No significant interaction was found between group and condition, $F(1,60) = 0.96$, $p = .33$, $\eta^2 = .02$.

Table 3

The mean (M) standard deviation (SD) and range of the training phase action scores (out of 4) split by group and condition.

	ASC			TD		
	M	*SD*	Range	*M*	*SD*	Range
Label and Description	0.94	1.57	0-4	1.19	1.52	0-4
Description only	1.88	1.15	0-4	1.44	1.31	0-4

Exploration Phase

First Action.

This section investigated the first item in the array that the participant performed the described action upon in the mapping and generalisation tests for all four trials. We first looked at the data qualitatively (Lobo, Moeyaert, Cunha, & Babik, 2017) and found that a similar number of participants consistently selected the target object first in both the mapping and generalisation tests across conditions for each trial (M_{label} = 59.4%, $M_{nolabel}$ = 57.0%), and this was slightly higher in the TD group compared to the ASC group (M_{ASC} = 52.4%,

M_{TD} = 64.1%) . In this section, we analysed specifically whether participants performed the described action first on the target object in the array (out of a total of four trials combined – see Table 4). This was analysed using a two-way ANOVA with group and condition as factors.

Mapping test. Whether participants performed the described action first on the target object did not differ between groups, $F(1,60) = 0.77$, $p = .38$, $\eta^2 = .01$, or conditions, $F(1,60) = 0.77$, $p = .38$, $\eta^2 = .01$. No significant interaction was found between group and condition, $F(1,60) = 1.28$, $p = .26$, $\eta^2 = .02$.

Generalisation test. Whether participants performed the described action first on the target object did not differ between groups, $F(1,60) = 1.16$, $p = .29$, $\eta^2 = .02$, or conditions, $F(1,60) = 0.42$, $p = .52$, $\eta^2 = .01$. No significant interaction was found between group and condition, $F(1,60) = 0.05$, $p = .83$, $\eta^2 = .001$.

Table 4

The percentage of 'first actions' performed on each of the stimuli - combined across the four trials for the mapping and generalisation tests.

Mapping Test					
	ASC			TD	
Response	Label and Description	Description Only	Response	Label and Description	Description Only
Target Picture	0%	1.6%	Target Picture	0%	0%
Target Object	73.4%	60.9%	Target Object	71.9%	73.4%
Distractor Picture	0%	0%	Distractor Picture	0%	0%
Distractor Object	15.6%	17.2%	Distractor Object	17.2%	9.4%
None	10.9%	20.3%	None	10.9%	17.2%

Generalisation Test					
	ASC			TD	
Response	Label and Description	Description Only	Response	Label and Description	Description Only
Target Picture	0%	1.6%	Target Picture	0%	0%
Target Object	65.6%	62.5%	Target Object	76.6%	70.3%
Distractor Picture	0%	0%	Distractor Picture	0%	0%
Distractor Object	15.6%	14.1%	Distractor Object	9.4%	7.8%
None	18.7%	21.9%	None	14.1%	21.9%

Time Spent Performing the Action.

We here analysed the proportion of time spent performing the action on the target object across all four trials combined using two-way ANOVAs with group and condition as factors (see Table 5 for all proportions).

Mapping test. There was no significant main effect of group, $F(1,58) = 0.30$, $p = .59$, $\eta^2 = .01$, with a similar proportion of time spent performing the action on the target object across groups. Despite a higher proportion of time spent performing the action on the target object in the label and description condition compared to the description only condition, we did not find a significant main effect of condition, $F(1,58) = 1.82$, $p = .18$, $\eta^2 = .03$. No significant interaction was found between groups and conditions, $F(1,58) = 0.14$, $p = .71$, $\eta^2 = .002$.

Table 5

The percentage of time spent performing the described action on each of the stimuli - combined across the four trials for the mapping and generalisation tests.

Mapping Test					
	ASC			TD	
Response	Label and Description	Description Only	Response	Label and Description	Description Only
Target Picture	0%	0.4%	Target Picture	0%	0.4%
Target Object	84.5%	77.9%	Target Object	81.0%	77.3%
Distractor Picture	0%	3.9%	Distractor Picture	0.5%	0%
Distractor Object	15.5%	17.7%	Distractor Object	18.5%	22.3%

Generalisation Test					
	ASC			TD	
Response	Label and Description	Description Only	Response	Label and Description	Description Only
Target Picture	0%	0.1%	Target Picture	0.6%	0%
Target Object	82.6%	74.6%	Target Object	85.6%	78.1%
Distractor Picture	0%	0%	Distractor Picture	0%	0%
Distractor Object	17.4%	25.3%	Distractor Object	13.8%	21.9%

Generalisation test. There was no significant main effect of group, $F(1,58) = 0.38$, $p = .54$, $\eta^2 = .01$, with a similar proportion of time spent performing the action on the target object across groups. Despite a higher proportion of time spent performing the action on the target object in the label and description condition compared to the description only condition, there was no significant main effect of condition, $F(1,58) = 2.10$, $p = .15$, $\eta^2 = .04$. The interaction between group and condition was not significant, $F(1,58) = 0.03$, $p = .96$, $\eta^2 < .001$.

Correlates of Performance

This section examined whether participant characteristics (age and receptive language score) were related to symbolic understanding (training phase action, first action and action time). Chronological age and receptive language score were not significantly correlated for the ASC group, $r = .04$, $n = 32$, $p = .83$, but they were significantly correlated for the TD group, $r = .90$, $n = 32$, $p < .001$.

Training Phase Action.

Children with ASC who had a poorer receptive language score performed the described action on the image in the training phase significantly more frequently than those with a greater receptive language score, $r = -.37$, $n = 32$, $p = .04$. In contrast, receptive language score did not significantly correlate with training phase action, $r = .17$, $n = 32$, $p = .35$, for the TD group. For both groups, age did not significantly correlate with training phase action: ASC group, $r = .08$, $n = 32$, $p = .67$; TD group, $r = .20$, $n = 32$, $p = .28$.

First Action.

For both groups, receptive language score was significantly positively correlated with performing the action first on the target object in the mapping test: ASC group, $r = .41$, $n = 32$, $p = .02$; TD group, $r = .47$, $n = 32$, $p = .01$, and the generalisation test: ASC group, $r = .57$, $n = 32$, $p = .001$; TD group, $r = .52$, $n = 32$, $p = .002$. For the TD group alone, age was significantly positively correlated with performing the action first on the target object in the mapping test, $r = .46$, $n = 32$, $p = .01$, and the generalisation test, $r = .49$, $n = 32$, $p = .004$, which is expected given the collinearity with receptive language score.

Time Spent Performing the Action.

For both groups, receptive language score was significantly positively correlated with the proportion of time spent performing the action on the target object in the mapping test: ASC group, $r = .62$, $n = 30$, $p < .001$; TD group, $r = .58$, $n = 32$, $p = .001$, and the generalisation test: ASC group, $r = .47$, $n = 30$, $p = .01$; TD group, $r = .43$, $n = 32$, $p = .02$. For the TD group alone, age was significantly positively correlated with the proportion of time spent performing the action on the target object in the mapping test, $r = .65$, $n = 32$, $p < .001$, and the generalisation test, $r = .43$, $n = 32$, $p = .02$.

Results Summary

Overall, we found no significant difference between groups and conditions in terms of symbolic understanding in the training phase or the exploration phase. Receptive language score mediated performance for both groups.

Discussion

This study investigated symbolic understanding and dual representation in ASC with an object exploration task, allowing for spontaneous word-picture-referent mapping through free-play. We investigated whether symbolic understanding would differ when participants were provided with a novel label alongside a description of the object's function (label and description condition) compared to when they were given a description of the object's function without a label (description only condition). We were also interested in whether symbolic understanding would differ between the ASC group and a receptive language matched control group. Contrary to predictions, we found no difference between the ASC and TD groups in terms of symbolic understanding. In line with predictions, we found no difference between the labelled and unlabelled conditions for the ASC group, however, in contrast with previous research, this was also this case with the TD group. Moreover, we found that receptive language ability mediated performance for both groups. We discuss these findings in turn.

In contrast with our predictions, we found no difference between the groups in terms of performance. We found a high level of symbolic understanding across both groups, with approximately 79.6% of time spent performing the action on the target object across the mapping and generalisation tests. Overall, both groups demonstrated low levels of associative responding across conditions, with associative responding on approximately 1 out of 4 images in the training phase and less than 1% of time spent performing the action on the target picture in the exploration phase. Moreover, despite ASC and TD groups spending 7.3% and 5.6% more time respectively performing the action on the target object in the mapping and generalisation tests in the label and description condition compared to the description only condition, this difference was not significant. This is in line with predictions for the ASC group, however this contrasts with our hypothesis that the TD group would demonstrate greater symbolic responding when the target was labelled compared to when the target was unlabelled.

There are several possible explanations for the high levels of symbolic understanding found across groups and conditions in our study. First, it was necessary to match our groups on receptive language ability as opposed to age, consistent with previous research in this field (Field, Allen, & Lewis, 2016a; Tager-Flusberg, 1985; Tek, Jaffery, Fein, & Naigles 2008). Therefore, our study used TD children of an older age than previous research in this area (M_{age} = 3 years 7 months), such as Preissler and Bloom (2007), who only tested 2-year-olds. Indeed, age correlated with performance for our TD group, with older children demonstrating more successful word-picture-referent mapping than younger children. As TD children demonstrate reliable symbolic understanding between 24-30 months of age (Ganea et al., 2009), our older sample may explain the high performance of our control group.

Second, research to date investigating symbolic understanding have used word-picture-referent mapping tasks, asking the child to select the referent of a symbol from a forced-choice array. Such studies have found poorer word-picture-mapping in the ASC group compared to TD controls (Hartley & Allen, 2014b, 2015a, 2015b). However, forced-choice tasks such as this are highly controlled and arguably dissimilar from every-day spontaneous symbol mapping in the environment (Baumann, 1982), and often include a social element, with children being asked to “show” the experimenter the target referent in the array (Hartley & Allen, 2015b). This may be an added complication for children with ASC, who often have difficulties with social interaction and reduced social motivation (Adamson et al., 2009; Adamson et al., 2010; Adamson et al., 2019; Neuhaus, Webb, & Bernier, 2019).

With our free-play paradigm, which allowed for spontaneous symbol mapping based on function, children with ASC interacted with the stimuli in the same way as the control group. Therefore, it is possible that a spontaneous measure of symbolic understanding, such as our object exploration task, may reveal competencies in word-picture-referent mapping in ASC.

Third, previous research investigating the influence of labelling on word-picture-referent mapping used black and white line drawings as opposed to coloured photographs, providing a lower level of pictorial iconicity than the current study (Hartley & Allen, 2015b; Preissler & Bloom, 2007). Aside from labelling, more highly iconic (realistic) images have been found to aid the referential understanding of children with ASC (Hartley & Allen, 2015a) and young TD children (Ganea, Pickard, & DeLoache, 2008). Although the influence of iconicity lessens with age in typical development, children with ASC often continue to rely on a high level of realism when matching a symbol to a real-world object (Hartley & Allen, 2014b; Hartley & Allen, 2015a). As our symbols had maximum transparency in terms of iconicity (Fuller, Lloyd & Stratton, 1997), it is possible that this may have negated the influence of labelling in this study, with the coloured photographs providing sufficient benefit to symbolic processing (Wainwright, Allen, & Cain, 2020). Future research could repeat our object exploration task with black and white symbols as opposed to coloured photographs to investigate whether labelling aids referential understanding of less iconic symbols, such as those used in Makaton sign language (Sheehy, 2005).

Receptive language ability was found to mediate performance for both groups. In the exploration phase, those with a higher BPVS score performed the action on the target object first more often than those with a lower BPVS score, also spending more overall time performing the action on the target object. In the ASC group alone, associative responding in the training phase was associated with a lower BPVS score. As this study required children to understand a verbal description of an object’s function and included novel labels, receptive language ability was a key skill in this task. In our TD control group, this finding may further be explained by the collinearity between receptive language and age, as older children scored more highly on the BPVS and older children have greater symbolic understanding than younger children (Ganea, et al., 2009; Preissler & Carey, 2004; Suddendorf, 2003).

Limitations

In addition to the limitations outlined above, we here discuss the four most pertinent for future research. First, our children with ASC had a lower mean SCQ score by 10 points compared to previous research investigating word-picture-referent mapping (Allen et al., 2015), suggesting that our sample consists of higher-functioning participants than past studies. This could explain the low levels of associative responding in this study, with lower-functioning individuals with ASC considered to be more natural associative learners (Preissler, 2008). To investigate this, future research should compare the performance of ASC participants with differing ability levels (low vs high functioning) on the same methodology.

Second, although our study has a greater sample size and goes beyond the single-trial, forced-choice methodology of previous studies in this area (Hartley & Allen, 2015a; Hartley & Allen, 2015b; Preissler, 2008) the relatively small sample size and limited number of trials may still not be generalisable to symbol learning at large (Wainwright et al., 2020). Moreover, despite participants demonstrating their symbolic understanding through spontaneous interaction and object exploration, the task was still dissimilar to everyday learning. In contrast to NDBI's, this study was not conducted during the child's daily routine and was performed within a controlled experimental setting with an unfamiliar adult (Schreibman et al., 2015). Therefore, future work should increase the generalisability of findings to real-world symbol learning by increasing the sample size and the number of trials. Moreover, future research could incorporate the task into the child's everyday routine using the child's own teacher to increase the generalisability of the results to real-world symbol learning.

Third, it is possible that a greater proportion of time spent performing the action on the target object is not indicative of symbolic understanding and is instead measuring a preference towards interactive objects. Children often prefer objects to pictures (Geraghty, Waxman, & Gelman, 2014), especially interactive stimuli with multimedia features such as sound effects (Takacs, Swart, & Bus, 2015). Although we found that a greater proportion of time was spent performing the action on the target object compared to the target picture for both groups, this may simply be indicative of higher engagement with objects compared to pictures. However, despite this, children spent on average 19.1% of time performing the action on the distractor objects across groups and conditions compared to 80.2% of time performing action on the target objects. Therefore, this suggests that the time data in this study is not indicative of an object bias.

Finally, we only examined immediate word-picture-referent mapping in this study and did not examine how participants retained this information after a delay. Therefore, although we found a high level of immediate symbolic responding regardless of condition, we cannot examine how long-term retention/learning of a symbol was influenced by labelling. Future research should consider including follow-up sessions of the exploration phase at multiple time points using the same methodology to examine the retention of new symbol knowledge after a delay, potentially making the findings more generalisable to real-world symbol learning.

Conclusion

Overall, this study suggests that providing a novel label alongside a description of an object's function does not influence the word-picture-referent mapping of children with ASC and a TD control group. Moreover, symbolic understanding does not differ between children with ASC and TD children on an object exploration task, with a high level of symbolic responding found across groups. Receptive language ability mediated symbolic understanding for both groups, as children had to understand the verbal descriptions of object function to be able to successfully complete the exploration phase. Taken together, our results suggest that a spontaneous measure of symbolic understanding (such as free-play) may reveal competencies in word-picture-referent mapping in ASC compared to traditional mapping tasks (Hartley & Allen, 2015a; Allen et al., 2015), and providing a high level of visual iconicity may mask the effect of labelling on symbolic understanding in typical development (Hartley & Allen, 2015b).

Novel Label Learning from Storybooks in Children with Autism Spectrum Condition and Typical Development

(Manuscript submitted for publication)

Abstract

Background: Children with Autism Spectrum Condition (ASC) may possess less efficient word learning mechanisms compared to their typically developing (TD) peers (Hartley, Bird, & Monaghan, 2019; Hartley, Bird and Monaghan, 2020). It is unclear how children with ASC learn new words from storybooks, in which new words are presented in a constrained time frame with often a limited number of label repetitions. E-books are widely considered to provide a more interactive learning experience than traditional storybooks, potentially increasing learner attention and engagement (Richter & Courage, 2017). However, it is not yet known how the label learning of children with ASC compares between both interactive and non-interactive mediums of story presentation (e-books and paper-books), and whether task engagement differs between mediums and relates to label learning for this population.

Methods: We investigated novel label recall and engagement with a storybook in children with ASC and a TD control group matched on receptive vocabulary and non-verbal IQ raw test scores. Participants were presented with a labelling activity embedded within a storybook (paper-book or e-book) and video recorded to allow for the coding of engagement (visual attention and communication). Label recall was tested immediately and after a 2-week delay.

Results: No significant difference in immediate and delayed label recall was found between groups, however the TD group alone demonstrated above chance levels of label retention. Group, condition, and engagement with the labelling activity were not significant predictors of recall, however different engagement patterns emerged between groups and conditions.

Conclusions: This study suggests that vocabulary learning does not significantly differ between paper-books or e-books for both children with ASC and TD children, and that task engagement does not influence learning for both groups. Children with ASC do not retain new labels from storybooks as successfully as TD children after a 2-week delay.

Keywords: label recall, vocabulary, autism, iPad, engagement

Novel Label Learning from Storybooks in Children with Autism Spectrum Condition and Typical Development

Children with Autism Spectrum Condition (ASC) often demonstrate significantly delayed receptive and expressive language skills, beginning early in development and persisting into later childhood and adolescence (Mitchell et al., 2006; Sigman & McGovern, 2005; Tager-Flusberg, 2015). Impaired vocabulary knowledge is one of the main reported language deficits in this population (Hudry et al., 2010; Manolitsi & Botting, 2011; Weismer, Lord, & Esler, 2010) and a language impairment is a significant predictor of future communicative outcomes (Paul, Chawarska, Klin, & Volkmar, 2017), social functioning (Gillespie-Lynch, 2012) and academic performance (Miller et al., 2017). For this reason, it is essential to gain a better understanding of the conditions that facilitate language and vocabulary learning in this population.

Shared reading of storybooks is a common activity between children and their caregivers (Bus, 2001). It provides opportunities for exposure to words and shared reading has been found to increase early receptive vocabulary in typically developing (TD) children (McLeod & McDade, 2011; Robbins & Ehri, 1994). A recent meta-analysis found a positive relationship between word learning and shared storybook reading, with children learning approximately 46% of the new words (nouns and verbs) encountered (Flack, Field, & Horst, 2018). However, the meta-analysis included studies that assessed retention of new words at varying time intervals, ranging from immediate recall (fast mapping tasks) to delayed recall of up to 10 weeks. Greater word learning may be apparent with shorter retention intervals, a process referred to as fast mapping which is considered the first step in new word learning. However, success at an immediate recall task does not equate to the consolidation and retention of new word information, which is tested after a longer retention interval (Munro, Baker, McGregor, Docking, & Arciuli, 2012).

Children with ASC may possess less efficient word learning mechanisms than TD children and may require more instances of repetition over longer periods of time to learn new words and labels (Hartley, Bird, & Monaghan, 2019; Hartley, Bird, & Monaghan, 2020).

Hartley et al. (2019) and Hartley et al. (2020) investigated the fast mapping and retention of new labels in children with ASC and receptive language matched TD children. Accuracy and speed at a cross-situational learning task (Hartley et al., 2020) and performance on a mutual exclusivity task (Hartley et al., 2019) were recorded. In both studies, participants were tested after a 5-minute delay to examine retention. Comparable fast mapping and label retention were found between both groups in both studies, with label recall accuracy dropping in the retention task 5 minutes later. However, the ASC group were significantly slower to identify the correct referent than the TD children (Hartley et al., 2020) and children with ASC less accurately employed mutual exclusivity to identify a referent (Hartley et al., 2019).

In both studies, the researchers concluded that children with ASC do not possess qualitatively different word learning mechanisms compared to TD children – word learning mechanisms may be delayed but not deviant in this population. It is suggested that multiple exposures to new words (preferably over multiple timepoints) could enhance label learning (Axelsson & Horst, 2014; Haebig et al., 2017; Hartley et al., 2020). However, this is not always possible in naturalistic settings (such as storybook reading) in which new labels may be presented quickly over a short period of time with little repetition. Despite this, little research has examined how children with ASC learn new vocabulary from storybooks (Allen, Hartley & Cain, 2015).

E-books have become a popular alternative to paper-based storybooks (Korat, 2010), providing new opportunities for interactive learning (Smeets & Bus, 2015) and engagement (Richter & Courage, 2017; Wainwright, Allen, & Cain, 2020b). However, the medium of presentation alone (iPad vs paper) did not influence new label learning in children with ASC and TD children in a specially designed word learning task (Allen et al., 2015), and a meta-analysis found that e-books did not significantly influence book-based or general vocabulary learning compared to paper-based alternatives in typical development (Takacs, Swart, & Bus, 2015). The interactive features and touch-screen capabilities of e-books may complement the preferred learning style of children (Highfield & Goodwin, 2013), potentially increasing task engagement (Richter & Courage, 2017; Wainwright, Allen, & Cain, 2020a) and allowing information to be processed as an active experience (Evans & Gibbons, 2007). Presenting information through multiple modalities (such as sound, vision and touch) may increase child interest and attention (Mineo, Ziegler, Gill, & Salkin, 2009). This may be particularly useful for children with ASC who often have difficulties maintaining task focus and sustained attention during learning (Mayes & Calhoun, 1999; Mayes & Calhoun, 2007). According to the cognitive theory of multimedia learning (Mayer, 1997) the presentation of information simultaneously to different modalities (such as visual and verbal) improves meaningful learning by allowing for the construction and co-ordination of multiple representations of the same information.

Wainwright et al. (2020a) investigated the influence of engagement on label recall in children with ASC and TD children using a single purpose iPad application, The researchers found greater visual attention towards interactive images compared to static images on the iPad for both groups. Visual attention was related to successful label recall for children with ASC alone, suggesting that engagement benefits immediate label recall in this population. In contrast, greater communication was found in the static image condition suggesting that, for both groups, interactivity may not be beneficial for fostering increased communication, and communication was not related to learning. It is possible that interactive and multimedia learning may be particularly beneficial for children with ASC, who often demonstrate difficulties with task focus (Renner, Klinger, & Klinger, 2006; Townsend, Harris, & Courchesne 1996; Werner, Dawson, Osterling, & Dinno, 2000).

However, the influence of storybook presentation (interactive vs non-interactive) on label learning in typical development is very much in debate and has not yet been investigated in children with ASC. Some studies report that TD pre-schoolers gain more vocabulary from a story presented on an interactive e-book compared to a static e-book with no interactive features (Smeets & Bus, 2015); whilst others do not (Kelley & Kinney, 2017). Moreover, existing research comparing learning and engagement from storybooks (e-books and paper-books) has focussed on narrative comprehension of the overall text rather than the learning of new labels (Moody et al., 2020; Richter & Courage, 2017; Wainwright, Allen,

& Cain, 2020b). No research to date has investigated how task engagement influences label learning from e-books vs paper-books in typical and atypical development.

The present study aimed to address the gaps in the literature by exposing children with ASC and TD children to two novel labels (labelled twice) in a labelling activity embedded within a storybook (e-book vs paper-book). We then examined the fast mapping (immediate recall) and retention (delayed recall) of new labels for both groups and compared task engagement between conditions. Engagement is here defined as a child's ability to orient their visual attention towards the screen/page when presented with the labelled stimuli and spontaneously repeat the new labels after initial exposure (Kaderavek, Guo, & Justice, 2014; Moody et al., 2010; Richter & Courage, 2017; Roskos et al., 2012). Crucially, we also investigated whether there was a relationship between task engagement and label learning for both groups, as per Wainwright et al. (2020a).

It is important to note that this study is embedded within a separate experiment examining the role of adult involvement in storybook reading (Wainwright et al., 2020b), in which one paper-book condition (read by the experimenter) and two e-book conditions (read by either the experimenter or an in-app narrative voiceover) were included. In the current study the labelling activity was always narrated by the experimenter regardless of condition. However, we have retained the three conditions from Wainwright et al. (2020b) in our analysis because the different narration experiences prior to this labelling activity may have influenced task performance.

First, we predicted that the TD group would demonstrate greater immediate and delayed label recall compared to the ASC group, as children with ASC may possess less efficient word learning mechanisms (Hartley et al., 2019; Hartley et al., 2020) and consequently may find label learning more challenging within a storybook in which new labels are presented quickly over a short period of time with little label repetition (Axelsson & Horst, 2014; Haebig et al., 2017). Second, as interactivity has been found to complement the preferred learning style of children, potentially increasing interest and sustained attention (Highfield & Goodwin, 2013; Mineo, Ziegler, Gill, & Salkin, 2009), we predicted greater immediate and delayed label recall in the e-book conditions compared to the paper-book condition for both groups. Third, despite different experiences of narration prior to the labelling activity, we expected no difference between the two e-book conditions for both groups as the labelling activity was narrated by the experimenter in all conditions. Fourth, as per previous research we expected task engagement (visual attention and communication) to differ between mediums of presentation, with greater visual attention in the e-book conditions and greater communication in the paper-book conditions for both groups (Richter & Courage, 2017; Wainwright et al., 2020a). Finally, as per Wainwright et al. (2020a) we predicted a relationship between task engagement (specifically visual attention) and label learning for both groups.

Method

Participants

Eighty-four participants were recruited comprising 42 children with ASC and 42 TD children (see Table 1 for all descriptive statistics), from eight specialist and primary schools and one nursery in North Wales and the north west of England. Children with ASC had been assessed by a qualified psychologist using standardised measures (ADOS, ADI-R), and received a clinical diagnosis of autism. Teachers completed the current version of the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) to further characterise the functioning of our sample[1]. The groups were matched on a pairwise basis for receptive vocabulary using raw scores of the British Picture Vocabulary Scale-3 (BPVS-3; Dunn & Dunn, 2009) and non-verbal IQ (NVIQ) using raw scores from either the Raven's Coloured Progressive Matrices (CPM; Raven 1998) or the Block Design task of the Wechsler Preschool and Primary Scale of Intelligence – third edition (WPPSI-3; Wechsler, 2002)[2]. (see

[1] 34 participants scored 15 or above, the suggested cutoff for ASC. 3 participants scored between 12-14, and 5 participants scored below 12. As all of our participants had a clinical diagnosis of autism, and given the caution regarding false negatives obtained with the SCQ (Rutter, Bailey, & Lord, 2003), and suggestion that lower cutoffs are sometimes appropriate (Eaves, Wingert, Ho, & Mickelson, 2006; Norris & Lecavalier, 2010) we included all participants in the analysis.
[2] All children were first administered the CPM, however only 25 children with ASC successfully completed the CPM. An additional 17 children with ASC who could not complete the CPM due to difficulty were assessed with the WPPSI-3. The same number of TD children also completed the CPM and WPPSI-3 to allow pair-wise matching with the ASC group.

Table 1). Raw scores were used instead of standardised scores as many children with ASC scored too low to fall into an average range of performance for their chronological age. The same absolute level of performance on each measure was used to match each child with a control ensuring that there was a range of abilities in each condition and a non-significant difference in performance between each group and condition. Where score ranges differ between groups, the two lowest and two highest performing children from each group were pairwise matched. No non-verbal children took part in this study and all children could produce some spoken language (confirmed by the class teacher).

Table 1

Mean (M), standard deviation (SD), range and number (N) of participant characteristic measures (age in years and gender), social communication questionnaire (SCQ) scores and the raw scores for the British Picture Vocabulary Scale 3 (BPVS3), Raven's Coloured Progressive Matrices (CPM) and Wechsler Preschool and Primary Scale of Intelligence (WPPSI-3).

	ASC				TD				T-Test
	M	*SD*	Range	*N*	*M*	*SD*	Range	*N*	*p*
Age	9.08	1.44	6.42-12.42	42	5.83	1.83	2.92-8.25	42	<.001
Gender(f)	---	---	---	6	---	---	---	13	---
SCQ	18.38	5.60	10-32	42	---	---	---	0	---
BPVS3	71.67	24.54	24-129	42	79.38	32.07	28-134	42	.22
CPM	22.04	6.83	9-31	25	22.56	4.44	13-31	25	.75
WPPSI 3	18.94	7.33	6-32	17	16.76	7.89	6-32	17	.41

Experimental task materials

The labelling activity was a self-contained section embedded in the storybook "Who Stole the Moon?" by Helen Stratton-Would (2010). The story was presented either as a paper-book or an interactive e-book (narrated by either the experimenter or an in-app voiceover in Wainwright et al, 2020b). However, as previously explained, in the current study the experimenter always labelled the target pictures in the labelling activity regardless of presentation condition, and the three conditions were retained only due to the different narration experiences prior to this labelling activity. Fourteen participants from each group (ASC and TD) were included in each condition (paper-book, experimenter narrated e-book and iPad narrated e-book).

The labelling activity consisted of a section, 11 pages into the book, of eight nocturnal animals that were not previously or subsequently mentioned. In the e-book conditions, the nocturnal animals responded to touch through movement and sound effects. The experimenter labelled two of the unfamiliar nocturnal animals (a kiwi and a cuttlefish) with novel labels – “this is a miggy/diffle.” Unfamiliar animals were not native to the UK and were not included in the Oxford CDI (a checklist of words familiar to children over 11 months old). No participants expressed familiarity towards the unfamiliar animals. Labels were repeated twice (see also Allen et al., 2015) to encourage retention (McMurray, Horst, & Samuelson, 2012; Munro et al., 2012). The remaining six nocturnal animals (2 unfamiliar, 4 familiar) were accompanied by the prompt “look at this.”

Label recall was tested immediately after the labelling activity in a task comprising of two trials (immediate recall task). In trial one, a printed picture of the first labelled target animal was shown alongside two printed pictures of unlabelled distractor animals seen in the labelling activity (one unfamiliar and one familiar) in a counterbalanced order. The child was asked to “show me the miggy/diffle.” After the child had made their selection, the three images from the first trial were discarded and no pictures from trial one were shown again in trial two. In trial two, a printed picture of the second labelled target animal was shown alongside two printed pictures of different unlabelled distractor animals seen in the labelling activity (one unfamiliar and one familiar), again in a counterbalanced order. The child was asked to “show me the miggy/diffle.” Both trials were repeated approximately two-weeks later to test label retention after a delay (delayed recall task).

Procedure

Testing took place individually over three days. On the first day, participants were administered the receptive vocabulary and cognitive measures. On the second day, participants heard the story (and the embedded labelling activity) in one of the three presentation conditions. They completed the label recall task immediately after the storybook reading (immediate recall task) and again approximately two-weeks later (delayed recall task) (M_{days} = 14.19; SD_{days} = 0.74).

Engagement coding

Videos of the labelling activity were analysed for engagement by two independent video coders using a rubric (see Table 2). Video coding was split between the two video-coders (half each), with an overlap of 20 videos to check for inter-rater reliability. To be clear, only the labelling activity was coded for engagement and the subsequent immediate and delayed recall tasks were not coded. As per previous research (Moody et al., 2010; Richter & Courage, 2017; Wainwright et al., 2020a), videos were coded for visual attention and communication. Visual attention was measured by calculating the total looking time towards the two target/labelled animals. As all animals were presented on the screen/page one at a time, looking time towards the screen/page during the presentation of each target animal was taken to be indicative of on-task visual attention. Communication was measured by coding whether the participant repeated the two target labels (miggy or diffle) during the labelling activity (out of a total of two possible instances of labelling). An intra-class correlational analysis with fixed effects and absolute agreement for each sub-category separately found excellent agreement for 20 videos (all ratings ≥.98, Cicchetti, 1994).

Table 2

Description and examples of the two engagement categories

Engagement Category	Description
Visual attention: Total looking time	Combined total looking time at both target animals (in seconds).
Communication: Label Repetition	Whether or not the participant verbally repeats the label of each target animal (out of a total of two possible instances).

Results

Label Recall

We here combined scores from both trials to examine consistency of label recall – whether participants successfully mapped the labels to the two target images immediately and after a two-week delay (see Table 3 for scores). Scores were analysed using logistic regression to investigate the predictive value of group (TD, ASC), presentation condition (paper-book, experimenter narrated e-book, iPad narrated e-book), participant characteristics (chronological age, BPVS raw score) and engagement (total looking time, label repetition). Group and presentation condition were entered first, followed by participant characteristics and then engagement.

Table 3

The number and percentage of participant immediate and delayed recall for all groups and conditions

		ASC			TD		
		Paper-book	iPad adult narrated	iPad e-book narrated	Paper-book	iPad adult narrated	iPad e-book narrated
Immediate	Both correct	5 (35.7%)	5 (35.7%)	8 (57.1%)	9 (64.3%)	10 (71.4%)	8 (57.1%)
	One correct	8 (57.1%)	7 (50.0%)	4 (28.6%)	4 (28.6%)	4 (28.6%)	4 (28.6%)
	None correct	1 (7.1%)	2 (14.3%)	2 (14.3%)	1 (7.1%)	0 (0.0%)	2 (14.3%)
Delayed	Both Correct	1 (7.7%)	3 (23.1%)	2 (15.4%)	5 (35.7%)	4 (33.3%)	2 (15.4%)
	One correct	9 (69.2%)	8 (61.5%)	8 (61.5%)	5 (35.7%)	8 (67.7%)	10 (15.4%)
	None correct	3 (23.1%)	2 (15.4%)	3 (23.1%)	4 (28.6%)	0 (0.0%)	1 (7.7%)

Table 4

Regression coefficients for the six variables predicting immediate and delayed label recall

Immediate Label Recall									
	Model one			Model two			Model three		
Variables	*B*	Exp(B)	*p* value	*B*	Exp(B)	*p* value	*B*	Exp(B)	*p* value
Group	.87	2.39	.06	1.00	2.72	.22	1.01	2.77	.24
Condition	-.35	.71	.54	-.44	.64	.47	-.49	.61	.45
Chronological age	---	---	---	.01	1.01	.77	.01	1.01	.72
BPVS raw score	---	---	---	.03	1.03	.01*	.03	1.03	.01*
Total looking time	---	---	---	---	---	---	.02	1.03	.59
Label Repetition	---	---	---	---	---	---	.11	1.12	.76
Delayed Label Recall									
	Model one			Model two			Model three		
Variables	*B*	Exp(B)	*p* value	*B*	Exp(B)	*p* value	*B*	Exp(B)	*p* value
Group	.76	2.14	.19	1.06	2.88	.29	1.29	3.63	.27

Condition	.48	1.62	.51	.46	1.58	.53	.52	1.68	.53
Chronological age	---	---	---	.01	1.01	.73	.02	1.02	.50
BPVS raw score	---	---	---	-.01	.99	.68	-.003	1.00	.83
Total looking time	---	---	---	---	---	---	.11	1.12	.05
Label Repetition	---	---	---	---	---	---	.37	1.45	.42

$^*p<.05$

For immediate recall scores, the model did not reach significance with group and presentation condition alone (p = .26), accounting for only 6.4% of variance in performance (Nagelkerke r^2 = .064). When participant characteristics were added, the model was significant (p = .01), accounting for an additional 17.8% of variance in performance (Nagelkerke r^2 = .242); BPVS raw score was the only significant predictor (p = .01). Engagement scores accounted for an additional 0.5% of variance (Nagelkerke r^2 = .247) and the model remained significant (p = .02); BPVS raw score remained the only significant predictor of performance (p = .01).

For delayed recall scores, the model did not reach significance with group and presentation condition alone (p = .39), accounting for only 5.9% of variance in performance (Nagelkerke r^2 = .059). Participant characteristics did not explain significant variance in performance (p = .67; Nagelkerke r^2 = .063), but engagement accounted for an additional 9.4% of variance in performance (Nagelkerke r^2 = .157), however the model did not reach significance (p = .31).

Label Retention

We here investigated whether participants who correctly recalled both labels in the immediate recall task did so again after a two-week delay in the delayed recall task, and whether this was significantly above chance levels of performance. Due to absences only 78 out of 84 participants were tested after the two-week delay (92.9%): Three children with ASC (7.1%) and three TD children (7.1%) were absent. Despite these absences, both groups remained matched on receptive vocabulary and non-verbal IQ across conditions. As the probability of correctly selecting the two target images in the retention test was 11%, our critical probability was set at 0.11. Ten out of the remaining 39 TD participants correctly recalled the target labels at both time points. A binomial test found that the TD group performed significantly above chance levels (p = .01), with 25.64% demonstrating correct delayed label recall after successful immediate recall. Four out of the remaining 39 participants with ASC correctly recalled the target labels at both time points. A binomial test found that the ASC group did not perform significantly above chance (p = .55), with only 10.26% demonstrating correct delayed label recall after successful immediate recall. However, a chi square analysis revealed that this group difference did not reach statistical significance, $X^2(1, N = 79) = 3.31$, p =.07.

Participant Engagement Coding

In this section, task engagement - visual attention (total looking time) and communication (label repetition) - was analysed using two-way ANOVAs with group and presentation condition as factors.

For total looking time, a main effect of group was found, $F(1,75) = 4.60$, $p = .04$, η^2 = .06, with greater looking time in the TD group (M = 11.37 seconds) compared to the ASC group (M = 8.12 seconds). No main effect of presentation condition was found, $F(2,75)$ = 2.41, p = .10 , η^2 = .06, and there was no interaction between group and presentation condition, $F(2,75) = .55$, $p = .58$, $\eta^2 = .02$.

For label repetition, a main effect of group was found, $F(1,75) = 9.51$, $p = .003$, η^2 = .11, with more instances of label repetition in the ASC group (M = 0.69 instances) compared to the TD group (M = 0.22 instances). A main effect of presentation condition was found, $F(2,75) = 3.36$, $p = .04$, $\eta^2 = .08$. Tukey post-hoc analysis showed significantly more instances of label repetition the paper-book condition (M = 0.72 instances) compared to the iPad narrated e-book condition (M = 0.26). There was no interaction between group and presentation condition, $F(2,75) = 2.42$, $p = .10$, $\eta^2 = .06$.

Table 5

Mean (and standard deviation) of engagement scores averaged across trials one and two. Looking times are calculated in seconds. Label repetition is calculated in instances (out of a total of 2)

			Presentation Condition	
Groups	Variables	Paper-book	iPad adult narrated	iPad e-book narrated
ASC	Total looking time	9.92 (4.01)	7.46 (3.18)	9.07 (3.69)
	Label Repetition	1.15 (0.80)	0.62 (0.87)	0.29 (0.73)
TD	Total looking time	11.64 (2.37)	9.07 (1.64)	13.38 (11.34)
	Label Repetition	0.29 (0.61)	0.14 (0.36)	0.23 (0.60)

Discussion

We investigated novel label recall and engagement with a storybook (e-book vs paper-book) in children with ASC and a TD control group matched on receptive vocabulary and non-verbal IQ raw test scores. Contrary to predictions, group, e-book vs paper-book and engagement were not significant predictors of immediate label recall (fast mapping) or delayed label recall (retention). Task engagement differed between groups and presentation condition. The TD group alone demonstrated above chance recall of the novel labels after a two-week delay. We discuss these findings in turn.

Contrary to our hypothesis, group was not a significant predictor of performance, with receptive vocabulary the only significant predictor of immediate label recall. Despite slightly more TD participants demonstrating consistent label recall (recalling both labels) both immediately and after a delay, this finding was not significant. This finding provides no strong evidence that label learning differed between the children with ASC and TD children: other studies in the field also report similar performance levels for groups matched for receptive vocabulary (Kalandadze et al., 2018). When examining retention of learning, only the TD children performed above chance (11%), with 25.64% recalling the label consistently in both the immediate and delayed recall tests; in contrast just 10.26% of the children with ASC did so. The difference between groups was not statistically significant. Other work indicates that children with ASC do not possess qualitatively different word learning mechanisms compared to TD children (Hartley et al., 2019; Hartley et al., 2020). However, this population may find word learning from storybooks, in which new words are presented faster in a shorter/constrained time frame, more challenging (Axelsson & Horst, 2014; Haebig et al., 2017; Hartley et al., 2020). Successful immediate recall (fast mapping) is only the first step in the slow and effortful word-learning process (Axelsson & Horst, 2014) and two repetitions of a novel label may not be sufficient to translate immediate recall of a new word into learning for children with ASC (Haebig et al., 2017; Hartley et al., 2020). Future research could expand upon the current study by comparing the label learning of participants who experienced a single storybook reading and those who experienced several readings over multiple time points to investigate whether repeating storybooks (and thus increasing exposure to new labels) increases the immediate and delayed label recall of children with ASC.

Furthermore, the current research examined the learning of only two new labels from a storybook. As we used a storybook that was not specifically designed for the task, consequently only four unfamiliar animals were present in the labelling activity. Two of the four unfamiliar animals were required to serve as distractor images. Therefore, it was not possible to present more than two target labels in the current study. This limited number of trials may not be comparable to everyday label learning (Wainwright et al., 2020a; Wainwright, Allen, & Cain, 2020c), in which school-aged children learn up to 12 new words per day (Bloom, 2000). Future research could expand the number of trials (possibly by creating an e-book specifically for the task) to examine the learning of multiple new labels from storybooks and increase the generalisability of the experiment to real world label learning.

Contrary to our hypothesis, presentation condition did not significantly predict immediate or delayed label recall, with a similar pattern of performance across all conditions for both groups. Therefore, this study provides no strong evidence that presentation condition (electronic vs paper-book) influences label recall despite the interactive features provided by the iPad (Kelley & Kinney, 2017), extending this finding to ASC and adding to the scant literature in this area. As previously explained, the labelling activity was narrated by the experimenter in all conditions and the two separate e-book conditions (experimenter narrated vs iPad narrated) were only included as participants had differing experiences of narration prior to the labelling activity. As expected, there was no difference in terms of performance between the two e-book conditions, suggesting that they may not have been sufficiently different to capture a difference in performance.

Contrary to predictions, visual attention did not significantly predict performance and did not differ between conditions. This contrasts with Wainwright et al. (2020a), who found a relationship between visual attention and label recall in children with ASC and greater visual attention in the interactive condition compared to the non-interactive conditions. However, Wainwright et al. presented the target stimuli on a purpose-built iPad application with a blank background, whereas the current task was presented via a storybook, with extraneous information (such as a patterned background, movement and sound effects) potentially competing for attentional resources and increasing cognitive load (Kirkorian, 2018). Consequently, we do not know what children are engaging with on the screen in this task. Previous research suggests that multimedia features (such as sound and animation) can enhance learning if they are specifically related to the task, whereas extraneous information can impede learning by distracting the learner away from relevant information (Mayer & Moreno, 1998). This may be particularly relevant for children with ASC who often experience weak central coherence, the tendency to prioritise the processing of local (sometimes irrelevant) detail at the expense of the gestalt (Frith, 1989). Therefore, presenting irrelevant local details in the form of background information and sound effects may lead some children with ASC to orient their attention away from the task. Future research could use eye-tracking to investigate specific looking patterns during the task and examine the influence of relevant/irrelevant visual features on label recall.

It is also possible that the labelling activity was not of sufficient length to capture variability in visual attention. On average, children with ASC and TD children spent 10 seconds looking at the target animals in the labelling activity. Such a short amount of time may not have been enough to capture variability in visual attention between conditions. Future research could instead measure visual attention across the entire labelling activity as opposed to the target animals/stimuli alone, increasing the amount of looking time recorded.

As predicted, more label repetition was found in the paper-book condition compared to the e-book conditions for both groups. This is potentially due to the interactive stimuli within the e-book, such as sound effects and animations, increasing cognitive load and consequently reducing communication (Kirkorian, 2018; Richter & Courage, 2017; Wainwright et al., 2020a). This suggests that interactive presentation mediums may not be the optimal method to foster social engagement and communication during a task (Wainwright et al., 2020a). However, it is important to note that there are other forms of communication that do not require the use of spoken language, such as pointing and other forms of gesture (Roskos et al., 2012) that could potentially be coded alongside spoken language in future research to create a more comprehensive measure of communication.

Although not predicted in our hypotheses, different patterns of engagement emerged between groups. Greater visual attention was found in the TD group compared to the ASC group. Some children with ASC have difficulty orienting their attention towards a task and sustaining their attention over time (Renner, Klinger, & Klinger, 2006; Townsend, Harris, & Courchesne 1996; Werner, Dawson, Osterling, & Dinno, 2000). Therefore, this finding is potentially due to the known attention dysfunction characteristic of ASC (Mayes & Calhoun, 2007). The ASC group repeated more labels than the TD group. This is perhaps surprising, as children with ASC often demonstrate impaired expressive communication compared to TD peers (Wodka, Mathy, & Kalb, 2013). However, although we did not include non-verbal children in our sample, we did not measure expressive language ability in this study. Echolalia, the tendency to repeat single words or utterances (Neely, Gerow, Rispoli, Lang, & Pullen, 2016), is another possible cause for greater label repetition in the ASC group.

Implications

The findings of this study could potentially inform the teaching of new labels to children with ASC and guide educators in the use of interactive iPad applications within the classroom. First, children with ASC may find the retention of new labels from storybooks more difficult than their TD peers, despite successful fast mapping of new labels. Additional reinforcement and exposure to new words may be required to foster label learning in children with ASC (Haebig et al., 2017; Hartley et al., 2020). Potentially, this could be achieved by spending more time on new labels during storybook reading, or repeating storybooks at multiple time points. This finding further highlights that fast mapping is only the first step in the slow and effortful word learning process and that fast mapping is not equivalent to long term retention (Axelsson & Horst, 2014).

Second, despite no strong evidence that presentation condition (e-book vs paper-book) influences label learning, both groups demonstrated decreased communication in the iPad narrated e-book condition compared to the paper-book condition. It is possible that the self-contained nature of iPad learning (Allen, Hartley, & Cain, 2016) combined with the increased cognitive load provided by interactive touchscreen features (Kirkorian, 2018; Richter & Courage, 2017) may diminish the need to communicate, fostering a more solitary learning style than paper-based mediums (Radesky, Schumacher, & Zuckerman, 2015; Schugar, Smith, & Schugar, 2013). If e-books reduce communication in typical and atypical development, this finding could contribute towards an informed decision when choosing between electronic and paper-based mediums depending upon the specific needs and communicative goals of the learner (Wainwright et al., 2020a).

Limitations

In addition to the limitations outlined above, we here outline the three most pertinent for future research. First, we note the use of two different NVIQ measures to match our participants. Children who found the Raven's CPM too difficult were instead administered the Block Design task of the WPPSI-3, ensuring that an equal number of participants from both groups completed each test for matching purposes. However, the Raven's CPM and the

Block Design task suit different information processing styles (global and local detail processing respectively). The Block Design task may provide an advantage for children with ASC, who often demonstrate weak central coherence - a bias towards local detail processing at the expense of global detail processing (Frith, 1989). Future research could keep this constant by recruiting children whose ability levels allow the same test to be used with all participants.

Second, children with ASC and TD children were not matched on their chronological age, as per previous research (Field et al. 2016; Maljaars et al. 2012; Tager-Flusberg 1985; Tek et al. 2008), as children with ASC are a heterogenous population in which receptive language ability and NVIQ can vary considerably despite chronological age (Weismer et al., 2010). Despite this, we acknowledge that the groups may differ in terms of life experience, as children with ASC were significantly older than their TD peers. For example, the TD group may have had substantially less exposure to text and younger children may not have been able to follow task instructions to the same extent as older children. However, children begin the shared reading of storybooks from early infancy (McLeod & McDade, 2011; Robbins & Ehri, 1994), allowing for exposure to new vocabulary. At such a young age, storybooks are read aloud to children (as with the current study), negating the influence of previous exposure to print and reading ability. Furthermore, task instructions were basic – e.g. “show me the miggy/diffle” - which only required the child to point at the target stimulus. Indeed, even the youngest children in this study could successfully follow task instruction and age did not impede understanding in this study.

Finally, we urge caution when interpreting the non-significant effects in this study due to our small sample size (14 participants in each condition per group). Although the inclusion of two e-book conditions was necessary due to the differing experiences of narration prior to the labelling activity, we acknowledge that the inclusion of a third condition may have reduced the power of the experiment. However, this sample size is in line with other studies of word learning in this field (Allen et al., 2015; Kelley & Kinney, 2017; Wainwright et al., 2020a; Wainwright et al., 2020c).

Conclusion

Overall, we found that novel label recall from a storybook does not significantly differ between e-book and paper-based mediums for children with ASC and TD children. Despite successful immediate recall for both groups, only the TD group demonstrated above chance label retention. Engagement with the labelling activity does not predict performance for both groups. Taken together, our findings suggest that children with ASC do not retain new labels after a single labelling activity as successfully as TD children, despite successful immediate recall. Moreover, presentation condition and engagement do not significantly influence label recall for both groups. This study may have practical implications for educators, suggesting that immediate recall of new labels may not translate into above chance-level label retention in children with ASC when learning new words from a storybook. Furthermore, interactive iPad applications may not be the optimal method to foster increased communication in children with ASC and TD children (Wainwright et al., 2020a).

Narrative comprehension and engagement with e-books vs paper-books in autism spectrum condition.

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CHAPTER 5: NARRATIVE COMPREHENSION AND ENGAGEMENT

Abstract

Background and aims: Children with autism spectrum condition (ASC) often have specific difficulties with narrative comprehension, a skill which has a strong association with both concurrent and longitudinal reading comprehension. A better understanding of narrative comprehension skills in ASC has the potential to provide insight into potential later reading comprehension difficulties and inform early targeted intervention. In the current study, the main objective was to investigate how differences in the medium of story presentation (paper-book vs e-book) and differences in story narration (adult narration vs in-app narration) would influence narrative comprehension in general, and between groups (ASC and a receptive language-matched control group). We were also interested in how task-engagement (visual attention and communication) differed between group and conditions and whether task-engagement was related to narrative comprehension.

Method: 42 children with ASC and 42 typically developing (TD) children were read a story either via a paper-book or an e-book with interactive and multimedia features. The e-book was either narrated by the experimenter (adult narrated iPad condition) or narrated by an in-app voiceover (e-book narrated iPad condition). Children's behaviour during storybook reading was video recorded and coded for engagement (visual attention and communication). They then completed two measures of narrative comprehension: multiple-choice questions (measuring recall of literal information) and a picture ordering task (measuring global story structure).

Results: Contrary to predictions, we did not find any significant group or condition differences on either measure of narrative comprehension, and both groups demonstrated a similar level of narrative comprehension across the three conditions. We found differences in engagement between conditions for both groups, with greater visual attention in the e-book conditions compared to the paper-book condition. However, visual attention only significantly correlated with narrative comprehension for the TD group.

Conclusion: Overall, this study suggests that children with ASC are just as able as language-matched peers to comprehend a narrative from storybooks. Presenting a story on

an iPad e-book compared to a paper-book does not influence narrative comprehension, nor does adult narration of the story compared to in-app narration. However, on-task engagement is linked to narrative comprehension in TD children.

Implications: Taken together, our findings suggest that e-books may be more successful than paper-based mediums at encouraging visual attention towards the story, but no better at supporting narrative comprehension and eliciting communication.

Narrative Comprehension and Engagement with E-Books vs Paper-Books in Autism Spectrum Condition.

Autism Spectrum Condition (ASC) is a lifelong condition that affects around 1% of the population, beginning early in development (Lai, Lombardo & Baron-Cohen, 2014). It is characterised by diverse symptoms of varying severity, with cognitive impairments and learning difficulties present in over half of individuals (Solomon, Smith, Frank, & Carter, 2011). Children with ASC often have specific difficulties with narrative comprehension (Diehl, Bennetto, & Young, 2006), which involves the successful coordination of language knowledge bases and skills, such as vocabulary and the generation of inferences, to make sense of the relations between events in a story and the character's motivations and responses to those events (Perfetti, Landi, & Oakhill, 2005; Silva & Cain, 2015). Narrative comprehension concerns the understanding of narrative texts as opposed to expository (or informational) texts (Cain, 2010). There is a strong association between narrative comprehension and concurrent and longitudinal reading comprehension scores in typically developing (TD) populations (Cain, Oakhill, & Bryant, 2004; Oakhill & Cain, 2012). Given the high incidence of reading comprehension difficulties in children with ASC (Nation, Clarke, Wright, & William, 2006) better understanding of their early narrative comprehension skills has the potential to provide insight into these later reading comprehension difficulties and inform early targeted intervention.

Before learning to read, 4-to-5-year-old TD children demonstrate successful comprehension of basic spoken and pictorial narratives (Trabasso & Nickels, 1992). This skill becomes more advanced with age and continues to develop into adulthood (van den Broek, Lorch, & Thurlow, 1996; van den Broek et al., 2003) with older children acquiring the ability to comprehend more complex narratives as they become sensitive to the underlying causal structure of a narrative – how events within a story causally relate to one another (Lynch et al., 2008; Zwaan, Langston, & Graesser, 1995). However, children with ASC often do not follow this developmental trajectory, demonstrating poor narrative comprehension into later childhood (Baron-Cohen, Leslie, & Frith, 1986; Loveland, McEvoy, Tunali, & Kelley, 1990; Nuske & Bavin 2011).

Children with ASC can have receptive language difficulties (Manolitsi & Botting, 2011; Weismer, Lord, & Esler, 2010), processing biases (Norbury & Bishop, 2002) and attentional difficulties (Noterdaeme et al., 2001) compared to TD children, each of which may contribute to their poor narrative comprehension. Vocabulary knowledge is a key predictor of narrative comprehension (Lepola et al., 2016), explaining up to 8% unique variance in narrative comprehension (Sénéchal, Ouellette, & Rodney, 2006). Without understanding the meaning of individual words children cannot extract the overall meaning from a story (Nation et al., 2006).

Aside from receptive language difficulties, weak central coherence, the tendency to prioritise the processing of local detail over the gestalt (Frith, 1989), has been used to explain narrative comprehension difficulties (Diehl et al., 2006). The relevance of weak central coherence to narrative comprehension can be understood in relation to the Construction Integration Model (Kintsch, 1988). Comprehension of text (either narrative or expository) requires the individual to combine information across sentences to create a coherent mental representation of the text (Zwaan, & Radvansky, 1998), typically referred to as a situation model. Creating a coherent situation model requires temporal sequencing of events within the story alongside inference making abilities, such as the integration of text information with the participant's own knowledge. Children with ASC often demonstrate weak central coherence, potentially impairing comprehension by disrupting the creation of a coherent and integrated mental representation of the narrative (Norbury & Bishop, 2002). This contrasts with TD children, who can utilise both local processing (for individual facts) and global processing (for inference-making) depending on their reading goals (Booth, 2006).

Much research has posited a link between weak central coherence in ASC and narrative comprehension (Norbury & Bishop, 2002; Nuske & Bavin, 2011). Norbury and Bishop (2002) compared the narrative comprehension of children with ASC and TD children for both literal (fact-based) and inferable information from stories. TD children outperformed the ASC group on questions tapping both types of information. Children with ASC demonstrated particular difficulty answering inferential questions, often making inferences that were not relevant to the overall context of the story. Norbury and Bishop theorised that this may be due to individuals with ASC failing to integrate their knowledge with the global context of the story. Moreover, Nuske and Bavin (2011) found that 4 to 7-year-old children with ASC had greater difficulties with inferential questions regarding a narrative compared to TD controls. The researchers proposed that, while weak central coherence may lead to difficulty comprehending events within a global context, a tendency towards local processing may lead to an advantage at tasks requiring the participant to recall individual facts out of context, such as non-inferential comprehension questions. Indeed, studies have found that children with ASC often match the performance of their TD peers on fact-based questions (Jolliffe & Baron-Cohen, 2000) while scoring poorly on questions requiring inference-making and sequencing of key events in the story (Baron-Cohen, Leslie, & Frith, 1986; Loveland, McEvoy, Tunali, & Kelley, 1990). In the current study, we assessed narrative comprehension with two tasks: questions that tapped story facts and a picture ordering task to assess understanding and memory of global story structure.

Children with ASC often exhibit attention dysfunction (Mayes & Calhoun, 2007) which may contribute to poor narrative comprehension in this population. Attention is here defined as the ability to focus and actively engage with a task, with low distractibility and behavioural problems (Language and Reading Research Consortium (LARRC), Jiang, & Farquharson, 2018; Miller et al., 2014). Comprehension of spoken narratives is found to be impaired in children with low attentional abilities (McInnes et al., 2003). Studies of TD children show that weak attention is associated with weaker reading and listening comprehension (Cain & Bignell, 2014). A recent study by LARRC et al. (2018) found that behavioural attention was a significant predictor of listening comprehension in 6- to 8-year-old children. A potential explanation is that individuals with weak attention cannot successfully allocate attention to relevant information (Pennington & Ozonoff, 1996), leading to reduced narrative comprehension in populations with known attentional problems including ASC.

The desire to focus children's attention and engagement on learning tasks has driven the popularity of tablets such as the iPad in the classroom and home (Kagohara et al., 2013; Neumann, 2018). Presenting information on a screen has been found to help children with ASC to focus attention on relevant stimuli and ignore distractions (Mineo, Ziegler, Gill, & Salkin, 2009). Studies demonstrate the efficacy of iPad-based learning to promote the learning of key language skills, including expressive language (Xin & Leonard, 2015) and vocabulary knowledge (Ganz, Boles, Goodwyn, & Flores, 2014). However, such studies have the disadvantage of small sample sizes and do not investigate the efficacy of e-books relative to paper-based alternatives to promote narrative comprehension in this population. Thus, research to date has not demonstrated the extent to which e-books might benefit narrative comprehension in general.

For TD children, the efficacy of e-books as a learning tool is very much in debate. Whilst an e-book may focus attention away from external distractors (Mineo et al., 2009), many e-books are programmed with interactive features that are not related to the central plot line or events in the text. This may explain why interactive games within narrated e-books are correlated to poorer narrative comprehension in TD primary school children, with 43% of time spent playing games rather than listening to the story (De Jong & Bus, 2002). This, and other research, suggests that controlling the interactivity available within storybooks is essential for adequate narrative comprehension (De Jong & Bus, 2002). However, a metanalysis of over 2000 young children across 43 studies, which compared learning from stories presented via technology and traditional storybooks, demonstrated greater narrative comprehension for stories presented via digital technology (Takacs et al., 2015).

Technology may be used to support and enhance narrative comprehension when used in targeted ways. For example, Takacs et al. (2015) found that multimodal features (the combination of auditory and visual features) were associated with greater learning, potentially through increasing learner engagement and reinforcing key information through different modes of representation. In contrast, interactive features (such as touchscreen exploration and games) were found to significantly reduce learning, potentially distracting the child from key information. When carefully designed to control for extraneous information, presenting learning material on an iPad has the potential to improve the narrative comprehension of children with ASC through highlighting central information through multimodal features (Omar & Bidin, 2015) and maintaining attention through increased engagement with touchscreen media (Mineo et al., 2009).

Shared reading of storybooks, in which an adult narrates the story, has been found to benefit the literacy development of young TD children and children with ASC (McLeod & McDade, 2011; Robbins & Ehri, 1994). Shared reading is considered to support greater learning/comprehension by enabling joint attention and a personalised learning experience compared to solitary learning, thus facilitating greater comprehension and the scaffolding of literacy skills (Hindman et al., 2008; Mucchetti, 2013; Sénéchal & LeFevre, 2002). A common feature of multimodal e-books is the availability of in-app narration of text (H. Schugar, Smith, & J. Schugar, 2013), but the efficacy of replacing adult narration with in-app narration is in debate. Whilst some studies show that computer narration of a story can be as beneficial to narrative comprehension as adult narration, at least for 5-year-olds (Segers, Takke, and Verhoeven (2004), others propose that adult involvement is critical for maintaining learner attention (Falloon & Khoo, 2014). However, very little research to date compares the influence of adult and in-app narration on narrative comprehension in typical development. In addition, it is possible that in-app narration may complement the preferred learning style of children with ASC, a population that often has low social motivation and a preference for solitary learning experiences (Chevallier et al., 2012). However, no research to date investigates this in ASC. Therefore, whether in-app narration is as successful as adult narration for eliciting narrative comprehension in the context of e-books is an open and essential question for both typical and atypical development (H. Schugar et al., 2013).

With a controlled multimodal design, e-books have been found to successfully aid the narrative comprehension of young children (Takacs et al., 2015), with e-books widely credited with increasing learner engagement (Moody, Justice, & Cabell, 2010). It is possible that engagement may be the mechanism through which e-books result in better comprehension in typical development (Richter & Courage, 2017). One claim is that iPads foster more active involvement for young children, rather than passively listening to information in the classroom (Kucirkova, 2014). Radesky, Schumacher and Zuckerman (2015) found that on-screen presentation increased reading skills in young children and concluded that touchscreen mediums provide real-time feedback and appropriately timed responses which are more engaging and similar to real-life interactions. Indeed, children consistently express a preference towards iPad-based learning compared to paper-based alternatives (Dixon, Verenikina, Costley, & Pryor, 2015; Kurcikova, 2014).

Moody et al. (2010) compared paper-book and e-book mediums of storybook presentation in terms of pre-schooler task engagement (measured through visual attention, persistence and communication). Results showed greater attention and persistence in the e-book condition, however more instances of communication in the paper-book condition. Although attention and persistence (which were greater in the e-book condition) were considered important for learning, the researchers stressed that communication during storybook reading (which was greater in the paper-book condition) was also an important means to support and facilitate comprehension. Roskos, Burstein and You (2012) coded the behaviour of 12 pre-schoolers during the shared-reading of an e-book and created a typology for engagement consisting of control behaviours (operating the e-book), multisensory behaviours (such as looking and gesturing) and communication (such as making noises and using language). This engagement coding system was expanded by Richter and Courage (2017), who compared engagement and narrative comprehension between e-books and paper-books in a sample of pre-schoolers. Engagement was measured through visual attention (looking time at the book/screen, adult and off-book/screen), communication (such as labelling and speech relevant to the story), and ‘persistence, enthusiasm and compliance.’ Children were then tested on their narrative comprehension. Results showed greater on-task looking time for the e-book compared to the traditional book and higher persistence, enthusiasm and compliance. Low levels of communication were reported across both conditions, which the authors note may be due to the young age of the participants. Despite higher engagement in the e-book condition, storybook comprehension did not differ between conditions. It was concluded that e-books may be beneficial for motivating and engaging learners, although the researchers did not examine the relationship between engagement and learning.

To date, research on narrative comprehension and engagement with e-books has focussed on typical development and has not investigated this in ASC. Neither has it examined the role of an adult facilitator during story reading in this population. Very little research attempts to define engagement into measurable categories (Moody et al., 2010; Richter & Courage, 2017; Roskos et al., 2012), with no research to date examining the relationship between engagement and narrative comprehension. With the increasing popularity of iPads as a learning tool in specialist education (Chmiliar, 2017; Whitehouse et al., 2017), it is crucial to investigate the educational value of e-books in ASC and whether engagement with this medium of presentation benefits learning.

Our main objective was to investigate whether narrative comprehension would differ between the ASC and TD group, and how differences in narrative presentation would influence performance in general, and between groups. Children were read a story from an e-book or a paper-book. The paper-book was narrated by the experimenter, and there were two iPad e-book conditions: one in which the story was narrated by the experimenter (adult narrated iPad condition) and one with in-app narration (e-book narrated iPad condition). Thus, we were able to determine whether the medium of presentation influenced performance on two assessments of narrative comprehension (multiple-choice questions that tapped literal information from the narrative and a picture ordering task that assessed memory of global story structure), and also whether the narrator had an effect. A secondary objective was to examine how engagement with the task (Moody et al., 2010; Richter &

Courage, 2017; Roskos et al., 2012) differed by group, presentation and narration medium, and whether this influenced narrative comprehension. As the current study includes children with ASC, who may have varying expressive language abilities, gesture (which was first included by Roskos et al., 2012) was also coded as a non-verbal component of communication.

As children with ASC have difficulties with global information processing (Diehl et al., 2006; Hudrey et al., 2010; Nuske & Bavin, 2011), it was hypothesised that TD children would have greater narrative comprehension than children with ASC on the picture ordering task (requiring the sequencing of temporal information to create a coherent story), but similar scores on the fact-based multiple-choice questions (requiring local information processing) across all conditions. Furthermore, as previous research provides conflicting evidence regarding the efficacy of e-books to enhance narrative comprehension compared to paper-books (Takacs et al., 2015), we anticipated a difference in narrative comprehension between the mediums for both groups, but did not make directional predictions. Moreover, if children with ASC benefit from both adult and computer narration in a similar way to TD children, both groups should show no difference in comprehension when the experimenter narrates the story (paper-book and e-book) compared to when the app narrates the story (Segers et al., 2004). As iPad learning has been found to complement the preferred learning style of children (Highfield & Goodwin, 2013), it was expected that, in line with Richter and Courage (2017), children in both groups will exhibit greater engagement (through increased visual attention and communication) in the e-book conditions compared to the paper-book condition. Finally, due to consistent user-preference towards touchscreen mediums (Dixon et al., 2015) accompanied with the active learning experience provided by e-books (Kucirkova, 2014) we expect greater engagement to be contingent with narrative comprehension.

Method

Participants

Eighty-four participants (19 female) were recruited for this study. There were 42 children with ASC (6 female) whose ages ranged from 6 years 5 months to 12 years 5 months (M_{age} = 9 years 1 month, SD_{age} = 17.24 months)[1]. They were recruited from six schools in North Wales and the north west of England and had been assessed by a qualified psychologist using standardised measures (ADOS, ADI-R), subsequently receiving a clinical diagnosis of autism. Teachers scores on the current version of the Social Communication Questionnaire further characterised the functioning of our ASC group (M_{score} = 18.38; SD_{score} = 5.60; range = 10-32)[2]. iPads/tablets were used in the classroom by 97.20% of children with ASC. Forty-two TD children (13 female) also participated in the study, with ages ranging from 2 years 11 months to 8 years 3 months (M_{age} = 5 years 10 months, SD_{age} = 22.00 months). They were recruited from one nursery school and two primary schools in the North Wales area and 64.30% used iPads/tablets in the classroom. As shown in Table 1, children with ASC were more frequent users of iPads or touchscreen devices (once a week or more) in school, χ^2 (1, N = 78) = 12.90, p < .001.

[1] As this is a task measures narrative comprehension, it was important that both groups had equivalent vocabulary skills. Therefore, participants with ASC and TD participants were matched on receptive language ability and were not matched on chronological age. This study is consistent with previous research matching on receptive language ability that have comparable age ranges and mean ages for both groups (Allen, Hartley, & Cain, 2015; Field, Allen, & Lewis, 2016; Hartley & Allen, 2014; Hartley & Allen, 2015b; Maljaars, Noens, Scholte, & van Berckelaer-Onnes 2012; Tager-Flusberg, 1985; Tek, Jaffery, Fein, & Naigles 2008).

[2] 34 participants scored 15 or above, the suggested cut-off for ASC. Three participants scored between 12-14, and 5 participants scored below 12. Corsello et al (2007) suggest that cut-offs for the SCQ should be adjusted depending on the purpose of administering the questionnaire, especially when children vary in age across the sample. Eaves et al. (2006) suggest that children with a diagnosis of autism who score below established cut-offs in the SCQ may be higher-functioning individuals. As all of our participants had a clinical diagnosis of autism, and given the caution regarding false negatives obtained with the SCQ (Rutter, Bailey, & Lord, 2003), and suggestion that lower cut-offs are sometimes appropriate (Eaves, Wingert, Ho, & Mickelson, 2006; Norris & Lecavalier, 2010) we included all participants in the analysis and used the SCQ only to further characterise the functioning of our sample.

Table 1

The percentages (and frequencies) of iPad/tablet use in school/nursery for participants with ASC and TD participants.

Question: Do children have experience with iPads or touchscreen devices in the nursery/in school?		
	ASC	TD
Every day	13.90% (5)	42.90% (18)
3-4 times a week	33.30% (12)	0.00% (0)
1-2 times a week	50.00% (18)	21.40% (9)
Never	2.80% (1)	35.70% (15)

Children with ASC and TD children were matched on a pairwise basis for receptive language and non-verbal IQ (NVIQ) (see Table 2) and participants were assigned to conditions based on their receptive language and NVIQ raw scores. Raw scores were used instead of standardised scores as many children with ASC scored too low to fall into an average range of performance for their chronological age (see Table 2 for the standardised scores of remaining participants). The same absolute level of performance on each measure was used to match each child with a control (see Table 3), ensuring that there was a range of abilities in each condition and a non-significant difference in performance between each group. Where score ranges differ between groups, the two lowest and two highest performing children from each group were pairwise matched. Receptive language for all participants was measured using the British Picture Vocabulary Scale-3 (BPVS-3; Dunn & Dunn, 2009). The mean receptive language raw score for the BPVS-3 was 71.67 (range = 24-129) in the ASC group and 79.38 (range = 28-134) in the TD group, a non-significant difference, $t(82) = 1.24$, $p = .22$, $d = 0.27$. Age-equivalent scores cannot be reported here as some children were younger than the lowest age-equivalent of 45 months. However, the standardised scores for those in the TD group over the age of 36 months were all within an age-appropriate (average) range.

NVIQ was measured using either the Raven's Coloured Progressive Matrices (CPM; Raven, 1998) or, if the participant found the CPM too difficult and could not complete the assessment, the Block Design task of the Wechsler Preschool and Primary Scale of Intelligence – third edition (WPPSI-3; Wechsler, 2002). Twenty-five children with ASC (59.52%) completed the CPM and 17 children with ASC (41.48%) completed the WPPSI-3. They were matched on a pairwise basis with TD children who completed the same NVIQ assessment. The mean CPM raw score for children with ASC was 22.04 (range = 9-31) and 22.56 for TD children (range = 13-31), a non-significant difference, $t(48) = 0.32$, $p = .75$, $d = 0.09$. The mean WPPSI-3 raw score for children with ASC was 18.94 (range = 6-32) and 16.76 for TD children (range = 6-32), a non-significant difference, $t(32) = -0.83$, $p = .41$, $d = -0.29$. The standardised scores for the TD group were all age-appropriate for both the CPM and WPPSI-3.

Table 2

The mean (M), standard deviation (SD), range and number (N) of chronological age (in years) and raw and standardised scores of participants for the British Picture Vocabulary Scale 3 (BPVS3), Raven's Coloured Progressive Matrices (CPM) and Wechsler Preschool and Primary Scale of Intelligence (WPPSI-3),

	ASC				TD			
	M	*SD*	Range	*N*	*M*	*SD*	Range	*N*
Age	9.08	1.44	6.4-12.4	42	5.83	1.83	2.9-8.3	42
BPVS3 raw	71.67	24.54	24-129	42	79.38	32.07	28-134	42
BPVS standardised	82.83	13.40	70-113	12	96.83	13.43	78-132	41
CPM raw	22.04	6.83	9-31	25	22.56	4.44	13-31	25
CPM standardised	87.94	11.73	70-105	17	94.40	13.10	65-130	25
WPPSI 3 raw	18.94	7.33	6-32	17	16.76	7.89	6-32	17
WPPSI standardised	57.00	2.83	55-59	2	65.24	8.65	54-84	17

Table 3

The distribution of age (in months), gender, British Picture Vocabulary Scale 3 (BPVS3) scores, Raven's Coloured Progressive Matrices (CPM) scores and Wechsler Preschool and Primary Scale of Intelligence (WPPSI-3) scores across groups and conditions.

	ASC			TD		
	Paper-book	iPad adult narrated	iPad e-book narrated	Paper-book	iPad adult narrated	iPad in-app narrated
N(female)	14 (2)	14 (2)	14 (2)	14 (7)	14 (3)	14 (3)
Age	108.14 (12.23)*	106.79 (20.44)*	110.57 (19.03)*	71.57 (22.18)	72.21 (21.83)	66.36 (23.12)
BPVS3	69.93 (23.16)	69.79 (21.58)	75.29 (29.59)	78.57 (29.21)	82.21 (25.43)	77.36 (41.59)
CPM	22.88 (8.06)	19.63 (6.44)	23.44 (6.19)	22.56 (3.75)	21.75 (5.18)	23.38 (4.84)
WPPSI-3	19.50 (6.95)	17.17 (8.59)	20.40 (7.37)	15.20 (10.06)	21.17 (7.11)	14.67 (5.54)

Note: * denote significant differences in age between groups for each of the conditions

Experimental task materials

Storybook/e-book. The storybook "Who Stole the Moon?" by Helen Stratton-Would (2010) was selected to measure narrative comprehension. The story concerns a child's quest to find the missing moon with the help of nocturnal animals. The story was either presented via the iPad e-book or a printed picture-book version (between-subjects design). The e-book allowed for interactive picture pages (responsive to touch), sound effects and a male voice over narration. There were two conditions involving iPad e-book presentation: experimenter-narrated or e-book-narrated. All of the interactive e-book features were available in both conditions, the only difference being the narration. For both e-book conditions, "Who Stole the Moon?" was downloaded as an application from the Apple App-Store and presented on a 32G iPad air 2. A third non-interactive paper-book condition was created by taking a screenshot of each individual page. Pages were then printed, laminated and bound single-sided with comb binding to create an A5 book (approximately the same size as the iPad screen).

Comprehension questions. Two tasks were created to assess narrative comprehension: multiple-choice questions and a picture ordering task. Ten multiple-choice questions were created to test the memory of facts from the story. The distribution of correct answers was counterbalanced between three options (two distractor options) and no questions were directly linked to one another. The two distractor options for each question did not reference other facts from the story and were not repeated for different questions. Questions were presented one to a page. Participants could either verbally answer the questions or point to their answer selection. Answers were read out twice, and a third time if participants did not make a selection after 10 seconds. After each question, the experimenter recorded the participant’s answer on paper and moved on to the next question. If a participant did not answer, they were excluded from the task. To check that the target responses were passage-dependent rather than passage independent (Keenan & Betjemann, 2006), a group of 10 children who had not heard the story completed 10 multiple-choice questions. Two of the questions were answered by 7 or more children and so were excluded from the analysis. The remaining 8 questions were selected by only 0 to 3 children. Thus, the total correct score was calculated out of the 8 questions where the target answer was not obviously correct.

The picture ordering task was created to test memory of global story structure (as per Oakhill & Cain, 2012). The task included 6 A6 laminated images from the story, which were selected to represent three episodes of the story - with two from the beginning, two from the middle and two from the end. The images were presented in a fixed, incorrect order and participants were asked to put the pictures in the order they saw in the story. Up to three verbal prompts of “can you put the pictures in order?” were given if the participant did not make an attempt to order the pictures. If the participant had not made an attempt to order the pictures within 60 seconds they were excluded from the task. As with the multiple-choice questions, a separate group of 10 children who had not heard the story completed the picture ordering task to check that the task was passage-dependent. No picture was placed in its correct position by more than 3 children (range = 1-3) and so all 6 pictures were included in the task and a correlational score was calculated comparing the participant's order to the correct order.

Four children with ASC did not make a response in either comprehension task due to behavioural difficulties and fussiness and so were excluded from the experiment. An additional 4 children were recruited to maintain a total of 42 children. One child with ASC, after successfully completing the multiple-choice questions, did not attempt the picture ordering task alone due to behavioural difficulties and fussiness and so was excluded from that particular task. All TD children made a response in both comprehension tasks. None of the excluded participants are included in the matching data above or the descriptive statistics of the overall sample.

Procedure

Testing took place individually over two consecutive days. On the first day, participants were administered the receptive language and NVIQ measures. On the second day, participants were taken individually to the testing room, sat adjacent to the experimenter and were told that they were going to hear a story. A Samsung camcorder was positioned on a tripod to record participant engagement throughout the experiment. The participants heard the story read them in one of the three conditions: paper-book, adult narrated iPad or e-book-narrated iPad. The participants were administered the comprehension measures (multiple-choice questions and picture ordering task) immediately after the storybook reading.

As participant engagement was measured in this study, the experimenter followed a strict protocol during the storybook reading to prevent encouraging additional engagement in the task. The experimenter could only redirect the child's attention towards the story if the child removed themselves from their chair. The experimenter did not engage the child in conversation. If the child attempted to make conversation with the experimenter a short reply was given and the story was continued. The experimenter did not encourage touching the page. Finally, if the child skipped a page, the experimenter would not turn the page back.

Engagement coding

Engagement is here defined as a child's ability to maintain visual attention throughout the storybook reading and spontaneously communicate about the content of the story (Kaderavek, Guo, & Justice, 2014; Moody et al., 2010; Richter & Courage, 2017; Roskos et al., 2012). Engagement categories were adapted from the coding scheme proposed by Richter and Courage (2017) (see Table 4). Videos of participants during storybook presentation were analysed for engagement by two independent video-coders. Video coding was split between the two video-coders (half each), with an overlap of 20 videos to check for inter-rater reliability. An intra-class correlational analysis with fixed effects and absolute agreement was conducted between the video-coders for each sub-category separately and all ratings were found to be greater than .98. This represents high agreement according to Cicchetti (1994) where scores on or above .75 are classified as 'excellent'.

Table 4

Description and examples of the 2 engagement categories and their sub-categories.

Engagement Category	Sub-Category	Description	Example
Visual attention	Total Screen/Page Looking Time	Total amount of time the participant looks the screen.	
	Adult-Oriented Looking Time	Total amount of time the participant looks at the adult.	
	Off-Focus (Environment) Looking Time	Total amount of time the participant looks away from the	

		screen/page (excluding looking time at the adult).	
Communication	Relevant Speech/Non-Verbal Utterances	Total instances of speech/non-verbal utterances relevant to the content of the story.	E.g. "Wow, the hedgehog stole the moon!" Making the sound of a rocket
	Irrelevant Speech/Non-Verbal Utterances	Total instances of speech/non-verbal utterances irrelevant to the content of the story.	E.g. "My mum is picking me up from school today!" Making the sound of a car
	Gesture	Total instances of gesture that were explicitly relevant to the story.	E.g. pointing, waving at characters or putting hand to mouth (to denote surprise).

Results

Storybook Comprehension

Scores from the two tasks to assess narrative comprehension were analysed in separate two-way ANOVAs. Group and condition were between-subjects factors. In each analysis, performance on the task was the dependent variable.

Multiple-Choice Questions

Table 5 shows the scores for each group and condition. Performance was negatively skewed, with participants scoring highly across groups and conditions. Each condition had a score range between 1 and 8, showing that some children obtained a perfect score, with 31.0% of participants with ASC and 40.5% of TD participants achieving a score of 8. The TD group consistently scored higher than the ASC group, with higher scores in the paper-book and adult narrated iPad conditions compared to the e-book-narrated iPad conditions for both groups.

Table 5

Mean (and standard deviation) of multiple-choice question scores and picture ordering task correlations split by group and condition.

		Multiple-Choice Questions	
Group	Book	iPad adult narrated	iPad e-book narrated
ASC	5.93 (2.37)	5.57 (2.41)	5.00 (2.69)
TD	6.64 (1.39)	6.50 (1.65)	6.14 (2.48)
		Picture Ordering Task	
Group	Book	iPad adult narrated	iPad e-book narrated
ASC	0.62 (0.51)	0.56 (0.55)	0.43 (0.50)
TD	0.65 (0.43)	0.58 (0.51)	0.34 (0.65)

Despite the TD group obtaining higher scores than the ASC group, the main effect of group did not reach conventional levels of statistical significance, $F(1,78) = 3.69$, $p = .06$, $\eta^2 = .05$. Although scores were highest for the paper-book and adult narrated iPad conditions for both groups, the main effect of condition was not significant $F(2,78) = 0.75$, $p = .48$, $\eta^2 = .02$. The same pattern was found for both groups with the highest scores in the paper-book and adult narrated iPad conditions and lowest scores in the e-book-narrated condition, and the interaction between group and condition was not significant $F(2,78) = 0.07$, $p = .94$, $\eta^2 = .002$.

Picture Ordering Task

Table 5 shows the correlational scores for each group and condition. Performance was negatively skewed, with participants scoring highly across groups and conditions. The maximum score of 1 was achieved by 34.1% of participants with ASC and 33.3% of TD participants. Both groups had similar performance and the main effect of group was not significant, $F(1,77) = 0.01$, $p = .91$, $\eta^2 < .001$. There were higher scores in the paper-book and adult narrated iPad conditions compared to the e-book-narrated iPad conditions for both groups, but the main effect of condition did not reach significance, $F(2,77) = 1.70$, $p = .19$, $\eta^2 = .04$. No significant interaction was found between groups and conditions, $F(2,77) = 0.12$, $p = .89$, $\eta^2 = .003$.

Participant Engagement Coding

This section examines participant engagement during the storybook in terms of visual attention and communication (as per Moody et al., 2010; Richter & Courage, 2017; Roskos et al., 2012). Both the adult narrated iPad condition ($M = 709.24$ seconds) and the e-book narrated iPad condition ($M = 696.82$ seconds) took longer to read than the paper-book condition ($M = 358.09$ seconds), a significant difference, $F(2,75) = 31.83$ $p < .001$, $\eta^2 = .46$. Due to the variability in reading time, subsequent analysis of visual attention was conducted on proportional time values.

Visual attention.

For both groups, the majority of time was spent looking at the screen/page, indicating a high level of engagement in the task (see Table 6 for all visual attention and communication proportions). Children with ASC spent 92.15% of time looking at the screen/page compared to 1.86% looking towards the adult and 5.95% looking off-focus (environment). TD children spent 90.54% of time looking at the screen/page compared to 4.29% looking towards the adult and 5.12% looking off-focus (environment).

A two-way ANOVA was used to examine differences in the proportion of time spent looking at the screen/page between group and conditions. The effect of group was not significant, $F(1,75) = 0.51$ $p = .48$, $\eta^2 = .01$. Despite a greater proportion of looking time at the screen/page in the adult narrated iPad condition ($M = 0.93$) and the e-book narrated iPad condition ($M = 0.93$) than the paper-book condition ($M = 0.88$), no significant main effect of condition was found, $F(2,75) = 2.28$, $p = .11$, $\eta^2 = .06$. No significant interaction was found between group and condition, $F(2,75) = 0.58$, $p = .56$, $\eta^2 = .02$.

Off-screen looking was split into adult-oriented looking and off-focus (environment) looking. As these measures are mutually exclusive, only the proportion of off-focus (environment) looking is reported here. Differences in the proportion of time spent looking off-focus (environment) were analysed using a two-way ANOVA with group and condition as factors. No effect of group was found, $F(1,75) = 0.30$, $p = .59$, $\eta^2 = .004$, with a similar proportion of off-focus (environment) looking for both groups. A main effect of condition was found, $F(2,75) = 5.60$, $p = .01$, $\eta^2 = .13$, with a greater proportion of time spent looking off-focus (environment) in the paper-book condition ($M = 0.10$) compared to the adult narrated iPad condition ($M = 0.03$) and the e-book narrated iPad condition ($M = 0.04$). No interaction was found between group and condition, $F(2,75) = 0.14$, $p = .87$, $\eta^2 = .004$.

Table 6

Mean (and standard deviation) of visual attention and communication proportions (gestures reported in instances) split by group and condition.

Groups	Variables	Conditions		
		Paper-book	iPad adult narrated	iPad e-book narrated
ASC	Screen/page looking	0.87 (0.11)	0.95 (0.05)	0.94 (0.07)
	Adult-oriented looking	0.02 (0.03)	0.01 (0.01)	0.02 (0.04)
	Off-focus (environment) looking	0.10 (0.11)	0.04 (0.05)	0.04 (0.05)
	Relevant speech	0.90 (0.13)	0.81 (0.33)	0.72 (0.28)
	Irrelevant speech	0.10 (0.13)	0.19 (0.33)	0.28 (0.28)
	Gesture	4.00 (4.65)	0.31 (0.75)	0.64 (1.39)
TD	Screen/page looking	0.89 (0.11)	0.91 (0.09)	0.91 (0.13)
	Adult-oriented looking	0.02 (0.03)	0.06 (0.08)	0.05 (0.06)
	Off-focus (environment) looking	0.09 (0.10)	0.03 (0.02)	0.04 (0.08)
	Relevant speech	0.90 (0.23)	0.95 (0.08)	0.81 (0.33)
	Irrelevant speech	0.10 (0.23)	0.05 (0.08)	0.19 (0.33)
	Gesture	2.29 (4.05)	1.29 (2.27)	1.92 (4.09)

Communication.

Communication is here reported in terms of relevant and irrelevant speech and instances of gesture. No relevant or irrelevant speech was made by 17.5% of participants with ASC and 31.7% of TD participants. For the remaining participants, the majority of speech was task-relevant, indicating a high level of engagement. For children with ASC, 81.73% of speech was task-relevant and 18.27% was task-irrelevant. For the TD children, 88.86% of speech was task-relevant and 11.14% was task-irrelevant. The following sub-sections analyse differences in speech proportions and instances of gesture by group and condition using two-way ANOVAs (see Table 6).

Speech. Speech was split into relevant and irrelevant speech. As these measures are mutually exclusive, only relevant speech is reported here. Despite a slightly larger proportion of relevant speech in the TD group compared to the ASC group, no significant effect of group was found, $F(1,75) = 1.39$, $p = .24$, $\eta^2 = .03$. Children produced more relevant speech in the paper-book and adult narrated iPad conditions compared to the e-book narrated iPad condition, although this effect of condition was not significant, $F(2,75) = 1.70$, $p = .19$, $\eta^2 = .06$. No interaction was found between group and condition, $F(2,75) = 0.45$, $p = .64$, $\eta^2 = .02$.

Gesture. On average, children produced 1.73 instances of gesture during the storybook. No difference in gesture was found between groups, $F(1,75) = 0.07$, $p = .80$, $\eta^2 = .001$, but a main effect of condition was found for gesture, $F(2,75) = 4.01$, $p = .02$, $\eta^2 = .10$. Participants produced more instances of gesture in the paper-book condition ($M = 3.14$ instances) compared to the adult narrated iPad condition ($M = 0.80$ instances). No interaction was found between group and condition, $F(2,75) = 1.78$, $p = .18$, $\eta^2 = .05$.

Correlates of Narrative Comprehension

This section examines whether participant characteristics (BPVS score and chronological age) and participant engagement during the storybook reading (visual attention and communication) are related to comprehension scores on the multiple-choice questions and the picture ordering task for each group. Because there was no significant overall effect of condition in terms of narrative comprehension, here we combine conditions for the analyses. However, as there was a difference between groups (although non-significant) for the multiple-choice questions, we analyse groups separately. All correlations for both groups can be found in Table 7.

Table 7

Correlations for the ASC (upper diagonal) and TD (lower diagonal) groups for participant characteristics, engagement measures and narrative comprehension performance.

		1	2	3	4	5	6	7	8	9
1)	Age	--	.15	-.05	.13	-.03	-.01	.03	-.26	-.06
2)	BPVS	.85**	--	.67**	.60**	.26	-.06	-.26	.18	-.14
3)	Multiple-Choice Questions	.73**	.75**	--	.61**	.27	-.01	-.30	.06	-.13
4)	Picture Ordering Task	.78**	.74**	.75**	--	.28	-.21	-.23	-.12	-.07
5)	Screen/page looking	.63**	.59**	.33*	.56**	--	-.43**	-.94**	-.23	-.46**
6)	Adult Looking	-.41**	-.36*	-.18	-.42**	-.72**	--	.09	.28	.18
7)	Off-focus looking	-.57**	-.55**	-.33*	-.46**	-.85**	.24	--	.15	.44**
8)	Relevant speech	-.10	-.03	-.01	.03	-.36*	.43**	.17	--	.40*
9)	Gesture	-.42**	-.46**	-.25	-.41**	-.72**	-.56**	-.59**	.62**	--

* <.05

** < .01

Participant Characteristics

For the ASC group, BPVS scores were strongly positively correlated to performance on both the multiple-choice questions and the picture ordering task, however chronological age was not. Neither BPVS score nor chronological age were correlated with the engagement measures. BPVS scores and chronological age were also not correlated. For the TD group, BPVS score and chronological age were also strongly positively correlated to performance on both the multiple-choice questions and the picture ordering task. BPVS score and chronological age were strongly positively correlated to visual attention towards the page/screen. In contrast to the ASC group, BPVS scores and chronological age were also strongly positively correlated.

Engagement Measures

Visual attention. For the ASC group, visual attention measures (proportion of page/screen looking, proportion of adult-looking and proportion of off-focus looking) were not correlated with performance on the comprehension tasks. In contrast, for the TD group, the proportion of page/screen looking time was moderately positively correlated to performance on the multiple-choice questions, and strongly positively correlated to performance on the picture ordering task. The proportion of adult looking was moderately negatively correlated to performance on the picture ordering task alone. Moreover, the proportion of off-focus looking was moderately negatively correlated with performance on both the multiple-choice questions, and the picture ordering task.

Communication. For the ASC group, no correlation was found between communication measures (instances of gesture and relevant speech) and performance on the comprehension tasks. In contrast, for the TD group, instances of gesture were moderately negatively correlated with performance on the picture ordering task alone. No correlation was found between instances of relevant speech and performance on the comprehension tasks.

Discussion

This study investigated how differences in the medium of presentation of a narrative (paper-book vs e-book), and different forms of narration (adult narration vs in-app narration) would influence narrative comprehension and task engagement for children with ASC and a TD control group. Contrary to predictions, we did not find any significant group or condition differences on either measure of narrative comprehension; both groups demonstrated a similar level of narrative comprehension across the three conditions. We found differences in visual attention and communication between conditions for both groups, but engagement only significantly correlated with narrative comprehension for the TD group. We discuss these findings in turn.

As expected, we found no significant difference in performance on the multiple-choice questions between groups, despite the TD group scoring approximately 1 point higher across conditions. This is in line with previous research, suggesting that the narrative comprehension of individual story facts is not impaired in ASC (Jolliffe & Baron-Cohen, 2000), potentially due to intact local information processing despite an impairment in global information processing in this population (Nuske & Bavin, 2011). However, contrary to our hypothesis, we also found no significant difference in performance on the picture ordering task between conditions. Our results suggest that children with ASC in this sample do not have a deficit in narrative comprehension on either fact-based or event sequencing tasks compared to TD children.

A possible explanation is that our tasks are not fully tapping into the inference-making abilities of children with ASC, who often exhibit weak central coherence, potentially leading to a failure to create a holistic mental representation of meaning (Norbury & Bishop, 2002). The comprehension tasks used in this study measured both the participant's knowledge of individual facts from the story (multiple-choice questions) and the memory of the global story structure (picture ordering task), the latter requiring some inference-making ability to allow for the integration of temporal story information to create a coherent narrative (Oakhill & Cain, 2012). While our picture ordering task measured the integration of information across the story, it did not require the integration of text information with the participant's own knowledge – another key element of inference-making (Cain & Oakhill, 2014; LAARC & Muijselaar, 2008; Tarchi, 2015). Therefore, this task may not sufficiently tap the construct of inferential comprehension. Future research could expand the multiple-choice question task to include both literal questions (as with the current study) and questions that require inference-making to capture a more complete picture of narrative comprehension in ASC.

Contrary to our hypothesis, no difference in narrative comprehension was found between conditions for both groups. The same pattern of performance was found for both narrative comprehension tasks, with higher scores in the paper-book condition, followed by the adult narrated iPad condition and then the e-book narrated iPad condition, however, this did not reach significance. This suggests that the medium of presentation (paper-book vs e-book) does not influence the narrative comprehension of both groups. One possibility is that our tasks are not sufficiently difficult to capture variability amongst the more-able participants in our sample. Indeed, approximately one third of participants scored full marks in both comprehension tasks. However, it is important to note that although the paper-book did not have a significant advantage in terms of performance, children took half the time to finish the book compared to the e-book conditions and had scored slightly higher on the multiple-choice questions. This suggests that overall time on the story does not benefit performance and a paper-book may elicit the same narrative comprehension as an e-book in a shorter time.

Aside from no comprehension differences between presentation mediums, no difference in performance was found between types of narrations (adult vs in-app) for both groups. Although children in the adult narrated iPad condition scored slightly higher on both comprehension tasks than those in the e-book narrated iPad condition, this did not reach significance. This finding supports previous research which suggests that computer-based narration can be as successful as adult narration at eliciting narrative comprehension (Segers et al., 2004), and extends this finding to ASC. However, our finding contradicts previous research which suggests that shared-reading is beneficial for narrative comprehension and early literacy more-so than reading alone in typical and atypical development (Boyle, McNaughton, & Chapin, 2019; Hindman et al., 2008; Mucchetti, 2013). For example, Boyle et al.'s (2019) meta-analysis of 11 studies investigating the efficacy of shared-reading interventions with children with ASC showed a significant increase in narrative comprehension amongst children with ASC who took part in the shared-reading exercise.

In the current study, although the adult was not narrating the story in the e-book narrated iPad condition (and the experimenter followed a strict protocol to avoid adding any additional guidance or communication) the adult was still present during the experiment for the child to interact with if they chose to. In the e-book narrated condition, 2% and 5% of time was spent looking at the adult for the children with ASC and TD children respectively. This is comparable to the adult narrated iPad condition (ASC = 1%, TD = 6%). Moreover, we found a comparable average of instances of relevant speech (particularly for the ASC group) between the adult narrated iPad condition (ASC = 9.92 instances, TD = 10.57 instances) and the e-book narrated iPad condition (ASC = 9.00 instances, TD = 7.92 instances). These findings demonstrate similar levels of adult interaction regardless of narration. Despite removing the adult narration, the presence of the adult beside the child may be sufficient to create a shared-reading situation, which is beneficial to the narrative comprehension of both typically and atypically developing children (Mucchetti, 2013; Zevenbergen & Whitehurst, 2003). Future research could examine this theory by creating another condition in which the child experiences the e-book narrated iPad condition without the adult sitting beside them during the story, investigating whether the presence of the adult alone is sufficient to create a shared-reading environment.

Consistent with our hypothesis, we found a high level of visual attention across all conditions for both groups, with greater off-focus looking in the paper-book condition compared to the e-book conditions. Our results suggest that children in the e-book conditions were more engaged than those in the paper-book condition, consistent with previous research (Moody et al., 2010; Richter & Courage, 2017) demonstrating that interactive and multimodal features can prevent distraction from external stimuli (Holmes, Josephson, & Carney, 2012), leading to less looking away from the screen and potentially allowing for synchronisation of narrative information with visual pictorial information (Takacs & Bus, 2015). However, it is important to note that although greater visual attention was found in the e-book conditions compared to the paper-book condition, most time was spent engaged in the task across all conditions. Moreover, although not proportionally, more time was spent off-focus in the e-book conditions as children took approximately twice the time to finish the story. As mentioned earlier, this is a potential advantage for the paper-book medium of storybook presentation, allowing for the same level of narrative comprehension with less overall reading time.

We found no significant difference in relevant speech across conditions for both groups. Although this finding contrasts with our hypothesis, that we would observe more instances of communication in the e-book conditions compared to the paper-book condition, it is consistent with Richter and Courage (2017), who also found no difference in communication between presentation media. Our finding suggests that e-books are no more successful at eliciting social communication than paper-books. However, for the ASC group alone we found that instances of relevant speech dropped in the adult narrated iPad condition (M = 9.92) and the e-book narrated iPad condition (M = 9.00) compared to the paper-book condition (M = 13.15). We also found more instances of gesture in the paper-book condition compared to the e-book conditions for both groups. Therefore, it is possible that e-books may not be the optimal method to foster social communication and engagement between the teacher and the learner, a skill that is typically diminished in children with ASC (Wodka, et al., 2013), potentially due to the increased cognitive load provided by interactive touchscreen features (Kirkorian, 2018). Another possible explanation for the fewer instances of gesture observed in the e-book conditions is that children may have been occupied manipulating the interactive features on-screen and did not have their hands free to make communicative gestures (Kirkorian, 2018).

As expected, we found that visual attention (page/screen looking time) was positively correlated with performance for the TD group. This suggests that greater on-task engagement is linked to narrative comprehension in typical development. However, contrary to our hypothesis, we found no link between engagement and narrative comprehension in ASC. This suggests that, despite a high level of visual attention across all conditions, on-task engagement does not benefit narrative comprehension for this group.

However, we do not know what children are visually attending to during the task. Although children may demonstrate a high level of visual attention towards the screen/page across all groups, it may be that the groups are focussing on different things. The weak central coherence exhibited by children with ASC may mean that children are not attending to the central plot of the story and are instead visually engaged with miscellaneous interactive features that are not relevant to the narrative (Frith, 1989, Norbury & Bishop, 2002), despite similar comprehension scores to the TD group. The story used in the current study had a mixture of relevant and irrelevant multimodal features and interactivity, which may not have successfully highlighted the essential learning information to children with ASC (Mineo et al, 2009; Omar & Bidin, 2015) while still providing a high level of engagement and interest. This would explain the high overall on-task engagement in the absence of a positive correlation to narrative comprehension. Future research could investigate this by highlighting either relevant or irrelevant information with multimodal and interactive features and examining whether this influences narrative comprehension in ASC. Moreover, eye-tracking could be used to examine which features on the screen/page children are visually attending to during storybook reading and compare those who are attending to central or peripheral information on narrative comprehension score and engagement.

For the both groups, receptive language score was positively related to performance on both comprehension tasks. However, chronological age was only related to performance for the TD group alone. This may be because children with ASC who possess language and cognitive impairments are very distinct from younger TD children and often do not follow the same developmental trajectory, demonstrating different strengths and weaknesses from TD children in areas of language and cognition (Baron-Cohen et al., 1986; Baron-Cohen, 1991; Loveland et al., 1990; Nuske & Bavin 2011; Shah & Frith, 1993). For children with ASC, some skills may be age-appropriate, whereas others may be delayed or deviant compared to typical development (Baron-Cohen, 1991). Therefore, it is important to note that young TD children may not be cognitively comparable to older children with ASC.

For the TD group, receptive language score related both positively (screen/page looking) and negatively (adult looking, off-focus looking and gesture) to engagement measures. However, for the ASC group, receptive language score was not related to any engagement measures. A possible explanation for this is that, for the TD group, chronological age related to engagement measures in the same way as receptive language ability, with receptive language ability and chronological age also strongly positively correlated. As receptive language ability was age-appropriate for the TD group, it may be that TD children with greater receptive language ability were older and thus had a greater capacity for sustained attention and inhibition control (Betts, Mckay, Maruff, & Anderson, 2006; Reck & Hund, 2011). Betts et al. found that sustained attention rapidly increased with chronological age throughout early childhood until the age of 10. Moreover, Reck and Hund found that inhibitory control significantly increased with age, with 6-year-olds demonstrating greater inhibitory control than 3-year-olds. For the ASC group, receptive language scores were not age-appropriate and receptive language ability and chronological age were not correlated. This may explain why children with ASC did not demonstrate the same link between receptive language ability and engagement measures.

Limitations

In addition to limitations about question type and task performance discussed above, we also note the limitation of using two different measures of non-verbal IQ in this study (WPPSI Block Design and Raven's CPM) as some children failed to complete the CPM – a task designed for older children - due to difficulty. However, the Block Design Task may be biased towards proposed processing strengths of children with ASC – an advantage towards local detail processing due to weak central coherence (Shah & Frith, 1993). In contrast, the Raven's CPM may be biased against this processing style, requiring the participant to create a whole pattern by selecting the correct missing segment (Raven, 1998). Despite this, children with ASC were pairwise matched with TD children, minimising this influence. Future research may work with a different ability range to ensure the same test can be used with all the participants.

Moreover, the sample of children with ASC used in the current study had poorer receptive vocabulary and NVIQ scores compared to previous research investigating narrative comprehension in this population (Diehl et al., 2006; Norbury & Bishop, 2002; Nuske & Bavin, 2011). Norbury and Bishop (2002) used participants with ASC who scored within standardised norms on the BPVS and Raven's CPM, in contrast to the current study in which many children with ASC scored too low to calculate a standardised score. Moreover, Diehl et al. (2006) only included participants who had a NVIQ greater than 80 and Nuske and Bavin (2011) included participants with ASC who scored approximately 9 points higher on the Block Design Task of the WPPSI-3 compared to the current study. Therefore, this suggests that the current sample of participants with ASC have a different receptive vocabulary and NVIQ profile to previous studies and consequently the results of this study cannot be directly compared.

Conclusion

Overall, this study suggests that children with ASC are just as able as language-matched peers to comprehend a narrative from a storybook. Presenting a story on an iPad e-book compared to a paper-book does not influence narrative comprehension, nor does adult narration of the story compared to in-app narration. Children learn just as well from paper-books in half the time it takes for them to finish the same story on an e-book, potentially providing an advantage for paper-based mediums. Consistent with previous research, both groups exhibit greater visual attention when viewing an e-book compared to a paper-book (Moody et al., 2010; Richter & Courage, 2017), with visual attention related to narrative comprehension for the TD group alone. No difference in relevant speech was found between conditions for both groups, potentially due to the increased cognitive load provided by interactive touchscreen features (Kirkorian, 2018). Taken together, our findings suggest that e-books may be more successful than paper-based mediums at encouraging visual attention towards the story, but no better at eliciting narrative comprehension and communication.

6. General Discussion

This thesis explored the gaps in the literature through four experiments that collectively aimed to answer the following questions: (i) does iPad interactivity benefit the task performance of children with ASC? (ii) how do children with ASC engage with interactive iPad learning materials? (iii) is there a relationship between engagement and task performance in children with ASC? (iv) does adult involvement benefit the task performance of children with ASC?

Study 1 (Chapter 2) examined how iconicity (three-dimensional context) and interactivity influenced word-picture-referent mapping. This study aimed to investigate how children with ASC and TD children learned and engaged with an interactive iPad task and whether engagement was related to symbol learning. Participants viewed coloured pictorial symbols of a novel object (given a novel name) on an iPad in one of three conditions: static 2D images and either automatically or manually rotating images (providing a three-dimensional context). They were then tested on their symbolic understanding through a 'mapping test' and a 'generalisation test,' and again two-weeks later in a 'retention test' to examine learning after a delay. Engagement was video recorded throughout the experiment, coded and examined in relation to symbolic understanding. Despite no significant difference in immediate symbolic responding and retention across groups and conditions, significantly greater visual attention was found when manually rotating the images. Greater visual attention was related to more successful immediate word-picture-referent mapping for children with ASC alone. This suggests that interactive iPad tasks may increase visual attention in typical and atypical development, and visual attention may be related to immediate word-picture-referent mapping for some children with ASC.

Study 2 (Chapter 3) investigated whether providing a label, alongside the function of an object, benefitted symbolic understanding. This study aimed to investigate whether labelling symbols benefitted task performance in typical and atypical development. Participants were shown a pictorial symbol and given a description of the object's function, with or without a novel label. Children were then given 30 seconds to interact with an array of stimuli (pictures and interactive and non-interactive objects) in a ‘mapping test’ and a ‘generalisation test’ for each trial. Participant responses were coded to measure whether symbolic understanding differed between the labelled and unlabelled conditions. No significant difference in word-picture-referent mapping was found, with a high level of symbolic responding across groups and conditions. This suggests that labelling does not influence the symbolic understanding of some children with ASC and TD children, and a spontaneous measure of symbolic understanding (such as free-play) may reveal competencies in word-picture-referent mapping in ASC.

Whereas Study 1 (iconicity and symbol learning) investigated how children with ASC learn from a single-purpose iPad application, Studies 3 and 4 (Chapters 4 and 5) examined how children with ASC and a TD control group learn and engage with an interactive e-book, a setting more similar to every-day learning (Bus, 2001; McLeod & McDade, 2011). Study 3 investigated label learning in children with ASC and TD children. This study aimed to investigate how both groups learned and engaged with e-books compared to paper-books and whether engagement was related to label recall both immediately and after a delay. Participants were shown a series of novel and familiar animals during a self-contained labelling activity within a storybook (an e-book or a paper-book). They were given a new label for two novel animals and were subsequently tested on their label learning immediately and after a delay. Their engagement (visual attention and communication) was measured throughout the labelling activity. No difference in immediate label recall was found between groups or conditions, however the TD children alone demonstrated above chance levels of label retention after a two-week delay. Engagement with the labelling activity was not a significant predictor label of recall, however different engagement patterns emerged between groups – with TD children demonstrating greater visual attention and children with ASC demonstrating more instances of communication. This study suggests that vocabulary learning does not differ between paper-books or e-books and that some children with ASC do not retain new labels after a single labelling activity.

Study 4 examined the narrative comprehension of children with ASC and TD children. This study aimed to investigate how both groups learned and engaged with e-books compared to paper-books and whether engagement was related narrative comprehension on two tasks – multiple choice questions and a picture ordering task. A further aim was to investigate the influence of adult/experimenter involvement through comparing experimenter vs in-app voiceover narration of the e-book. No difference in performance was found across groups or conditions for either measure of narrative comprehension. Children with ASC were just as able as their language-matched peers to comprehend a narrative from a storybook. However, less off-focus looking time was found in the e-book conditions compared to the paper-book condition for both groups, suggesting greater visual attention towards the e-book. Visual attention was related to narrative comprehension for the TD children alone. These findings suggest that presenting a story on an iPad e-book compared to a paper-book does not influence narrative comprehension, nor does adult/experimenter narration of the story compared to in-app narration. Despite this, greater visual attention benefits narrative comprehension in typical development.

This final chapter will discuss the findings of the four studies with regards to the research questions presented above – evaluating how the current research aligns with the existing literature, outlining potential explanations for the findings and suggesting areas for future research. It is important to note that on average the current sample of children with ASC in this project were high-functioning individuals and so results of the four studies may not be directly generalisable to children with ASC with differing levels of functioning. Implications of the findings and potential limitations will be discussed followed by concluding comments.

6.1. Question 1: Does interactivity benefit the task performance of children with ASC?

No difference in task performance was found between interactive and non-interactive learning materials for children with ASC and TD children. Interactive learning materials are here defined as those that allow for touchscreen manipulation of on-screen stimuli. Non-interactive learning materials are here defined as images that do not respond to touch (static and automatically rotating images) and traditional paper-books. Study 1 (iconicity and symbol learning) found no significant difference in symbolic understanding between the interactive condition (manually rotating images) and the non-interactive conditions (automatically rotating images and static 2D images) with a high level of performance across groups. Study 3 (label learning) found no significant difference in label recall both immediately and after a delay between the e-book conditions and the paper-book condition. Finally, Study 4 (narrative comprehension) found no significant difference in performance on two comprehension measures between the e-book conditions and the paper-book condition. This suggests that, for both children with ASC and TD children, interactivity did not influence learning across different paradigms and materials. Previous research suggests that touchscreen interactivity may allow information to be processed as an active experience (Russo-Johnson et al., 2017), changing the way information is processed and retained (Highfield & Goodwin, 2013). Several studies have found that interactive iPad applications are more effective than paper-based mediums in improving the communication and vocabulary of children with ASC (Lorah et al., 2013; Lorah, et al., 2015; Sigafoos et al., 2013). However, the current findings suggest that, despite positive opinion and user-preference towards iPads (Clark et al., 2015; Richter & Courage, 2017), interactive learning materials may not translate into superior learning outcomes compared to traditional paper-based mediums. Overall, interactive features do not directly positively or negatively influence the task performance of children with ASC and TD children in the current research. Potential explanations for these findings will be outlined in this section.

There is a possibility that the materials used in the current research may not have been sufficiently sensitive to detect any benefit of interactivity. In Study 1 (iconicity and symbol learning) a high level of robust symbolic responding was found across all conditions (2D, automatic rotation and interactive), for both groups. This is encouraging, suggesting that coloured photographs are enough to create symbols with maximum ‘transparency’ (Fuller, 1997), and that additional measures to further improve pictorial realism (such as three-dimensional context and interactivity) are not necessary for symbol learning. Coloured photographs may provide the optimal conditions to foster symbolic understanding in children with ASC, enabling this population to perform as well as their TD peers. However, as coloured photographs were the baseline level of iconicity within this study, potentially accounting for the low levels of associative responding (3.1%), this may have masked the influence of interactivity within this experiment. Three-dimensional context (provided through interactivity and animation) may improve the pictorial realism of symbols that are not already considered ‘transparent’, such as ‘translucent’ black and white photographs or cartoons (Fuller, 1997). Future research could replicate this study using ‘translucent’ symbols, potentially increasing the sensitivity of the experiment to measure the influence of interactivity and animation on symbolic understanding.

In Studies 3 and 4 (investigating label learning and narrative comprehension respectively), the e-book used was not specially designed for the experiments and invited interaction with both relevant features and non-essential components within the story. In Study 3, both the target and distractor animals could be interacted with simultaneously during the labelling activity, responding to touch through animation and sound effects. In Study 4, the e-book provided sound effects and animations that highlighted both the central plot and miscellaneous features that were peripheral to the main storyline. Therefore, the interactive features within the e-book may not be highlighting salient learning information, potentially encouraging participants to focus on irrelevant details (De Jong & Bus, 2002; Krcmar & Cingel, 2014).

Children with ASC may be more susceptible to the detrimental influence of extraneous interactive and multimedia features due to weak central coherence, the tendency to prioritise the processing of local detail at the expense of the gestalt (Frith, 1989; Omar & Bidin, 2015). Moreover, some children with ASC experience executive dysfunction, potentially leading to increased distractibility and difficulty shifting attention between relevant and irrelevant stimuli (Christ et al., 2007; Richard & Lajiness-O’Neill, 2015; Rinehart et al., 2001). However, although the extraneous features included with the e-book had the potential to disadvantage performance, it is noteworthy that children with ASC did not perform significantly worse using the e-book compared to the paper-book for both experiments, despite slightly higher comprehension scores in the paper-book condition compared to the e-book conditions in Study 4 for both groups. Any potential bias towards extraneous information in the e-book conditions did not lead to significantly poorer learning. Despite this, it is possible that using interactive and multimedia features in more targeted ways (such as highlighting only relevant learning information) would improve learning in both children with ASC and TD children (Frith, 1989; Omar & Bidin, 2015; Takacs et al., 2015). Future research could investigate this by manipulating the relevance of the interactive and multimedia features within an e-book and examining this influence on the label learning and narrative comprehension of children with ASC and TD children. This could be achieved by creating three different versions of the same e-book story that highlight different information through interactivity and multimedia features. Children could experience a story and labelling activity in one of three conditions. First, an e-book that highlights only the relevant learning information. Second an e-book that highlights both relevant learning information and irrelevant information. Finally, an e-book that highlights only irrelevant information. Children could then be tested on their label recall and narrative comprehension to compare learning between conditions. Engagement could be measured in the same way as the current research during storybook reading and compared to performance on a label recall task and narrative comprehension measures to investigate whether engagement with relevant/irrelevant features influences learning.

Study 2 (labelling and symbol learning) did not involve iPad interactivity nor compared symbolic understanding between interactive and non-interactive conditions. However, the inclusion of interactive objects (responsive to touch with light up and sound effect features) allowed for a spontaneous measure of word-picture-referent mapping through free-play and object exploration as opposed to the forced-choice design of previous studies in which non-interactive objects were used. Such studies found that TD children more often demonstrated referential responding when the target was labelled compared to when it was not (Hartley & Allen, 2015b; Preissler & Bloom, 2007). This contrasted with participants with ASC, who exhibited no significant difference in referential responding between the labelled and unlabelled conditions (Hartley & Allen, 2015b). In the current study, although no significant difference was found between the labelled and unlabelled conditions, children with ASC performed as well as their TD peers, with a high level of symbolic responding across groups and conditions. It is possible that a spontaneous measure of symbolic understanding, such as free-play with interactive objects, may reveal competencies in word-picture-referent mapping in some children with ASC. Interactive object exploration may allow for a more naturalistic measure of symbolic understanding, more similar to everyday learning than forced-choice tasks and allowing for active task participation (Schreibman et al., 2015; Yurovsky, Boyer, Smith, & Yu, 2013).

However, it is important to note that all pictures presented alongside the objects in the exploration phase (to test for associative responding) were coloured photographs, providing maximum iconicity and ‘transparency’ (Fuller, 1997), potentially masking the influence of labelling within this experiment. As previously mentioned with regards to Study 1 (iconicity and symbol learning), future research could replicate Study 2 using ‘translucent’ black and white symbols as opposed to coloured photographs, potentially increasing the sensitivity of the experiment to measure the influence of labelling on symbolic understanding.

6.2. Question 2: How do children with ASC engage with interactive learning materials?

Overall, a different pattern of engagement (visual attention and communication) was found between interactive and non-interactive learning materials for children with ASC and TD children. In Study 1 (iconicity and symbol learning) visual attention was greater for children with ASC and TD children in the interactive condition compared to the 2D condition. However, more instances of communication were found in the 2D condition compared to the interactive condition. Although communication was not measured in Study 2 (labelling and symbol learning), children with ASC and TD children showed a higher level of interest (through play) towards the interactive objects compared to printed pictures and non-interactive objects during the exploration phase for each trial. In Study 3 (label learning), no significant difference in visual attention was found between conditions for children with ASC and TD children. However, more instances of communication were found in the paper-book condition compared to the e-book condition for both groups. Finally, in Study 4 (narrative comprehension), greater visual attention was found in the e-book conditions compared to the paper-book condition for children with ASC and TD children. Moreover, more instances of communication were found in the paper-book condition compared to the e-book conditions for both groups. Overall, the current studies suggest that interactive learning materials can be beneficial to certain types of engagement (visual attention) and detrimental to others (communication). If the aim is to reduce problem behaviour and increase task focus, interactivity may foster greater task oriented visual attention and reduce environmental distractibility. If the aim is to increase communication and joint engagement in children with ASC and TD children, non-interactive learning materials may foster a more social learning style than interactive alternatives. This pattern of engagement will be described in more detail within the following sub-sections.

6.2.1. Visual attention

Children with ASC and TD children were more visually engaged with interactive tasks/stimuli compared to non-interactive tasks/stimuli in Study 1 (iconicity and symbol learning), Study 2 (labelling and symbol learning) and Study 4 (narrative comprehension). No significant difference in visual attention was found between conditions in Study 3 (label learning). It is possible that this may be due to the short length of the task. On average, children with ASC and TD children spent 10 seconds looking at the target animals in the labelling activity. Such a short amount of time may not have been enough to capture variability in visual attention between conditions. It is possible that measuring visual attention across the entire labelling activity as opposed to the target animals alone may have been sufficient to capture variability in looking time in this study.

In Study 1 (iconicity and symbol learning) children with ASC and TD children visually attended to the task for approximately 13 seconds longer in the interactive condition compared to the 2D condition. The automatic condition (non-interactive animation) facilitated greater visual attention than the 2D condition but less than the interactive condition. In Study 2 (labelling and symbol learning), children with ASC and TD children exhibited greater interest and attention (through play) towards the interactive objects, with approximately 80.2% of time performing the action on the interactive objects compared to the pictures (0.7%) and non-interactive distractor objects (19.1%). In Study 4 (narrative comprehension), children with ASC demonstrated approximately 8% more visual attention towards the book/screen in the interactive e-book conditions compared to the paper-book condition, suggesting greater engagement with the e-book. TD children demonstrated only 2% more visual attention towards the book/screen in the interactive e-book conditions compared to the paper-book condition, suggesting that interactivity enhances the visual attention of children with ASC more so than TD children in this study.

It is possible that interactivity may facilitate a more active learning style than non-interactive tasks (Kucirkova, 2014). For example, in Study 1 (iconicity and symbol learning), participants in the interactive condition were able to manually manipulate pictures on the touchscreen to control their exploration. This is opposed to the 2D condition (in which the images were static) and automatic condition (in which the images rotated without user-involvement). Similarly, in Study 4 (narrative comprehension), participants in the e-book conditions could interact with characters and events within the story through manual manipulation of on-screen stimuli as opposed to the non-interactive printed paper-book condition. Such active involvement, through exploration and play, has been found to complement the preferred learning style of children (Highfield & Goodwin, 2013), potentially leading to less disengagement from the task. Although Study 2 (labelling and symbol learning) and Study 3 (label learning) did not measure task disengagement, Study 1 (iconicity and symbol learning) and Study 4 (narrative comprehension) found this to be the case. In Study 1, there was significantly more off-focus looking in the 2D condition for children with ASC and TD children (M_{ASC} = 13.06 seconds, M_{TD} = 7.90 seconds) compared to the interactive condition (M_{ASC} = 3.0 seconds, M_{TD} = 3.37 seconds). This was especially marked for children with ASC in this study. Moreover, in Study 4, there was a significantly greater proportion of off-focus looking in the paper-book condition for children with ASC and TD children (M_{ASC} = 0.10, M_{TD} = 0.09) compared to the two e-book conditions (M_{ASC} = 0.04,

M_{TD} = 0.04). These findings are consistent with previous research suggesting that interactive iPad applications may be beneficial for reducing distractibility in children with ASC and TD children by increasing interest and active task involvement (El Zein et al., 2016; Fletcher-Watson et al., 2015; Lee et al., 2015; Oakes, Ross-Sheehy, & Kannass, 2004).

Moreover, the findings of Study 2 (labelling and symbol learning) suggest that interactive objects (with light up features and sound effects) elicit a higher level of visual attention and interest compared to printed pictures and non-interactive objects. However, it is important to note that the interactive objects in Study 2 were also the target objects (the referent of the picture shown in the training phase). It is possible that the high level of visual attention and interest in the target object (exhibited through performing the action on the target object as opposed to the target picture and non-interactive distractor objects) is indicative of symbolic understanding as opposed to engagement. Participants who understood the referential nature of the symbol in the training phase may have spent more time interacting with the target object in the exploration phase. Future research should investigate whether the higher level of interest towards the target object in this study was due to engagement or symbolic understanding. This could be achieved by repeating this study with distractor objects that also have interactive features that are different to the target objects. If the participant demonstrates greater interest towards the target object (through performing the described action) compared to the distractor object, this would be indicative of greater symbolic understanding. However, if the participant demonstrates the same level of interest towards the target object and the distractor object, this would be indicative of engagement towards interactive objects.

6.2.2. Communication

Across the three studies measuring communication, children with ASC and TD children demonstrated more instances of communication in the non-interactive conditions compared to the interactive conditions, the opposite pattern to visual attention. In Study 1 (iconicity and symbol learning), instances of relevant speech were 50% higher in the 2D condition compared to the interactive condition. In Study 3 (label learning), instances of labelling doubled in the paper-book condition compared to the e-book conditions for children with ASC. Finally, in Study 4 (narrative comprehension), instances of gesturing increased significantly in the paper-book condition compared to the e-book conditions, with approximately 18% more relevant speech in the paper-book condition for children with ASC. Study 2 (labelling and symbol learning) did not measure communication and so is not included in this section. The current findings suggest that interactive tasks are not beneficial for increasing instances of communication and social engagement, particularly for some children with ASC. This aligns with the findings of Krcmar and Cingel (2014) who found more relevant discourse between adults and TD pre-schoolers when learning via paper-books compared to e-books, extending this finding to high-functioning children with ASC. It is possible that the self-contained nature of iPad learning (Allen et al., 2016) combined with the increased cognitive load provided by interactive touchscreen features (Kirkorian, 2018; Richter & Courage, 2017) may diminish the need to share salient information with the adult, fostering a more solitary learning style than paper-based mediums (Radesky et al., 2015; Schugar et al., 2013). This may hinder the facilitation of social interaction in individuals with ASC, who often experience wide-ranging social and communicative impairments (Kjelgaard & Tager-Flusberg, 2001; Pelphrey et al., 2011). Moreover, some children with ASC often become fixated on a topic/item of interest at the expense of other stimuli (Bryson et al., 2004; Liss et al., 2006; Zwaigenbaum et al., 2005). Consequently, children with ASC may be preoccupied with interactive and multimedia features, leading to less communication and adult orientation.

6.3. Question 3: Is there a relationship between engagement and task performance in children with ASC?

A relationship between visual attention and task performance was found in Study 1 (iconicity and symbol learning) and Study 4 (narrative comprehension), however this was not the case in Study 3 (label learning). A different pattern of results emerged between children with ASC and TD children in Studies 1 and 4. Study 2 (labelling and symbol learning) did not examine the relationship between engagement and task performance and so will not be discussed in this section. In Study 1 (iconicity and symbol learning), children with ASC who exhibited greater visual attention towards the task (regardless of condition) demonstrated more robust symbolic responding in the test phase. Despite also exhibiting a high level of visual attention throughout the training phase, visual attention was not related to robust symbolic responding for TD children. In Study 4 (narrative comprehension), TD children who exhibited greater visual attention during the storybook reading (regardless of condition) demonstrated higher scores on both measures of narrative comprehension - multiple choice questions (measuring fact-based knowledge of the story) and a picture ordering task (measuring temporal sequencing of the narrative). This suggests that visual attention predicts the performance of TD children on tasks tapping different aspects of narrative comprehension. Although children with ASC were also highly visually engaged throughout the storybook reading, visual attention was not related to narrative comprehension for this group. No relationship between engagement and performance was found in Study 3 (label learning). As previously mentioned, this may be due to the short length of the task resulting in a failure to capture variability in visual attention between conditions.

The findings of Study 1 (iconicity and symbol learning) and Study 4 (narrative comprehension) suggest that, for children with ASC, the relationship between visual attention and performance may be dependent on the design of the task. When information was presented via a specially designed, single-purpose iPad application (Study 1), visual attention towards the task was beneficial for learning in this population. Symbols were presented one at a time on a blank white background, eliminating the potential influence of extraneous on-screen information. Visually engaging and relevant stimuli may increase the child's attention away from environmental distractors (Oakes et al. 2004), particularly aiding the learning of children with poorer executive functioning (Richter & Courage, 2017), such as those with ASC (Finnegan & Mazin 2016; Richard & Lajiness-O'Neill, 2015; Rinehart et al., 2001). In contrast, when information was presented via an e-book compared to a paper-book (Study 4), visual attention only benefitted the learning of TD children. Both relevant and irrelevant information was presented through interactive and multimedia features in the e-book. Despite children with ASC demonstrating a high level of visual attention while listening to the story, with 92% of time spent orienting their gaze towards the page/screen, visual attention was not related to narrative comprehension for this group. As children with ASC often demonstrate weak central coherence (Frith, 1989; Omar & Bidin, 2015), this population may be more easily distracted by irrelevant information presented within a task compared to TD children (Renner et al., 2006; Townsend et al., 1996; Werner et al., 2000).

Despite demonstrating less distractibility in the e-book conditions in Study 4 (narrative comprehension) (El Zein et al., 2016; Fletcher-Watson et al., 2015; Lee et al., 2015; Oakes et al., 2004), it cannot be determined whether children were visually attending to information that was relevant to the central plot of the story or miscellaneous background illustrations and animations. Eye-tracking could be used in future research to examine which features on the screen/page children are visually attending to during storybook reading (Caruana et al., 2017). This could then be used to compare those who are attending to central or peripheral information to test the theory that engagement (visual attention) influences narrative comprehension. If children visually attend to central information that is relevant to the plot, it is expected that they would exhibit greater narrative comprehension than those who visually attend to peripheral/extraneous information during storybook reading, especially for children with ASC (Frith, 1989; Renner et al., 2006; Townsend et al., 1996; Werner et al., 2000).

It is also noteworthy that no relationship between visual attention and task performance was found in Study 1 (iconicity and symbol learning) for TD children. A potential explanation is that this population may already possess robust symbolic understanding and consequently demonstrate no variability in performance (Ganea et al., 2009). This study included a TD group with an average age of 3 years and 5 months. As 2-year-old TD children have been found to demonstrate reliable referential responding (Preissler & Carey, 2004; Samuelson & Smith, 1999), this skill may already be well-established for the TD children. This contrasts with children with ASC, who can often experience difficulties with symbolic understanding into later childhood (Hartley & Allen, 2015a; Hartley & Allen, 2015b).

Consequently, the TD children may not have needed to be as attentive to the task as the children with ASC to learn new symbols.

In contrast to visual attention, no relationship was found between oral communication and task performance for both children with ASC and TD children. Although measures such as task relevant and irrelevant speech may indicate engagement/disengagement (Moody et al., 2010; Richter & Courage, 2017) such measures are prone to variability due to individual differences in verbal ability (Smith, Mirenda, & Zaidman-Zait, 2007; Speidel, 1989). Despite not including any entirely non-verbal children in the studies, the level of verbal ability was not measured. Therefore, future research investigating the relationship between communication and task performance should include a measure of verbal ability to control for individual differences in expressive language for both populations.

In terms of gestural communication, gesture was negatively related to narrative comprehension in Study 4 for TD children only. Gesture was also negatively related to chronological age and receptive vocabulary score for this population. Therefore, children who produced more gestures were also younger and thus may have had a poorer capacity for sustained attention and inhibition control (Betts, Mckay, Maruff, & Anderson, 2006; Reck & Hund, 2011). This may explain the relationship between gesture and poorer learning outcomes in TD children.

Overall, the current studies suggest that the relationship between visual attention and performance is dependent on the design of the task for some children with ASC. Task-oriented visual attention benefitted the symbol learning of children with ASC from a single purpose iPad application (Study 1), presenting symbols one at a time against a blank background. However, when both relevant and irrelevant multimedia and interactive features were included, task-oriented visual attention was not related to narrative comprehension for children with ASC (Study 4). This research suggests that perceived attentiveness towards a task may not translate into learning outcomes for this population. Finally, expressive language ability should be measured and controlled for within future studies, to allow for the use of oral communication as a measure of task engagement.

6.4. Does adult/experimenter involvement benefit the task performance of children with ASC?

Adult involvement, through experimenter labelling (Study 2) and experimenter narration (Study 4) did not significantly benefit the task performance of children with ASC or TD children. Specifically, in Study 2 (labelling and symbol learning) a label was provided alongside a description of an object’s function, but this did not increase symbolic understanding in children with ASC or TD children. Moreover, Study 4 (narrative comprehension) found that narrative comprehension was not influenced by the type of story narration (experimenter vs in-app voiceover). Despite slightly higher narrative comprehension scores for both groups when the experimenter narrated the storybook, there was no significant difference in narrative comprehension between the types of storybook narration. The level of adult/experimenter involvement was not manipulated in the training phase in Study 1 (iconicity and symbol learning) and the labelling activity in Study 3 (label learning), with the experimenter providing the same level of interaction and information across all conditions. The findings of Study 2 are in line with previous research regarding the influence of labelling on the symbolic understanding of children with ASC (Harley & Allen, 2014b), however the current findings contrast with previous research for TD children, who have been found to benefit from experimenter labelling when learning new symbols (Hartley & Allen, 2014b; Preissler & Bloom, 2007). Moreover, the findings of Study 4 contrast with previous research that found adult/experimenter involvement to be beneficial to narrative comprehension for children with ASC and TD children (Hindman et al., 2008; Mucchetti, 2013; Sénéchal & LeFevre, 2002). The following findings may be explained by several factors.

First, as with Study 1 (iconicity and symbol learning), it may be that iconicity is masking the influence of labelling on the symbolic understanding of children with ASC in Study 2. All images were ‘transparent’ coloured photographs (Fuller et al., 1997). This contrasts with Preissler and Bloom (2007) and Hartley and Allen (2015b) who used ‘translucent’ black and white line drawings in their research. As previously explained, children with ASC have been found to benefit from a high level of pictorial iconicity when matching symbols to real-world referents (Hartley & Allen, 2015a). Therefore, it is possible that any potential benefit from labelling may be obscured by ceiling effects caused by using highly iconic symbols in this study. Indeed, a high level of symbolic responding and symbol generalisation was found across groups and conditions, suggesting that all participants were demonstrating robust symbolic understanding in this study (Ganea et al., 2009). As suggested for Study 1, future research could replicate this study using ‘translucent’ symbols, potentially increasing the sensitivity of the experiment to measure the influence of labelling on symbolic understanding in this population.

Second, the experimenter still maintained task involvement across Study 2 (labelling and symbol learning) and Study 4 (narrative comprehension) regardless of condition. In Study 2, the experimenter provided a description of the object’s function with and without labelling the target item – e.g. “this lights up if you press the white button”. Therefore, the experimenter was involved in the task regardless of condition. Previous research has found that providing a description of an object’s function can facilitate the successful use of symbols in 14-month-old TD children (Booth & Waxman, 2002) and that children with ASC possess a ‘function bias’ in symbol generalisation, more often generalising a label to a referent based on function rather than shape (Field, Allen & Lewis, 2016b). Therefore, this information provided by the experimenter may have been enough to facilitate symbolic responding in typical and atypical development regardless of labelling.

Moreover, in Study 4 (narrative comprehension), the experimenter may have been mediating performance through co-viewing in all conditions (Nathanson, 2001). Although the experimenter adhered to a strict protocol to avoid providing additional guidance to the child, the experimenter was still present beside the child throughout the duration of the storybook reading regardless of narration. Participants could still interact with the experimenter if they chose to. A similar percentage of adult oriented looking time was found in the e-book narrated iPad condition (ASC = 2%, TD = 5%) compared to the experimenter narrated iPad condition (ASC = 1%, TD = 6%). Moreover, comparable levels of relevant speech were found between the experimenter narrated iPad condition (ASC = 9.92 instances, TD = 10.57 instances) and the e-book narrated iPad condition (ASC = 9.00 instances, TD = 7.92 instances), particularly for children with ASC. These findings suggest that children demonstrate the same levels of orientation towards the experimenter regardless of narration. Therefore, the presence of the experimenter beside the child may be enough to create a shared reading situation in all conditions, which is beneficial to the narrative comprehension of both typically and atypically developing children (Mucchetti, 2013; Zevenbergen & Whitehurst, 2003). Future research could manipulate the presence of the experimenter beside the child during the task. This could be achieved by repeating Study 4 (narrative comprehension) with two conditions. In both conditions the e-book could be read using in-app narration, with the experimenter either sitting beside the child or exiting the room during the story. Narrative comprehension could be compared between conditions to investigate the influence of co-viewing on performance.

Overall, the current studies suggest that certain aspects of adult/experimenter involvement (such as labelling and story narration) do not significantly influence the task performance of some children with ASC and TD children. However, it is still unclear whether other aspects of experimenter involvement (such as providing descriptions of object function and co-viewing) influence learning in both populations. Therefore, further research is needed to fully examine the influence of adult/experimenter involvement on task performance for children with ASC and TD children to inform the use of independent iPad learning within the classroom.

6.5. Theoretical Implications

Study 1 has contributed to the theory of iconicity in symbol learning, suggesting that there is a threshold over and above which any enhancement to iconicity will not benefit performance. Previous research has theorised that children with ASC rely on a high level of iconicity to successfully map symbols with their intended referents (Hartley & Allen, 2015a). Greater pictorial realism (such as coloured photographs) has been found to improve symbolic understanding compared to abstract symbols (such as line drawings) (Fuller et al., 1997; Hartley & Allen, 2015b). However, it was not known whether three-dimensional and interactive symbols presented on a screen would improve iconicity and the realism of the images beyond the realms of 2D coloured photographs – potentially increasing symbolic understanding in ASC. Study 1 found that 2D coloured photographs are enough to elicit successful symbol learning in ASC, and under such conditions children with ASC perform as well as their TD peers. Consequently, any additional measures to improve the iconicity of images are not necessary to foster symbolic understanding for children with ASC. This could potentially inform the teaching of new symbols to children with ASC within the classroom, suggesting that 2D coloured photographs are the optimal stimuli to foster symbolic understanding in this population.

Study 2 examined the theory that language (specifically labelling) scaffolds symbolic understanding in typical development (Callaghan, 2008). Previous research suggests that TD children demonstrate greater symbolic understanding and generalisation to different category members when a symbol is labelled compared to when it is unlabelled (Booth & Waxman, 2002; Preissler & Bloom, 2007; Waxman & Booth, 2003). However, Hartley and Allen (2015b) found that this was not the case for children with ASC, who exhibited no difference in symbolic understanding when the symbol was labelled compared to when it was unlabelled. The current study included both TD children and children with ASC and compared symbolic understanding between labelled and unlabelled conditions. No significant difference was found between conditions, with a high level of symbolic understanding for both groups. It may be that naming is no more beneficial than other forms of information, such as description of function (Field, Lewis, & Allen, 2016b). As previously explained, a description of the target object’s function was provided alongside the symbol in the training phase regardless of condition, and consequently a linguistic cue was provided to every child. This may explain the high level of symbolic understanding across conditions. However, it is important to note that, as with Study 1 (iconicity and symbol learning), symbols used in this study were realistic coloured photographs and so it is difficult to know whether the high level of symbolic understanding is due to language or iconicity – which has been found to benefit symbolic understanding in ASC (Hartley & Allen, 2014b; Hartley & Allen, 2015a; Hartley & Allen, 2015b).

Study 3 contributed the theory of word/label learning in children with ASC and typical development. Previous research suggests that children with ASC do not possess qualitatively different word learning mechanisms to TD children, however word learning mechanisms may be less efficient in ASC (Hartley et al., 2019; Hartley et al., 2020). Children with ASC may require multiple exposures to new words to facilitate successful delayed recall (Haebig et al., 2017; Hartley et al., 2019; Hartley et al., 2020) due to the language difficulties experienced by this population (Kjelgaard & Tager-Flusberg, 2001; Pelphrey, Shultz, Hudac, & Vander Wyk, 2011). In the current study, children with ASC and TD children were given two new labels for novel animals, repeated twice in a labelling activity. They were then tested on their label recall immediately and after a two-week delay. Robust label recall was examined – whether participants correctly recalled both labels immediately and after a delay. TD children performed above chance (11%), with approximately 26% of participants correctly recalling both labels at both time points, compared to approximately 10% of children with ASC. Despite comparable immediate recall between groups, TD children more often retained the new label information over time. This finding could potentially guide the teaching of new vocabulary to children with ASC within the classroom, suggesting that two exposures to a new word is not enough to facilitate successful label retention in some children with ASC. This finding also emphasises that successful immediate recall (fast mapping) is only the first step in the slow and effortful word learning process (Axelsson & Horst, 2014).

Study 4 has contributed to the theory of narrative comprehension in children with ASC. Specifically, that children with ASC have a deficit in inferential narrative comprehension (requiring the sequencing of key events and the integration of text information with the participant's own knowledge) while performing as well as their TD peers on fact-based comprehension questions (Norbury & Bishop, 2002; Nuske & Bavin, 2011). Researchers have theorised that this disparity in performance is due to weak central coherence in ASC –

the tendency to prioritise the processing of local information at the expense of the gestalt (Frith, 1989). In the current study, participants were administered multiple-choice questions (measuring knowledge of individual facts) and a picture ordering task (measuring the sequencing of key events) immediately after storybook reading. As expected, children with ASC performed as well as their TD peers on the fact-based questions. However, contrary to predictions, children with ASC also performed as well as their TD peers on the picture ordering task – requiring some inference-making abilities. This suggests that some children with ASC do not have a deficit in narrative comprehension compared to TD children on both fact-based and inferential comprehension questions. However, it is important to note that while the picture ordering task required some inference-making ability to allow for the integration of temporal story information to create a coherent narrative (Oakhill & Cain, 2012) it did not fully tap into the inference-making abilities of children with ASC. For example, it did not require the integration of text information with the participant's own knowledge – another key element of inference-making (Cain & Oakhill, 2014; LAARC & Muijselaar, 2008; Tarchi, 2015). To fully investigate this theory, future research could expand the multiple-choice question task used in the current study to include questions that require inference-making and the integration of the child's own experience with storybook information.

Study 1 (iconicity and symbol learning) and Study 4 (narrative comprehension) provide further evidence to support the weak central coherence theory (Frith, 1989), in addition to the 'Coherence Principle' in multimedia learning (Harp & Mayer, 1997). Previous research suggests that the simultaneous presentation of information to multiple modalities can be conducive to learning when minimal miscellaneous information is included (Mayer & Moreno, 1998). Moreover, irrelevant information is particularly detrimental for individuals learning a new skill (Mayer & Moreno, 1998) and young children with limited cognitive resources (Kirkorian, 2018), potentially increasing cognitive load and subsequently adding strain to working memory (Sweller, 2005). Although the relevance of multimedia and interactive information was not directly manipulated in the current research, a different relationship between engagement and learning can be found between children with ASC and TD children in Studies 1 and 4. When symbols were presented one at a time on the screen against a blank background (Study 1), greater visual attention towards symbols was related to more robust symbolic understanding in children with ASC. In contrast, when both relevant and irrelevant information was presented on an e-book (Study 4), greater visual attention was only related to performance for the TD group.

The findings of Studies 1 (iconicity and symbol learning) and 4 (narrative comprehension) suggest that the relevance of information may be particularly important for some children with ASC, as TD children in Study 4 were not impeded by the mixture of relevant and irrelevant interactive and multimedia features within the e-book. This may be due to the weak central coherence and executive dysfunction experienced by some children with ASC (Christ et al., 2007; Frith, 1989; Omar & Bidin, 2015; Richard & Lajiness-O'Neill, 2015). Although not directly measured within this thesis, the findings of Studies 1 and 4 are consistent with the weak central coherence theory of ASC, suggesting that children with ASC, who may have difficulty with global information processing, are more susceptible to the distracting influence of irrelevant information during a task.

6.6. Methodological Implications

Considering the findings of the thesis, two methodological implications are here suggested. First, the current research refined existing engagement coding schemes to create a more concise coding rubric, measuring only visual attention and communication, to avoid overlapping engagement categories (Moody et al., 2010; Richer & Courage, 2017; Roskos et al., 2012). The current coding scheme removed measures such as 'persistence, enthusiasm and compliance' (Richter & Courage, 2017), which involved coding the same behaviour (such as relevant speech and task oriented looking time) in multiple categories. Moreover, the current research has increased the generalisability of engagement coding to different tasks and populations. In previous research, task engagement was coded only for TD pre-schoolers whilst listening to a storybook/e-book (Moody et al., 2010; Richter & Courage, 2017; Roskos et al., 2012). Study 1 (iconicity and symbol learning), Study 3 (label learning) and Study 4 (narrative comprehension) demonstrate that this engagement coding scheme can be successfully used to code the engagement of children with ASC *and* TD children when learning from a storybook/e-book and a single-purpose iPad application with a high degree of inter-rater reliability. All reliability ratings across the three studies were found to be greater than .97, representing high agreement according to Cicchetti (1994) where scores on or above .75 are classified as 'excellent'. Therefore, the research presented within this thesis has created a more refined and generalisable engagement coding scheme than previous research, which can be successfully applied by multiple observers with a high level of accuracy and agreement.

Second, the spontaneous measure of symbolic understanding in Study 2 (labelling and symbol learning) may reveal competencies in word-picture-referent mapping in some children with ASC. Study 2 measured the influence of labelling on symbolic understanding using an object exploration task, in which participants could interact freely with an array of stimuli. This differed from the forced-choice design of previous mapping tasks (Hartley & Allen, 2015b; Preissler & Bloom, 2007), allowing for spontaneous word-picture-referent mapping through free-play. Previous research suggests that, while children with ASC may find highly structured tasks useful for teaching new skills (Callenmark, Kjellin, Rönnqvist, & Bölte, 2014; Lovaas, 1987; Paul & Cohen, 1985; Schreibman, 2005) a more naturalistic approach, such as free-play, may suit the preferred learning style of children by fostering active task participation (Yurovsky, Boyer, Smith, & Yu, 2013). Children with ASC have been found to demonstrate increased symbolic understanding and generalisation of skills to different tasks and settings when learning using naturalistic approaches and activities (Carr & Kologinsky, 1983; Draget et al. 2006; McGee, Krantz, Mason, & McClannahan, 1983; Schreibman et al., 2015). Indeed, Study 2 found that children with ASC performed as well as their TD peers across all conditions. However, it is important to note that the current experiment is still dissimilar to everyday learning. The study was still conducted in a controlled experimental setting alongside an unfamiliar adult as opposed to the class teacher or caregiver. Therefore, despite including a free-play paradigm as opposed to forced-choice mapping, the findings still may not be generalisable to real-world symbol learning (Schreibman et al., 2015).

6.7. Educational Implications

Aside from the educational implications presented in section 6.5, three further educational implications are here suggested. First, the findings suggest that interactive iPad applications may not be any more effective at improving learning than paper-based/non-interactive mediums for some children with ASC and TD children. No *direct* influence of interactivity was found on the learning of typically and atypically developing children regarding three skills - symbolic understanding, label learning and narrative comprehension. In Study 1 (iconicity and symbol learning) no difference in symbolic understanding was found between the presentation conditions (2D, automatic rotation and interactive) for children with ASC and TD children. In Study 3 (label learning) and Study 4 (narrative comprehension) no difference performance was found between the interactive e-book conditions compared to the paper-book condition. Additionally, in Study 4 it took half the time to finish the paper-book compared to the e-book while eliciting the same performance. Therefore, paper-based and non-interactive learning materials may deliver the same benefits to learning as interactive materials in half the time.

Second, engagement may be the mechanism through which interactivity *indirectly* influences learning. In a single-purpose iPad application (Study 1 – iconicity and symbol learning) showing only relevant information, visual attention (which was greater in the interactive condition compared to the non-interactive conditions) was related to greater robust symbolic understanding for children with ASC. Moreover, in a storybook/e-book with both relevant and irrelevant multimedia features (Study 4 – narrative comprehension), visual attention (which was greater in the e-book conditions compared to the paper-book condition) was related to greater narrative comprehension for TD children alone. This suggests that, when including only relevant interactive and multimedia effects, the greater visual attention elicited from interactive tasks can benefit the learning of some children with ASC.

Finally, as previously explained, interactive tasks may benefit certain types of engagement (visual attention) while being detrimental to others (communication). Study 1 (iconicity and symbol learning) found greater visual attention in children with ASC and TD children when participants could manually interact with the symbols on the iPad screen compared to when the symbols were static (2D) or automatically rotating. In contrast, children with ASC and TD children demonstrated less communication in the interactive condition compared to the 2D and automatic conditions. Despite no significant difference in visual attention between conditions for children with ASC and TD children in Study 3 (label learning), both groups demonstrated less communication in the e-book conditions compared to the paper-book condition. Furthermore, greater visual attention towards the story was found in the e-book conditions compared to the paper-book condition for children with ASC and TD children in Study 4 (narrative comprehension), with less communication in the e-book conditions compared to the paper-book condition. These findings suggest that interactive iPad applications may be beneficial for encouraging visual attention and a subsequent reduction in problem behaviour and restlessness. However, interactive iPad applications may be detrimental in terms of social engagement and communication. Therefore, this finding may guide educators towards appropriate use of interactive tasks dependent on the unique needs the learner.

6.8. Limitations

In addition to the limitations discussed above, the five most pertinent limitations for future research will be outlined in this section. First, the findings of the four studies in this thesis may have limited generalisability to real world learning due to the methodologies used across the four studies. Studies 1 and 2 investigated symbol learning using a single-purpose iPad application with two trials (Study 1) and an object exploration task with four trials (Study 2). Although both studies go beyond the single-trial methodology of previous research in this area (Hartley & Allen, 2015b; Preissler, 2008), such a limited number of trials still cannot be generalised to symbol learning at large. Moreover, Studies 3 and 4 measured label learning, narrative comprehension and engagement using a single e-book story, in contrast to previous research which measured learning from multiple short stories (Nuske & Bavin, 2015). Therefore, the findings of Studies 3 and 4 may not be generalisable to other storybooks or narrative texts. Future research could repeat the studies with a greater number of trials (for symbol learning) and storybooks (for narrative comprehension) to increase the generalisability of the results to real world learning.

Second, the findings in this thesis may have limited generalisability to real world learning due to the overlap in samples across the four studies. Some of the same children with ASC and TD children were used across studies, therefore the samples of the four studies were not entirely separate from one another. Some of the effects observed in the studies (such as robust symbol learning in Studies 1 and 2) may be due to having the same children who showed the same tendencies in each study. Therefore, the findings of all four studies cannot be generalised to a wider population of children with ASC and TD children. The findings may simply represent the individual tendencies of a small group of children. Future research could repeat the studies presented in this thesis with separate groups of children with ASC and TD children to increase the generalisability of the findings to real world learning.

Third, although this thesis has presented the weak central coherence theory and executive dysfunction (with a focus on attention) as potential explanations for learning difficulties in children with ASC (Frith, 1989; Mayes & Calhoun, 1999; Mayes & Calhoun, 2007), these theories were not directly manipulated within the experiments. For example, Study 3 (label learning) and Study 4 (narrative comprehension) did not manipulate the relevance of multimedia information and interactivity during storybook reading to measure the influence of weak central coherence on task performance in this population. Moreover, although children with ASC often have poorer attentional abilities than TD children (Mayes & Calhoun, 1999; Mayes & Calhoun, 2007), a standardised measure of attention was not used in the current studies. Therefore, the level of attention dysfunction within the current sample is not known. As previously suggested, future research could manipulate the relevance of interactive and multimedia features within a storybook/e-book to directly measure the influence of weak central coherence on the learning of children with ASC from interactive learning materials. Furthermore, future research should include a standardised measure of attention to further characterise the sample and allow for a comparison in task performance and engagement between children with low/high attentional abilities.

Fourth, in the studies of symbol learning (Studies 1 and 2), children with ASC scored lower on the Social Communication Questionnaire (SCQ) compared to previous studies of this type, suggesting that higher-functioning individuals were used in the current research. In Study 1 (iconicity and symbol learning) and Study 2 (labelling and symbol learning) children with ASC had a lower mean SCQ score by 8.17 points and 10.03 points respectively compared to previous research (Allen et al., 2015). It is possible that high-functioning individuals with ASC do not possess the same difficulties with symbolic understanding as lower-functioning individuals, who may be more natural associative responders (Preissler, 2008). This could account for the comparable levels of symbolic understanding between children with ASC and TD children in both studies. Future research could compare higher-functioning and lower-functioning individuals with ASC using the same methodology to compare performance amongst individuals with a range of abilities and allow results to be generalised to a wider population of children with ASC.

Finally, in all four studies children with ASC and TD children were not matched on their chronological age. This is in line with previous studies in a similar area of research that also did not match children with ASC and TD children on their chronological age (Field, Allen, & Lewis, 2016a; Maljaars, Noens, Scholte, & van Berckelaer-Onnes 2012; Tager-Flusberg, 1985; Tek, Jaffery, Fein, & Naigles 2008). As all tasks involved an aspect of language (e.g. labelling and narrative comprehension), children were instead matched on their receptive vocabulary score or their receptive vocabulary score and nonverbal IQ score. Chronological age was not a matching criterion as children with ASC are a heterogenous population in which overall receptive language ability and functioning can vary significantly despite chronological age (Weismer, Lord, & Esler, 2010). Thus, to match for chronological age would most likely have resulted in a control sample with higher verbal skills that fell into a narrower range of performance. However, although children with ASC do not follow the same developmental trajectory as TD children (Baron-Cohen et al., 1986; Baron-Cohen, 1991; Loveland et al., 1990; Nuske & Bavin 2011; Shah & Frith, 1993), some skills may be age-appropriate (Baron-Cohen, 1991), potentially leading to an ASC sample that is more cognitively advanced than the younger TD children. Despite this, no correlation was found between chronological age and performance for children with ASC across all studies, suggesting that older children with ASC did not have an advantage based on their age.

6.9. Conclusion

This thesis has provided a comprehensive literature review outlining the weaknesses in symbolic understanding, receptive vocabulary, and narrative comprehension in children with ASC. Populations with known attentional difficulties, such as those with ASC, may benefit from iPad-based learning (Boone & Higgins, 2007), and interactive iPad applications are proposed to aid children’s learning and engagement through increasing task interest and by providing opportunities for information to presented through multiple modalities – such as sound, touch and animation (El Zein et al., 2016; Kucirkova et al., 2014; Takacs et al., 2015). Such applications may complement a non-social learning style by reducing the need for adult involvement in the learning process (Pelphrey et al., 2011; Radesky et al., 2015; Schugar et al., 2013). However, despite positive user-perception, research to-date had yielded mixed results as to the efficacy of iPads to improve the learning of children with ASC (Fletcher-Watson et al., 2015; Kucirkova et al., 2014; Richter & Courage, 2017; Lorah et al., 2013; Lorah et al., 2015; Sigafoos et al., 2013). Moreover, engagement and its relation to learning outcomes had not yet been investigated in typical and atypical development (Moody et al., 2010; Richter & Courage, 2017; Roskos et al., 2012).

The four studies in this thesis addressed the gaps within the literature by investigating (i) whether interactivity benefits the task performance of children with ASC (ii) how children with ASC engage with interactive learning materials (iii) the relationship between engagement and task performance in children with ASC (iv) whether adult/experimenter involvement benefits the task performance of children with ASC. Study 1 (iconicity and symbol learning), Study 3 (label learning) and Study 4 (narrative comprehension) found that interactivity does not *directly* benefit the task performance of children with ASC and TD children, with no strong evidence of a difference in performance between interactive and non-interactive conditions for all studies. A different pattern of engagement was found between interactive and non-interactive conditions for children with ASC and TD children. In Studies 1 (iconicity and symbol learning) and 4 (narrative comprehension), greater visual attention was found towards the task in the interactive conditions compared to non-interactive conditions. However, greater communication was found in the non-interactive conditions compared to interactive conditions, especially for the children with ASC. These findings suggest that some children with ASC and TD children engage with interactive learning materials with a high degree of visual attention, and that this may be at the expense of social engagement for children with ASC.

Although no direct relationship was found between interactivity and task performance, an indirect relationship was found in Study 1 (iconicity and symbol learning) and Study 4 (narrative comprehension). Visual attention was greater in the interactive conditions, and greater visual attention was related to symbolic understanding (using a single-purpose iPad application) for children with ASC, and two measures of narrative comprehension (using an e-book) for TD children. This finding suggests that, when only relevant information is highlighted using interactive and multimedia features, visual attention may be the mechanism through which interactivity improves learning in some children with ASC. Finally, Study 2 (labelling and symbol learning) and Study 4 (narrative comprehension) suggest that adult/experimenter involvement does not significantly influence the symbol learning and narrative comprehension of children with ASC, although the presence of the adult through co-viewing in all studies may have influenced performance (Nathanson, 2001).

Overall, the current research suggests that interactive learning materials do not directly positively or negatively influence task performance for children with ASC and TD children compared to paper-based/non-interactive learning materials. However, interactive learning materials may elicit greater visual attention towards a task, which in turn may benefit learning in typical and atypical development depending on the design of the task. Adult/experimenter involvement (through labelling and narration) may not be necessary for learning in some children with ASC and TD children. Considering the findings, this thesis suggests theoretical, methodological, and educational implications regarding how interactive iPad tasks could be used within research and the classroom and provides direction for future research.

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