Reading Between the Lines… Reading in Typical and Atypical Development

Rebecca May Lucas

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Department of Psychology
Royal Holloway, University of London

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Declaration of Authorship

I, Rebecca May Lucas, hereby declare that this work was carried out in accordance with the Regulations of the University of London. I declare that this submission is my own work, and to the best of my knowledge does not represent the work of others, published or unpublished, except where duly acknowledged in the text. No part of this thesis has been submitted for a higher degree at another university or institution.

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Abstract

This thesis presents a series of studies investigating the reading skills of children aged 7-14 with Autism Spectrum Disorders (ASD). The first three studies systematically investigated whether there is an intimate relationship between oral language skill and both decoding and comprehension for children with ASD, as is the case for their typically developing (TD) peers. Study 1 assessed single word reading and attainment was influenced by language ability, whilst reading mechanisms were associated with ASD diagnosis. Study 2 investigated reading comprehension. Despite being able to read single words, many children with ASD and concomitant language impairments were unable to read connected text. However children with ASD who could read accurately and fluently at the sentence level did benefit from semantic coherence, but were less sensitive to syntactic coherence. Passage level reading comprehension was predicted by vocabulary knowledge; ASD status did not account for any unique variance. Study 3 explored one specific component of reading comprehension, namely the ability to make inferences. Inferencing skill aligned with language competence and participants with language impairments had an increased likelihood of a disproportionate difficulty with inferencing. For TD children, there is a relationship between reading development and the home literacy environment. Study 4 determined that child characteristics influence the HLE of children with ASD. Children with ASD and language impairment engage in shared book reading more frequently than their proficient ASD peers, however children with ASD (regardless of language phenotype) engage in shared book reading for a shorter duration than their TD peers. The thesis then transitions from how children with ASD 'learn to read' to whether those that can read subsequently 'learn through reading'. Study 5 presents the first evidence that the presence of orthography during vocabulary teaching facilitates the phonological, semantic and orthographic learning of children with ASD.

Dissemination of Findings

Publications

Lucas, R., & Norbury, C. (2014). Orthography facilitates vocabulary learning for children with Autism Spectrum Disorders. *The Quarterly Journal of Experimental Psychology.*

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Conference Presentations

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Lucas, R., & Norbury, C. (2013). Orthography facilitates vocabulary learning for children with Autism Spectrum Disorders. *Poster presented at the International Meting for Autism Research (IMFAR), May 2013, San Sebastian, Spain*

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Chapter One: General Introduction

Thesis Overview

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterised by a) impairments in social interaction and social communication and b) a restricted repertoire of interests and behaviours (American Psychological Association, 2013a). These differences can impact upon many areas of development, including reading proficiency. In 1943, Kanner noted that “Reading skills are acquired quickly, but the children read monotonously, and a story or moving picture is experienced in unrelated proportions rather than in its coherent totality” (p.250). This profile of precocious decoding skill, but impaired reading comprehension has been consistently reported (cf. Brown, Oram-Cardy & Johnson, 2013). Research has explored the extent to which cognitive deficits that characterise ASD, specifically the Theory of Mind account (Baron-Cohen, Leslie, & Frith, 1985), Executive Dysfunction theory (Hill, 2004) and Weak Central Coherence (Happé & Frith, 2006), can account for this reading profile (Chapter 2).

Fewer studies have examined the extent to which factors influencing the reading skill of TD children impact upon the reading development of children with ASD. Despite the well-evidenced relationship between language skill and reading competence in typical development, it is only relatively recently that researchers have explored the extent to which language ability influences the reading skill of children with ASD. Within ASD there is great heterogeneity in language competence and this had led to the proposal that there are two distinct language phenotypes, some children with ASD have age-appropriate structural language skills (ALN, autism language normal), whilst others have language impairments (ALI, autism language impaired). It may be expected that contrasting reading profiles would be evident for these differing subgroups (Chapter 2).

In addition to individual differences in language competence, the home literacy environment (HLE) can influence the reading development of TD children (cf. Bus, van IJzendoorn & Pellegrini, 1995; see Chapter 7). There is a paucity of research exploring whether this is also the case for children with ASD. Aspects of autistic phenotype, such as difficulties with social interaction, may impede HLE practices such as shared book reading.

It is also uncertain whether children with ASD are able to actively use print to support learning. TD children can, and do, use the written form of a word to facilitate explicit vocabulary learning (Reitsma, 1983; Ricketts, Bishop, & Nation, 2009; Rosenthal & Ehri, 2008; Chapter 8). Despite the frequent use of print in educational contexts, there is a dearth of research indicating that children with ASD are able to use the written form to learn new words.

In the first chapter of this thesis, key issues regarding reading in typical development will be introduced, in order to situate the literature on reading in ASD. The chapter begins with a brief overview of the concept of reading, as a preface to detailed discussion of reading accuracy in typical development. This includes models of reading accuracy, namely the dual-route cascade model (DRC; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) and the triangle model (Plaut, 1996). This is followed by a synthesis of reading comprehension in typical development, which is framed within the Simple View of Reading (Gough & Tunmer, 1986). The chapter then explores the relationship between the HLE and literacy attainment and concludes with a summary of the extent to which TD children can use their reading skills to learn new vocabulary.

What is Reading?

Reading is "a highly complex task that involves the rapid co-ordination of visual, phonological, semantic, and linguistic process" (Plaut, 2007, p. 24). There are two core components; initially the symbols of a word are decoded, then the meaning of the word is identified (Hoover & Gough, 1990). Decoding and comprehension typically develop in tandem (Gough, Hoover, & Peterson, 1996), but decoding skills are essential for, and predict, reading comprehension (Perfetti, Beck, Bell, & Hughes, 1988). Indeed, the Simple View of Reading (SVR; Gough & Tunmer, 1986) presents reading as the product of decoding and listening comprehension (see Figure 1.1). Proficient oral language skills facilitate both decoding and comprehension (cf. Roth, Speece, Cooper & Paz, 1996).

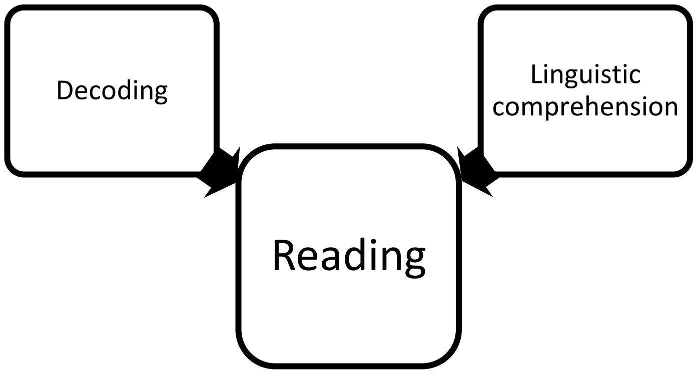

Figure 1.1 *Diagram Illustrating the Simple View of Reading (Gough & Tunmer, 1986)*

The National Early Literacy Panel (National Early Literacy Panel, 2008) defined two types of literacy skills - emergent and conventional. Emergent literacy components include linguistic processing skills such as oral language and phonological awareness, as well as print related skills. These include print concepts knowledge (i.e. environmental print recognition, knowledge of print forms and conventions, and knowledge of print's function), alphabetic knowledge (knowledge of both letter names and sounds) and emergent writing (e.g. name writing). These skills precede and predict conventional literacy skill (Bloodgood, 1999; Bond & Dykstra, 1997; Catts, Fey, Zhang, & Tomblin, 1999; Christian, Morrison, & Bryant, 1998; Melby-Lervåg, Lyster, & Hulme, 2012; Sénéchal & LeFevre, 2002; Share, Jorm, Maclean, & Matthews, 1984) Conventional literacy is the ability to read words accurately and fluently and comprehend those words in context, as well as the faculty to spell and write. Conventional literacy is essential to access the educational curriculum and is associated with educational attainment (Pretorius, 2000). Thus, reading can support learning. Importantly it is a valuable skill for functioning in every-day life and reading ability positively correlates with both health (Baker, Parker, Williams, Clark, & Nurss, 1997; Datar, Sturm, & Magnabosco, 2004; Eveland-Sayers, Farley, Fuller, Morgan, & Caputo, 2009; Grissom, 2005; Marwick, 1997) and employment (Wright & Stenner, 1999).

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Reading Accuracy in Typical Development

Word Identification

There are two key ways that written words in the English language can be decoded, either through phonological decoding or whole word recognition. Phonological decoding involves identifying the individual letters or morpheme combinations in a word and mapping them to their corresponding sounds. These units are then blended together to pronounce the word. Whole word recognition relies on memory; words are recognised from sight and read as a whole. At points in this thesis, the specific strategy used to read words will either be unknown or irrelevant. In these instances, the terms 'word identification' or 'reading accuracy' will be used to refer to the process of reading words aloud.

Words in the English language are variable with regards to the consistency of their orthography-phonology mappings. Regular words, such as '*sheaf*', conform to consistent grapheme-phoneme correspondences and therefore can be read via phonological decoding. However, once familiar, they can also be identified through whole word recognition. In contrast, irregular words, such as '*yacht'*, have inconsistent orthography-phonology mappings and therefore cannot be accurately read through phonological decoding. These words have to be learnt as a whole and read through sight word recognition. As a result, the purest test of whole word recognition is an irregular word reading task. The purest test of phonological decoding skill is a non-wording read task. Non-words (e.g. '*tegwop*') are not real words and therefore cannot be read through recognition, only through decoding.

Development of Word Identification

Stage models of reading specify stages or phases of reading development that children pass through when learning to read. Three core models have been proposed and the key components of the models and the overlap between them are outlined in Table 1.1 (page 17). Marsh, Friedman, Welch and Desberg (1981) proposed a cognitive developmental theory of literacy acquisition and postulated four stages of reading development. They proposed that initially children 'read' by rote guessing from visual cues, and then they learn to predict words from the context. Following this, children learn to decode sequentially then hierarchically. Finally, they read by analogy to known sight words that are stored in memory. For example, knowing the word ‘beak’ may enable the reader to decipher ‘peak’ and ‘freak’, by generalising the pronunciation of the letter combination ‘eak’ and blending this with the sub-units of new words.

This model was modified by Frith (1985) who divided reading development into three stages, which were categorised by three distinct strategies. The first strategy/stage is logographic. Frith agreed with Marsh et al. (1981) that initially children acquire a small sight word vocabulary of familiar words and identify words by salient visual cues. For example, in the this stage the word ‘yellow’ may be identified by the two stalks created by the ‘ll’. However, this method relies heavily on memory and therefore is costly in terms of storage. Furthermore, confusion between visually similar words, such as ‘bellow’ and ‘fellow’ may occur. If the child is unable to identify the word on the basis of salient graphic features, they may make an attempt to guess the word, utilising contextual or pragmatic cues. Once phonological knowledge develops, children begin to sound out unfamiliar words by blending phonemes and/or morphemes together. This strategy/stage is termed alphabetic. After a word has been encountered (usually multiple times) and word-specific knowledge has been consolidated, the word can be read by sight as a morphological or orthographic unit. This is the orthographic stage.

It has been argued that these reading strategies are not used in distinct stages, but that overlap can occur. Ehri proposed a phase model of reading development, with four components (L.C. Ehri, 1995, 1996, 1998, 2005; L.C. Ehri & McCormick, 1998). The first phase is termed pre alphabetic. Like Marsh et al. (1981) and Frith (1985), Ehri considered primary word identification to occur through the use of visual cues. However, unlike the other researchers, Ehri proposed that the visual properties are associated with meaning. As phonological knowledge develops, children will use orthography-phonology mappings to decode words. Initially partial connections will be made, with emphasis on the initial and end letters of words (the partial alphabetic phase). As skill develops, and all components of words can be decoded, children progress to the full alphabetic phase, which aligns with Frith's alphabetic stage. With practice, children reach the consolidated alphabetic phase, and are able to use morphological and orthographic units to read words. This corresponds to Frith's orthographic stage.

Table 1.1

Table Illustrating the Overlap Between Three Core Stage/Phase Models of Reading Development

Strategy	**Marsh et al.**	**Frith**	**Ehri**
Recognition from visual cues	Rote learning	Logographic stage	Pre-alphabetic phase
Prediction from context	Linguistic guessing		
Phonological decoding	Sequential decoding	Alphabetic stage	Partial alphabetic phase
	Hierarchical decoding		Full alphabetic phase
Sight word recognition	Analogy	Orthographic stage	Consolidated alphabetic phase

The process of learning to read is therefore seen as 'self-teaching'; a child can only build up word specific knowledge through phonological decoding, which in turn allows the development of orthographic representation and enables a lexical route to reading to develop (Share, 1995, 1999). During reading development, phonological decoding is a foundational skill and word recognition is effortful and protracted. However, once an individual becomes a skilled reader they will predominantly read through whole word recognition, except in the case of unfamiliar words. The stages of learning to read result in the development of a new orthographic lexicon, which complements the existing phonological lexicon. Specifically, "The human brain has not evolved to read, but it has the potential to acquire an additional lexicon in a new modality (usually visual)" (Ramus, 2004, p. 821).

Although stage models provide a framework of reading development, there are critical limitations. For example, the models are descriptive, rather than enabling predictions to be made. Consequently, researchers are now focussing on individual differences, which can serve as predictors of reading development.

The Influence of Language Ability on Reading Accuracy

Oral language skills include phonology (the 'rules' for combining speech sounds), semantics (meaning), pragmatics (language use) and syntax, grammar and morphology. There is substantial evidence that these skills contribute to the development of word identification (see Roth et al., 1996 for a review). First, the relationship between phonological awareness (PA) and reading accuracy will be discussed. Then, evidence regarding the contribution of non-phonological oral language skills to both the development of prerequisite reading skills (i.e. PA) and to word identification will be presented[1].

Phonological Awareness (PA)

As previously discussed, learning to read requires mapping of orthography to phonology. Such an accomplishment is reliant on phonological knowledge and it would therefore be expected that phonological awareness, i.e. knowledge of sounds at the structural levels of syllables, onsets and rhymes, and phonemes, would be predictive of decoding competence. Evidence to support this notion is provided by the results of studies which have explored the developmental relationship between PA and reading skill, as well as the impact of PA interventions on reading ability. PA can be assessed in multiple ways, but the core assessments fall into two main categories, rhyme awareness and phonemic awareness. Details of a selection of PA assessments, along with examples, are provided in Table 1.2.

[1] It is acknowledged that other factors, such as speed of processing (cf. Denckla & Rudel, 1976; Swanson et al., 2003), may also influence word identification. However as the focus of the thesis is the influence of language ability, additional factors shall not be explicitly discussed here.

Table 1.2

Examples of Phonological Processing Tasks

Task	Procedure	Example
Rhyme awareness		
Rhyme detection	Children have to identify whether two words rhyme	Q : hat pet A: no
Rhyme generation	Children have to list as many words as possible that rhyme with a target word	Q: hot A: cot, dot, not…
Rhyme oddity	Children hear several words and have to identify which word does not rhyme i.e. is the odd one out	Q: sat mat dog hat A: dog
Phonemic awareness		
Onset identification	Children hear two words and have to determine whether they start with the same sound	Q: hot house A: yes, same sound
Phoneme blending	Children are presented with sounds and then instructed to blend them together to make a word. Depending upon the assessment they then either say the word, or identify the correct response from presented option	Q: /g/ /r/ /ā/ /t/ Great or skate? A: great
Phoneme deletion / elision	Children have to delete phonemes from either the beginning, middle, or end of a word and say the word that remains	Q: say star without the s A: tar
Phonemic isolation	Children hear words which contain the same sound and have to identify whether that sound is in the beginning, middle or end of the word	Q: map cat A: middle
Phoneme segmentation	Children have to separately articulate each phoneme in presented words	Q: cat A: / c/ /a/ /t/
Non-word repetition	Children hear a non-word, then repeat it	Q: zoinep A: zoinep

Seminal research exploring the relationship between PA and reading ability was conducted by Bradley and Bryant (1978, 1983). They compared the PA skills of proficient and poor readers, reporting that the proficient readers performed significantly better on tasks of rhyme oddity and rhyme production. Since the 1980s, a wealth of research exploring the relationship between phonological ability and reading skill has been published, and this has been synthesised in two key meta-analyses. Swanson, Trainin, Necoechea and Hammill (2003) conducted a meta-analysis of 35 studies from the correlational literature, concluding that PA was moderately correlated with both real word reading (r = .41) and non-word reading (r = .43). A decade later, Melby-Lervåg, Lyster and Hulme (2012) conducted a meta-analytic review of 135 correlational studies. Again, there was a moderate correlation between phonemic awareness and word reading (r = .57), and the magnitude of the correlation did not differ as a function of the reading test (i.e. real word reading, non-word reading, or a composite of both). There was also a moderate correlation between rhyme awareness and word reading (r = .43), although this correlation was significantly lower than the correlation between phonemic awareness and word reading. This suggests that word identification may be associated with phonemic awareness more than with rhyme awareness.

The relationship between PA and reading accuracy is further evidenced by the findings of longitudinal studies (e.g. Bradley & Bryant, 1983; Bryant, MacLean, Bradley & Crossland, 1990; Muter, Hulme, Snowling and Stevenson, 2004; Stuart & Masterson, 1992). Bradley and Bryant (1983) assessed the sound categorisation skills of 403 children aged 4-5 (before they had learnt to read), then three years later assessed the reading ability of 368 of these children. There was a moderate correlation between sound categorisation and single word reading accuracy for the children who were aged 4 at time 1 (r = .44) and those aged 5 at time 1 (r = .57). More recently, Muter et al. (2004) conducted a two-year longitudinal study of 90 British children and at time 1 the children were aged 4-5 years. Phoneme awareness at time 1 was a significant predictor of reading accuracy at time 2, but rhyme awareness was not. This provides further evidence of the pivotal role of phoneme awareness for word identification.

However, it is noteworthy that both these studies included a measure of single word reading that included both regular and irregular words. It may be anticipated that phonemic awareness would be particularly critical for reading words with regular orthography-phonological mappings, more so than for words with irregular mappings. This was assessed by Stuart and Masterson (1992) who examined the relationship between pre-reading phonological skill and reading competence at age 10 for a sample of 20 British children. The results of six PA assessments all loaded onto a single factor, so a composite was created. IQ was partialled out, and there was a significant, strong positive correlation between PA and both non-word reading and regular word reading, whilst the relationship between irregular word reading and PA failed to reach significance. This suggests that PA is associated with phonological decoding skill more than whole word recognition.

This proposed causal hypothesis is strengthened by the results of training studies. Bradley and Bryant (1983) provided children with 40 hours of either sound or semantic categorisation training. The sound training session taught children that words can contain the same sounds as other words and this overlap can occur at the beginning, in the middle or at the end of words. The group receiving this training attained higher reading accuracy scores than those who participated in the semantic categorisation training. However, the children who were taught how sounds correspond to the letters of the alphabet in addition to the sound or categorisation training attained the highest accuracy scores. This finding has since been replicated multiple times (e.g. Fox & Routh, 1984; Hulme, Bowyer-Crane, Carroll, Duff, Snowling, 2012; Lundberg, Frost, & Peterson, 1988; Schneider, Küsbert, Roth, Visé & Marx, 1997; Schneider, Roth & Ennemoser, 2000).

Nevertheless, it is also possible that proficient PA may be a *consequence* of reading experience (Goswami, 2002), as learning to read may change the nature of phonological representations (Goswami, 2002). More specifically, phonological representations may initially be stored in a holistic form, but later become represented segmentally (Muneaux & Ziegler, 2004). Thus, in addition to PA facilitating reading development, reading proficiency in turn may enhance PA. This was explicitly assessed in a longitudinal study conducted by Nation and Hulme (2011), which included 215 children. Consistent with previous studies, performance on a phoneme elision task at age 6, predicted single word reading ability at age 7, although non-word repetition (also an index of PA) did not. However, of particular interest is the finding that single word reading ability at age 6 predicted non-word repetition performance at age 7 and notably this relationship was independent of earlier non-word repetition (the autoregressor effect). This demonstrates that reading development results in growth in related domains, such as phonological awareness and highlights the reciprocal relationship between PA and reading.

Non-Phonological Oral Language Skills

Early in development, oral language skills contribute indirectly to reading development through their impact on precursor skills, namely letter sound knowledge and phonological awareness. For example, Lonigan, Burgess and Anthony (2000) found that preschool oral language skills predicted letter sound knowledge and phonological awareness upon school entry, and these skills were later unique predictors of reading. Storch and Whitehouse (2002) also found that oral language skills predicted phonemic awareness and in turn phonemic awareness predicted reading accuracy. In early elementary school, oral language skill did not contribute unique variance to reading accuracy, yet later in elementary school, there was a direct link.

A direct link between oral language skill and reading accuracy was also reported by Nation and Snowling (2004). Seventy two children completed oral language and reading assessments first at age 8, then again four and a half years later. Vocabulary knowledge, listening comprehension and a composite measure of semantics at age 8 predicted concurrent and later word reading accuracy. The finding that vocabulary knowledge predicted both phonological decoding and whole-word recognition has been consistently reported (Catts, et al., 1999; McKay, Davis, Savage, & Castles, 2008; Ouellette, 2006; Snow, Tabors, Nicholson, & Kurland, 1995; Verhoeven, van Leeuwea, & Vermeerb, 2011). Similar to Nation and Snowling (2004), Verhoeven et al. (2011) conducted a five year longitudinal study, but with a large sample of Dutch children. Vocabulary knowledge at age 6 was a significant predictor of later single word reading. In addition, word identification competence influenced later vocabulary knowledge. This suggests that exposure to written words may facilitate vocabulary development, a hypothesis which is explicitly assessed in Chapter 8 of this thesis. Thus, as is the case for phonological awareness, there is a bi-directional relationship between word identification skill and vocabulary knowledge.

Additional evidence regarding the causal relationship between oral language skill and reading accuracy is provided by studies reporting that an oral language deficit between the ages of two and four has been identified as a risk factor for later literacy impairments (Aram & Nation, 1980; Bishop & Adams, 1990; Catts, 1993; Catts, et al., 1999; Scarborough, 1990; Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998). This will shortly be discussed in more detail.

Conclusion

Learning to read is a multi-faceted skill which is strongly influenced by individual differences in oral language ability. Phonological awareness, and particularly phoneme awareness, correlates with, and is a longitudinal predictor of reading accuracy (cf. Bradley & Bryant, 1983; Swanson et al., 2003; Melby-Lervåg et al., 2012). It is especially instrumental in the decoding of words with consistent orthography-phonology mappings (Stuart & Masterson, 1992). Early in development, PA is influenced by general non-phonological language competence, especially vocabulary knowledge. However, as reading skill develops there is a corresponding increase in PA (Nation & Hulme, 2011), because reading experience can change the nature of phonological representations (Goswami, 2002). Once children begin to accurately decode, oral language skills assume a greater role in reading accuracy (Storch & Whitehurst, 2002) and vocabulary knowledge is a key influence (Catts et al., 1999; McKay et al., 2008; Ouellette, 2006; Snow et al., 1995; Verhoeven et al., 2011). However, the relationship is bi-directional, as decoding competence can facilitate vocabulary development (Verhoeven et al., 2011). Thus, it is evident that phonological and non-phonological oral language skills facilitate the development of word identification, but that literacy proficiency also enhances language ability.

Dyslexia

For the majority of children, the process of learning to read follows a typical development trajectory. However, 5-10% of children have reading disorders, experiencing difficulty with decoding, comprehension or both (Figure 1.2). DSM-V includes the category 'Specific Learning Disorder' which is defined as difficulty learning and using academic skills. This includes impairments in reading and dyslexia is defined as "difficulties characterised by problems with accurate or fluent word recognition, poor decoding, and poor spelling abilities…" (p.67, APA, 2013a). The difficulties must be substantially and quantifiably below the person's chronological age, and not be better accounted for by intellectual disability or inadequate educational instruction. Prevalence rates of dyslexia vary depending upon the assessments administered, cut-off criteria for impairment (e.g. 1.5 or 2 SD below the normative mean) and the age of the children (Snowling, 2000). Nevertheless, prevalence estimates for dyslexia tend to range from 2-7% (Rodgers, 1983; Shaywitz, Fletcher, Holahan, & Shaywitz, 1992; Yule, Rutter, Berger, & Thompson, 1974).

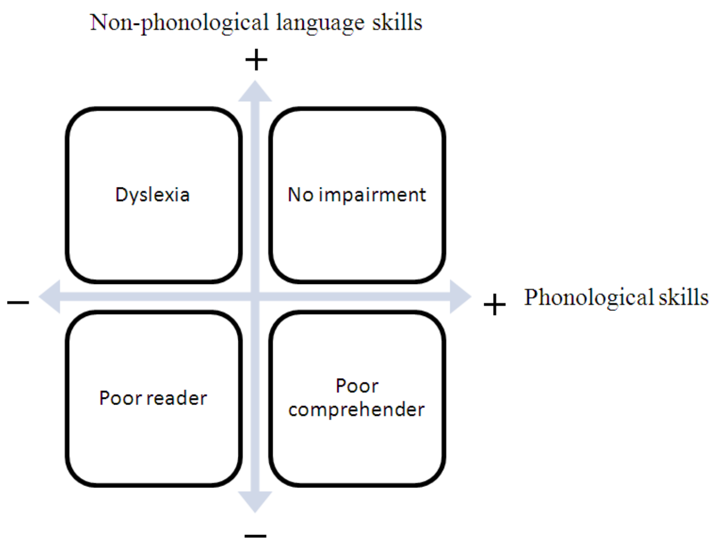

Figure 1.2 *Diagram Illustrating the Spectrum of Reading Disorders. Adapted from Bishop and Snowling (2004).*

Two prominent hypotheses of dyslexia have been proposed; the phonological deficit hypothesis and the double deficit hypothesis. Bradley and Bryant (1978, 1983) found that that poor readers achieved lower scores on tasks of rhyme oddity and production than proficient readers, leading them to propose the phonological deficit hypothesis (Bradley & Bryant, 1983). This posits that failure to develop proficient phonological skills interferes with learning of grapheme-phoneme correspondences, thus impairing phonological decoding processes. This hypothesis is supported by the well-established relationship between PA and reading accuracy (Melby-Lervåg et al., 2012; Swanson et al., 2003),

The phonological deficit hypothesis is supported by the results of a longitudinal study, conducted by Pennington and Lefly (2001), which investigated the language and literacy skills of 57 children at low genetic risk of dyslexia and 67 at high genetic risk of dyslexia (by virtue of having a parent with dyslexia). The children were originally seen at age 5 and then assessed at three time points over the next three years. A third of at-risk children met diagnostic criteria for dyslexia at time points three and four. At all four time points, these children performed significantly worse than low risk children on both implicit phonological processing measures (verbal STM and rapid serial naming), and explicit phonological processing tasks i.e. tasks of phonological awareness. This finding has been reported many times, and Melby-Lervåg et al. (2012) conducted a meta-analysis of 88 independent comparisons between children with dyslexia and their TD peers. The children with dyslexia consistently performed worse on measures of PA, with a large and significant effect size (Cohen's d = -1.37, 95% CI [-1.50, -1.23]).

Evidence of a causal relationship between PA deficits and dyslexia is also provided by longitudinal studies (Pennington & Lefly, 2001; Scarborough, 1990; Snowling, Gallagher & Frith, 2003). For example, Scarborough (1990) recruited a sample of 52 children aged 2.5 years (32 children at high-family risk of dyslexia and 20 at low-risk) and assessed their academic progress at multiple time points. At age 8, 20 of the children at high family risk met criteria for dyslexia and these children had weaknesses in phonological awareness and letter sound knowledge at age 5. Similarly, Snowling et al. (2003) recruited a sample of 56 children at high-family risk and 29 low risk controls and followed them from the age of 3 until they were 9 years old. At age 8, 66% of the children in the high-risk group met the study's diagnostic criteria for dyslexia, relative to only 13% of children in the control group. There were two key predictors of single word reading ability and these were grapheme-phoneme skill (non-word reading and phonetic spelling) and phonological awareness. These studies provide additional evidence of the intimate relationship between phonological awareness and literacy skill.

Additionally, it is noteworthy that the high-risk children in Snowling et al.'s study (2003) who did not meet diagnostic criteria for dyslexia had significant deficits in grapheme-phoneme skill. Likewise, Pennington and Lefly (2001) found that a group of 44 children at high family risk of dyslexia, but who did not met diagnostic criteria for dyslexia at age 8, performed worse on measures of phonological awareness and literacy than peers at low risk of dyslexia. This further emphasises the relationship between phonological awareness and word identification and suggests that the family risk of dyslexia is continuous, rather than discrete. The children at high-risk for dyslexia who did not meet diagnostic criteria for dyslexia had greater oral language competence generally than the high-risk children who did meet diagnostic criteria for dyslexia (Snowling et al., 2003; Snowling, 2008) and this suggests that oral language competence may have offered a 'protective' factor. This again evidences the relationship between language and literacy.

As PA is particularly important for reading words with consistent phonology-orthography mappings (Stuart & Masterson, 1992), it would be a reasonable hypothesis that children with dyslexia would find reading words that require phonological decoding to be challenging. Indeed, Rack, Snowling and Olson (1992) conducted a review of studies comparing the non-word reading skills of children and adolescents with dyslexia to a non-dyslexic comparison group and two thirds of studies reported that the dyslexic group had specific difficulties reading via phonological decoding. On this basis, it may also be expected that children with dyslexia would have greater difficulty using phonological decoding strategies relative to whole word recognition. Although this is the case for approximately 25% of children with dyslexia (Castles & Coltheart, 1993; Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996; Stanovich, Siegel, & Gottardo, 1997), the majority of children have difficulties with both phonological decoding strategies and whole word recognition (Manis et al., 1996). Additionally, some individuals with dyslexia are more proficient at phonological decoding than whole word recognition, although the presence of such a reading profile is contested with prevalence estimates ranging from 2% (Manis et al., 1996; Stanovich et al., 1997) to 20-30% (Castles & Coltheart, 1993). As a result of these different reading profiles, some researchers have argued that there are distinct sub-types of developmental dyslexia (e.g. Castles & Coltheart, 1993). Specifically, superior whole word recognition relative to non-word reading is termed phonological dyslexia and the opposite profile (a bias towards non-word reading) is labelled surface dyslexia. However, this remains a contentious issue, with other academics suggesting that deficits occur along a continuum. Indeed, the majority of children with dyslexia present with difficulties with both non-word and exception word reading (Manis et al., 1996) and dyslexia appears to be underpinned by phonological deficits, regardless of whether a surface or phonological dyslexia profile is displayed (Sprenger-Charolles, Colé, Lacert, & Serniclaes, 2000).

Although the phonological deficit hypothesis is successful in accounting for the phonological weakness frequently associated with dyslexia, it does not take into consideration other difficulties that are frequently associated with dyslexia such as impairment in speed of processing. Speed of processing is frequently assessed through a rapid automatised naming (RAN) task, which measures how quickly individuals can name aloud objects, pictures, colours, or symbols (letters or digits). Performance on the RAN task correlates with, and predicts, both sight word reading and non-word reading. The consistency of this finding has been confirmed through a meta-analysis of 35 studies (Swanson et al., 2003). The average correlation between RAN and real-word reading was $r = .42$ and the average correlation between RAN and non-word reading was $r = .52$.

On this basis, it would be expected that children with dyslexia would complete RAN tasks more slowly than TD peers. This is the case for children reading opaque orthographies such as English/American (Denckla & Rudel, 1976; Marshall, Snowling, & Bailey, 2001), as well as for readers of transparent orthographies such as Chinese (Ho & Lai, 1999) and Japanese (Kobayashi, Haynes, Macaruso, Hook, & Kato, 2005). Wolf and Bowers (1999) proposed the double-deficit hypothesis of dyslexia, suggesting that dyslexia is driven by deficits in both processing speed and phonology. An individual with dyslexia can present with either or both of these deficits, and if the pair are present the severity of dyslexia will be greater (Bowers, 1995; Wolf & Bowers, 1999).

However, it is important to note that in addition to measuring processing speed, RAN tasks also assess access to phonological forms. Based on the wealth of literature demonstrating the relationship between literacy skill and phonology, it could be argued that the relationship between RAN performance and literacy is attributable to the phonological component. It is therefore prudent to consider speed of processing on non-phonological tasks. The literature suggests that individuals with dyslexia do perform more slowly on speed of processing tasks that utilise non-linguistic auditory and visual stimuli, such as tones and flashes (Breznitz & Meyler, 2003; Nicolson, 1994; Sobotka & May, 1977; Stringer & Stanovich, 2000).

Models of Skilled Reading

Over a century ago, the German neurologist, Carl Wernicke, proposed that all word knowledge is stored in ‘Wortschatz’, that is, a ‘word treasury’ (Wernicke, 1874). Early models of visual word processing, which were incorporated within larger models of language processing, maintained this view. Morton’s early work (Morton, 1964, 1969) proposed that upon visual (or auditory) perception, a word is analysed, the entry in the lexicon (which he termed the ‘dictionary’) is accessed and a response is generated. Concurrently, Foster (1976, 1979) developed the Serial Search Model. He proposed that upon visual or auditory perception of a word, the lexicon is searched on the basis of the perceptual features of the word, until the correct representation is identified. These models have since been modified (e.g. Morton, 1981) and alternative models, which apply solely to visual word recognition, rather than language processing in general, have been proposed. Recently, these have been in the form of implemented computational models, i.e. a computer programme which uses the same information-processing systems that are specified in a theory to carry out the cognitive task that is of interest. Computational models are advantageous as they can, as noted by Lewandowsky, “reveal previously hidden insufficiencies and simulations allow for experimentation and modification until known empirical benchmarks are accommodated" (1993, p. 237). The remainder of this section will focus on two of the most prominent models of skilled reading, namely the dual-route cascaded model (DRC; Coltheart et al., 2001) and the triangle model (Plaut, 1996; Seidenberg & McClelland, 1989).

DRC Model

The dual-route cascaded model of reading (DRC; Coltheart et al., 2001) is a computational model of the dual-route theory of reading proposed by Coltheart (1978). Coltheart's models were developed from theoretical accounts of visual word recognition, as well as behavioural data from adults. The DRC model proposes two routes to word identification – the indirect grapheme-phoneme route (GPC) and the direct lexical route (as illustrated in Figure 1.3). Reading via the indirect GPC route involves 'sounding out' each letter or letter string before blending these parts and pronouncing the word as a whole. This decoding strategy enables unfamiliar regular words to be read correctly (for example '*sheaf*'), however irregular words (e.g. '*yacht*') will be regularised. Regular words may be accurately pronounced but not necessarily understood and this route is considered to be slower than the direct lexical route. When reading via the lexical route, the mental representation of the word is accessed from the lexicon, either directly or via the semantic system. This route is more efficient when reading known words and irregular words. These two lexical routes involve interactive and parallel processing.

Models of reading should account for observed human behaviour. Coltheart et al. (2001) assessed the ability of the DRC model to account for factors which affect human reading aloud. For example, humans read regular words faster than non-words (e.g. McCann & Besner, 1987), low-frequency regular words faster than low-frequency irregular words (e.g. Paap & Noel, 1991), and higher frequency words faster than lower frequency words (e.g. Forster & Chambers, 1973). Additionally, pseudohomophonic non-words, for example 'brane' are read aloud faster than non- pseudohomophonic non-words, such as 'brene' (e.g. McCann & Besner, 1987). The model performed similarly to human readers with regard to word regularity, frequency and non-word reading. For example, under speeded reading conditions 27 irregular words were regularised. However, when the pace was reduced, 26 of the 27 words were pronounced correctly, which mirrors human reading. Phonological decoding competence was also examined, and from 7000 non-words only 75 errors were made, of which 84% were lexical captures (i.e. the word was pronounced in a same way as an orthographically or phonologically similar word).

Nevertheless, the model has two crucial limitations. The model posits that the lexical route subdivides into the semantic and non-semantic pathways, but it does specify the basis on which this occurs. Additionally, the model does not account for the role of knowledge acquisition, for example learning that a word is irregular and thus its pronunciation cannot be mapped from the orthographic form. As a result, it is non-developmental. However this limitation is acknowledged by the authors and they state that that ". . . unless the learning procedure itself is known to be psychologically real, it may not be able to learn what people learn" (Coltheart et al. 2001, p. 216).

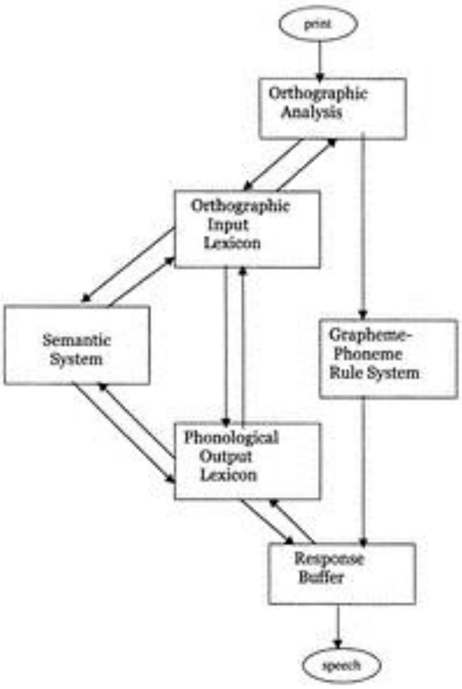

Figure 1.3 *Dual-Route Cascaded Model of Visual Word Recognition and Reading Aloud.* Source: Coltheart et al., 2001

Triangle model

Connectionist models implement 'neuron-like' units and connections in order to attempt to represent processing. The connectionist 'triangle' model of reading (Plaut, 1996) posits that upon visual perception of a word, the lexical information activates codes pertaining to orthographic, phonological and semantic components. Two processing pathways are proposed; a phonological pathway which contains orthographic and phonological connections and a semantic pathway which maps associations between semantic, orthographic and phonological representations (as illustrated in Figure 1.4). The phonological pathway is considered to provide a greater contribution to reading in the initial stages of learning to read as it is more direct and therefore faster, yet when words are irregular or low frequency the semantic pathway becomes more dominant. This is supported by research demonstrating that reading of trained novel words is facilitated by semantic involvement, but only when the words have inconsistent pronunciations (McKay et al., 2008). Additionally, children's word knowledge (considered to be a proxy for the skills and information that contribute to the semantic pathway) has been found to account for unique variance in word reading, even after variance associated with decoding and phonological skills was taken into account (Nation & Snowling, 2004).

In contrast to the DRC model, the triangle model is developmental and accounts for learning and modifications to associated mental representations. It proposes that these occur via the model attempting to pronounce a word and receiving feedback regarding the correct pronunciation. The connections between the orthography and the phonological representation are strengthened and the probability of future pronunciation attempts being correct is increased. Therefore the model emphasises the role of statistical learning rather than reading different types of words (i.e. grouping by regularity) through different methods.

As this model incorporates feedback it can successfully account for the word frequency effect and it 'reads' frequent words faster than less frequent words. Additionally it is sensitive to word neighbours. Words which are spelt and pronounced similarly (i.e. cash and dash) activate similar patterns in the orthographic and phonological layers, whereas words which are spelt similarly but pronounced differently (i.e. cash/dash and wash) will have a different pattern of activation.

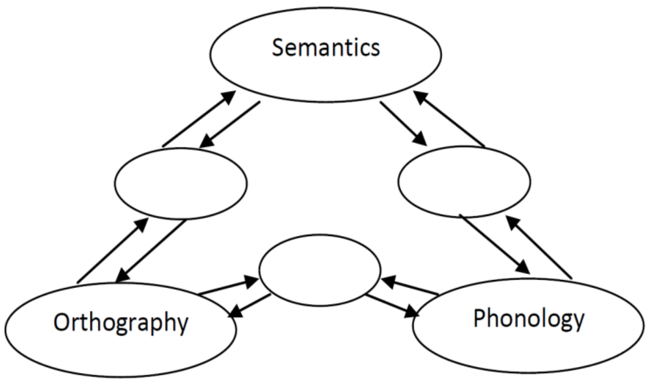

Figure 1.4 *The Triangle Model of Visual Word Recognition and Reading Aloud.*
Source: Plaut et al., 1996.

Applicability of models to developmental reading disorders

As the DRC model postulates two routes to reading, the GPC route and the lexical route, it may be possible to observe a dissociation between non-word and irregular word reading ability. Some children with developmental dyslexia present with a dissociation of reading skills, with estimates of the prevalence of phonological dyslexia at around 25% (Castles & Coltheart, 1993; Manis et al., 1996; Stanovich et al., 1997) and surface dyslexia estimates ranging from 2% (Manis et al., 1996; Stanovich et al., 1997) to 20-30% (Castles & Coltheart, 1993). Disruption to either the GPC or the lexical route of the DRC model can account for this dissociation. The DRC model can effectively simulate phonological and surface dyslexia (Coltheart et al., 2001). To simulate surface dyslexia the rate of access to the orthographic lexicon was reduced, and this resulted in impaired irregular word reading (the words were regularised) whilst regular and non-word reading skills remained intact. By slowing down the non-lexical route non-word reading was impaired whilst real word reading was unharmed. However, the majority of children with dyslexia present with difficulties with both non-word and exception word reading (Manis et al., 1996). This could be explained in terms of impairments in both the GPC and lexical routes, however the DRC model does not provide an explanation to account for the finding that the majority of children have difficulty with both word types.

The ability of the DRC model to effectively account for different types of developmental dyslexia was further assessed by Ziegler and colleagues (2008). They administered tasks of letter search, picture naming and phoneme matching to 24 children with dyslexia and 24 TD peers. Performance on these tasks was used to add the corresponding quantity of noise to the stages of the DRC model. Simulations for each individual participant were run, and the results averaged across the group. The ability of the computer model to read regular, irregular and non-words was compared to the reading of the dyslexic children. For both the human and the model data there was a significant effect of group, with control participants/data achieving higher accuracy and shorter reading latencies. There was also a significant effect of regularity, with both the children and the model reading regular words most accurately and quickest. The model was also able to account for patterns of dyslexia, specifically surface, phonological, mixed and mild dyslexia. Whilst the model was effective at predicting group reading profiles, it was less accurate for individual reading patterns. Specifically three children were proficient non-word readers, yet the model predicted strong non-word reading deficits. This is likely to have resulted from the children's poor performance on the three skill tasks.

Harm and Seidenberg (1999) attempted to simulate developmental dyslexia using the triangle model by 'lesioning' their model with two degrees of severity. Both methods successfully impaired the model's ability to read non-words, however when the impairment was more severe the model was also impaired at reading real-words. Therefore they were unable to simulate 'pure' severe phonological dyslexia. Similarly, by severely impairing the models ability to read irregular words, the ability to read regular and non-words was also impaired. Therefore the model was also unable to simulate 'pure' surface dyslexia. However, as already acknowledged, the majority of children with dyslexia present with difficulties with both non-word and exception word reading (Manis et al., 1996).

To date, neither the DRC nor the triangle model can adequately account for the reading profiles seen within developmental dyslexia. Peterson, Pennington and

Olson (2013) explicitly tested the predictions of both these models and concluded that "our results did not clearly support one model over another" (p.35). They assessed the reading skills of 437 children aged 8-13 years with dyslexia; 15.6% had a 'pure' phonological dyslexia and 2.3% a surface dyslexia reading profile (impairment in one skill, but more proficient in the other). When slightly less stringent criteria were used, i.e. impairment in one skill relative to the other, 41% of the sample had a phonological dyslexia profile and 7.8% a surface dyslexia pattern. However, around a third of the sample had a mixed profile, or only mild impairments. Some of the findings were problematic for both of the models, for example those pertaining to orthographic coding. Orthographic coding, as defined by Vellutino, Scanlon, and Tanzman (1994), is the "the ability to represent the unique array of letters that defines a printed word" (p.314) and is typically indexed by orthographic choice tests, homophone choice tests and spelling tasks. Peterson et al. found that a) a small number of children with phonological dyslexia had intact orthographic coding abilities and b) some control participants with age-appropriate reading skill had poor orthographic coding skills, which were on par with the skills of the surface dyslexics. The authors suggest that the models could be improved with increased reference to the role of semantics and that future investigations should take into consideration the roles of processing speed, cognitive ability and verbal-short term memory, consistent with developmental data.

Reading Comprehension in Typical Development

Reading comprehension is defined as understanding of a written text. One may decode text without understanding it, for example it is possible to sound out the words of some foreign languages without understanding the meaning. Reading comprehension assessments typically require students to read passages of text aloud and then answer orally presented comprehension questions. Frequently used standardised assessments include the Neale Analysis of Reading Ability (NARA; Neale, 1966, 1986, 1997, 1999), the York Assessment for Reading Comprehension (YARC; Snowling et al., 2009) and the Wechsler Objective Reading Dimensions (WORD; Rust, Golombok, & Trickey, 1993).

Like decoding, comprehension is a complex and multifaceted process. Accordingly, "there is room for lots of things to go wrong when comprehension fails" (Perfetti, 1994, p. 885). The Simple View of Reading (SVR) presents reading comprehension as the product of decoding and listening comprehension (Gough & Tunmer, 1986). However, the relative importance of each component changes with development. Specifically, alphabetic knowledge is a key predictor of reading comprehension in early childhood, yet by the onset of adolescence, oral language skills and non-verbal cognitive ability assume greater importance (cf. Adlof, Catts, & Lee, 2010).

The SVR proposes that word recognition and oral language comprehension make relatively independent contributions to reading comprehension and this is supported by the dissociations between these components observed in children with reading disorders (see Figure 1.2, on page 26). Approximately 7-10% of children have a 'Poor Comprehender' profile, in which comprehension lags behind reading accuracy and chronological age expectations (Clarke, Snowling, Truelove, & Hulme, 2010; Nation, Cocksey, Taylor, & Bishop, 2010; Nation & Snowling, 1997; Stothard & Hulme, 1995; Yuill & Oakhill, 1991). The criteria used to define a Poor Comprehender reading profile varies depending upon the study, but emphasises a discrepancy between word reading and comprehension skills. For example, Henderson, Clarke and Snowling (submitted) specified that Poor Comprehenders had a reading comprehension standard score <89, and a single word reading accuracy in the >85, as well as a discrepancy of at least 1 SD (i.e. ≥15) between single word reading accuracy and reading comprehension.

Factors influencing reading comprehension

The influence of decoding skill on reading comprehension shall be discussed, followed by the impact of linguistic comprehension. For each component, research conducted with typically developing children will be presented, followed by research with Poor Comprehenders. Additional evidence of the relationship between reading comprehension and decoding and linguistic comprehension is provided by examination of the reading skills of children with oral language impairments, which is detailed later.

Decoding

When word reading is effortful and protracted, resources are dedicated to decoding, with fewer reserves available for comprehension. As a result, word decoding skills are predictive of comprehension (Perfetti et al., 1988). For example, Åsberg and Sandberg (2010) found a strong association between word decoding fluency and sentence reading comprehension, even after controlling for age and verbal IQ. Similarly, Sénéchal and LeFevre (2002) found that word reading at age 6 predicted passage reading comprehension at ages 8-9. However, the relationship between decoding and comprehension is bi-directional. This expedites the Matthew effect, ‘the rich get richer and the poor get poorer’. Poor Comprehenders read less (C. Clark & Foster, 2005) and learn less from their reading experiences (Cain, Oakhill, & Elbro, 2003) which negatively impacts their subsequent reading and learning opportunities (Stanovich, 1986).

Due to their comprehension difficulties, Poor Comprehenders are less proficient at using context to facilitate word reading, which impedes development of sight word recognition. Nation and Snowling (1998a) compared reading accuracy and fluency for words read in isolation, relative to the same words read in a constraining context. When presented in isolation, there were no group differences between Poor Comprehenders and TD controls, yet when the words were presented in context, the Poor Comprehenders showed less facilitation. The TD children were able to employ their vocabulary knowledge and use the linguistic context to facilitate identification of the target words, for example by generating predictions, whereas the Poor Comprehenders were less proficient at this.

Decoding skill is particularly influential in the earliest stages of reading, but later oral language skills assume greater importance (Adlof, Catts, & Lee, 2010; Ouellette & Beers, 2010). For example, Ouellette and Beers (2010) found that for children aged 5-7, both word and non-word single word reading contributed unique variance to reading comprehension, but neither listening comprehension nor vocabulary contributed unique variance. However, for children aged 11-12 years, vocabulary explained unique variance even after word and non-word reading were accounted for.

Oral Language Skills

The SVR hypothesises a strong relationship between linguistic comprehension and reading comprehension. This section will consider *why* linguistic comprehension is so important for reading comprehension, and which specific components are pivotal. Both lower-level oral language skills, such as semantic knowledge, and higher-level discourse processing skills such as inferencing, comprehension monitoring and text integration (across passages and with existing knowledge) are crucial and will be discussed in turn.

In order to understand a text, the reader must be able to comprehend the vocabulary – without understanding the individual words the text will also not be completely understood, although the 'gist' may be attained. Vocabulary is learned both indirectly and directly through exposure to both oral and written language and the more language experience the child has, the more vocabulary they learn (Armbruster, Lehr, & Osborn, 2001). There is a strong relationship between semantic knowledge and reading comprehension. For example, semantic knowledge in kindergarten (age 4-6) predicts reading comprehension at ages 6-8 (Muter et al., 2004; Roth, Speece, & Cooper, 2002; Snow et al., 1995) and vocabulary knowledge at age 7-8 predicts reading comprehension at ages 8-9 (Oakhill, Cain, & Bryant, 2003). Similarly, Storch and Whitehurst (2002) reported that there was a high degree of continuity in vocabulary skill from age 4 to age 10 and that early vocabulary knowledge was predictive of later reading comprehension.

However, these studies did not take into account earlier reading comprehension skill, although it is acknowledged that this is difficult to assess in early readers. It is more feasible to do with older readers, and the effect of the autoregresser was considered by Nation and Snowling (2004). They found after controlling for both decoding competence and earlier reading comprehension, vocabulary knowledge at age 7-10 still predicted reading comprehension at age 12-14

Evidence of the importance of the relationship between vocabulary knowledge and reading comprehension is also provided by comparison of Poor Comprehenders and TD peers. For example, Nation and Snowling (1998b) found that reading comprehension aligned with performance on a synonym judgment task, in which pairs of spoken words were presented and participants decided whether the words had similar meanings. There were no group difference for high-imageability pairs (e.g. rug and mat) but Poor Comprehenders were less accurate and slower than their TD peers to make decisions about low imageability pairs (e.g. 'fast' and 'quick').

Nevertheless, the language deficits of Poor Comprehenders extend beyond vocabulary and may also include grammar and pragmatic skills. Nation, Clarke, Marshall and Durand (2004) explored the abilities of 25 Poor Comprehenders aged 8-9 compared to 23 TD peers matched for non-verbal ability and decoding skill. The Poor Comprehenders performed significantly worse than control on all tasks assessing semantics, morphosyntax and higher-level language skills.   Many Poor Comprehenders would meet diagnostic criteria for language impairment, but perhaps go unnoticed because of their adequate phonological skills. The groups did not differ on tasks of non-word repetition, phoneme deletion and rhyme oddity.

Inferencing and Integration

Comprehension relies on understanding of explicitly stated information, as well as the ability to make an inference (Bowyer-Crane & Snowling, 2005; Cain & Oakhill, 1999). Making an inference requires that an individual goes beyond what is explicitly stated and integrates textual information with prior linguistic and socio-cognitive knowledge. To illustrate, an example passage of text and the corresponding literal and inferential questions are provided in Figure 1.5. In order to successfully draw an inference the reader must recognise the need to make an inference and have the vocabulary and general knowledge base to support that inference. Thus, to answer the 1st inferential question 'How did John travel to school?' it is necessary to know that 'pedalling' is not a form of transport, but instead is a verb which describes the action required to operate a bicycle. It is also necessary to suppress irrelevant information that might interfere with inferencing and check that the inference makes sense. For example, to answer question two (What did John do when he decided to take a break?) it would be important to ignore the information that he 'noticed the clock on the chair' as it could be interpreted that he spent his break looking at it. If this incorrect inference was made, it would be then necessary to notice that this inference was anomalous with the phrase ‘he opened his eyes’. If his eyes were shut, he could not have spent his break looking at the clock. Additionally it is important to be able to understand the mental states of others and that their feelings can mirror your own. Thus, in order to answer question 2 it is important to infer that when someone is tired they may take a nap, in the same way that the person answering the questions may.

<table>
<tr><td colspan="2"> Story: John’s Big Test John had got up early to learn his spellings. He was very tired and decided to take a break. When he opened his eyes again the first thing he noticed was the clock on the chair. It was an hour later and nearly time for school. He picked up his two books and put them in a bag. He started pedalling as fast as he could. However, John ran over some broken bottles and had to walk the rest of the way. By the time he had crossed the bridge and arrived at class, the test was over.</td></tr>
<tr><td>Literal questions
1. What was John trying to learn?
2. Where was the clock?
3. How many books did John pick up?
4. What did John have to cross on his way to school?</td><td>Inferential questions
1. How did John travel to school?
2. What did John do when he decided to take a break?
3. Why did John have to walk some of the way to school?
4. How do you know that John was late for school?</td></tr>
</table>

Figure 1.5 *Sample Passage and Corresponding Literal and Inferential Questions.* Source: Oakhill, 1984.

Deficits in inferencing competence have been causally attributed to poor comprehension in both the oral (Cain, Oakhill, Barnes, & Bryant, 2001; Oakhill, 1982) and written domain (Cain & Oakhill, 1999; Oakhill, 1984; Oakhill et al., 2003). Oakhill et al. (2003) conducted a longitudinal study exploring the language and reading skills of 96 primary school children. They found that inferencing skill at age 7-8 predicted unique variance in reading comprehension a year later, even after vocabulary knowledge was accounted for. In addition, Poor Comprehenders are poorer at inferencing than their TD peers. Oakhill (1984) asked 7-8 year old children to read four short stories and after each story they were asked literal questions and questions which required an inference to be made. Poor Comprehenders made significantly more errors than their peers on both literal (PC = 29.20%; controls = 10.90%) and inferential questions (PC = 45.80%; controls = 15.6%). To assess whether group differences could be exacerbated by memory demands, the children also answered the questions with access to the text. Once the text was available for reference, the groups did not differ on literal questions, but the Poor Comprehenders made significantly more errors than their peers on inferential questions (PC = 35.40%; controls = 9.90%). Oakhill proposed two reasons to account for differences in inferencing ability. First, less skilled readers may not have the necessary constructive processes to draw inferences, that is, they are unable to actively connect and interpret the individual components; alternately they may not have the prerequisite knowledge base to support the inference.

The first proposal was assessed by Cain and Oakhill (1999). Although Poor Comprehenders were initially worse at making inferences than their TD peers (PC = 56%, TD = 77%), when encouraged to actively search the text for the information required to make the inference the performance of the Poor Comprehenders increased to 85% accuracy, although still worse than the TD controls (96% accuracy). Thus, Poor Comprehenders are able to make inferences, but fail to do so spontaneously.

To explore whether inferencing difficulties are attributable to lack of necessary background knowledge, Cain, Oakhill, Barnes and Bryant (2001) taught 13 skilled and 13 less skilled comprehenders (matched on passage reading accuracy) facts about a world called GAN (e.g. turtles wear skates, bears have blue fur). A multi-episode story was read to the children and their ability to make inferences was assessed. Despite having the appropriate knowledge, the Poor Comprehenders remained less able to make inferences than TD peers, suggesting that having the prerequisite knowledge base does not ensure successful inferencing. Cain et al. assessed four other potential causes of inference failure, namely failure to retrieve the correct premise from the text, failure to recall the relevant item from the knowledge base, failure to integrate the information in the text and the taught knowledge, and failure to generation the correct (as opposed to incorrect) inference. Poor Comprehenders were less competent than skilled comprehenders at retrieving the correct premise from the text and at recalling the relevant item from the knowledge base. However they were no worse at integrating information than their peers and their poorer performance was not attributable to generation of incorrect inferences, as both groups made very few incorrect inferences. Thus, inferencing is particularly challenging for Poor Comprehenders as they struggle to retrieve the information that is required in order to make the inference. This relates to Perfetti's (2007) lexical quality hypothesis, which proposes that "variation in the quality of word representations has consequences for reading skill, including comprehension" (p.357).

Monitoring

Comprehension monitoring is an 'executive' skill that involves recognition of what is understood, awareness of what is not understood, and deployment of strategies to resolve discrepancies. Dissonance can be resolved by rephrasing the misunderstood information, re-reading the previous text, or continuing on to the next section as clarification may be provided (Armbruster et al., 2001). In other words, the reader must engage with the text.

Comprehension monitoring is usually assessed through error detection tasks. Participants are presented with text which contains contradictory or incoherent information and instructed to identify anything anomalous. Children who are skilled comprehenders detect more inconsistencies, look back at inconsistencies more and remember more inconsistencies than Poor Comprehenders (Ehrlich, Remond, & Tardieu, 1999; Zabrucky & Horn Ratner, 1989). Even when explicitly instructed that a text contains nonsense and phrases, Poor Comprehenders spot fewer anomalies than comparison groups (Yuill & Oakhill, 1991).

However, comprehension monitoring can be fluid. DeSousa and Oakhill (1996) asked 8-9 year old children to read passages of text and identify whether they were accurate or contained nonsense words, inconsistencies and prior knowledge violations. Crucially, the tasks were either presented as an editing task, or as a detective task in which participants were required to identify whether the passage was written by a criminal (passage contained errors) or an innocent person (no errors). The skilled comprehenders performed equally well in both tasks, whereas the Poor Comprehenders performed better on the task that they considered to be more enjoyable. This indicates that comprehension monitoring may be susceptible to motivational influences, and as a result, it be may be possible to boost monitoring proficiency.

Conclusion

Reading comprehension relies upon lower-level oral language skills such as semantics and syntax, as well as higher-level discourse processing skills such as inference making, comprehension monitoring and text integration (across passages and with existing knowledge). Poor Comprehenders find these tasks challenging, but difficulties are not static and therefore can potentially be resolved through intervention (cf. Clarke et al., 2010). Indeed, Clarke et al. (2010) found that oral language interventions enhanced expressive vocabulary, which facilitated reading comprehension for Poor Comprehenders. Additionally, inferencing interventions can be effective at improving the reading comprehension of less skilled comprehenders. For example, Yuill (1988) found that less skilled comprehenders who received inference skill training made greater gains in comprehension than their peers who received rapid decoding practice. Similarly McGee and Johnson (2003) found that comprehension was facilitated more by inferencing training than comprehension practice. These studies are discussed in more detail in the discussion of Chapter 6.

Home Literacy Environment (HLE)

In addition to individual differences in language competence, the reading development of TD children can be influenced by the home literacy environment (HLE; cf. Bus, van IJzendoorn & Pellegrini, 1995). The "environmental opportunity hypothesis" (Stanovich, Cunningham, & West, 1998) posits that children raised with minimal stimulation and reduced opportunity for language and literacy development are at greater risk of reading difficulties than children raised in literacy rich environments (Snow, Burns, & Griffin, 1998).

The HLE includes both parental characteristics and parental behaviours. Parental education is one of the most consistent predictors of children's academic achievement and of particular relevance to the current study is the relationship between parental education and children's vocabulary and literacy skills (Bracken

& Fischel, 2008; Christian, Morrison, & Bryant, 1998). Similarly, socioeconomic status (SES) has been reported to differentiate reading outcomes (Fitzgerald, Spiegel, & Cunningham, 1991; Sénéchal, LeFevre, Thomas, & Daley, 1998). However, the influence of parental education and/or SES is likely to be attributable to the relationship between parental education and the execution of family reading behaviours that are known to facilitate literacy development, such as provision of resources, reading and writing tuition and shared book reading activities (Bracken & Fischel, 2008; Christian et al., 1998; Cottone, 2012; Roberts, Jurgens, & Burchinal, 2005; Sénéchal & LeFevre, 2002; Share, Jorm, Maclean, Matthews, & Waterman, 1983; Weigel, Martin, & Bennett, 2006). For instance, the quantity of reading materials available to children in their homes moderately correlates with later literacy achievements (Walberg & Tsai, 1985). However, Weigel, Martin and Bennett (2006) reported comparable numbers of books in the homes of children with developed and less developed emergent literacy skills. This indicates that the provision of literacy materials may be necessary, but not sufficient, for literacy proficiency. Instead, it may be the utilisation of these materials which is of utmost importance, for example through activities such as shared book reading.

Shared book reading promotes a positive attitude towards reading (Rowe, 1991). It also cultivates familiarity with oral and written language structures and therefore facilitates both language and literacy development (Bracken & Fischel, 2008; Sénéchal & LeFevre, 2002). Story book exposure is associated with concurrent and longitudinal receptive language development (Bennett, Weigel, & Martin, 2002; DeBaryshe, 1993; Sénéchal & LeFevre, 2002) and expressive language skills, particularly when there is emphasis on active discussion and open-ended questioning (Bennett et al., 2002; Bus, van IJzendoorn, & Pellegrini, 1995; Richman & Colombo, 2007; Whitehurst & Lonigan, 1998).

Shared book reading also facilitates both reading accuracy and comprehension (Bingham, 2007; Bus et al., 1995; Rowe, 1991; Scarborough, Dobrich, & Hager, 1991; Share et al., 1983), especially if there is an emphasis on the printed word, rather than pictures (Justic & Ezell, 2002). Parental support for reading is associated with parental enjoyment of reading (DeBaryshe, 1995). This in turn is related to the child's literacy competence, potentially due to the affective quality of shared book reading interaction. DeBaryshe (1995) found that parental interest in books was strongly correlated with facilitative maternal reading practices, which may result in more effective tuition.

In addition to exposing children to text through shared book reading, parents can also promote reading development via more structured, formal reading instruction. Sénéchal and LeFevre (1998) found that the frequency with which parents taught their 5-7 year old children to read predicted emergent literacy skills. This was further explored by Sénéchal and LeFevre (2002) who found parental teaching predicted emergent literacy skills at age 5-6, although at age 6-7 the effect of parental teaching was indirectly mediated by emergent literacy skills. However, at age 8-9 parental teaching was not a significant predictor once reading skill at age 6-7 was taken into account.

To summarise, the optimal HLE is literacy rich in terms of the provision and utilisation of resources. Specifically, exposure to text, via activities such as shared book reading and parental instruction, promotes literacy and language development, especially if reading is accompanied by discussion. However, it is noteworthy that these studies concentrate on the relationship between the HLE and the language and literacy attainment of pre-school and infant school children (i.e. ages 2-7). Can the HLE also foster the language and literacy skills of older children? There is little research with older school children; however extant research indicates that the HLE can impact the reading behaviour of older children and adolescents (cf. Klauda, 2009).

For children aged 10-11, parental provision of literacy resources and encouragement of reading positively correlates with the amount of time children spend reading for leisure (Neuman, 1986) and for children aged 8-11, provision of resources positively correlates with reading accuracy and comprehension (Halle, Kurtz-Costes, & Mahoney, 1997). In contrast with younger children, parental instruction does not significantly correlate with reading attainment (Halle et al., 1997). However, this finding may be an artefact of the index of parental instruction utilised. Halle et al.'s measure was the frequency with which parents spoke to their children about four topics, such as how to pronounce words correctly. Such interactions may be more effective at facilitating language development than literacy development, although there is evidence that vocabulary training can promote reading comprehension (Clarke et al., 2010; H. Nash &

Snowling, 2006). Another potential explanation for the lack of relationship between parental instruction and reading attainment is that parental input for older children may be similar regardless of reading ability; proficient readers are likely to be able to read independently, therefore need less parental input, whereas poorer readers are likely to be less willing to spend time reading due to the challenges they face (Chall & Jacobs, 2003; C. Clark & Foster, 2005).

From 'Learning to Read' to 'Learning through Reading'

As well as being a source of pleasure, reading can provide an opportunity to learn new information, including novel vocabulary (Nagy, Herman, & Anderson, 1985). Ehri (1992, 1999, 2005) suggested that familiarity with the written from of a word enhances word learning because the letters in the printed word provide cues to pronunciation, therefore facilitating mapping of orthography to phonology. Similarly, it has been suggested that the written form generates an orthographic image pertaining to the word and this supports memory of the pronunciation (Ricketts, Bishop, & Nation, 2009; Rosenthal & Ehri, 2008). This is consistent with dual-coding theory (Sadoski, 2005) which proposes that additional sources of information, for example a visual representation supplementing verbal representation, strengthen the mental representations of a word within the lexicon, aiding future access and retrieval. Exposure to the orthographic form may enable more fine-tuned specification of the phonological representation (Muneaux & Ziegler, 2004) and potentially enhance semantic learning. For example, adults learn definitions more rapidly for words presented with orthography relative to those presented only in the auditory domain (Nelson, Balass, & Perfetti, 2005). Furthermore, children learn visual-verbal pairings more easily than verbal-verbal pairings (Hulme, Goetz, Gooch, Adams, & Snowling, 2007).

Orthographic Learning in Typical Development

Experimental research has consistently demonstrated that orthography, in addition to phonological and semantic information, facilities oral vocabulary learning for TD children (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008). These studies introduce children to novel phonological forms and referents while manipulating the presence of orthography. For instance, Reitsma (1983) taught 16 TD children (mean age 8;3) six non-words, three with orthography present (OP) and three with orthography absent (OA). During the learning phase they categorised the stimuli as either animals or fruits and this continued until the children could correctly classify all six words correctly. During the test phase, children were asked to categorise each word six times; words presented with OP stimuli were categorised faster and more accurately than words presented in the OA condition.

Recently, Ricketts et al. (2009) taught 58 TD children (aged 8-9 years) 12 non-words paired with pictures of novel objects. Children were familiarised with the words prior to learning and then exposed to each stimulus six times in the learning phase. Performance on a non-word to picture matching post-test was close to ceiling, but response times indicated that children responded more quickly to words learned in the OP condition relative to words learned without orthography.

Similar findings have also been reported by Rosenthal and Ehri (2008), who taught 52 TD children (mean age 7;7) real, low-frequency concrete rare nouns (e.g. cur, wimple). In addition to viewing a pictorial representation of the stimuli and the name being presented in isolation, they also heard the name embedded in a defining sentence, and repeated the word and sentence. Participants were faster to learn the names and definitions in the orthography present learning condition. Additionally, orthography facilitated semantic learning, as assessed via a word to definition matching task, and orthographic learning, as indexed by a spelling task. The presence of orthography also facilitated the phonological, semantic and orthographic learning of 32 older students (mean age = 10;11) who were taught 10 concrete, multisyllabic, low-frequency nouns.

This research indicates that TD children benefit from viewing the written form during oral vocabulary learning; specifically it helps them learn the pronunciation, meaning and spelling of the new word.

Poor Comprehenders

Poor Comprehenders are also able to use orthography to learn new phonological and orthographic forms, but have specific difficulty learning semantic information about novel words and objects (Nation, Snowling, & Clarke, 2007;

Ricketts, Bishop, & Nation, 2008). For example, Nation, Snowling and Clarke (2007) taught 8-9 year old children how to associate new phonological forms to pictures of novel objects and found that there were no differences between Poor Comprehenders and TD peers in the number of trials needed to learn the labels for the objects (phonological learning). In contrast, the Poor Comprehenders learnt less semantic information pertaining to the objects than the TD controls, as indexed by a definition knowledge task. Furthermore, performance on a definition naming task decreased from time 1 (immediately after learning) to time 2 (a week later), suggesting that new information was not well-established, whereas the recall of the TD group remained stable.

Similarly, Ricketts et al. (2008) taught 15 Poor Comprehenders and 15 TD peers how to pronounce 20 visually presented non-words. There were no group differences in the number of trials taken to learn the pronunciations (phonological learning). However, unlike, Nation et al. (2007), Ricketts et al. also assessed orthographic learning and there were no group differences in performance on an orthographic choice task or on a spelling task. This is consistent with reports that Poor Comprehenders do not have difficulty with phonology, or learning orthography-phonology mappings (Catts, Adlof & Ellis Weismer, 2006; Nation, Adams, Bowyer-Crane, & Snowling, 1999; Nation & Snowling, 1998a). Once the children had learnt to pronounce the words, they were given the opportunity to infer word meanings from story contexts; semantic learning was assessed via a non-word to picture matching task. The Poor Comprehenders learnt fewer word meanings than their TD peers, consistent with the view that Poor Comprehenders have semantic difficulties. This differs from the findings of Nation et al. (2007) who reported no group differences on a picture naming task, but this may be attributable to the mode of learning (implicit vs. explicit) and the degree to which inferencing was required.

Down Syndrome (DS)

Further insight into the role of orthography can be provided by considering whether children with other developmental disorders can use their reading skills to learn new words. Down syndrome (DS) is a genetic disorder, which is usually caused by an extra copy of chromosome 21. Many children with DS have intellectual and language impairments. Additionally, individuals with Down syndrome have decoding skills that are superior to text comprehension (Snowling, Nash & Henderson, 2008). Mengoni, Nash and Hulme (2013) taught 17 children with DS and 27 younger TD children matched for word reading ability 10 non-words, five with the orthography present and five with orthography replaced by three randomly selected Greek or Cyrillic letters. The participants were exposed to each item 12 times and learning was assessed 10-15 minutes after training. The presence of orthography aided spoken comprehension (word to picture matching) and production (picture naming) of the words and there were no significant differences between children with DS and the TD comparison group. These results are encouraging as they suggest that providing children with the written form may enhance knowledge of phonological aspects of new word, regardless of language or cognitive ability.

Language Impairment (LI)

What is Language Impairment (LI)?

In DSM-V, language impairment is termed 'language disorder' and is defined as persistent difficulty in the acquisition and use of spoken, written or signed language that causes a functional impairment and cannot be accounted for by deficits in general cognitive ability (APA, 2013a). Children with LI have a reduced vocabulary, limited sentence structure and impairments in discourse (APA, 2013a). However, there is heterogeneity in the severity of LI; some children have mild impairments, whereas others have severe and persistent difficulties. Although impairments must be substantially and quantifiable below age expectations, there are no specific criteria regarding diagnostic assessments or severity levels.

Estimates of the prevalence of LI vary from 2-19% depending upon the age of the sample and the diagnostic criteria employed (Law, Boyle, Harris, Harkness, & Nye, 2000). This is clearly illustrated by the results of a longitudinal epidemiologic study of 7,000 monolingual English-speaking children conducted by Tomblin et al. (1997). Tomblin et al. (1997) considered children to have a LI if they attained a standard score more than 1.25 SD below the norm on two of five composite language scores. When the children were aged 5-6, the prevalence of LI was 7.4%, however, one year later only 46% of these children still met criteria for SLI. This may reflect overly lenient criteria, which identifies ‘false-positives’.

Two sensitive psycholinguistic markers of LI are sentence repetition and non-word repetition tasks. As the names suggest, children are presented with a spoken sentence/non-word and instructed to repeat it; accuracy is recorded. Examples of frequently used tasks include the recalling sentences subtest of the Clinical Evaluation of Language Fundamentals (CELF; Semel, Wiig, & Secord, 2003) and the Children’s Test of Nonword Repetition (Gathercole & Baddeley, 1996). Conti-Ramsden (2003) examined four potential positive markers for SLI, namely non-word repetition, digit recall, past tense and noun plurals tasks. The scores of 32 five year old children with LI were compared to 32 TD peers. The tasks with the best overall accuracy at the 25th and 16th centile were the non-word repetition and the past tense task. More specifically, at the 16th centile, the past tense marking task had an overall predictive ability of 81.1%, with high sensitivity and specificity (both 81%). However, a third of the children with LI were unable to complete the practice trials of the past tense task, limiting its applicability. In contrast, all children completed the non-word repetition test and at the 16th centile its overall predictive ability was 81.3%, with high sensitivity (78%) and specificity (84%). Coady and Evans (2008) suggest that the non-word repetition task is such a powerful tool for identifying children with language impairments because it taps multiple language processes, including speech perception, phonological encoding, phonological memory, phonological assembly and articulation.

Nevertheless, sentence repetition may be a more accurate identifier of LI than non-word repetition. Conti-Ramsden, Botting and Faragher (2001) compared the potential of four tasks as positive psycholinguistic markers of LI. These were a third person singular task, a past tense task, a non-word repetition task, and a sentence repetition task. These measures were administered to 160 children aged 11 years with LI and 100 TD peers. Sentence repetition was found to be the most useful psycholinguistic marker of LI. It had high levels of overall accuracy (88%), as well as high sensitivity (90%) and specificity (85%). The non-word repetition task had slightly lower overall accuracy (82%), as well as slightly lower sensitivity (78%), but similar specificity (87%).

Thus, although the exact criteria used to identify LI vary, individuals with LI have impairments in phonological processing, semantic skills and sentence processing, all of which may affect how literacy develops.

Reading in Children with LI

Evidence of a link between language impairment and reading disabilities is provided by longitudinal studies. Over 30 years ago, Aram and Nation (1980) conducted a longitudinal study of 63 children with language impairments. They were assessed prior to school entry and again 4 to 5 years later. The children's teachers reported that a third were achieving below average scores on standardised reading assessments. Similarly, Catts et al. (2002) reported that, as a group, 200 children with LI had significantly lower standard scores than their TD peers for single word reading and reading comprehension at ages 7-8 and 9-10 At an individual level, 50% of the children with LI had reading comprehension scores $\geq$1SD below the mean, compared to only 8% of the control group. Moreover, the severity of LI at ages 6-7 was associated with reading achievement at ages 9-10.

Difficulties with reading persist into adolescence. Stothard et al. (1998) reported the literacy skills of 71 children with pre-school language impairments. At age 5;6, these children were divided into three groups; 26 children with resolved LI, 30 with persistent LI and 15 with general delay (language and cognitive impairments). At ages 15-16, literacy skills were assessed via three tasks which formed a literacy composite (single word reading, single word spelling and reading comprehension). All three clinical groups achieved significantly lower scores than their TD peers, although the resolved LI group attained higher scores than both the persistent LI and general delay groups. In addition, 93% of the persistent LI and 80% of the general delay group scored below the level expected of a 12-year old for reading accuracy, reading comprehension or spelling. In contrast, 52% of the resolved LI group and 22% of the comparison group scored below that level, demonstrating that the effects of language impairment on literacy skill are long-lasting, even if language skills improve.

On the basis of this evidence, effective oral language interventions should result in improvements in literacy skill. Clarke et al. (2010) conducted a randomised controlled trial to assess the efficacy of three interventions designed to improve the reading comprehension of Poor Comprehenders. These 20 week interventions involved text comprehension training, oral language training or a combination of the two. All three intervention groups showed greater improvements in text comprehension than waiting list controls, however only the group receiving the oral language training continued to show increases in comprehension between the end of the intervention and the 11 month follow-up. Both the oral language training, and the combination training, resulted in increases in participants' expressive vocabulary and this was a mediator of the improved reading comprehension. This provides further support for the intimate relationship between oral language and literacy competence.

Summary

This review has explored two components of reading, namely decoding and comprehension. Oral language skill facilitates the development of both facets. As a result children with reading impairments (i.e. dyslexia and poor comprehension) have poorer oral language skill than their TD peers; likewise children with LI have both decoding and comprehension deficits. Interventions targeting oral language skills can improve decoding and comprehension, although differential skills may need to be targeted for each disorder (cf. Snowling & Hulme, 2012). Additionally, these skills can be facilitated by the HLE, especially shared book reading practices. In turn, TD children and Poor Comprehenders can use their reading skill to facilitate language learning. Therefore there is a reciprocal relationship between linguistic and literacy competence.

However, it is uncertain whether such an intimate and reciprocal relationship is found for children with other developmental disorders, such as Autism Spectrum Disorder (ASD). ASD is characterised by impairments in social interaction and communication, in the context of a repetitive and restricted range of interests and behaviours (APA, 2013a). Additionally, around 50% of children with ASD also have language impairments. It may therefore be expected that these children would find learning to read especially challenging, more so than their non-language impaired autistic peers. However, it is only relatively recently that researchers have explored the reading skill of children with ASD with consideration of language phenotype. This thesis will systematically explore the single word, sentence and passage reading skills of ASD, as well as investigating the influence of language phenotype. In addition the HLE of children with ASD will be detailed, and the relationship between the HLE and the literacy and language attainment of children with ASD explored. The final study will assess whether children with ASD can use their reading skills to learn new information, specifically novel vocabulary. In order to situate these studies within the context of the existing literature, the next chapter will characterise ASD and different language phenotypes within ASD, and discuss what is already known about reading in ASD.

Chapter Two: Autism Spectrum Disorder (ASD)

Chapter Overview

Chapter 1 provided an overview of reading in typical development, in order to situate the literature on reading in ASD. The reading profiles of children with ASD may differ to those of their TD peers; factors associated with autistic cognition may either impair or facilitate reading development. Additionally, many children with ASD have concomitant language impairments and on the basis of the TD literature it would be expected that this would impede reading development. Following characterisation of ASD, the relationship between reading ability and both autistic cognition and language phenotypes within ASD will be examined. The chapter then explores whether children with ASD can learn through reading. It concludes with specification of the aims of this thesis.

What is ASD?

Autism Spectrum Disorder (ASD) is a developmental disorder that is characterised by persistent and pervasive impairments in social interaction and social communication in the context of restricted, repetitive behaviours, interests and activities (RRBs; American Psychological Association, APA, 2013a). Deficits in social interaction and communication may be manifested through impairments in social-emotional reciprocity, non-verbal communicative behaviours or in developing, maintaining and understanding relationships. RRBs can include stereotypy, insistence on sameness, ritualistic behaviour, restricted behaviour and hyper- or hypo-reactivity to sensory input. Under the new DSM-V criteria, both components are required for a diagnosis of ASD. Clinicians must also specify whether any other disorders/conditions are present, including but not limited to; intellectual impairment, language impairment, medical or genetic conditions, another neurodevelopmental, mental or behavioural disorder, or catatonia. Cognitive and linguistic impairments frequently co-occur with ASD, but are not core to diagnosis.

The DSM-V diagnostic criteria were published in May 2013, therefore participants in this thesis were categorised according to DSM-IV (American Psychological Association, 2000). In DSM-IV, ASD was characterised by a triad of impairments in the domains of reciprocal social interaction, verbal and nonverbal communication and restricted and repetitive behaviours. ASD included the sub-categories of autistic disorder, Asperger's disorder, childhood disintegrative disorder and pervasive developmental disorder - not otherwise specified (APA, 2000). One key difference between autistic disorder and Asperger's disorder was language development. Individuals diagnosed with autistic disorder tended to have early language delay, whereas individuals with Asperger's disorder do not.

In the UK, the prevalence of ASD is 116.1 per 10000 (Baird et al; 2006) with a male to female ratio of 4:1. Impairments must be present in the early developmental period (APA, 2013a) and early indicators of ASD include the attenuation of typical behaviours such as appropriate gaze, shared enjoyment or interest, gestures and response to name, as well as atypical behaviours such as unusual prosody, and repetitive movements of the body or objects (Wetherby et al., 2004). However, until social demands exceed an individual's capacity, symptoms may not become fully manifest (APA, 2013a) and the median age of diagnosis in the USA is five to seven years (Shattuck et al., 2009). There is a tendency for ASD to be diagnosed earlier if a child has cognitive impairments or they experience developmental regression (Shattuck et al., 2009).

Non-verbal abilities are variable in ASD. In general, cognitive assessment standard scores below 70 are indicative of intellectual impairment (APA, 2013a) and the authors of DSM-IV suggest that 75% of individuals with ASD may have intellectual impairments (APA, 2000). However, recent prevalence estimates have been lower. For example, in the US 41% of individuals with ASD were reported to score ≤ 70 on their most recent test of intellectual ability (Autism and Developmental Disabilities Monitoring Network, 2009). Similarly, Charman et al. (2011) found that 55% of their ASD sample had an IQ < 70. Whilst verbal and non-verbal abilities are moderately correlated in typical development (Wechsler, 1999), they may be discrepant in developmental disorders. Joseph, Tager-

Flusberg, and Lord (2002) assessed the cognitive ability of 47 children aged 6-13 who had clinical diagnoses of autism or PDD-NOS. Verbal and non-verbal IQ were assessed through subscales of the Differential Ability Scales (DAS; Elliot, 1990) and the mean standard scores were similar. Thus, at first glance, it would appear that non-verbal ability does align with verbal ability. However, when scores were examined at the participant level, discrepancies were evident for 62% of the children - which is considerably higher than in the DAS normative sample (c.a. 30%). Notably, discrepancies occurred in both directions, with 16 participants (34%) having greater non-verbal than verbal IQ, and 13 participants (28%) having higher verbal than non-verbal IQ. Siegel, Minshew, and Goldstein (1996) conducted a review of 16 studies and found that discrepancies were reported in 13 (81%) of the studies. For nine of the studies (56%) non-verbal IQ was greater than verbal IQ, whilst only four (25%) of the studies reported greater verbal than non-verbal IQ. This indicates that for many children non-verbal IQ may be greater than verbal IQ. Indeed, many studies providing descriptive statistics for their sample of ASD participants report lower verbal than non-verbal IQ scores (e.g. Norbury, Griffiths & Nation, 2010), especially for participants who have concomitant language problems (e.g. Lindgren et al., 2009; Kelly, Walker & Norbury, 2012).

Around 30% of individuals with ASD experience regression of skills (Johnson, Myers, & The Council on Children with Disabilities, 2007; Lingam et al., 2003; Pickles et al., 2009; Shattuck et al., 2009; Tuchman & Rapin, 1997), although estimates vary depending upon the nature of the sample, for example epidemiological vs. clinical (Ozonoff, Heung, Byrd, Hansen, & Hertz-Picciotto, 2008). Large population-based studies have found that 15-30% of children with ASD experienced regression (Fombonne & Chakrabarti, 2001; Lingam et al., 2003), whereas clinical studies report higher rates ranging from 20-50% (DeMyer, 1979; Lingam et al., 2003). Additionally, prevalence estimates differ according to the way in which regression is defined; there is debate whether classification of regression requires loss of language only, or in addition to other skills (such as social skills). Hansen at al. (2008) found that 41% of their sample met the criteria for regression when the definition specified that either language or social skills were lost, however, only 15% had experienced language regression in isolation.

Language Phenotypes in ASD

Children with ASD have difficulty with the social use of language, that is, pragmatics. Pragmatic impairment has been described as a primary impairment in ASD and as such is impaired in all individuals with ASD regardless of their place on the spectrum and independent of the existence of other linguistic impairments (Lord & Paul, 1997). In particular, children with ASD have difficulty understanding social norms and expectations (Ochs & Solomon, 2004). However, more generally, the linguistic profiles of children with ASD vary dramatically; some children are non-verbal, whereas others are verbose. Hus, Pickles, Cook, Risi, and Lord (2007) conducted a study of nearly 1,000 individuals with ASD aged 4-52 (mean age = 7.75, SD = 4.58) and found that 51% of the sample had delayed phrase acquisition, 41% had delayed word acquisition and that nearly 10% of the sample were completely non-verbal. Similarly, Wodka, Mathy, and Kalb (2013) assessed the language skills of 538 children with ASD (mean age = 11.6) and whilst 47% of the sample had fluent speech, 23% had phrase speech, and 30% had minimal expressive language skills, i.e. were unable to use phrases.

The relationship between ASD and language competence has been debated since the 1970s. Early researchers considered autistic symptomatology to be a manifestation of severe language impairment (Rutter, 1967) whilst, others argued against this on the grounds that ASD and LI can occur independently (Boucher, 1976). It was also suggested that some, but not all, children may have LI in the context of ASD (Bartak, Rutter, & Cox, 1975).

Kjelgaard and Tager-Flusberg (2001) investigated the language abilities of 89 children with ASD (aged 4-14) and found that scores on vocabulary tasks and the Clinical Evaluation of Language Fundamentals (CELF; Semel, Wiig & Secord, 2003) total language score (composite of receptive language, expressive language and grammatical knowledge) ranged from severely below average to above average. To explore the heterogeneity, the sample was divided into three groups on the basis of CELF total language scores. Only 44 of the children were able to complete the CELF and of these, 10 attained a score >85 and were classified as having ‘normal’ language. The 13 children with scores between 70 and 84 (i.e. 1-2 SD below the mean) were classed as ‘borderline’ and the 21 children scoring below

70 were considered to have impairments. Vocabulary knowledge aligned with core language ability, as did non-word repetition skill. As a group, the children with age-appropriate language skills attained an average non-word repetition score within the normal range, whereas the other two groups scored more than 1 SD below the population mean, although group differences were not statistically significant.

Thus, within ASD different language phenotypes are evident; some children have age-appropriate language skills (ALN; Autism, Language Normal), whilst others have deficits in receptive language, expressive language, grammatical knowledge and phonological processing (ALI; Autism, Language Impaired). The deficits exhibited by these children parallel the difficulties experienced by children with LI, suggesting there may be overlap in the impairments experienced by some autistic and non-autism children. However, there is contention over whether the language impairments experienced by children with LI and ALI are qualitatively similar or different, an issue which is still debated today.

Behavioural Evidence

Behavioural evidence of language phenotypes is provided by comparison of the performance of children with ALN and ALI on language measures. Researchers have consistently reported that children with ALN achieve higher scores on standardised assessments of expressive and receptive vocabulary and sentence comprehension then those with ALI (Kjelgaard & Tager-Flusberg, 2001; Lindgren, Folstein, Tomblin, & Tager-Flusberg, 2009; Loucas et al., 2008; Norbury, 2005a; Norbury & Nation, 2011; Tager-Flusberg & Cooper, 1999). Children with ALI also perform more poorly on psycholinguistic markers of LI. For example Norbury and Nation (2011) found that adolescents with ALI attained lower non-word repetition scores than their ALN and TD peers. Likewise, Riches, Loucas, Charman, Simonoff and Baird (2010) found that children with ALI attained lower sentence repetition scores than their TD peers, but were commensurate with non-autistic LI peers. This suggests that there is a common cognitive substrate to language impairment. However, whilst the LI groups demonstrated significant effects of complexity and adjective position the ALI children did not.

Whitehouse, Barry, and Bishop (2008) further explored whether the language impairments experienced by children with LI and ALI are qualitatively similar by comparing the non-word repetition skills of 32 children with ASD and 34 non-autistic children with LI. Participants were categorised as ALI/LI if they scored below the 10^{th} centile on two or more of six standardized language tests. Both the ALI (n=18) and non-autistic LI groups performed worse on the non-word repetition task than the ALN group (n=14). However, there was a different pattern of errors; although children with LI and ALI made a similar number of errors on words with two or three syllables, the LI group made significantly more errors on words with five syllables.

Loucas et al. (2008) assessed the language skills of 72 children with ASD who were drawn from a population cohort. Fifty-seven percent of the sample were identified as having language difficulties and they were compared to a sample of 25 non-autistic children with LI. The ALI and LI groups had similar expressive vocabulary, but the ALI group had poorer receptive language than their LI peers, and relative to their own expressive vocabulary scores. In contrast, the LI group had stronger receptive than expressive language. This finding is consistent with research conducted by Bartak, Rutter, and Cox (1975; 1977). Their groups of ASD and LI participants had similar deficits in expressive language and language production, but the ASD group scored significantly lower on measures of language comprehension. Likewise, Lloyd, Paintin, and Botting (2006) reported that their ALI group had weaker receptive than expressive language skills, as did Hudry et al. (2010). Thus, some children with ALI have poorer language comprehension than language expression, as indexed by standardised assessments, although this may not be the case for children with LI.

Another area of differentiation between ASD and LI is the phenomenon of language loss. Pickles et al. (2009) examined the prevalence of language loss in a sample of 328 children who had a diagnosis of either ASD or LI. Responses on the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) indicated that 15% of the children with ASD had language regression and for 72% of these children, the language loss occurred before the child said their first phrase.

In contrast, only 1% of the LI sample had language regression. Thus, language regression occurs more frequently in ASD and is not characteristic of LI.

To summarise, at the behavioural level there is considerable overlap between ALI and LI, however there are also some distinct differences. Analysis of brain structure may elucidate these findings and determine etiological foundations of the behavioural phenotypes. If the language phenotypes are indeed similar, it would be expected that similar atypical patterns of brain structure would be evident.

Neuroanatomy

Group differences have been identified in the brain structure of individuals with LI, relative to TD controls. For TD individuals, cortical regions, especially in key language areas such as the perisylvian region, planum temporale and Heschel's gyrus, are larger in the left hemisphere than the right hemisphere. However, for individuals with LI or language-based learning disorders (such as dyslexia) there is reduced or reversed asymmetries in these areas (M. Clark & Plante, 1998; Galaburda, 1989; Gauger, Lombardino, & Leonard, 1997; Jernigan, Hesselink, Sowell, & Tallal, 1991; C. Leonard et al., 1996; Plante, Swisher, Vance, & Rapcsak, 1991). Thus, if there is overlap between LI and ALI, it would be expected that this reversed asymmetry would be present for individuals with ALI. Herbert et al. (2002) analysed the magnetic resonance brain images of 16 boys with ASD, the majority of whom were believed to have language impairments, although language data was not obtained, and 15 TD peers. As expected, the volume of the inferior lateral frontal language cortex (pars opercularis, associated with Broca's area) was 17% larger in the left hemisphere than the right hemisphere for the TD boys. However, for the boys with ASD, the right hemisphere of this region was 27% larger than the left. The reversed asymmetry aligns with the profile for individuals with LI, indicating that the two groups have similar neuroanatomy. Direct comparison of ALN and ALI phenotypes relative to TD and LI peers would strengthen this supposition. Such a paradigm was employed by De Fossé et al. (2004) who scanned 42 children aged 6-13. The TD group had inferior frontal gyrus asymmetry, with larger volume on the left hemisphere and this profile was also evident for the boys with ALN. In contrast, the reverse asymmetry was found for the boys with LI, and those with ALI. This provides more concrete evidence of the overlap between LI and ALI. The results of these studies indicate that there is neuroanatomical overlap between ALI and LI suggesting a shared etiology. However, examination of genetic factors provides more equivocal evidence.

Genetic factors

LI is highly heritable, as evidenced by both family studies (Barry, Yasin, & Bishop, 2007; Lindgren et al., 2009; Whitehouse, Barry, & Bishop, 2007) and twin studies (Bishop, Adams, & Norbury, 2006; Bishop, North, & Donlan, 1996). In particular, performance on non-word repetition tasks is highly heritable (Bishop et al., 2006; Bishop et al., 1996; Lindgren et al., 2009; Whitehouse et al., 2007). If there is a shared etiological risk for both LI and ALI then language impairments and non-word repetition deficits specifically, should be highly heritable in ALI. However, this does not appear to be the case (Bishop et al., 2004; Lindgren et al., 2009; Whitehouse et al., 2007). For example, Whitehouse et al. (2007) found that the parents of ALN and ALI probands did not differ on any language measure. Similarly, Bishop et al. (2004) found that the relatives of ASD children with average non-word repetition ability did not differ from the relatives of probands with non-word repetition deficits.

It could be argued that the lack of group differences is attributable to the arbitrary divide of the high and low language groups. The only study which has directly compared heritability for clinically diagnosed ALN and ALI children was conducted by Lindgren et al. (2009). ALI probands had a history of language delay/deficit and scored >1 SD below the mean on either the CELF or a non-word repetition task. There was not an increased familial risk for non-word repetition deficits in siblings. There was an increased familial risk for mothers of ALI probands, although this was not the case for mothers of ALN probands. Therefore, there does not appear to be an increased prevalence of language impairments amongst families of ASD probands. This indicates that the language impairments of children with ASD are not necessarily heritable. Thus, ALI and LI may not have a shared genetic etiology. However, this conclusion is not consistent with the results of molecular genetic studies.

Molecular genetic studies identify chromosomal regions that are shared more frequently than would be expected by chance for individuals with a specific disorder. Studies exploring genetic factors have reliably identified that chromosomes 16q and 19q are linked with LI (SLI Consortium, 2002, 2004). More specifically, two specific risk alleles on chromosome 16 (CMIP and ATP2C2) independently modulate non-word repetition performance (Newbury et al., 2009). Non-word repetition is also associated with polymorphisms in the CNTNAP2 gene, a downstream target of FOXP2 located on chromosome 7 (Vernes et al., 2008). Notably, CNTNAP2 has been implicated in ASD (Alarcón et al., 2008; Arking et al., 2008), which suggests overlap between LI and ASD. This association at a molecular genetic level is contrary to the findings of familial studies.

Bishop (2010) attempted to reconcile behavioural and genetic studies using computer simulations to model potential genetic relationships between LI and ALI. The first model correlated additive risks and resulted in increased rates of co-morbidity. However, it did not account for the differential familial patterns for LI and ALI probands. A modified simulation incorporated nonadditive gene interactions, taking into account both additive effects of genes and interactions between genes. This model provided a better fit to the observed data, accounting for the familial differences, however the diagnostic criteria used to categorise language impairment influenced the degree of match.

Summary of Language Phenotypes Within ASD

To date, research suggests that the language impairments experienced by children with ALI are similar to those of non-autistic children with LI in terms of their type and severity. Furthermore, they potentially share causal risk factors. However, others aspects, such as a discrepancy between expressive and receptive vocabulary, as well as language regression, may be specific to ASD. Thus, both ASD-specific and non-specific language risk factors may influence the reading development of children with ASD and especially children with ALI.

Despite the wealth of evidence highlighting the intimate relationship between language and reading ability for TD children (Roth et al., 1996), little research has explored whether this is evident for children with ASD. Instead, the majority of research has examined the extent to which aspects of autistic cognition may influence reading ability.

Cognitive Theories of ASD

The majority of research exploring the reading skills of children with ASD has been conducted with reference to three major cognitive theories of ASD, namely the Theory of Mind account (Baron-Cohen et al., 1985), Executive Dysfunction theory (see Hill, 2004) and Weak Central Coherence (Happé & Frith, 2006). This section will detail these theories and discuss their contribution to the reading profile of individuals with ASD.

Theory of Mind Account

The term Theory of Mind (ToM) was coined by Premack and Woodruff (1978) and refers to the understanding of mental states, both those of oneself and others. These mental states include, but are not limited to: purpose or intention, knowledge, belief, thinking, doubt, guessing, pretending and liking. This capacity for inferring the mental states of others enables us to evaluate and predict their behaviour and thus is central to interaction. Baron-Cohen, Leslie and Frith (1985) posited that a deficit in ToM could contribute to the social impairments characteristic of ASD. They assessed this hypothesis through the classic 'Sally-Anne' false-belief task (Wimmer & Perner, 1983). In this test, participants are told a story about two girls, called Sally and Anne. At the start of the story, Sally puts a ball in a basket and then she goes out to play. Whilst she is outside, Anne removes the ball and hides it in a box. The participant is then asked where Sally will look for the ball when she returns. If they understand false belief, they will answer that Sally will look in the basket, despite their knowledge that the ball is actually in the box. Baron-Cohen et al. (1985) administered this task to 20 individuals aged 6-16 with ASD and compared their performance to 27 TD controls and 14 individuals with Down syndrome, which led to the conclusion that individuals with ASD have a domain-specific deficit in ToM. This notion has since been replicated with both language based (Happé, 1994) and pictorial tasks (Baron-Cohen, Leslie, & Frith, 1986; Leslie & Thaiss, 1992).

ToM impairments could impact upon the extent to which a text is comprehended; specifically, ToM deficits could result in reduced understanding of the mental states of story characters and how these internal states motivate character behaviour. It would therefore follow that comprehension would align with the extent to which the text is of a social nature. Brown et al. (2013) conducted a meta-analysis of reading comprehension stories and compared comprehension of high and low social texts. Comprehension of highly social texts was significantly impaired relative to TD controls, with the ASD standardised mean differences most frequently ranging from -2.0 to -1.0 SD. For less social texts, there was a trend of the ASD group to achieve lower scores but the standardised mean differences most frequently occurred between an interval of -0.5 SD and 0. This provides some indication that comprehension of texts is associated with the extent to which social knowledge is required. However, there is a tendency for texts with a high social orientation to be more complex (cf. White, Hill, Happé, and Frith, 2009), which may contribute to this finding.

One tool used to assess the influence of ToM on comprehension is the Strange Stories test, which was designed by Happé (1994). Participants read naturalistic stories which differ in the extent to which they rely on mentalising competency, and then answer comprehension questions. Four Strange Stories that do have a mentalising component were included in the test battery of Ricketts Jones, Happé and Charman (2013), who assessed the reading skills of 100 adolescents. When entered into regression models, performance on the Strange Stories task was a unique predictor of reading comprehension; however it only contributed 4-5% of unique variance, after word recognition and oral language were accounted for. Similarly, performance on the Frith-Happé animations task, in which participants attribute mental states to two interacting cartoon triangles, only predicted 2-3% of unique variance in reading comprehension. This suggests that ToM may exert a little additional influence on reading comprehension. However, it is unclear how many of the adolescents actually had ToM deficits; ToM deficits are not a universal feature of ASD (Bowler, 1992; Ozonoff, Rogers, & Pennington, 1991; White et al., 2009). It would be expected that comprehension difficulties would be particularly pronounced for individuals with large ToM impairments.

This was explicitly assessed by White et al. (2009) who administered the Strange Stories task to 45 children aged 7-12 with ASD, 15 with ToM impairments and 30 with better ToM. Participants with ASD and better ToM achieved similar reading comprehension scores to their TD peers, who were matched for both non-verbal and verbal IQ. However, those with ASD and poor ToM performed more poorly than their TD peers on the mental, human and animal stories, but not on the nature stories. The two ASD groups only differed on the mental stories task, with the ToM deficit group achieving lower scores. These results suggest that comprehension of stories which require mentalising is particularly challenging for individuals with ASD and ToM deficits, and that even when mental state attributions are not necessary, processing animate agents may still be difficult for these children.

However, it is noteworthy that success on ToM tasks is highly dependent on language ability (Farmer, 2000; Norbury, 2005b). Farmer found that children with LI (mean age = 10 years) had lower ToM scores than their TD peers. This finding was extended by Norbury, who administered a ToM task to 94 children with communication impairments and 34 TD peers aged 8-14. Children with ALN attained scores within normal limits, whereas children with ALI and non-autistic children with LI achieved significantly lower scores, which were nearly 2 SD below the population mean.

Executive Dysfunction Account

Executive function is an ‘umbrella term’ for a diverse array of cognitive functions that are involved in the conscious control of thought and action (Zelazo, Muller, Frye, & Marcovitch, 2003). It is a multi-faceted construct which encompasses control processes such as planning, inhibition, working memory, concept formation, problem solving, set-shifting, action monitoring and self-monitoring. These factors are discrete, as evidenced by the non-significant or low correlations between performance on different tasks, and the results of factor analyses which yield multiple factors (Brocki & Bohlin, 2004; Lehto, 1996; Welsh, Pennington, & Groisser, 1991). Executive function begins to develop prior to school entry (Garon, Bryson, & Smith, 2008) and some components, such as working memory, continue to develop into adolescence (Gathercole, Pickering, Ambridge, & Wearing, 2004).

When applied to the reading domain, difficulties with monitoring are particularly relevant. Monitoring of understanding, and acting to restore lost comprehension, are essential for successful reading. Snowling and Frith (1986) investigated comprehension monitoring in ASD. The first task comprised a text which contained ‘gaps’ for participants to complete with one of three provided words; one of the three words was ‘story appropriate’, another ‘contextually appropriate’ and the third ‘inappropriate’. Individuals with ASD and high verbal ability were just as likely to make story appropriate choices as TD children and individuals with cognitive impairments who were of similar reading age and verbal mental ability to the ASD group. Individuals with ASD and low-verbal ability completed the task as well as cognitively impaired peers, but both groups were less accurate than younger TD children. A potential limitation of this task is that it continually focuses attention and therefore may over-estimate comprehension. To control for this, Snowling and Frith (1986) created a second test which did not explicitly focus attention on specific words. In this task, participants were required to read a short story and cross out any anomalous words. There were no group differences for the high verbal participants, with all three groups performing close to ceiling. However, error rates for the low verbal autistic and cognitively impaired groups were high, indicating that either they did not identify the errors, or they did not understand the task.

These findings were replicated by Norbury and Nation (2011) who used slightly modified versions of the original tasks. On the first task, adolescents with ALN selected the optimal word to complete the sentence as frequently as their TD peers. In contrast, adolescents with ALI were less accurate and made significantly more ‘inappropriate’ selections than the other two groups. On the second task, the adolescents with ALN identified as many anomalous words as their TD peers, but those with ALI were significantly less successful. These studies indicate that comprehension monitoring is associated with language competence, rather than ASD *per se*.

Weak Central Coherence Account

Central coherence is the ability to understand the general meaning, the 'gist', of information, rather than focusing on each individual detail. It requires the amalgamation of information from different sources, including experiences and schemas, both internal and external, in order to glean a higher meaning. For example, after reading a story, the general meaning is retained, but each individual word is not remembered. This processing style is evident amongst TD individuals (see Kimichi, 1992), but argued to be deficient in ASD (Frith & Happé, 1994). Frith and Happé proposed the Weak Central Coherence (WCC) account of ASD, suggesting that individuals with ASD are impaired at processing stimuli globally, instead exhibiting a bias towards local processing of the individual components. It has since been argued that rather than individuals with ASD having deficits in global processing, they have enhanced orientation towards local processing, which is a discrete cognitive feature, rather than a comparison to global processing (Happé & Frith, 2006; Mottron, Dawson, Soulières, Hubert, & Burack, 2006; Plaisted, Saksida, Alcántara, & Weisblatt, 2003). This has been referred to as a 'detailed-focused' cognitive style.

Processing preferences have often been assessed through visuo-perceptual tasks, such as the Embedded Figure Test (Witkin, Oltman, & Karp, 1971). The task requires the participant to locate a simple geometric shape embedded within a larger, more complex picture. A faster time indicates a local processing bias, whereas a longer time reflects a more global bias. Shah and Frith (1983) found that children with ASD completed this task significantly faster than peers with moderate learning difficulties matched for non-verbal mental age, as well as younger children also matched on non-verbal mental age. This enhanced performance on the Embedded Figure Test has been replicated in many studies, for example Morgan, Maybery, and Durkin, (2003) and Pellicano, Maybery, Durkin, and Maley (2006).

Another task on which individuals with ASD generally outperform TD controls is the Block Design subtest of the Wechsler Intelligence Scale (Wechsler, 1999). Participants are presented with a design, which they must construct from individual blocks. The task is a modified version of Kohs Block Design Test and successful completion requires the design to be 'broken-up' into separate, isolated components (Kohs, 1923). Therefore performance will be facilitated by a local processing style. Shah and Frith (1993) found that there were no group differences on pre-segmented designs, but adults with ASD outperformed both TD adults and those with mild learning difficulties on designs which were not explicitly segmented. This suggests that individuals with ASD are more adept at segmenting a gestalt percept, providing support for the WCC account of ASD.

Whilst a detail-focused processing style may be beneficial for some tasks, it could negatively affect the extent to which text is comprehended; text comprehension requires information to be integrated and inferences drawn (e.g. Jolliffe & Baron-Cohen, 1999). Indeed, Kanner (1943) noted that children with ASD process the individual components of stories, rather than considering their "coherent totality" (p.250). A classic verbal-semantic coherence task is the homograph task (Frith & Snowling, 1983). The task measures the extent to which individuals use contextual information to modify pronunciation of homographs, for example, '*in her <u>eye</u> was a tear*' versus '*in her <u>dress</u> was a tear*'. Correct pronunciation of the homograph relies on global processing of the sentence as a whole. Several studies have found that individuals with ASD pronounce homographs less accurately than their TD peers, exhibiting a tendency to use the most frequent pronunciation, regardless of the context (Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 1999; López & Leekam, 2003). This suggests that individuals with ASD process sentences in a local, piecemeal manner and has been taken as evidence of WCC.

However, Brock and Bzishvili (2013) administered the homograph task to 40 university Psychology undergraduates and found that stimuli presentation order can affect task performance. Specifically, they assessed the extent to which accuracy of pronunciation varied as a function of trial number and condition, and found that accuracy increased across trials for the subordinate pronunciation of the homographs. In contrast, accuracy decreased across trials for the dominant meaning when the homograph appeared before the context in the sentence. Once participants had encountered the subordinate pronunciation of the homograph, they were more likely to produce it again, particularly in the homograph-first condition.

Additionally, eye to voice span (the time between the first fixation on the homograph and the onset of the vocalisation) increased throughout the trials, reflecting an increase in processing time. As a result, eye to voice span was a significant predictor of accuracy. Therefore the homograph task may not measure immediate and spontaneous use of context, as it is commonly assumed. Instead, success requires participants to reflect upon and modify their strategy and therefore performance may be influenced by monitoring and perseveration, two executive function skills.

Additionally, performance on the homograph task is dependent on language skill. Successful completion requires children to understand that homographs have multiple meanings, to know these multiple meanings and to know that they are associated with different pronunciations, to access the correct meaning/ pronunciation and to inhibit the incorrect meaning/pronunciation (even when it is of higher frequency). These skills are all reported to be poorer amongst children with language difficulties (cf. Norbury, 2005), in part due to reduced semantic knowledge. Indeed, Snowling and Frith (1986) administered the homograph task to 16 individuals with ASD and found that those with a verbal mental age greater than 7 years, were able to use sentence context to disambiguate the homographs, and did so as accurately as TD children matched for verbal mental age. In contrast, children with ASD and a verbal mental age less than 7 years usually produced the higher frequency pronunciation.

Summary of Cognitive Theories of ASD

In summary, each of three cognitive theories has attempted to contribute to our understanding of the literacy skills, and in particular the reading comprehension, of individuals with ASD. However, performance on ToM, executive function and central coherence tasks is highly dependent on language ability (Farmer, 2000; Norbury, 2005b; Norbury & Nation, 2011; M. Snowling & Frith, 1986). Furthermore, if autistic cognition exerts an influence on reading comprehension, then it would be expected that all children with ASD would experience comprehension difficulties, yet this is not the case. Reading comprehension aligns with language skill (cf. Brown et al., 2013). This motivates further explicit comparison of language phenotypes within ASD.

Hyperlexia

Despite numerous risk factors, early research focussed on surprising strengths in the reading skills of children with ASD. In 1943, Kanner published the first details of ‘infantile autism’, in which he described a specific syndrome for children who had previously been labelled ‘feeble-minded’, ‘idiotic’ or ‘imbecilic’. Kanner presented case studies of 11 children who were unable to “relate themselves in the ordinary way to people and situations” (p. 242). He delineated the academic attainment of these children and although there was heterogeneity in the level of literacy skill attained, there was consistency in the reading pattern. Specifically, he found that “reading skills are acquired quickly, but the children read monotonously, and a story or moving picture is experienced in unrelated proportions rather than in its coherent totality” (Kanner, 1943, p.250).

Reading characterised by word decoding skills that are in excess of comprehension has been termed ‘hyperlexia’ by Silberberg and Silberberg (1967). There continues to be much debate about how to define this phenomenon (Grigorenko, Klin, & Volkmar, 2003; Nation, 1999), for example, whether a diagnosis requires a reading age that is significantly higher than chronological age, or above cognitive ability. Also controversial is whether comprehension should be below chronological age and/or cognitive ability or just significantly different from word reading skills. Studies have generally focused on differences between accuracy and comprehension levels rather than on their relation to chronological age. There is also debate regarding whether hyperlexia is a primary disorder with a discrete diagnosis or whether it is a behavioural characteristic (Nation, 1999). It is also questionable whether hyperlexia is unique to ASD. However, Nation (1999) concluded that whilst “hyperlexia is not specific to autism… hyperlexia is so often a feature of autism” (p. 345).

This conclusion echoes the results of Grigorenko et al. (2002) who found that the prevalence of hyperlexia is greater within ASD than other developmental disorders. Their sample included 21 children with various developmental disorders and none had a hyperlexic reading profile. In contrast, 12 of the 59 children aged 2-12 with ASD (20%) were identified as hyperlexic. Burd and Kerbeshan (1985) also investigated the prevalence of hyperlexia and they found that 4/68 children aged 5-18 with ASD (6%) had a hyperlexic reading profile. This discrepancy could be associated with the age range of the participants: as age increases, the severity of hyperlexia decreases (Newman et al., 2007), perhaps because poor comprehension results in a reduction in reading frequency and/or duration, or new words are not learnt through reading, therefore decreasing word identification proficiency. Many young hyperlexic children tend to pursue reading intently (Bryson et al., 1994; Talero-Gutierrez, 2006) but special interests, and interests in general, change which can result in a reduction of reading frequency and duration (Bryson et al., 1994).

Many parents report that their child with hyperlexia showed an early interest in text and began reading prior to age 5 (sometimes as early as age 2-3), without any formal instruction (Atkin & Lorch, 2006; Cardoso-Martins & da Silva, 2010; Goldberg & Rothermel, 1984; Patti & Lupinetti, 1993; Turkeltaub et al., 2004). For example, Turkeltaub et al. (2004) described the case of Ethan, who had an intense interest in reading at age 1, could order the letters of the alphabet at 2;6 and by 3 years old corrected his mother if she pointed to the wrong line of text when reading out loud, before pointing to the words himself as she read. At ages 5;11 and 9;9 his real and non-word reading skills were greater than age-expectations. Similarly, Talero-Gutierrez (2006b) recorded the reading behaviour of two Spanish-speaking boys from Colombia, South America. Child 1 began to read and write at age 3, showing an extreme interest in ‘reading’ calendars, agendas, and the telephone book, but he was not interested in magazines and children's books. Later he learnt to read in three additional languages (English, Italian and Japanese). It is debateable whether early onset of reading and text pre-occupation are a prerequisite of hyperlexia, or simply a prevalent feature.

Given the relationship between oral language competence and both word identification and comprehension in TD populations (Roth et al., 1996), it would be difficult to predict the language skills of individuals with hyperlexia; concordantly there are contradictory reports. Case studies suggest children with hyperlexia have poor language skills. For example, Child 1 reported by Talero-Gutierrez (2006), had not yet said his first word by age 2 and required speech-language therapy. At age 9;7 he had severe expressive and receptive language deficits and was unable to complete all of the standardised assessments attempted. Similarly, Atkin and Lorch (2006) identified the case of a 4-year-old boy who was able to read many words that rarely or never appear in texts for children aged 9, but had a mental age of 1.5 years and no spontaneous speech (although he exhibited echolalia). There was no evidence of auditory-verbal, visual or written comprehension on any of eight assessments.

Nevertheless, not *all* children classified as hyperlexic have language deficits. Newman et al. (2007) assessed 20 children with ASD and hyperlexia and reported that their mean expressive vocabulary score was within the average range. The sample included 18 children with ASD and hyperlexia and 18 children with ASD without hyperlexia who were matched on mean full-scale IQ. These groups were compared to 14 TD peers. The TD group had greater expressive vocabulary than the ASD non-hyperlexic group, but the ASD hyperlexic group did not differ from either of the other two groups. The ASD hyperlexic group had better single word reading accuracy than the ASD non-hyperlexic group, but only the latter group differed from their TD peers. Similarly the ASD hyperlexic groups outperformed the ASD non-hyperlexic group on measure of non-word reading, although neither group differed from the TD controls. The authors investigated whether the superior reading ability of the ASD hyperlexic readers relative to the ASD non-hyperlexic readers was attributable to enhanced visual memory or precocious phonological awareness. Simple visual memory was assessed through the Visual Memory subtest of the Test of Visual Perceptual Skills (Gardner, 1996). Participants viewed a line drawing then identified the target from a set of similar pictures. Additionally, complex visual memory was assessed by presenting participants with a complex picture depicting a living room scene for 20 seconds then presenting a similar picture with 20 changes to identify. There were no group differences in either simple or complex visual memory. However, the ASD hyperlexic group out-performed both the ASD non-hyperlexic group and the TD group (matched for single word reading ability) on tasks of phonological awareness, including rhyming, deleting sounds from words, substituting sounds in words, and reversing the sounds of a word to create a new word. There is some evidence that phonological awareness skill increases with reading experience (Goswami, 2002; Nation & Hulme, 2011) and indeed the ASD hyperlexic group had greater single word reading ability than the ASD non-hyperlexic group. In addition, the mean single word reading score of the hyperlexic group was 12 standard points above the score of their TD peers, although this difference was not statistically significant.

In contrast, Cardoso-Martins and Da Silva (2010) found that both their ASD hyperlexic and non-hyperlexic groups performed worse on tasks of phonological awareness than TD peers. This discrepancy may be associated with participant characteristics: the ASD participants in the Cardoso-Martins and Da Silva study had poorer receptive vocabulary knowledge and lower cognitive ability than their TD peers, whereas the ASD hyperlexic participants in the Newman et al. (2007) study were matched to the TD group in terms of receptive vocabulary knowledge. It is therefore unclear whether hyperlexia is driven by superior phonological awareness or enhanced visual processing capabilities. Alternatively these skills may develop as a consequence of reading experience (cf. Åsberg & Dahlgren Sandberg, 2012; Nation & Hulme, 2011).

In the last 20 years, there has been a shift from research investigating hyperlexia, to research exploring the reading skills of more representative cohorts of children with ASD and recently the Simple View of Reading has been applied to the literacy skills of children with ASD (cf. Brown et al., 2013). In the next section, the decoding ability of children with ASD will be detailed and the relationship between decoding and text comprehension explored.

The Relationship Between Reading Accuracy and Oral Language Skill

Research investigating the non-word and real word reading skills of children with ASD has provided inconsistent results. Some studies have found decoding and recognition impairments (e.g. Åsberg, Dahlgren, Dahlgren Sandberg, 2008), while some report strengths (e.g. Newman et al., 2007) and others suggest typical skills (e.g. Nation, Clarke, Wright & Williams, 2006) . The variation is likely to be associated with the heterogeneity of the samples; group means can mask individual differences. For example, Jones et al. (2009) found that their ASD participants had an average word reading standard score of 85.20, suggesting that children with ASD have low-average reading ability. However, the scores ranged from 40-118, showing that whilst some children had severe impairments, other were achieving above average scores. Similarly, Ricketts et al. (2012) reported that their group of ASD participants attained a real word reading mean standard score of 85.24, with scores again ranging from 40-118. More specifically, 55% of adolescents achieved average, or above average, scores, whilst 45% had scores >1 SD below the population norm. The prevalence of word reading impairments appears to be greater amongst children with ASD than among their TD peers. Despite participant inclusion criteria specifying that participants must have measureable reading skill, Nation et al. (2006) found that nine of the 41 children aged 6-16 who they recruited were unable to read at all. Similarly, Henderson, Clarke and Snowling (submitted) reported that this was the case for one of the 54 children aged 7-15 recruited to their study and four other participants were able to read single words but not connected text. These ‘word readers’ achieved receptive vocabulary standard scores below 80, implying language deficits. Often variation in reading ability is not considered in relation to individual differences in oral language skill, however, when it is, there is a clear association between decoding ability and language phenotype (Lindgren et al., 2009; Norbury & Nation, 2011).

Phonological Awareness (PA)

The importance of phonological awareness for learning to read in typical development is well documented, but fewer studies have explored the phonological awareness skills of children with ASD. Bishop et al. (2004) administered a non-word repetition task to 69 children with ASD and 59 TD peers. Whilst the TD group achieved a mean standard score of 100.42 (SD = 12.89), the mean score of the ASD group was significantly lower (*M* = 82.85, SD = 16.26). Similarly, Smith-Gabig (2010) reported that 14 children with ASD achieved significantly lower scores than their TD peers on both the Elision subtest and the Sound Blending Words subtest of the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999). Thus, at first glance, children with ASD appear to have PA deficits, but closer inspection reveals that the ASD and TD groups were not stringently matched. For example, the ASD and TD groups in the Bishop et al. study were not matched for non-verbal or verbal ability, and the ASD group in the Smith-Gabig study had significantly lower non-verbal IQ and receptive vocabulary than the TD group. It is therefore uncertain whether group differences can be attributed to ASD phenotype or to cognitive and/or language deficits that frequently co-occur with ASD.

This notion is supported by further analyses conducted by Bishop et al. (2004). They reported a strong, significant, positive correlation between PA and verbal IQ. When the ASD and control groups were subdivided on the basis of verbal IQ, the ASD and TD low-verbal IQ groups did not differ on non-word repetition score and neither did the high-verbal IQ ASD and TD participants. Similarly, when the ASD group was divided on the basis of language proficiency at 36 months, the children with phrase speech at 36 months had a mean non-word repetition score within the average range (M = 89.44, SD = 22.17), whilst the group without phrase speech at 36 months performed significantly worse (M = 77.73, SD = 22.91). Moreover, 11 of the ASD children were unable to complete the non-word repetition task and all of these participants had verbal ability standard scores below 65. This suggests that there is a strong relationship between language ability and phonological skill. This was explicitly investigated by Tager-Flusberg (2006) who assessed the non-word repetition skills of 35 children with ASD, aged 7-15. As a group, the 15 children who achieved age-appropriate non-word repetition scores had higher expressive vocabulary scores than the group of 20 children who achieved below average non-word repetition standard scores. Likewise, Norbury and Nation (2011) reported that adolescents with ALI achieved lower non-word repetition scores than adolescents with ALN, who were akin to their TD peers. However, when the participants were initially assessed at age 10-11 there were no group differences.

To determine whether PA is closely associated with reading skill for children with ASD researchers have compared the PA skills of proficient and poorer readers and analysed the relationship between PA and decoding competence. The first methodology was employed by Newman et al. (2007). They found that precocious ASD readers attained higher scores than average ASD readers on a comprehensive phonological awareness task battery which included tasks requiring rhyme, deleting sounds from words, substituting sounds in words, and reversing the sounds of a word to create a new word.

White et al. (2006) also divided their ASD sample (22 children aged 9-12 years) into proficient (*n* = 9) and poorer readers (*n* = 13). PA was assessed through the Phonological Assessment Battery (Frederickson, Frith, & Reason, 1997) and whilst the proficient ASD readers did not differ to TD peers on any of the subtests, the poorer readers achieved significantly lower scores on the subtests of rhyme, spoonerisms and rhyme fluency. Additionally, they explored the relationship between PA and reading competence. There was also a significant, strong, positive correlation between PA composite and literacy skill (composite of single word reading, non-word reading and spelling) for both the ASD poorer readers and proficient readers , as well as the TD control group.

Similarly, Jacobs and Richdale (2013) recruited a sample of 26 children with ASD who were matched to 40 TD peers on non-verbal IQ, verbal IQ and decoding skill (a composite of single word reading, non-word reading and passage reading accuracy). However, unlike White et al. (2006) they included separate measures of PA (assessed through the Comprehensive Test of Phonological Processing) and RAN. The ASD and TD groups did not differ on either variable. For both the ASD and TD control groups (matched for age, non-verbal IQ and verbal IQ) there was a strong, significant, positive correlation between PA and decoding competence. Furthermore, PA was a unique predictor of decoding competence accounting for 39% of the variance for the ASD sample and 40% for the TD sample.

Additional evidence that PA aligns with reading competence is provided by Åsberg and Sandberg (2012) who examined the reading skills and reading-related language of 15 Swedish children aged 10–15 with ASD. As a group, the 10 children with ASD and age-appropriate reading skills did not differ from their TD peers on PA (a composite of a sound deletion tasks and two spoonerism tasks), but the poorer readers (who scored below the 10th percentile for decoding ability) were significantly worse. However, when the poorer readers were compared to younger reading level matched controls there were no group differences in PA. This provides further evidence that PA is associated with decoding skill, but that poor

PA is not a cause of the reading deficit. In order to draw the latter conclusion, the poor ASD readers would have needed to perform more poorly than the younger children matched for reading level (Bryant & Goswami, 1986). Thus, this finding aligns with Nation and Hulme (2011) who concluded that whilst PA skills facilitate reading development, reading experience can in turn enhance PA (Nation & Hulme, 2011).

To summarise, preliminary investigations reported that children with ASD have poorer PA than their TD peers, but these studies did not control for language ability. When participant groups are stringently matched, it is evident that the PA of children with ASD is associated with language competence rather than ASD status. There is a positive relationship between PA and decoding competence, and proficient readers have better phonological awareness than poorer readers. However, phonological weakness is not the sole cause of reading deficits, as the relationship between PA and decoding skill is likely bi-directional (Åsberg & Dahlgren Sandberg, 2012; Nation & Hulme, 2011). In order to determine whether this is indeed the case, it would be necessary to conduct a longitudinal study, first assessing phonological skill prior to reading development and then exploring the relationship between PA and decoding as reading competence develops.

RAN

For TD children, performance on the RAN task correlates with, and predicts, both real word and non-word reading (Swanson et al., 2003). Before exploring whether this is also the case for individuals with ASD, the RAN skills of children with ASD will be detailed. Welgreen (2008) found that children with ASD completed RAN tasks more slowly than TD controls. Specifically, 20 children with PDD-NOS performed more poorly than TD peers on four RAN assessments (objects, colours, numbers and letter) and children with Asperger syndrome were also slower than the controls on two of the tasks, namely RAN colours and letters. Similar results were reported by Losh, Esserman and Piven (2010), who found that children with ASD performed colour and object naming RAN tasks more slowly than TD peers.

However, the groups were not stringently matched on variables known to influence RAN in TD populations, such as language ability. For example, the ASD participants in the Welgreen (2008) study had significantly poorer language ability than the TD controls, achieving lower scores on tasks of phonological fluency, semantic fluency, noun naming, verb naming and sentence completion. The ASD participants in the Losh et al. (2010) sample were required to have an IQ $\geq$80 and fluent language abilities, but standardised assessments of language ability were not reported. It is therefore uncertain whether the poorer performance of the ASD group is attributable to ASD status, or associated language deficits.

Few studies have compared the RAN ability of proficient and poorer readers with ASD. White et al. (2006) compared the performance of 9 children with ASD and proficient reading skills to 13 children with ASD who were poorer readers. The proficient readers did not differ to TD peers on either rapid automatic picture naming or rapid automatic digit naming tasks. In contrast, the poorer readers were significantly slower than their TD peers on the digit naming task, although there were no group differences on the picture naming task. Similarly, Åsberg and Dalhgren Sandberg (2012) found that, as a group, 10 children with ASD and age-appropriate reading skills did not differ from their TD peers on a digit naming RAN task, but the group of five poorer readers performed significantly worse. This would suggest that processing speed is associated with reading skill for children with ASD. However, Newman et al. (2007) administered six measures of RAN to children with ASD (with and without hyperlexia) and TD peers and there were no group differences on any of the individual tests, nor when performance on the tasks was averaged. This finding may be contrary to expectations, but it should be noted that the non-hyperlexic group had a mean single word reading standard score of 99.65 (SD = 16.39). Thus, they were not poor readers, just less proficient than the hyperlexic group.

To conclude, when groups are well-matched on variables known to influence processing speed, children with ASD do not differ from their TD peers (Åsberg & Dahlgren Sandberg, 2012; Newman et al., 2007; White et al., 2006). Thus, impairments in processing speed are not characteristic of *all* children with ASD. Instead a sub-sample of children with ASD have processing deficits and these children also have reading impairments (Åsberg & Dahlgren Sandberg, 2012;

White et al., 2006). Therefore for children with ASD, processing speed aligns with single word reading ability, as is the case for TD children (Swanson et al., 2003).

Non-Phonological Oral Language Skills

Despite the wealth of research highlighting the relationship between word reading skill and oral language competence for TD populations, few studies have explored whether this relationship holds for individuals with ASD. Evidence is provided by three strands of research; comparison of the reading skills of children with ASD and different language phenotypes; comparison of the language skill of children with ASD and different reading competencies; and exploration of the relationship between language and reading skill in large ASD cohorts.

Direct comparison between groups of children with ASD and different language phenotypes (ALN and ALI) has shown that decoding skill aligns with oral language ability (Lindgren et al., 2009; Norbury & Nation, 2011). Lindgren et al. compared the reading skills of 52 children aged 6-16 with ASD and 36 non-autistic children with LI. They administered measures of both word and non-word reading and combined these to form a composite measure of single word reading. As a group, the ALN children had a mean standard of score of 110 (SD = 17.3) indicating that they could read single words at an age-appropriate level. The ALI and LI groups achieved significantly lower standard scores, although both groups had mean scores within the average range. Comparably, Norbury and Nation assessed the reading skills of 27 individuals with ASD, firstly at age 11 and again at age 14. On both occasions, the ALN group obtained similar single word reading scores to their TD peers, whereas the ALI group had impairments, scoring between the 10th and 15th centile. These findings demonstrate that children with ALI have impaired single word reading skills relative to their ALN peers, as is the case for non-autistic LI children (Lindgren et al., 2009; Norbury & Nation, 2011).

Åsberg and Sandberg (2012) examined the reading skills and reading-related language skills of 15 Swedish children aged 10–15 with ASD. Ten children with ASD and age-appropriate reading skills had similar receptive vocabulary standard scores to their TD peers, whereas the five ASD poor readers had significantly lower receptive vocabulary scores, although the mean was still within average range. Similarly, White et al. (2006) compared the semantic knowledge of nine proficient and 13 poorer ASD readers. They administered the Semantic Fluency subtest of the Phonological Assessment Battery (Frederickson et al., 1997); participants are given 30 seconds to name a) things to eat and b) animals. Contrary to expectations, both groups of ASD participants attained significantly lower mean standard scores than their TD peers, although mean standard scores were within the average range (> 90). However, the Semantic Fluency test is a complex and multi-faceted task and success is dependent upon world knowledge and fluency. The result may also reflect the small sample sizes and requires verification with larger participant groups.

Nevertheless, the results are consistent with Smith-Gabig (2010) who found that receptive vocabulary did not correlate with either word or non-word reading for their sample of 14 children with ASD. However, there was also no correlation within the TD group, which is contrary to previous research (e.g. Pennington & Lefly, 2001; Scarborough, 1990; Snowling, Gallagher, & Frith, 2003). Jacobs and Richdale (2013) also found that there was no relationship between decoding skill and semantic knowledge for their sample of 26 children with ASD, although for their TD peers there was a strong, significant, positive, moderate correlation between semantics and decoding (r = .38). However, for both the TD and ASD groups there was a significant, positive correlation between decoding and syntax. Syntactic knowledge may facilitate prediction of upcoming text.

To summarise, these results indicate that word identification does align with overall language skill (Lindgren et al., 2009; Norbury & Nation, 2011). However, the word reading of children with ASD may rely less on semantic knowledge than is the case for their TD peers (Jacobs & Richdale, 2013; Smith-Gabig, 2010; White et al., 2006). Instead syntax may be a better indicator of word reading for children with ASD (Jacobs & Richdale, 2013). However, it should be noted that these studies included a measure of word reading that comprised both regular and irregular words. Irregular word reading is likely to be particularly dependent upon semantic knowledge. This will be discussed in more detail in Chapter 4.

Reading Comprehension

There is a wealth of research investigating reading comprehension in ASD. Early research indicated that many children with ASD have impaired comprehension relative to decoding skill (e.g. Burd & Kerbesha, 1985; Frith & Snowling, 1983; Lockyer & Rutter, 1969; Rutter & Bartak, 1973). Likewise, recent studies consistently report that children with ASD achieve lower reading comprehension standard scores than their TD peers (e.g. Nation et al., 2006). These findings are supported by a recent meta-analysis, conducted by Brown et al. (2013) who reported that the reading comprehension of individuals with ASD ranges from below average to within the normal range, but more often than not, reading comprehension *is* impaired in ASD. The difference in comprehension between the ASD and comparison groups was both large and negative. Additionally, individuals with ASD have a disproportionate difficulty with comprehension relative to decoding (Henderson, Clarke, & Snowling, submitted; Huemer & Mann, 2010; Jones et al., 2009; Minshew, Goldstein, Taylor, & Siegel, 1994; Nation et al., 2006; Newman et al., 2007; Ricketts, Jones, Happé, & Charman, 2013). Approximately 30% of children with ASD demonstrate a 'Poor Comprehender' reading profile (Henderson, et al., Submitted; Nation et al., 2006), relative to 7-10% of TD children (Clarke et al., 2010; Nation et al., 2010; Nation & Snowling, 1997; Stothard & Hulme, 1995; Yuill & Oakhill, 1991).

Nation et al. (2006) examined the reading skills of 41 children aged 6-15 with ASD. Unlike many previous studies, they did not select participants on the basis of cognitive, language or reading ability, providing a more representative sample. Of the 32 participants with measureable reading ability, 65% attained a reading comprehension standard score at least 1 SD below the population mean, indicating poor reading comprehension. However, many of these children also had concomitant difficulties with reading accuracy, and therefore did not have disproportionate difficulty with comprehension. A quarter of the children achieved a reading comprehension standard score 1–2 SDs below their passage reading accuracy standard score and a further 10% obtained a comprehension score that was more than 2 SD below their accuracy score, suggesting a Poor Comprehender reading profile. Similarly, Henderson et al. (submitted) investigated the reading skills of 54 children aged 7-15 with ASD. Of the 49 children who were able to complete both the decoding and comprehension assessments, 24.5% had a Poor Comprehender profile, despite applying different criteria. In this study, the accuracy and comprehension measures were independent, thus performance on one measure could not influence performance on the other, unlike the Nation et al. study.

However, many, although not all, of these studies have included a heterogeneous group of individuals with ASD and have not taken into account either decoding or linguistic competence. It is primarily within the last decade that researchers have explored whether the Simple View of Reading (Gough & Tunmer, 1986) is applicable to developmental disorders. Nevertheless, the meta-analysis of Brown et al. (2013) confirms that word identification skill does underpin the sentence and passage reading comprehension of individuals with ASD; reading accuracy independently explained 55% of the variance in reading comprehension scores. Likewise, oral language skill predicted 57% of the variance in reading comprehension scores. Research exploring the relationship between oral language skills and reading comprehension in ASD is reported in Chapters 5 and 6. As a preface to this, the relationship between spoken language comprehension and language phenotypes is now discussed.

Spoken Language Comprehension

Norbury (2005a) investigated contextual influences on resolving ambiguous oral language. Participants were presented with spoken sentences containing ambiguous words (e.g. bank) and were instructed to decide whether a picture was consistent with the sentence. In addition to being less accurate than their TD and ALN peers, the ALI and LI children experienced less contextual facilitation from biased contexts (i.e. *'He fished from the bank'* relative to *'He ran from the bank'*). Norbury concluded that the extent to which children with ASD process context could be attributed to their verbal ability.

Similarly, Brock, Norbury, Einav, and Nation (2008) assessed the oral sentence comprehension of 24 adolescent boys and compared their understanding to 24 peers. Participants heard a sentence and were required to indicate whether any word in the sentence was represented by one of the four pictures on the computer screen. These pictures included a phonological distracter of the target item (e.g. hammer-hamster). During the task, gaze data was recorded in order to assess immediate and online language processing. In the constraining condition (in which the verb was strongly associated with the target) children with ALI and LI spent longer fixating on the (contextually inappropriate) phonological competitor than their ALN and TD peers, and language competence was a significant predictor of eye-movements in this condition. This suggests that oral sentence comprehension deficits are not a universal feature of ASD; instead adolescents with ALN have intact context processing, whereas individuals with ALI have reduced sensitivity to sentence context.

A similar profile is evident when examining pragmatic aspects of oral language comprehension, such as the ability to make inferences (Åsberg, 2010; Norbury & Bishop, 2002). Åsberg (2010) assessed the ability of 16 individuals (mean age = 13;0) with ASD to make inferences from oral discourse. The ASD and the TD comparison group were matched for age, receptive vocabulary and receptive grammar, indicating that the individuals with ASD had age-appropriate structural language skills. Although the participants with ASD achieved lower scores for inferential than literal questions, the discrepancy was in-line with the TD group, suggesting that the children with ASD did not have a disproportionate difficulty with inferencing. However, as the authors note, both groups performed near ceiling for the stated main ideas condition and this may have reduced the potential for discrepancy.

In contrast, Norbury and Bishop (2002) assessed the ability of 10 children with ASD and language impairments (mean age = 8;11) to answer both literal and inferential questions corresponding to stories that they were read. Eleven percent of TD children had a disproportionate difficulty making inferences, compared to 70% of the children with ALI, and 25% of children with LI. This indicates that children with language impairment have greater difficulty making oral inferences than their TD peers, and children with ALI find inferencing particularly challenging. Thus, both language skill and autistic phenotype may contribute to inferencing ability.

Home Literacy Environment (HLE)

There is a paucity of research exploring the HLE of children's with ASD. To date, the HLE has been detailed but the relationship between the HLE and language and literacy development has not been explored. The home literacy practices of children with ASD may reflect child characteristics. For example, difficulties with social interaction and communication may impede willingness to engage in facilitatory literacy practices such as shared book reading. This reluctance may be further increased for children with ASD and concomitant language impairments who are likely to find reading particularly challenging (cf. Lindgren et al., 2009; Norbury & Nation, 2011). The HLE of children with ASD and the relationship to reading competence is detailed in Chapter 7.

From 'Learning to Read' to 'Learning through Reading'

Presentation of the written form of a word can facilitate the oral vocabulary learning of TD children (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008), as well as Poor Comprehenders (Nation et al., 2007; Ricketts et al., 2008) and individuals with Down Syndrome (Mengoni et al., 2013). To date, studies of vocabulary acquisition in ASD have largely relied on the fast-mapping paradigm in which children briefly hear a novel word in conjunction with a novel referent and are then assessed on word recognition tasks immediately after learning. These indicate that many children with ASD have a reduced ability to learn new words from social cues (Akechi et al., 2011, Baron-Cohen, Baldwin, & Crowson, 1997; Gliga et al., 2012, Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007; Preissler & Carey, 2005).

Nevertheless, word knowledge is extremely variable within ASD; some children present with impoverished vocabularies while others develop extensive vocabularies that exceed expectations for age (Kjelgaard & Tager-Flusberg, 2001). Factors that may contribute to individual differences in word learning include cognitive and linguistic ability. For example, Luyster and Lord (2009) explored how effectively children with ASD learned word-object mappings. When matched for expressive language ability, children with ASD did not differ from their TD peers. However, eight children with ASD were excluded from the study as they were unable to pass the entry task and these children had significantly lower verbal and non-verbal IQ scores than participating children. Additionally, such heterogeneity in vocabulary knowledge suggests that some children with ASD may acquire vocabulary using alternative and less social mechanisms, such as reading.

Reading is one avenue to vocabulary growth that might be especially beneficial for children with ASD. As noted earlier, children with ASD are often reported to be skilled at word recognition and decoding, despite general weaknesses in reading comprehension (Brown et al., 2013; Randi, Newman, & Grigorenko, 2010). This suggests that while children with ASD may struggle to infer new meaning from connected text, they might be proficient at using orthography to support new word learning, an idea that underpins the regular use of written text in picture exchange communication systems.

One aspect of learning that might be particularly enhanced for individuals with ASD is phonological learning. Norbury, Griffiths and Nation (2010) taught 26 children aged 6-7 the names of new words, and participants with ASD demonstrated superior performance relative to their TD peers on a picture naming task administered immediately after learning. In contrast, semantic learning (as indexed by a definition task) was poorer for the children with ASD in comparison to the TD controls. Similarly, Poor Comprehenders have difficulty learning semantic information about new stimuli (Nation, Snowling & Clarke, 2007; Ricketts et al., 2008). Thus learning semantic information might remain challenging for children with ASD regardless of the availability of orthography.

Summary and Hypotheses

This chapter has provided an overview of characteristics of ASD, including associated language profiles. Within ASD there is great heterogeneity, particularly with regards to language competence. The relationship between these factors and both decoding and comprehension has been discussed. In general, the reading profiles of children with ASD are characterised by superior decoding relative to text comprehension (cf. Brown et al., 2013). Decoding competence is underpinned by language ability, whilst the influence of ASD-specific factors is controversial. It currently unclear whether the reading mechanisms of children with ASD differ to those of their TD peers. Similarly, autistic symptomatology contributes little to reading comprehension, which is more effectively predicted by decoding competence and oral language skill, in line with the Simple View of Reading (Gough & Tunmer, 1986). However, the level at which comprehension is most vulnerable warrants further investigation. There is also a dearth of research exploring the extent to which the HLE environment can impact upon the literacy development of children with ASD. Although limited research indicates that children with ASD have literacy rich home environments, the relationship between the HLE and reading development is uncertain. HLE practices such as shared book reading, which facilitate the literacy development of TD children (cf. Bus, et al., 1995), may be reduced in terms of frequency or duration due to difficulties with social interaction. Nevertheless, the majority of research exploring the literacy skills of children with ASD has focused on attainment and factors influencing reading outcome. Little is known about the way in which children with ASD use their reading skills to learn new information, for example whether they are able to use the written form of a word to facilitate explicit vocabulary learning, as is the case for TD peers (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008).

The studies reported in this thesis systematically assess influences on reading ability at the levels of single words, sentences and passages, as well as whether children with ASD can ‘read to learn’. The first experimental chapter explores whether quantitative differences in single word reading ability and qualitative differences in reading processes are driven by ASD phenotype or linguistic competence. It was hypothesised that reading skill would align with language competence, although individuals with ASD may read through a qualitatively different process to their non-autistic peers, relying less on phonological decoding. This was followed by investigation of the level at which comprehension is most vulnerable. It was predicted that children with ALI would have difficulties with sentence and passage comprehension, having an increased likelihood of a Poor Comprehender reading profile and finding inferencing especially challenging, whilst the comprehension of children with ALN would remain largely intact. Both language phenotype and autistic symptomatology were expected to influence the HLE. Children with ASD may be less willing to engage in facilitatory literacy practices such as shared book reading. Nevertheless, this does not necessary mean that children will read less. Children with ASD may be avid independent readers, especially children with ALN, who have sufficient literacy and language resources to do so.

However, it is uncertain whether children with ALN can and do use their reading skills. The final study explored whether they are able to use the written form of the word to facilitate learning of vocabulary that was explicitly taught, as TD children do (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008). I hypothesised that presentation of the written form would facilitate vocabulary learning for both children with ASD and their TD peers and that knowledge would be retained over 24 hours. However, I anticipated group differences on overall task accuracy; I predicted that children with ASD would be more proficient at picture naming than their TD peers (cf. Norbury et al., 2010), but poorer at semantic learning relative to TD peers (cf. Nation et al., 2007; Ricketts et al., 2008).

Chapter Three: Methodological Issues

Overview

This thesis investigates the reading skills of children with autism spectrum disorder (ASD), and includes both children with a typical developmental trajectory (TD) and children with language impairment (LI) for comparison. Research using such populations requires careful methodological consideration. This includes the choice of study design, the standardised assessments administered, and participant criterion. To enable brevity in each experimental chapter, this chapter will provide background information regarding each of these factors.

Study Design

The studies reported in this thesis examine the influence of both autistic diagnosis and language phenotype on reading competence in an attempt to elucidate which aspects of functioning are specific to ASD and which occur in the context of LI. Early research reported that children with ASD were poorer readers than their TD peers, however studies included heterogeneous ASD samples, and groups were not matched on crucial variables such as language ability. There is a wealth of literature demonstrating that the reading skills of TD children align with language skills, however it is only fairly recently that researchers have explored whether this is also the case for children with ASD. The influence of language ability on the reading skills of children with ASD can be explored by comparing children with different language phenotypes, that is children with ASD who have age-appropriate structural language skills (ALN) and children with ASD who have language impairments (ALI).

However, in order to see whether reading profiles are specific to ASD, it is necessary to compare children with ASD to non-autistic children. Children with ALN can be compared to TD peers with similar language skills. Children with LI are an ideal comparison group for those with ASD plus LI especially because of the suggestion that ALI represents a co-morbid disorder. If this is the case, then children with ALI and LI should have similar reading profiles. Thus, comparison of the reading skills of children with ASD who have different language phenotypes to non-autistic peers who have different language phenotypes enables the influence of ASD and the contribution of language ability to be disentangled. This design has successfully been implemented by previous studies exploring the reading skills of children with ASD (e.g. Lindgren et al., 2009; Nation & Norbury, 2011).

Three groups of participants are included in studies 1-4, namely TD children, children with ALN and children with ALI, see Figure 3.1. Two of these studies (single word reading and passage comprehension) also include non-autistic children with language impairments (LI). It would have been ideal to include a non-autistic LI group for study 2 as well (sentence reading) and this was the original intention. However, despite being able to read single words, many children with LI struggled to read connected text. Some of the children with LI were able to complete the passage reading task but not the sentence task due to the simpler language. They also found the passages more interesting, so persevered despite the challenging nature of the task. I also planned to include families with a child with LI in study 4 (HLE), however the parental questionnaire response rate was very low. Potential reasons for this and suggestions for solutions are presented in the Discussion of Chapter 7.

Study 5 (vocabulary learning) only compared children with ASD and TD peers, as I wanted to explore whether the paradigm could be utilised with children with ASD and whether there was any influence of ASD status, before investigating the role of language skill.

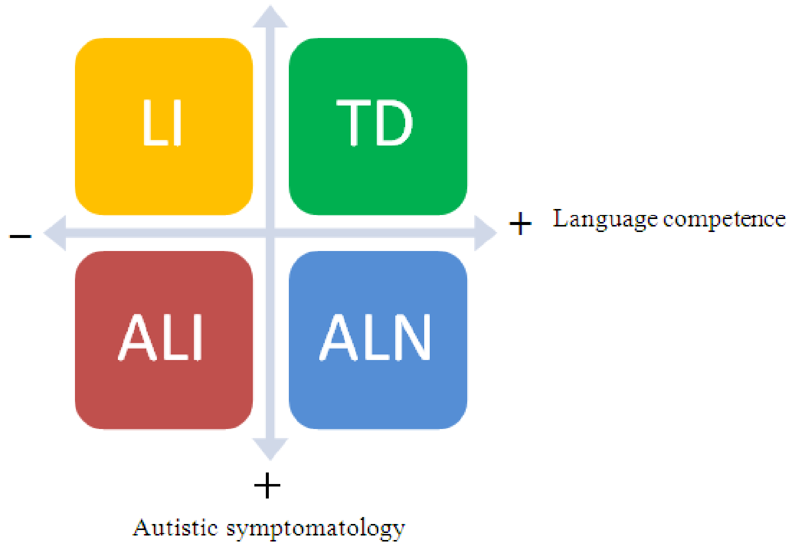

Figure 3.1 *Diagram Depicting Participant Groups*

Ethical Issues

The protocol for each study was approved by the Research Ethics Committee at Royal Holloway, University of London. Parents provided informed, written consent for their child to participate. At the time of testing, verbal assent was obtained from all children. It can be difficult to ensure that *informed* assent is attained from children, especially those with developmental disorders. To assist with this the children's teachers showed them a PowerPoint presentation the week before my visit, in which I outlined who I was, the purpose of my visit and details of the task in picture format. Prior to the testing session I reiterated the information and provided the opportunity to ask any questions. Children were asked 'Are you happy to take part?' and all children agreed.

Design Considerations

In order to ensure that any group differences are attributable to diagnostic status rather than other participant characteristics, it is important to ensure that the groups are 'matched' as closely as possible on potentially influential variables. When matching clinical and comparison groups there are several factors that should be taken into consideration. These include the type of comparison group, the type of score, criteria for considering groups matched, how 'impairment' should be defined and appropriate analysis techniques.

Comparison Groups

Selecting an appropriate comparison group for clinical population raises a number of issues. For example, how do you ensure that they are matched for factors which are known the influence the target variable? Of particular pertinence to the current study was an appropriate comparison group for the children with ALI. To disentangle autistic symptomatology and language skills, the comparison group was required to not have ASD, but to have similar language skill. This instantly raises the question of which aspects of language should be matched, phonology, vocabulary, grammar, or social use of language? Language is a multi-faceted construct, and there is no accepted prescription for which aspect of language, or which test(s) of language, is most appropriate for matching groups (Plante, Swisher, Kiernan, & Restrepo, 1993). One option is to match on vocabulary raw scores, but similar single word knowledge does not ensure similar sentence or discourse construction or comprehension. This limitation can be resolved by including a sentence processing measure. However, the third issue is more problematic. By definition, children with ASD are more likely than their peers to have difficulty with the social aspects of language. However, this has also been reported to be the case for non-autistic children with LI, although generally not to the same extent (Bishop & Norbury, 2002). Therefore peers with LI matched for severity of language impairment would be an appropriate comparison group.

An alternative would be a group of younger, typically developing children who are matched for language ability. However, younger, language matched groups present several problems. For example, they may differ as a result of life experiences. Of particular pertinence to the current study, is the fact that a younger comparison group are likely to have had less exposure to text and received less reading instruction. Depending on the language skills of the clinical group, they may not even have commenced reading instruction. Secondly, the experiences of children with developmental disorders are likely to differ from TD children in other ways, due to the nature of the disorder (Burack, Iarocci, Flanagan, & Bowler, 2004). This may result in differential vocabulary knowledge and social knowledge, which may particularly influence comprehension. A third option would be to include a group of young TD children matched for reading ability. However, given the level of reading ability of the ALI group, TD children of a similar reading ability are likely to have only just commenced reading instruction and therefore are likely to find reading connected text even more challenging. Furthermore, due to their age, these children are likely to have been exposed to a smaller range of vocabulary, which will impede both task instruction delivery and reading comprehension.

Thus, although the life experience of children with ASD and their peers with LI will differ, they are likely to differ less so than the life experiences of clinical groups and younger TD peers. Additionally, children with ALI and LI are likely to have more similar language skills than children with ALI and younger language or reading matched children. As a result, LI peers were selected as an appropriate comparison group for the ALI children, instead of a group of younger

TD children. This also enabled direct comparison between the TD and LI groups. Nevertheless, it is acknowledged that a comparison group of younger children would facilitate determination of whether the reading skills of children with ALI are developmentally ‘immature’ but follow a typical pattern of development.

Group Matching Criteria

In order to ensure that any group differences on a target variable cannot be attributed to associated characteristics, groups are matched on potentially confounding variables. For example, when investigating the influence of clinical diagnosis on reading skill, clinical and comparison groups should be matched for factors such as age and language ability.

Determination that the groups do not differ on the control variable usually is based on the results of a test of the difference between groups (e.g. a t-test). Mervis and Klein-Tasman (2004) recommended that a p value $\geq .50$ should be attained in order to consider a variable matched. To illustrate the impact of the criteria for considering groups matched, Mervis and Klein-Tasman (2004) presented data examining the abilities of children with either Williams syndrome or Down syndrome (Klein & Mervis, 1999). They manipulated the *p* level used to judge whether the groups were matched on cognitive ability (the control variable) to illustrate the influence on group differences in receptive vocabulary (the target variable). When the cognitive ability of the groups was ‘matched’ at $p = .106$ there was a significant difference in the groups receptive vocabulary, yet when the cognitive ability of the groups was more stringently ‘matched’ at $p = .650$, there were no groups differences in receptive vocabulary. Thus the group differences in the target variable were dependent upon the criteria for considering the control variable matched.

Nevertheless, researchers tend to accept the null hypothesis that the groups are equivalent when $p > .05$ and the same practice is implemented in the current thesis. It is acknowledged that a higher p-value would be preferable, but when attempting to match multiple groups on multiple criteria this is very difficult to attain. This is especially problematic when these groups include children with developmental disorders, as these children often have an uneven profile of development (Jones et al., 2009; M. Snowling et al., 2008). Additionally, even when groups are matched on mean scores it is importance for the variance to be similar in each group, as variance can mask potentially significant group differences (Tager-Flusberg, 2004).

Cognitive Ability

One topic which is hotly debate is whether clinical and comparison groups should be matched for non-verbal cognitive ability. The rationale being that matching for cognitive ability will ensure that groups are equally capable of meeting task demands.

The cognitive ability of children with ASD is as heterogeneous as many other aspects of the disorder, although many children with ASD do have cognitive impairments (Autism and Developmental Disabilities Monitoring Network, 2009; Edelson, 2006). Likewise, many studies include an ASD group in which IQ scores range from below to above average (e.g. Ricketts et al., 2013). However, it is uncertain whether the results of such studies are applicable to participants with cognitive ability within the normal range *and* the subsample of participants with cognitive impairments. One solution would be to specify the cognitive ability of participants within the inclusion/exclusion criteria, as this would clarify the sample that the results are applicable to. Researchers would then need to acknowledge that the target variable may have a different developmental trajectory for children with different cognitive profiles.

Children with ASD and ‘average’ cognitive ability can be matched to TD controls for both chronological age and for non-verbal reasoning scores. In contrast, if a sample has low cognitive ability it is clearly not possible to match this group with TD participants on both factors. This again raises the issue of appropriate comparison groups. One solution would be match to a clinical group characterised by cognitive impairments, and this is the procedure implemented in the current study.

Deciding which aspects of cognitive ability to ‘match’ is itself problematic. As noted previously, children with developmental disorders often have an uneven profile of cognitive development (R. Joseph et al., 2002). Thus, matching groups for full-scale IQ may ensure that groups have the same ‘average’ ability, but the profile of component skills may not be of equivalent ability (cf. Klein & Mervis, 1999). Therefore both the non-verbal and verbal cognitive ability of participants in the studies reported here were assessed, but full scale IQ score was not calculated. Instead, the separate variables were used for group matching.

I did attempt to match all groups for non-verbal ability, but similar to other studies, I found that non-verbal and verbal abilities were highly correlated (cf. Conti-Ramsden et al., 2012; Dennis et al., 2009), such that children with more severe language impairments tended to have lower non-verbal ability scores (cf. Dennis, et al., 2009). Thus, all groups were matched for age, but the TD and ALN groups were also matched for both non-verbal and verbal cognitive ability. The ALI and LI groups were also matched for non-verbal and verbal cognitive ability, but both groups had lower scores than the ALN and TD groups.

It is often argued that non-verbal ability should be controlled for in statistical analyses (such as ANCOVA or regression). However, Dennis, et al. (2009) argued that this is theoretically and statistically inappropriate. By including non-verbal reasoning ability as a covariate in the analysis, I may also be controlling for language ability, the variable of interest. Miller and Chapman (2001) also argue that a variable that is associated with group membership should not be used as a covariate in statistical analysis.

Definition of Impairment

Excluding participants or defining groups on the basis of ‘average’ or ‘impaired’ ability raises a number of questions. For example, at what level is a score considered to indicate impairment? There is not a clear link between scores attained on standardised assessments and functional attainment. For many assessments the mean standard score is 100 and the standard deviation is 15. On this basis scores <85 would indicate an impairment, which would apply to 16% of the national population. However, this figure is much higher than the percentage of children typically reported to experience clinically significant difficulties, and meet diagnostic criteria for disorders such as dyslexia (Rodgers, 1983; Shaywitz, Fletcher, Holahan, & Shaywitz, 1992; Yule, Rutter, Berger, & Thompson, 1974) and language impairment (Tomblin et al., 1997). Furthermore, the ICD-10 criteria for language disorder requires a standard score at least 2 SD below the norms (World Health Organization, 1992).

This suggests that maybe there are differing levels of impairment and indeed, manuals providing a ‘guide to interpreting standard scores’ tend to have several description categories, such as ‘below average’ and ‘low/poor’. However, these categories do not always correspond to the standard deviation of the assessment. For example, The Receptive One-Word Picture Vocabulary Test (Gardner, 1990b) has a mean of 100 and a SD of 15, yet the manual suggests that only scores between 89 and 110 are ‘average’, whilst scores falling at the outer edge of the 1SD from the norm are considered to be below/ above average (i.e. 85-88, 111-115). The same applies to Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999). The TOWRE manual suggests that scores <80 are ‘poor’ and it could be argued that in order to be conservative this would be the recommended level of achievement for classification of impairment. Indeed, a score <80, is below the 10th percentile, suggesting significant difficulty (Crouse, 2006).

Thus, classification of impairment is arbitrary, dependent upon the criterion utilised and not consistent across studies. Of particular pertinence to the current study is the criterion for Poor Comprehenders. Nation et al. (2006) classified participants as Poor Comprehenders upon attainment of a NARA-II reading comprehension standard score below 85 and an accuracy standard score above 85. However, a key limitation of Nation et al.’s criteria is that on standardised passage reading assessments, such as the Neale Analysis of Reading Ability (NARA-II; Neale, 1997) text reading accuracy and comprehension scores are not measured independently and therefore comprehension score is limited by the accuracy score. Thus using a separate standardised measure of reading accuracy to analyse discrepancy is advised (Nation, 2005).

This is overcome by Henderson et al.’s (submitted) criteria. They specified that Poor Comprehenders had a reading comprehension standard score below 89, and a single word reading accuracy (TOWRE SWE) in the normal range (i.e. ≥85), as well as a discrepancy of at least 1 SD (i.e. ≥15) between single word reading accuracy and reading comprehension. Another advantage of Henderson et al.’s criteria is that a discrepancy in single word reading and comprehension is ensured. Using Nation et al.’s criteria a child could receive an accuracy score of 86 and a comprehension score of 84 and be classed as a Poor Comprehender, whereas in reality their accuracy and comprehension aligns. However, Henderson et al. have less stringent criteria regarding the level of reading comprehension impairment. Utilising a cut-off score of 89 may identify children whose level of comprehension does not cause impairment or impact upon their education. Therefore in this thesis a combination of these criteria were employed. More specifically, Poor Comprehenders were defined as children with NARA-II comprehension standard scores of less than 85, in the context of TOWRE Total scores above 85, with a score discrepancy of at least 10 standard points between single word reading accuracy and reading comprehension.

Test Scores

Cognitive ability, language competence and reading skill will be assessed through standardised assessments. These produce three types of scores: raw scores, standard scores and age-equivalent scores. Raw scores provide detail of the child's actual level of attainment, but no detail of performance relative to same-age peers. Additionally, scores are not comparable across assessments – a raw score of 50 on a task of receptive vocabulary and a task of expressive vocabulary does not indicate that performance on these two aspects of language is equivalent.

Age-equivalent scores refer to the median chronological age at which that specific raw score was obtained. They pose similar problems to raw scores, in that they do not reflect standing relative to peers and performance is not comparable across different assessments; age-equivalent scores that are substantially above or below chronological age may actually be well within the average range for the child's chronological age. Additionally, age-equivalent scores are not measured on an interval scale, so the difference between scores is not equivalent. For example, the difference in language skill of infants with age-equivalent language scores of 1;4 and 1;8 is not equivalent to the 4-month difference in language between 6;4 and 6;8. Vocabulary growth is much greater between 1;4 and 1;8 than it is between 6;4 and 6;8. As a result academics advise against using age-equivalent scores (e.g. Mervis and Klein-Tasman, 2004). Furthermore assessment manuals do not recommend their use, and specify that they are only provided as they are required by educational agencies and school systems (e.g. Gardner, 1990a,b; Torgesen et al., 1999).

In contrast, standard scores take into account participant age and enable comparison with peers. It is possible to determine whether a person is performing at the level expected for their chronological age, or whether they have impairments or superior capabilities. Thus, in this thesis standard scores will be reported. In cases where the participant performs below the floor, a score one point below the standardisation floor was awarded. Similarly, participants who performed at ceiling were awarded a score one point above the standardised ceiling. This procedure was implemented by Nation et al. (2006) and Henderson et al. (submitted). However, it is noted that this will provide a conservative estimate of the participant's ability, and such standard scores may correspond to a wide range of raw scores. Fortunately this only applies to a handful of participants included in the current studies. If this occurred frequently, then the raw scores of the participants would also be examined to determine whether they matched, as advised by Mervis and Klein-Tasman (2004).

Analysis

For the first three studies, analysis begins with exploration of group differences in reading ability. However, even in cases of significant group differences overlap in score distribution is possible. Participant data will therefore also be examined at the level of the individual to determine whether the target characteristic (e.g. a Poor Comprehender reading profile) is applicable to each group, or differentiates individuals in the autistic or language impaired groups from their TD peers. This will illustrate whether a particular reading profile is more common in a particular clinical group or phenotype.

However, it could be argued that group distinctions are arbitrary. In order to account for this, regression analysis will also be conducted on either the whole sample, with diagnostic status as variable, or two models will be run, one with autistic individuals (ALN and ALI) and the other with the non-autistic groups (TD and LI). This will be dependent on the specific question that is being addressed. For example, different factors may predict the reading profile of children with ASD and non-autistic children, for example their ability to read irregular words.

Standardised Assessments

Each child completed the following standardised assessments, unless the assessment was beyond their capabilities. The purpose of administering these assessments was three-fold. First, to characterise the cognitive, linguistic and reading profiles of the participant groups, second to facilitate group matching and third to explore how cognitive ability, linguistic competence and autistic symptomatology relate to reading proficiency. Table 3.1 provides a summary of the assessments (see page 103).

Background Measures

Non-verbal and Verbal Reasoning

Non-verbal reasoning was assessed through the Matrix Reasoning sub-scale of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). Participants complete gridded patterns by choosing the correct response from five possible options. It is a measure of nonverbal fluid reasoning and general intellectual ability (Wechsler, 1999). Participants score one point for each correct response, and the assessment is discontinued after four consecutive scores of zero, or four errors within five consecutive items. The Matrix Reasoning subtest was chosen over the Block Design subtest as it is quick and easy to administer and is untimed. Therefore children with language impairments, who often have speed of processing impairments, are not unduly disadvantaged (L. Leonard et al., 2007; Miller, Kail, Leonard, & Tomblin, 2001).

Verbal reasoning was assessed through the Vocabulary sub-scale of the WASI (Wechsler, 1999). This assessment requires participants to provide verbal definitions of auditorily presented words and the quality of each response is scored on a 3-point scale. The assessment is discontinued after five consecutive scores of zero. The task assesses expressive vocabulary, verbal knowledge and fund of information, as well as crystallised and general intelligence (Wechsler, 1999).

For both the non-verbal and verbal reasoning tasks raw scores are transformed to t-scores, which have a mean of 50 and a SD of 10. Thus, a score of 40-60 is considered to be within normal range and a t-score <35 indicates below average reasoning ability (approximately 10^{th} centile). All participants attained non-verbal IQ scores ≥ 35. The WASI has high internal consistency, with coefficients of .92 for the Matrix Reasoning subtest and .89 for the Vocabulary subtest. It also has adequate test-retest stability. The average coefficients corrected for age were .77 for the Matrix Reasoning subtest and .85 Vocabulary subtest.

Vocabulary

Expressive vocabulary was assessed through the Expressive One-Word Picture Vocabulary Test (Gardner, 1990a). This assessment requires participants to name objects or a group of objects. The assessment is discontinued once six consecutive responses are incorrect. Receptive vocabulary was assessed through the Receptive One-Word Picture Vocabulary Test (Gardner, 1990b). This test requires participants to select the picture which corresponds to a spoken word from a choice of four. Responses are scored as either correct and receive one point, or incorrect and receive zero points. The assessment is discontinued once six responses within eight consecutive items are incorrect. On both assessments, a standard score below 80 is below the 10^{th} centile.

The assessments were co-standardised on the performance of 2,327 individuals from 117 cities in 32 states of the USA. For the Expressive One-Word Picture Vocabulary Test, the internal consistency has an alpha of .96 and the re-test reliability is .90. For the Receptive One-Word Picture Vocabulary Test, the internal consistency has an alpha of .96 and the re-test reliability is .84.

Autistic Symptomatology

Autistic symptomatology was assessed through the Social Communication Questionnaire (SCQ; Berument, Rutter, Lord, Pickles, & Bailey, 1999) and the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000). The SCQ is a 40 item dichotic answer questionnaire which provides parental report of current behaviour and lifetime behaviours that are indicative of ASD. Questions pertain to both areas of the autism dyad, namely social interaction and communication, as well as restricted/repetitive interests and behaviours. For children <8 years old scores ≥ 11 are indicative of ASD and for children aged ≥ 8 scores ≥ 15 are indicative of ASD[2].

[2] As the SCQ is a screening tool, it was not utilised for group classification purposes. Thus, in some instances, children in the ASD groups attained a score below the ASD cut-off and children in the LI group received a score above the ASD cut-off. It is not unusual for non-autistic children with LI to achieve elevated scores on the SCQ (Bishop & Norbury, 2002; Norbury, 2005a).

The initial validation study of the SCQ was conducted with 200 individuals aged 4-40. This included 160 participants with ASD and 40 with non-ASD clinical diagnosis. The alpha reliability coefficient for the total scale was 0.90 and there was good discrimination between ASD and non-ASD cases, with a sensitivity of 0.85 and a specificity of 0.75 (Berument, Rutter, Lord, Pickles, & Bailey, 1999). However, the study has been criticised as many of the ASD participants were adults, whilst the non-autistic participants were predominantly children. Nevertheless, similar figures have been attained in a more recent study, which included two samples of children (Chandler et al., 2007) . In a population cohort of 411 children with special educational needs (mean age = 10.30, SD = .40), the SCQ had a sensitivity of 0.88 and a specificity of 0.72. Similarly, in a sample of 247 children from the general population (mean age = 12.00, SD = .30), the SCQ had a sensitivity of 0.90 and a specificity of 0.86.

Diagnostic Measures

Autistic Symptomatology

The Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) is regarded as a gold standard tool for research diagnosis (Tager-Flusberg, 2004), although for the purposes of this thesis it was used to quantify ASD symptomatology. All of the children included in the ASD groups had already received a clinical diagnosis of ASD from a multi-disciplinary team. The ADOS is a semi-structured interview which provides a current observation of behaviour across four domains; social interaction, communication skills, imagination and repetitive behaviours. The administrator engages the student in standard activities that “allow the examiner to observe behaviours that have been identified as important to the diagnosis of autism spectrum disorders” (Lord, et al., 2000, p.1). Examples of the tasks include telling a story from a picture book, having a discussion about friends and relationships and creating a story from a selection of objects. Frequency and quality of elements such as offering of information, demonstrating insight into social relationships, evidencing creativity/imagination and excessive interest in unusual/highly specific topics are scored on a three point scale. The scores for the social and communication domains are summed and for module 3 a score $\geq$7 indicates that the child presents with behaviours consistent with ASD. Children with ASD who participated in the studies reported in this thesis were administered module 3, which is aimed at verbally fluent children and young adolescents. It takes 30-45 minutes to administer (Lord et al., 2000). Module 3 was validated on a sample of 136 individuals aged 3-17. Inter-rater reliability for the individual items was high, and the mean percentage of agreement was 88.20% across all items. For module 3, inter-rater reliability for diagnostic classification was 100%.

Language Competence

Language competence was quantified through the Recalling Sentences (RS) subtest of the Clinical Evaluation of Language Fundamentals (CELF; Semel, Wiig & Secord, 2003). The task requires the child to listen to a sentence and repeat it. An exact replication receives three points, one error receives two points, two-three errors receives one point and four or more errors results in a score of zero. Errors include omissions and additions. The task is discontinued once five consecutive responses are incorrect. The mean scaled score for the subtest is 10 with a standard deviation of three. A RS scaled score ≤ 6 is within the bottom 10th centile and is thus considered to be indicative of a language impairment.

The CELF-4 was standardised on over 4,500 individuals aged 5-21 from the USA and 571 children aged 5-16;11 from the UK. For the RS subtest, the internal consistency reliability coefficient was .91. Test re-test reliability was assessed with a sample of 320 examinees from the standardisation sample. The average corrected stability coefficient across all ages was .90, indicating excellent test re-test reliability.

The RS subtest was selected from the CELF battery as it is a sensitive diagnostic marker of language impairment in non-autistic children with LI (Conti-Ramsden et al., 2001) and in children with ASD (Botting & Conti-Ramsden, 2003). The complete CELF was not administered. Children in the LI and ALI groups had already received a clinical diagnosis of LI, had a statement of special educational need for LI and attended a specialist school. A measure of language competence was required for quantification not classification. It was therefore deemed inappropriate to subject participants to an extensive battery of language assessments that they would find challenging and time consuming. Additionally, many CELF subtests assess grammar and the relationship between grammatical knowledge/utilisation and reading was not the focus of this thesis.

Reading Ability

Single Word Reading

Single word reading accuracy was assessed through two tasks. Firstly, the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner & Rashotte, 1999) which was administered to all participants in all studies. Additionally, for Study 1 the Castles and Coltheart 2 (CC2, Castles et al., 2009) was administered.

The TOWRE assesses both reading accuracy and fluency. The Sight Word Efficiency (SWE) subtest assesses ability to recognise words as whole units. This is achieved by asking children to read a list of real printed words and recording the number successfully read in 45 seconds. The Phonemic Decoding Efficiency (PDE) subtest assesses ability to quickly 'sound out' words. Participants are required to read a list of pronounceable non-words and the number accurately decoded within 45 seconds is recorded. The standard scores on each subtest have an age-normed mean of 100 and a SD of 15. Standard scores from the SWE and PDE subtests can be transformed into a total reading standard score (M = 100, SD = 15). The TOWRE was normed on a sample of over 1,500 individuals aged 6-24, half of whom were aged 6-11. The test-retest reliability of the TOWRE was assessed with a sample of 46 students aged 6 to 18. The raw scores from time 1 and time 2 were correlated and coefficients ranged from .83-.97 across the subtests and age ranges.

The TOWRE manual suggests that attainment of a standard score below 90 is below average. However, the majority of research investigating children's reading skills considers scores below 85 (<15th centile) to be indicative of reading difficulties (cf. Brown et al., 2013). To enable direct comparison with published studies I am using the latter criteria within my thesis.

For study 1, single word reading accuracy was also assessed through the CC2 (Castles et al., 2009). This measure was used in addition to the TOWRE in order to directly assess lexical and non-lexical reading processes. However, it was not administered in all studies as it is time-consuming and not standardised on children $\geq$11;6. The 120 stimuli includes 40 regular words, 40 irregular words and

40 pronounceable non-words, and the regular and non-words are matched on frequency, imageability, length and grammatical class. The non-words range from monosyllabic three-letter strings to bi-syllabic twelve letter strings. The words are presented individually in a fixed order of ascending difficulty. To minimise guessing the words from each category were presented in a mixed fashion. Administration of a word type discontinues when a child makes five consecutive errors on that word type, and the test continues with the remaining two, then final word type, until either the discontinuation criteria are met for regular, irregular and non-words, or until the assessment is complete.

Task performance is standardised based on normative data for over 988 Australian children aged 6-11;5. The authors state that "the decision about what should be considered impaired performance in a child is in part up to the clinician, teacher or researcher and what their particular purpose is in carrying out the test". However, they continue to say that, in general terms, a score above the 15th percentile indicates that the child does not have single word reading difficulties.

Passage Reading

Passage reading accuracy and comprehension was assessed through the Neale Analysis of Reading Ability II (NARA-II, Neale, 1997). Children read aloud passages of increasing length and complexity and are scored for reading accuracy and the time taken to read them. They then answer literal and inferential comprehension questions relating to the text. An example of a passage is provided in Appendix D. The assessment is discontinued once a child makes $\geq$16 reading errors within one passage. Errors include mispronunciations, substitutions, refusal, additions, omissions and reversals. The NARA-II has been used extensively to identify poor reading comprehension in non-autistic children (Nation et al., 2010) and children with ASD (Nation et al., 2006). The NARA-II includes two equivalent forms and children participating in the studies reported in this thesis were administered Form 2. Form 2 was standardised on the scores of 1,546 children. Parallel form test-retest reliability was calculated on the scores of 428 pupils, from 74 schools and reliability was .89 for accuracy, .82 for comprehension and .66 for rate.

Table 3.1
Summary of Standardised Measures

Assessment	Measures	Study	Groups
WASI Matrix Reasoning	Non-verbal reasoning	All	All
WASI Vocabulary Definitions	Verbal reasoning	All	All
Expressive one-word picture vocabulary test	Expressive vocabulary	All	All
Receptive one-word picture vocabulary test	Receptive vocabulary	All	All
CELF Recalling Sentences	Integration of semantic information with structural aspects of a sentence	All	All
Test of Word Reading Efficiency (TOWRE)	Single word reading ability and fluency	All	All
Castles and Coltheart 2 (CC2)	Single word reading ability	1	All
Neale Analysis of Reading Ability II (NARA-II)	Passage reading accuracy and comprehension	2 and 3	All
Social Communication Questionnaire (SCQ)	Autistic symptomatology	All	All
Autism Diagnostic Observation Schedule	Autistic symptomatology	All	ASD only

Participants

Recruitment

Typically developing children were recruited from primary schools in Surrey. Children with ASD and LI were recruited from specialist schools and units throughout England. Schools were recruited to the study in one of four ways. Firstly, schools that had previously been involved in research conducted by the LiLaC Lab at RHUL were contacted and invited to take part. Secondly, the Surrey County Council website was searched to identify schools in Surrey with specialist educational provision. Contact was made with the school via a letter or email inviting the school to take part in the research. This was followed up with a telephone call, resulting in a conclusion regarding participation. Thirdly, contacts at two of the schools I visited offered to inform colleagues at other schools about the research programme and this resulted in the involvement of those schools. Participants were also recruited to the study through the RHUL Psychology Summer Camp.

Schools provided the pupils in their school (aged 6-13) with details about the study to take home to their parents. If they were happy for their child to participate, parents provided informed, written consent. At the time of testing, verbal assent was obtained from all children. Participants were tested in a quiet room in their school, at home or at the LiLaC Lab at Royal Holloway, University of London. The test battery varied in length depending upon the study, but usually took around 3 hours to administer. To avoid participant fatigue this was divided into sessions of around 1 hour. Children completed all of the tasks in the battery that were within their capabilities.

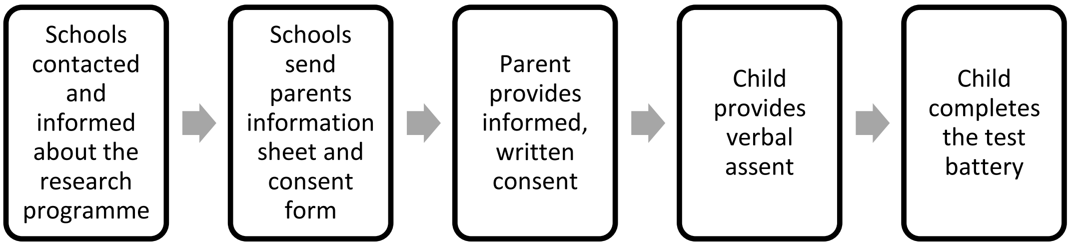

Figure 3.2 *Flow Diagram of the Recruitment Procedure*

Age Range

Participants aged 6-13[3] were recruited to the studies (age 7-14 at the time of testing). The age range of the participants was chosen for two reasons. Firstly, children were required to have a minimum age of 7 to ensure that they had already received formal reading instruction and were likely to be able to at least read at the single word level. This would therefore minimise the number of children being excluded due to insufficient reading ability to complete the tasks. The upper age limit of 12 was selected for study 1 (single words) and study 3 (passage reading) due to the standardisation data available for the CC2 and NARA-II. For study 5 (vocabulary learning), an upper age of 12 was selected to reduce the likelihood that the participants would have previously encountered the words; older children may be familiar with the words and therefore their data could not have been included.

[3] The maximum age was capped at 13 as often there is a delay between receiving consent and beginning testing in schools.

An upper age limit of 14 was selected for the remaining studies (study 2, sentence reading and study 4, the HLE) to increase participant numbers.

Applying a maximum age of 12 for these studies would have ensured continuity across all studies. However, this would have resulted in even fewer children with ALI being able to complete the sentence reading task. Notably, there was a trend for the ALI children who could read accurately and fluently at the sentence level to be older than the ALI word readers (mean ages = 11.77 and 10.79 respectively). Similarly, extending the age range increased the number of potential families who could participate in the HLE study. An age limit of 14 was specified as parental report of ASD symptom severity reduces during adolescence, although diagnostic criteria for ASD are still met (McGovern & Sigman, 2005). It was deemed important to ensure that all children were currently exhibiting ASD symptomology to a similar degree.

Group Criteria

Group criteria are summarised in Figure 3.3. Children included in the ASD groups all held an existing diagnosis of ASD based on DSM-IV/ICD-10 criteria from a multi-disciplinary team external to the research group and were currently in receipt of a statement of special educational need for placement in a specialist school or unit serving children with ASD. They met criteria on the relevant module of the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999). Children included in the ALN group were required to have a Clinical Evaluation of Language Fundamentals (CELF) Recalling Sentences scaled score ≥ 7 and not be receiving specialist support for structural language difficulties. Children with ALI were required to have a CELF scaled score <7 and be receiving specialist support for structural language difficulties.

Children included in the language impaired (LI) group all held an existing diagnosis of language disorder from a speech-language pathologist external to the research team, were receiving full-time special educational support for language impairment and obtained scaled scores below 7 on the Recalling Sentences subtest of the CELF-4UK. These children were recruited through their specialist schools/units.

Typically developing (TD) children did not have any special educational needs or a history of ASD, language delay or literacy difficulties, according to teacher or parent report.

Participant Numbers

In total, 153 children were participants in the five experimental studies detailed in this thesis. The participants' ranged in age from 6.61 years to 14.48 years, with a mean age of 10.32 years. The diagnostic status of the participants is represented in Figure 3.3. The majority of children participated in more than one study.

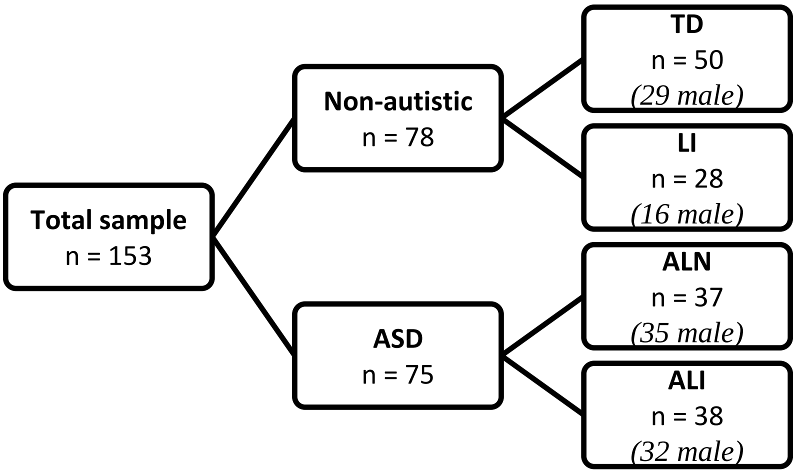

Figure 3.4 *Participant Groups*

Summary

This thesis reports the reading skills of children with ASD. Before running the studies, careful consideration was given to the study design, for example in regards to potential comparison groups, 'matching' criteria and the analysis plan. For all studies, the samples were characterised in terms of their cognitive, language, reading, and social-communication skills. Similar standardised assessments were administered for each study. This chapter aimed to facilitate understanding of the methodological nuances of this thesis. The next chapter reports the results of study 1, which explored the influence of language ability on the single word reading skills of children with ASD.

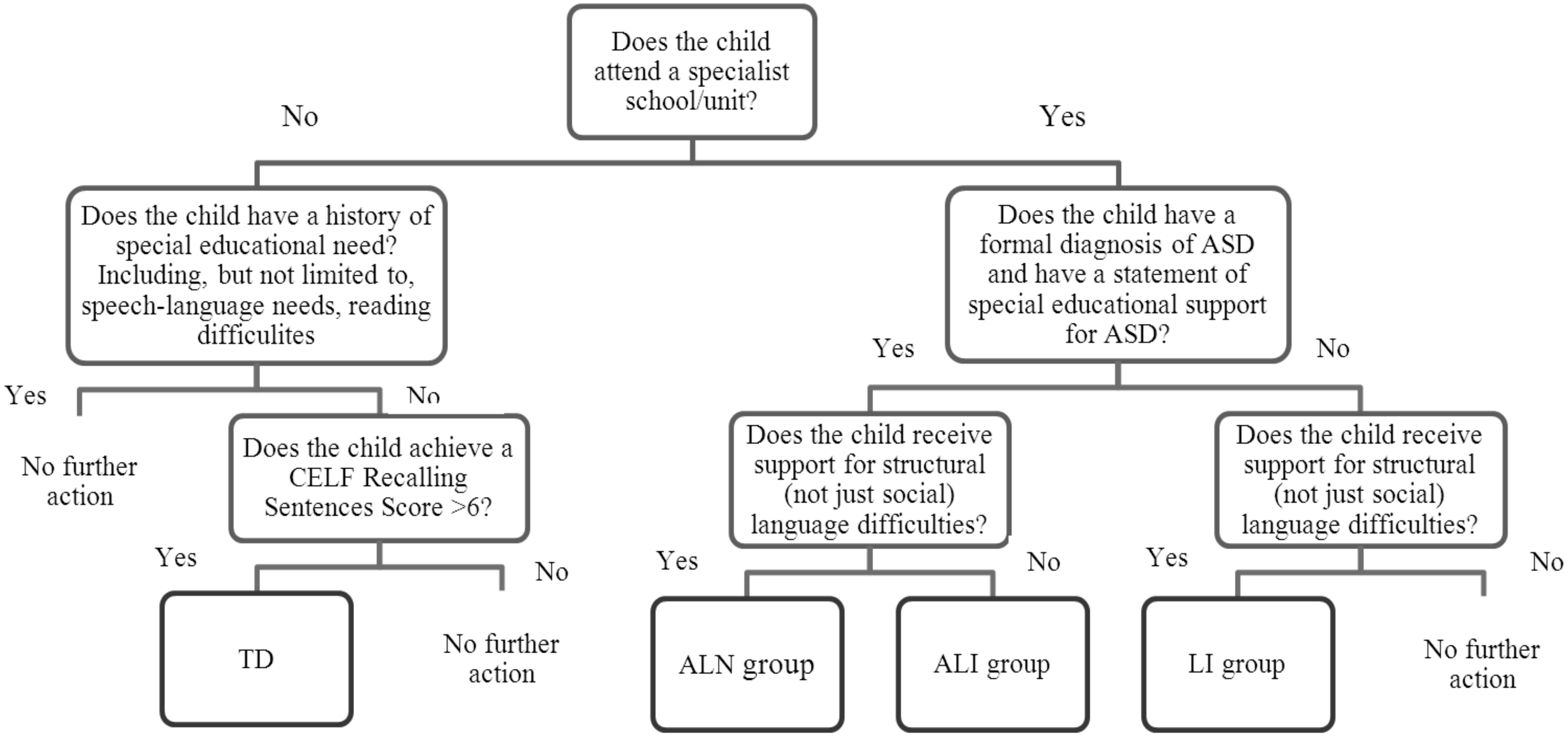

Figure 3.3 *Flow Diagram Depicting the Group Characterisation Process*

Chapter Four: The Influence of Language and ASD Diagnosis on Single Word Reading

Chapter Overview

Words can be read via phonological decoding or whole-word recognition mechanisms, and typically developing children (TD) become skilled at both. This study investigated whether this is also the case for children with Autism Spectrum Disorders (ASD) and whether concomitant language impairments influenced word reading mechanisms. The single word reading skills of 51 children with ASD were compared to 28 TD peers and 22 non-autistic peers with a language impairment (LI). The ASD group included 23 children with age-appropriate structural language skills (ALN) and 28 children with language impairments (ALI). Reading was assessed via the Castles and Coltheart 2 single word reading assessment (CC2, Castles et al., 2009). The TD and ALN children demonstrated age-appropriate word reading skills, whereas the children with ALI and LI had significantly poorer reading ability. Although the majority of children with ASD read through both phonological decoding (as assessed by non-word reading accuracy) and whole-word recognition (as assessed by irregular reading accuracy), nearly 40% of the children with ASD exhibited a bias towards whole-word reading, compared to only 14% of non-autistic children. These results suggest that word reading ability is influenced to a greater extent by language ability than ASD symptomatology, but that individuals with ASD may read through a qualitatively different process, which is less reliant on phonological decoding.

Introduction

Reading is a complex cognitive process with two core components, decoding and comprehension (Hoover & Gough, 1990) and this chapter will focus on decoding. There are two key ways through which words can be decoded, either through phonological decoding or through whole-word recognition, and typically developing (TD) children become skilled at both. At the earliest stages of reading, children identify words by recognition of visual cues and making predictions from the context, but then they learn to use phonological decoding strategies (Ehri & Wilce, 1985). Once words have been encountered several times, they can then be read by sight. By age 8, TD children competently use whole-word recognition strategies, reserving phonological decoding for unfamiliar words (Schmalz, Marinus, & Castles, 2012). This study investigated whether children with Autism Spectrum Disorders (ASD) are also proficient at reading using both phonological decoding and whole-word recognition processes, and whether concomitant language impairments influence word reading mechanisms.

The triangle model of reading (Plaut, 1996) posits that upon visual perception of a word the lexical information activates codes pertaining to semantic, phonological and orthographic components and the process is highly interactive. Two pathways are proposed; a phonological pathway which contains orthographic and phonological connections and a semantic pathway which maps associations between semantic, orthographic and phonological representations. Thus reading difficulties will occur as a consequence of disruption to these pathways. Specifically, disruption to the phonological pathway will impair learning of grapheme-phoneme correspondences and disruption to the semantic pathway will disturb whole-word recognition. Impairments in phonological decoding *or* whole-word recognition can result in an over-reliance on the alternative reading mechanism. For example, in the case of phonological decoding deficits, the semantic pathway can compensate and children may learn to read by developing their whole-word vocabulary (Hulme & Snowling, 1992).

The purest measure of phonological decoding ability is a non-word reading task. Non-words (for example 'frip') are unfamiliar and lack semantic content so they can only be accurately read by mapping orthography and phonology. In contrast, whole-word recognition is typically assessed through an irregular word reading task. Attempting to 'sound-out' irregular words (such as 'yacht') will result in regularisation errors.

In typical development, raw scores for non-word reading accuracy exceed irregular word reading accuracy, which is taken into account with standard scores (e.g. Castles & Coltheart, 1993, 2010). This further emphasises the importance of phonological decoding in establishing reading competence. Nevertheless, most children are able to read words through both phonological decoding and whole-word recognition and for TD children, the correlation between word and non-word reading is typically around 0.80 (Nation & Snowling, 1997; Roch & Jarrold, 2008; Torgesen et al., 1999).

However, for some children there is dissociation between non-word and irregular word reading competence and this is particularly evident amongst children with dyslexia. For example, Griffiths and Snowling (2002) explored the reading skills of 59 children aged 9-15 with dyslexia and found that the correlation between non-word and irregular word reading was low, although statistically significant. The discrepancy was attributable to particular difficultly with non-word reading. Although the majority of children with dyslexia have difficulties with both non-word and irregular word reading, some researchers have argued for sub-types of developmental dyslexia (e.g. Castles & Coltheart, 1993). Specifically superior whole-reading reading relative to non-word reading is termed phonological dyslexic and the opposite profile (a bias towards non-word reading) is called surface dyslexia. The prevalence of each sub-type varies depending upon the discrepancy criteria utilised but approximately 25% of children with dyslexia demonstrate a ‘pure’ phonological dyslexia profile (Castles & Coltheart, 1993; Manis et al., 1996; Stanovich et al., 1997). The prevalence of surface dyslexia is more contentious with figures ranging from 2% (Manis et al., 1996; Stanovich et al., 1997) to 20-30% (Castles & Coltheart, 1993).

Many children with language impairments (LI) are poorer readers than their TD peers (Bishop & Adams, 1990; Botting, Simkin, & Conti-Ramsden, 2006; H. Catts et al., 2002; Conti-Ramsden, Donlan, & Grove, 1992; M. Snowling, Bishop, & Stothard, 2000). However, it is currently unclear whether children with LI have a discrepancy between word recognition and phonological decoding (as is the case for some children with dyslexia) due to the paucity of research directly comparing irregular and non-word reading competence.

It is therefore expected that children with neurodevelopmental disorders accompanied by language impairments would also experience literacy challenges. However, characteristics associated with different disorders may be protective, which is exemplified by the genetic disorder Down syndrome (DS). For many individuals with DS, decoding is an area of strength relative to cognitive ability, language ability and reading comprehension (Bryne, Buckley, MacDonald, & Bird, 1995; Snowling et al., 2008). Yet there is a discrepancy between phonological decoding and whole-word reading ability; children with DS are more proficient at whole-word reading than non-word reading (Bird, Cleave, & McConnell, 2000; Byrne, Buckley, MacDonald, & Bird, 1995; Roch & Jarrold, 2008, 2012). Although non-word reading competence aligns with phonological awareness (Bird et al., 2000; Cardoso-Martins & Frith, 2001; Roch & Jarrold, 2008, 2012), real-word reading is better than vocabulary knowledge expectations (Byrne et al., 1995). This has been linked to strengths in visual processing (Fidler, Most, & Guiberson, 2005) and suggests that children with DS may be recruiting a different set of neuropsychological skills. For example, they may capitalise on the visual memory of the word rather than utilising prior phonological or semantic knowledge. Thus semantic knowledge can facilitate, but not be necessary for accurate sight-word reading. There is a parallel here with ASD; children with ASD also exhibit superior decoding relative to comprehension (Huemer & Mann, 2010; Jones et al., 2009; Nation, et al., 2006) and there is some evidence for visual processing strengths (Simmons et al., 2009).

Word Reading and ASD

For many children with ASD, language profile aligns with reading ability (Brown et al., 2013; Lindgren et al., 2009; Norbury & Nation, 2011; Ricketts et al., 2013). However, the relationship is not as strong as expected (Nation & Norbury, 2011) and case studies have described children who have enhanced word reading ability relative to their chronological age or non-verbal reasoning ability, despite severe cognitive and language impairments (Atkin & Lorch, 2006; Bryson, Landry, & Smith, 1994; Talero-Gutierrez, 2006a; Turkeltaub et al., 2004). This suggests that the reading development of some children with ASD may not be underpinned by the same foundational skills.

Some children with ASD have an intense preoccupation with reading, or read profusely to support a special interest and this repeated exposure to words may enhance reading progression (Bryson, 1994; Talero-Gutierrez, 2000). Cognitive traits associated with ASD may also affect the reading mechanisms children with ASD employ. There is some evidence that children with ASD have enhanced visual processing skills (Simmons et al., 2009) and this may facilitate whole-word reading. In contrast, phonological awareness aligns with oral language skill (Lindgren et al., 2009; C. McGee, 2001; Norbury & Nation, 2011; Tager-Flusberg, 2006).

In order to assess whether successful reading is underpinned by phonological decoding or whether there is an over-reliance on whole-word recognition mechanisms (as evidenced by superior irregular word reading) for children with ASD, reading accuracy for non-words and irregular words should be directly compared. Very few studies have made this comparison. The notable exception is an early study conducted by Frith and Snowling (1983). They hypothesised that children with ASD would rely heavily on visual strategies, recognising words on the basis of shape or pattern and capitalising on rote learning, thus facilitating irregular word reading. However, both the TD and ASD groups read phonetically regular words more accurately than irregular words. This suggests that the ASD individuals were reading using similar processes to the TD children. However, the older ages of the ASD children indicates that the ASD participants had delayed reading development. This preliminary exploration with a small number of participants (*n*=8) and stimuli (12 non-words and 12 irregular words) requires replication in order for the results to be generalised to the wider ASD population.

Newman et al. (2007) also assessed whether reading in ASD is driven by enhanced visual memory. There was a trend for visual memory to align with word reading however, there were no consistent differences in the visual memory ability between ASD exceptional readers, ASD average readers and a TD comparison group. This suggests that word reading in ASD is not driven by visual memory skill. Additionally, the children with ASD attained similar standard scores on both word and non-word reading tasks (as did their TD peers), indicating that there was not an over-reliance on whole-word reading. However, the task included both regular and irregular words and therefore is not a ‘pure’ assessment of whole-word recognition; regular words can also be read through phonological decoding.

Numerous research studies have reported the real-word and non-word reading skills of children with ASD (e.g. Castles et al., 2010; Henderson, Clarke & Snowling, 2011; Henderson, Clarke & Snowling, submitted; Heumer & Mann, 2010; Minshew et al., 1994; Nation et al., 2006; Jones et al., 2009; Nation & Norbury, 2011; Newman et al., 2007). However, they have done so in order to characterise their samples, and have not explicitly compared word and non-word reading. The studies that have done so, have reported conflicting results. Minshew et al. assessed the reading skills of high-functioning adolescents and young adults with ASD. As a group, performance did not differ on word and non-word reading tasks, with mean standard scores for both tasks being slightly above age-appropriate levels. Norbury and Nation (2011) also found that word and non-word reading skills were similar for children aged 11 with ASD. This remained the case for the children with ALI when assessed again aged 14, however the children with ALN then attained significantly higher scores on a non-word relative to real-word reading assessment.

However, Henderson et al. (submitted) found that children with ASD had superior word reading relative to non-word reading. From the original sample of 54 children with ASD and their 49 TD peers, 25 children with ASD were matched to 25 peers for real-word reading raw scores. When the non-word reading raw scores of these groups were compared, the ASD had group had significantly lower scores. This aligns with Nation et al. (2006) who found that, on average, children with ASD attained word reading standard scores six points higher than non-word reading standard scores. This suggests that for children with ASD, word reading is a strength relative to non-word reading.

Additionally, some children with ASD appear to learn to read without establishing orthography-phonology mappings, which suggests that proficient non-word decoding skills may not be a prerequisite for achieving age-appropriate word reading skill. Nation et al. (2006) found that five of 42 children (15.60%) scored at floor on a non-word reading test despite achieving word reading standard scores >95. Similarly, Henderson et al. (submitted) found that 16% of their ASD sample were unable to read a single non-word, despite being unable to read real words. However, the authors did not report whether these children had age-appropriate or impaired real-word reading.

Nevertheless, there is great variability in the non-word reading standard scores achieved by groups of individuals with ASD. Some studies report that non-word reading is ‘above-average’ (e.g. Minshew et al., 1994), some ‘average’ (e.g. Huemer and Mann, 2010; Nation et al., 2006) and others ‘below average’ (Henderson et al., submitted). This variance could be attributed to the language competence of the children; these studies included heterogeneous groups of participants. Indeed, children with higher receptive vocabulary scores also achieve higher non-word reading scores (Henderson et al., submitted; Newman et al., 2007; Norbury & Nation, 2011), which suggests that non-word reading ability aligns with oral language competence for children with ASD, as is the case for TD children (Ouellette, 2006). A relationship is also evident between vocabulary knowledge and word reading (e.g. Henderson, et al., submitted; Norbury & Nation, 2011).

Fewer studies have reported the irregular word reading capabilities of children with ASD. Castles, Crichton and Prior (2010) detailed the literacy skills of two boys with ASD, language difficulties and hyperlexia. JY and AD read aloud 36 irregular words, provided oral definitions and completed a spoken word-picture matching task for the same words. Whilst the boys read a similar number of irregular words as their TD peers, they had less semantic knowledge of the words. JY’s reading accuracy did not differ as a function of semantic knowledge; he accurately read 92% of known and unknown words. In contrast, AD accurately read all of the words that were known to him, yet only read 72% of unknown words. This suggests that semantic knowledge of the words facilitated accuracy, although the difference in accuracy for known and unknown words was not statistically significant. Nevertheless, it is evident that both children accurately read words for which they were unable to provide even a vague description. This suggests that although semantic knowledge may facilitate reading accuracy, it is not necessary for accurate word recognition.

This is consistent with TD literature which indicates that accurate single word reading is facilitated by, but not reliant on semantic knowledge. Nation and Cocksey (2009) found that seven year old TD children were two-three times more likely to accurately read aloud words for which they had pre-existing semantic knowledge of and this was particularly evident for irregular words. However, 6% of unknown words were read correctly despite the child not being able to identify whether the word was 'real' or not, and 14% of unknown words were read correctly despite the child not being able to provide a definition of the word.

Further evidence regarding the role of semantic knowledge is provided by Nation et al. (2007). TD children aged 8-9 years were taught novel words, either in isolation, or accompanied by meaningful semantic information. Learning was assessed via an orthographic choice task, and there were no differences in accuracy for words learnt in the two different conditions. Thus, reading of word forms is not dependent on meaning-based information. Nevertheless, Henderson et al. (2013) found that immediately after learning there were no differences in recall for words taught with or without semantic information, however, after a 1 week delay, the children who received the semantic training recalled a greater number of words.

Summary

The majority of children with ASD read using both phonological decoding and whole-word recognition processes, but some may have a bias towards whole-word recognition (Henderson et al., submitted; Nation et al., 2006). There may also be subtle differences in irregular word reading processes; children with ASD may rely less on semantic knowledge and more on visual memory. This may be particularly pertinent for children with ALI who have weaker vocabulary knowledge. However, there is a dearth of systematic investigation directly comparing reading accuracy for irregular and non-words. In addition, the influence of language phenotype has not been subject to the explicit investigation.

The Current Study

The current study explicitly examined the mechanisms children with ASD use to read, taking into consideration different language phenotypes. To accomplish this, four groups of children were compared, typically developing children (TD), children with ALN, children with ALI and non-autistic children with LI. Three questions were posed:

1. Does the single word reading accuracy of children with ASD align with diagnosis or language phenotype?

   It was hypothesised that language competence would exert a greater influence on reading accuracy than ASD symptomatology. Specifically, ALN children would achieve similar reading accuracy scores to their TD peers, whereas ALI children would achieve lower scores, commensurate with their non-autistic LI peers (cf. Nation & Norbury, 2011).

2. Do children with ASD have superior irregular word reading relative to non-word reading?

   It was hypothesised that children with ALN and ALI would have a bias towards whole-word recognition (cf. Henderson et al., submitted). This bias was not expected to be evident amongst their non-autistic peers.

3. Can children with ASD learn to read without establishing phonological decoding?

   Difficulties decoding non-words in the absence of difficulties with whole-word recognition were predicted to be more prevalent amongst children with ASD (cf. Henderson et al., submitted; Nation et al., 2006). This may be especially true for children with ALI, due to potential phonological awareness impairments that are a common feature of oral language weaknesses (Lindgren et al., 2009; C. McGee, 2001; Norbury & Nation, 2011; Tager-Flusberg, 2006).

To summarise, it was hypothesised that language phenotype would predict reading accuracy, whilst ASD phenotype would predict reading pattern.

Method

Participants

One hundred and one children aged 7-12 years were recruited to the study. The ASD group of 51 children included 23 children with ALN (21 male) and 28 children with ALI (23 male). Two non-autistic comparison groups were included; 22 children with LI (12 male) and 28 TD peers (16 male). All participants met the diagnostic and group classification criteria outlined in Chapter 3.

Single word reading accuracy was assessed through two tasks. Firstly, the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner & Rashotte, 1999) was used to assess word and non-word reading fluency. The inclusion of this measure will allow direct comparison with other ASD study samples. However, as previously discussed, the sight-word reading task includes both regular and irregular words and therefore is not a 'pure' measure of whole-word recognition skill. Therefore the Castles and Coltheart 2 (CC2, Castles et al., 2009) was administered to specifically assess regular and irregular word reading separately. In accordance with the procedure implemented by Castles and Coltheart (1993) children were excluded from analysis if they were unable to read at least six words from one word type, as it was not deemed possible to accurately examine the reading strategies these children were using. This applied to one ALN child (aged 8.14 years), 7 ALI children (25% of the ALI sample, mean age = 10.49) and six LI children (27% of the LI sample, mean age = 9.93). The ALI readers and ALI non-readers were of similar chronological age and non-verbal cognitive ability, but the ALI readers attained higher vocabulary and CELF standard scores (Table 4.1). The LI readers and LI non-readers were also of a similar chronological age, however the LI readers had higher non-verbal ability, as well as better expressive and receptive vocabulary knowledge and higher CELF scores (Table 4.1). Due to the small number of participants in the non-reader groups, statistical analyses were not performed.

All four groups were matched for chronological age. In addition, the TD and ALN groups were matched on non-verbal ability and language measures. The ALI and LI groups were also matched on all cognitive and language measures, although they had significantly lower scores than the TD and ALN groups. The ALN and ALI groups were also matched on autistic symptomatology, as indexed by the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) and the Social Communication Questionnaire (SCQ; Rutter, Bailey and Lord, 2003) scores.

When the four groups were dichotomized, the ASD and non-ASD groups were matched for age and non-verbal cognitive ability (both *p*s > .05). The ASD group had significantly lower expressive and receptive vocabulary raw and standard scores (all *p*s < .05), although mean standard scores were $\geq$ 95. See Table 4.2 for participant characteristics.

Table 4.1

Comparison of readers and non-readers

Variable	ALI readers n=21 *M (SD)*	ALI non-readers n=7 *M (SD)*	LI readers n=16 *M (SD)*	LI non-readers n=6 *M (SD)*
Chronological age (Years)	10.98 (1.32)	10.11 (1.15)	10.18 (1.31)	9.93 (1.39)
WASI matrix reasoning, NVIQ (T-score)	44.15 (10.70)	37.00 (17.06)	45.50 (9.63)	31.00 (8.74)
Language skill:				
Expressive vocabulary (Standard score)	84.43 (11.99)	60.71 (11.90)	92.63 (11.24)	68.33 (5.28)
Receptive vocabulary (Standard score)	79.05 (11.45)	61.29 (9.41)	90.13 (15.84)	81.17 (8.42)
CELF Recalling Sentences (Scaled score)	4.41 (3.55)	At floor	4.25 (2.21)	2.50 (1.73)
Autistic symptomatology:				
SCQ	21.61 (8.38)	—	13.40 (5.06)	13.00 (3.27)

Note: When assessment performance was below floor, a score one point below the standardisation floor was awarded (as implemented by Nation et al., 2006). This applied to two ALI readers for the expressive vocabulary test and one of these children also scored below floor on the receptive vocabulary test. Five ALI non-readers also scored below floor on the expressive vocabulary test, two of whom also scored below floor on the receptive vocabulary test. One LI non-reader scored below floor on the expressive vocabulary test.

Table 4.2

Participant ages and standard scores by group

Variable	TD n=28 *M (SD)*	ALN n=22 *M (SD)*	ALI n=21 *M (SD)*	LI n=16 *M (SD)*	F value	p value
Chronological age (Years)	10.01[a] (0.84) 8.83– 12.03	10.25[a] (1.95) 7.18-12.99	10.98[a] (1.32) 8.32-12.95	10.18[a] (1.31) 8.11-12.00	2.13	.102
Gender Male	16	20	18	8	Non-ASD vs. ASD:	
Female	12	2	3	8	x^2= 10.56, p = .001	
WASI matrix reasoning NVIQ (T-score)	54.71[a] (7.80)	54.45[a] (8.78)	44.15[b] (10.70)	45.40[b] (9.63)	8.89	<.001
Language skill:						
WASI definitions VIQ (T-score)	59.36[a] (9.70)	53.14[a] (12.67)	39.20[b] (7.82)	45.38[b] (9.72)	14.58	<.001
Expressive vocabulary (Standard score)	122.69[a] (11.97)	115.85[a] (16.82)	84.43[b] (11.95)	92.63[b] (11.24)	42.04	<.001
Receptive vocabulary (Standard score)	114.56[a] (10.36)	110.50[a] (18.03)	79.05[b] (11.45)	90.13[b] (15.84)	32.31	<.001
Recalling Sentences CELF (Scaled score)	10.65[a] (1.77)	9.80[a] (3.71)	4.41[b] (3.55)	4.25[b] (2.21)	20.69	<.001
Reading skill:						
TOWRE SWE (Standard score)	113.50[a] (10.44)	105.80[a] (11.51)	82.03[b] (19.08)	78.69[b] (19.97)	29.22	<.001
TOWRE PDE (Standard score)	117.19[a] (15.60)	110.50[a] (18.03)	85.34[b] (21.50)	86.75[b] (16.06)	22.23	<.001
Autistic symptomatology:						
SCQ	4.00[a] (3.58)	20.11[b] (6.86)	21.61[b] (8.38)	13.40[c] (5.06)	26.96	<.001
ADOS (Total)	NA	10.32[a] (3.11)	12.17[a] (3.43)	NA	t =1.55	.132

Values with the same superscript to do not differ when p < .05

Note: When assessment performance was above ceiling, a score one point above the standardisation ceiling was awarded. This applied to three TD and one ALN child for the expressive vocabulary test and one TD child for the receptive vocabulary test. Additionally when assessment performance was below floor, a score one point below the standardisation floor was awarded. This applied to two ALI children for the expressive vocabulary test and one of these children also scored below floor on the receptive vocabulary test. This procedure was implemented by Nation et al. (2006).

Materials

Single word reading accuracy was assessed through the Castles and Coltheart 2 (CC2, Castles et al., 2009), a reading assessment specifically designed to directly assess lexical and non-lexical reading processes. The 120 stimuli includes 40 regular words, 40 irregular words and 40 pronounceable non-words, and the regular and non-words are matched on frequency, imageability, length and grammatical class. The non-words range from monosyllabic three-letter strings to bisyllabic twelve letter strings. The words are listed in Appendix A.

Task performance is standardised based on normative data for children aged 6-11;5. In the current sample, twenty children were slightly older than the standardisation range (1 TD, 7 ALN, 8 ALI and 4 LI). The raw scores of these children were standardised based on the scores of children aged 11;5. Analyses were re-run excluding the children outside of the standardisation range, and the results are presented in Appendix B.

Procedure

Participants were tested in a quiet room in their school, at home or at Royal Holloway, University of London. The CC2 words were viewed on a laptop computer and presentation was controlled by E-Prime version 2. A fixation cross was displayed in the centre of the screen for 500ms, followed by a single word in black Times New Roman font, size 18. Once the child had read the word aloud the next word was presented. Words were presented in order of ascending difficulty following the order specified by Castles et al., (2009) and the discontinuation rule was adhered to. If a child consecutively read five words of the same type incorrectly, then words of that category were no longer administered. Reading accuracy was recorded by the experimenter during the task, plus responses were audio recorded using version 5.2.37 of Praat (Boersma & Weenink, 2011) to enable experimenter accuracy to be checked.

Results

Does the Single Word Reading Accuracy of Children with ASD Align with Diagnosis or Language Phenotype?

Each group was matched for chronological age, but as the number of words attempted and the number of words accurately read were ‘raw’ scores, I considered conducting these analyses using a one-way analysis of covariance (ANCOVA), with age as the covariate. However, correlation analysis indicated that although there was a significant positive relationship between age and number of words attempted for the TD and ALN groups, this was not the case for the ALI and LI groups. Thus, age does not influence reading accuracy in the same way for each group, so the ANCOVA assumptions of homogeneity were violated.

One child with ALN, the youngest child, was an outlier; the number of words he attempted and accurately read was more than 3SD below the ALN group mean and therefore he was excluded from this analysis.

Number of Words Attempted

A one-way analysis of variance was conducted on the number of words attempted (Table 4.3). There was a significant main effect of Group, $F(3,85) = 17.14$, $p < .001$, $\eta^2 = .39$. This was further explored through post-hoc comparisons, specifically Games-Howell, as the assumption of homogeneity was violated $F(3,82) = 31.06$, $p < .001$. The number of words attempted by the TD and ALN groups did not differ ($p = .995$) and the ALI and LI groups did not differ ($p = .648$). However, the TD children attempted more words than their ALI ($p = .002$, Cohen’s $d = 1.28$) and LI peers ($p = .002$, Cohen’s $d = 1.60$). Likewise the ALN children attempted more words than the ALI ($p = .003$, Cohen’s $d = 1.23$) and LI children ($p = .002$, Cohen’s $d = 1.56$).

Number of Words Accurately Read

A one-way ANOVA was conducted on total reading accuracy (Table 4.3). There was a significant main effect of Group, $F(3,85) = 23.72$, $p < .001$, $\eta^2 = .47$. This was further explored through post-hoc comparisons, specifically Games-Howell, as the assumption of homogeneity was violated $F(3,82) = 12.97$, $p < .001$. The number of words accurately read by the TD and ALN groups did not differ (*p*

= .521) and the ALI and LI groups did not differ (p = .796). However, the TD children accurately read more words than the ALI (p < .001, Cohen's d = 1.81) and LI (p < .001, Cohen's d = 1.88). Likewise the ALN children accurately read more words than the ALI (p < .001, Cohen's d = 1.51 and LI groups (p = .001, Cohen's d = 1.63).

Table 4.3

CC2 Raw Scores

Group	Total attempted *M (SD)*	Total accurate *M (SD)*	Irregular accurate *M (SD)*	Non-words accurate *M (SD)*
TD	116.89 (4.56) 101-120	97.68 (12.72) 65-117	25.89 (4.87) 14-37	33.96 (6.07) 18-40
ALN	116.19 (5.57) 101-120	92.33 (13.97) 60-114	25.57 (5.94) 10-36	30.86 (5.34) 20-40
ALI	94.57 (24.34) 38-120	61.24 (25.49) 16-97	17.10 (6.33) 6-26	17.71 (11.46) 0-37
LI	84.13 (28.56) 40-120	52.38 (31.63) 13-99	12.88 (8.02) 1-25	16.31 (11.97) 3-35

What Factors Predict Single Word Reading Accuracy in ASD?

To determine whether autistic symptomatology exerts *any* influence on reading accuracy, regression analysis was conducted with the total number of words accurately read as the outcome variable (see Tables 4.4 and 4.5). Initially the model was run twice; once solely including the ASD participants (ALN and ALI) and again just with the non-autistic participants (TD and LI). However, the significant predictors were the same in each model, thus all four groups were entered into the final model to increase the sample size and statistical power.

Non-verbal IQ was not considered an appropriate covariate due to the relationship with group membership (cf. Dennis et al., 2009). Also, there was a positive correlation between non-verbal IQ and language ability for the TD, ALN and LI groups (r > .55, p <.005) and the relationship approached significance for the ALI group (r = .41, p = .074). The strong correlation between expressive and receptive vocabulary raw scores ($r = .88$, $p < .001$) justified the use of a vocabulary composite (created by averaging the two raw scores). The SCQ was utilised as the index of autistic symptomatology for three reasons. Firstly, the range of potential scores on the SCQ is greater than the range of the ADOS, thus enabling greater variability in autistic characteristics. Secondly, only the children with ASD were administered the ADOS. Thirdly, ADOS score is not a continuous variable and therefore the appropriateness of using it as such is questionable. The final model included age, vocabulary and SCQ score and accounted for 64% of the variance in reading accuracy. Age was a significant predictor of reading accuracy, contributing unique variance (unique $r^2 = -.26$ $p = .031$), as was vocabulary (unique $r^2 = .76$ $p < .001$). In contrast, the SCQ did not predict additional unique variance (unique $r^2 = .00$, $p = .998$).

To determine whether the predictors of irregular and non-word reading accuracy differ, I also conducted regression analyses with irregular word reading and non-word reading accuracy raw scores as the outcome variables (Table 4.5). For irregular word reading the final model including age, vocabulary and SCQ score accounted for 61% of the variance in irregular word reading. Vocabulary composite was the only unique predictor (unique $r^2 = .75$ $p < .001$); neither age (unique $r^2 = -.11$, $p = .392$) nor SCQ score predicted additional unique variance (unique $r^2 = .11$, $p = .197$). For non-word reading the final model including age, vocabulary and SCQ score accounted for 64% of the variance in non-word reading. Both age (unique $r^2 = -.34$ $p = .005$) and vocabulary composite predicted unique variance (unique $r^2 = .76$, $p < .001$). SCQ score did not predict any additional unique variance (unique $r^2 = -.08$, p .523).

Table 4.4

Correlations Between Child Characteristics and Reading Accuracy

	Total reading accuracy	Irregular word reading accuracy	Non-word reading accuracy
Chronological Age	.117	.005	.059
Vocabulary composite	.781**	.735**	.762**
SCQ sum	-.554**	-.544**	-.436*

*$p < .05$ **$p \leq .001$

Table 4.5

Regression Analyses Predicting Reading Accuracy

Total accuracy			
Predictor	β	t	Unique R^2
Age	-.19	-2.20	-.26*
Vocabulary	.84	9.56	.76**
SCQ score	<.001	-.003	-.00
Irregular word reading			
Predictor	β	t	Unique R^2
Age	-.08	-.86	-.11
Vocabulary Composite	.84	9.24	.75**
SCQ score	.14	1.63	.20
Non-word reading			
Predictor	β	t	Unique R^2
Age	-.24	-2.91	-.34*
Vocabulary composite	.82	9.44	.76**
SCQ score	-.05	-.64	-.08

*$p < .05$ **$p < .001$

Do Children with ASD have Superior Irregular Word Reading Relative to Non-word Reading?

A 4 (group; TD vs. ALN vs. ALI vs. LI) x 2 (word type standard scores; irregular vs. non-word) repeated measures analysis of variance was conducted and the means and standard errors are presented in Figure 4.1.

There was no significant main effect of condition, $F(1,83) = 2.95$, $p = .090$, but there was a main effect of group $F(1,83) = 27.67$, $p < .001$. Levene's assumption of homogeneity was met for irregular word reading, $F(3,83) = .74$, $p = .533$, but was violated for non-word reading, $F(3,83) = 3.44$, $p = .020$, so post-hoc tests were conducted using Games-Howell. As before, both the TD and ALN groups achieved higher accuracy scores than the ALI and LI groups (all $p < .001$), but the TD and ALN ($p = .940$) and ALI and LI ($p = .998$) groups did not differ.

However, there was a significant interaction between group and condition $F(3,83)=5.99$, $p = .001$. To explore this, four paired samples t-tests were conducted by group and Bonferroni correction was applied, so $p < .0125$. For the TD group there was not a significant difference between irregular and non-word standard scores, $t(27) = -.07$, $p = .942$, and this was also the case for the LI group $t(15) = -1.83$, $p = .087$ and their ALI peers, $t(21) = 1.03$, $p = .314$. However the ALN group achieved significantly higher standard scores for irregular words than the non-words, $t(20) = 4.52$, $p < .001$. This suggests that the ALN group have superior irregular word reading relative to non-word reading.

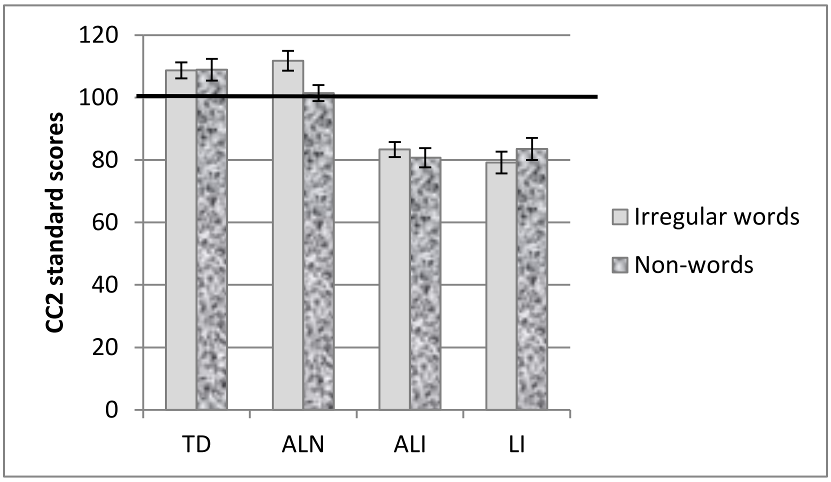

Figure 4.1 *Mean Reading Accuracy Standard Scores. Error Bars Represent Standard Error*

To further explore the reading profiles of the group each child's standard scores were considered to determine whether they achieved similar non-word and irregular word standard scores (<10 point difference) or were superior at reading non-words or irregular words (>10 point difference). A difference of 10 standard points was selected as this was considered to be a significant difference between the two skills. As illustrated by Figure 4.2, the majority of participants in each group had similar non-word and irregular word standard scores, with 5-25% of children demonstrating superior non-word reading relative to irregular reading. However, nearly 40% of the children with ASD had irregular word reading standard scores that were >10 points higher than non-word standard scores (45.46% of the ALN sample and 33.33% of ALI sample), compared to 21% of the TD group and none of the LI group. These group differences were statistically significant, with a greater percentage of children with ASD (ALN and ALI combined) exhibiting an irregular word reading bias relative to their non-autistic peers (TD and LI combined), $x^2(1, n=87) = 6.23$, $p = .013$. When the ASD children with an irregular word reading bias were compared to the remaining ASD children, there were no group differences in terms of age, cognitive ability or vocabulary knowledge (all $t < .88$, $p > .35$). This outcome remained consistent when the ALN and ALI groups were examined separately.

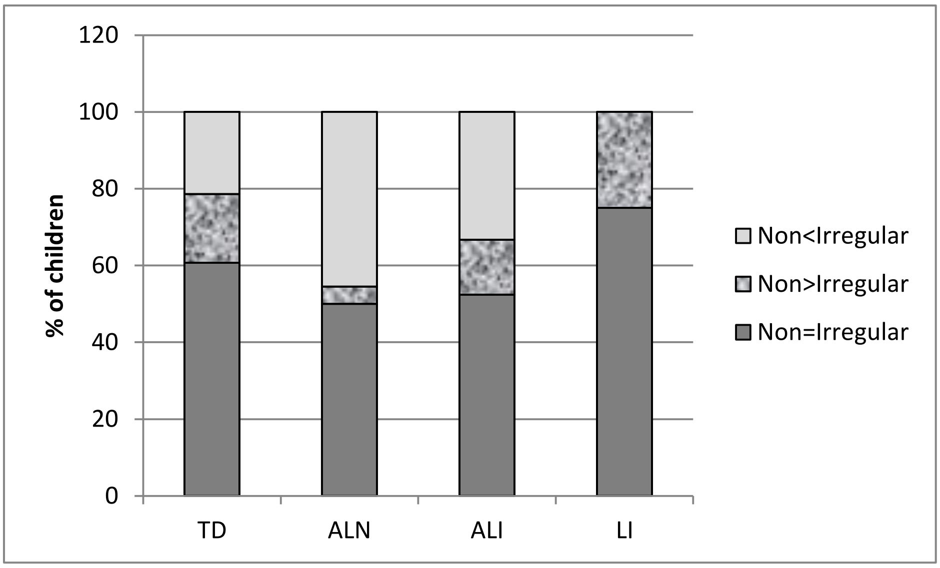

Figure 4.2 *Percentage of Children with Non-word and Irregular Word Reading Standard Score Discrepancies*

Can Children with ASD Learn to Read without Establishing Orthography-Phonology Mappings?

For all four groups there was a significant positive correlation between irregular and non-word standard scores (TD: $r = .74$, $p < .001$, ALN: $r = 0.70$, $p < .005$, ALI: $r = 0.60$, $p = .004$, LI: $r = 0.77$, $p < .001$). However, low levels of non-word reading were particularly apparent in the ALI group. One ten year old child with ALI failed to read a single non-word, despite accurately reading six irregular words and 10 regular words (word length range = 3-6 letters). Nevertheless, inspection of performance on the phonemic decoding subtest of the TOWRE determined that he was able to read two letter non-words correctly, and the difficulty arose when the non-words contained three letters. Additionally, 33.33% (n=7) of the ALI children had age-appropriate irregular word reading (i.e. SS >77) but impaired non-word reading (i.e. SS <77). When more stringent criteria were applied, using a standard score of 85 (i.e. 1 SD from the population mean) 19% (n=4) of the ALI children received an age-appropriate irregular word reading score but a non-word score below average.

Discussion

This study investigated the single word reading of children aged 7-12 with ASD and compared their reading profile to non-autistic peers. Consistent with previous research, the ASD children's reading skill aligned with their language profile (Brown et al., 2013; Lindgren et al., 2009; Norbury & Nation, 2011; Ricketts et al., 2013) and autistic symptomatology did not contribute any unique variance to reading accuracy. The ALN children were reading at an age-appropriate level, whereas the ALI group were reading at a significantly lower level, on average 1.25 SD below the population mean and at an equivalent level to their LI peers. Additionally 7 (25%) ALI and six (27%) LI children were excluded from the analysis due to their limited reading ability. This suggests that single word reading competence aligns with language ability, rather than ASD status. However, subtle differences between the ASD and non-autistic groups emerged in reading patterns.

Do Children with ASD have Superior Irregular Word Reading Relative to Non-word Reading?

To date, there has been a lack of systematic research directly comparing the contribution of phonological decoding and whole word recognition to reading. Furthermore, there has been no investigation of how reading patterns may differ according to language phenotype. In the current study, the non-autistic participants (TD and LI) achieved similar non-word and irregular word reading standard scores, indicating that they are utilising decoding and recognition strategies with equivalent competency. In contrast, at a group level the children with ALN attained higher irregular word reading than non-word reading standard scores, although this was not the case for the children with ALI. However, at an individual level, 45% of children with ALN and 33% of children with ALI had a discrepancy between irregular and non-word reading competence, with superior irregular word reading, relative to 14% of their non-autistic peers. This suggests that some children with ASD may utilise whole-word recognition strategies more effectively than phonological decoding strategies. This finding is consistent with Henderson et al. (submitted), who found that children with ASD are more proficient at reading words than non-words. However it contrasts with the findings of Norbury and Nation (2011) and Minshew et al. (1994). The contrasting findings may be attributable to the different ages of the samples. If children with ASD have impaired comprehension and are less able to learn new words from text, the advantage for words relative to non-words may decrease over time.

In order to explore whether superior irregular word reading is driven by semantic knowledge, the vocabulary knowledge of the ASD children with the irregular word reading bias was compared to the ASD children without the discrepancy. The groups did not differ, which suggests that irregular word reading is not necessarily reliant upon semantic knowledge. However, semantic knowledge clearly facilities reading; vocabulary knowledge was a significant predictor of irregular word reading accuracy. Similar results have been reported by Castles, Crichton and Prior (2010) and Nation and Cocksey (2009) who found that semantic knowledge facilitates, but is not necessary for, accurate irregular word reading. Likewise, Henderson et al. (2013) found that semantic knowledge facilitates, but is not essential for vocabulary learning.

Another potential explanation for the identified discrepancy is that children with ASD may have a bias towards visual recognition strategies. Indeed, they are often regularly exposed to visually presented materials in order to aid their communication and understanding, for example through the Picture Exchange Communication System. However, Newman et al. (2007) found that visual memory does not consistently align with irregular word reading for children with ASD. The participants in the Newman et al. sample ranged from average to exceptional readers. It is possible that children with poor irregular word reading skills also have poor visual memory skills. This was not explicitly assessed in the current study and therefore remains an important avenue for future research.

Can Children with ASD Learn to Read Without Establishing Orthography-Phonology Mappings?

Despite the children in the sample having a minimum age of 7, over 25% of the language-impaired children recruited were excluded from analysis due to their limited reading ability. Inclusion criteria required children to be able to read at least six words from at least two of the three categories (regular words, irregular words and non-words). One child with ALI was able to read 16 real-words, but unable to read a single non-word. This suggests that it is possible to learn to read without establishing orthographic-phonology mappings (cf. Henderson et al., submitted). However, it is possible that the ALI child in the current sample and the children in Henderson et al.'s study were in the very earliest stages of learning to read, and thus had not yet learnt to read via phonological decoding. This would align with Frith's (1985) notion of the logographic stage of reading and Ehri's (L.C. Ehri, 1995, 1996, 1998, 2005; L.C. Ehri & McCormick, 1998) pre-alphabetic phase.

It is noteworthy that in the current study, around a quarter of children with ALI had age-appropriate irregular word reading but impaired non-word reading. Similarly, Nation et al., (2006) found that five of 42 children (15.6%) scored at floor on a non-word reading test despite achieving word reading standard scores >95. This suggests that some children with ASD can acquire age-appropriate whole-word recognition skills, despite having phonological decoding impairments.

Theoretical Implications

The triangle model of reading (Plaut, 1996) proposes that unfamiliar words are read by mapping phonology and orthography, with identification of familiar words supported by, but not dependent upon, semantic knowledge. Similar to previous research, we found that children with ASD can read using both phonological decoding processes (Huemer & Mann, 2010; Minshew et al., 1994; Nation et al., 2006; Norbury & Nation, 2011) and whole-word recognition. This indicates that they utilise both the phonological and semantic pathways proposed by the triangle model of reading.

However, nearly 40% of the ASD sample demonstrated a bias towards irregular word reading, relative to 14% of the non-autistic children, indicating that the reliance on each pathway may differ for children with developmental disorders. For children with ASD, whole-word recognition is facilitated by semantic knowledge, but superior irregular word reading is not dependent upon exceptional vocabulary knowledge. This is consistent with Castles, Crichton and Prior (2010) who found that the irregular word reading of two boys with ASD and hyperlexia was not reliant on item-specific semantic knowledge. This aligns with literature demonstrating that the single word reading of TD children is facilitated by, but not reliant on semantic knowledge (Nation et al., 2010). These findings may be more readily explained by the DRC model which suggests that words can be read through the direct lexical route without going via the semantic system. However, more research is needed before either the triangle or DRC model is accepted as an account of reading in ASD.

Educational Implications

This study demonstrates that, at least for children with ASD, it is possible to become a proficient reader of whole words, whilst struggling to 'sound-out' words (see also Henderson et al., submitted; Nation et al., 2006). This finding has two key educational implications. Firstly, this finding suggests that reading tests which only assess real-word reading may not be an accurate indicator of children's overall single reading ability; phonological decoding ability may not be equal. As a result practitioners (and researchers) would be advised to report both real and non-word reading ability, in order to avoid over-estimating competence.

Secondly, although being able to decode words phonetically is fundamental to successful identification of unfamiliar words presented in isolation, if children are struggling to use phonological decoding strategies it may be beneficial to temporarily focus on whole-word recognition strategies. This may enable children to improve their reading skills, which could facilitate vocabulary development, support learning in other areas of the curriculum and assist with daily functioning. Furthermore, as whole-word recognition skills develop, knowledge of orthographic-phonemic connections may progress, enabling skill at translating orthography to phonology to evolve. Indeed, research with individuals with Down syndrome has demonstrated that non-word reading can be facilitated by whole-word reading (Roch & Jarrold, 2012). Whether this is also the case for children with ASD is an interesting and valuable topic for future research. All teachers reported that the students in the current study received reading tuition that emphasised phonemic decoding strategies, but these were taught in conjunction with whole-word recognition strategies.

Limitations

The results of this study should be interpreted with consideration of two limitations; one concerning the participants and the other the depth of investigation. The CC2 is standardised for children aged 6-11;5, however 20 of the participants (15 ASD, 5 non-autistic) were aged 11;6-12;11. In order to take this into consideration all analyses were run with and without the older participants and results did not differ (Appendix B). Although not ideal, older children were included because once data collection began it was evident that many of the children with ALI were struggling to read and it was anticipated that increasing the age range would increase the likelihood of children being able to read enough words to explore qualitative differences in reading patterns. However, comparison of ALI readers and non-readers indicated no effect of age; the groups only differed in terms of vocabulary. This further emphasises the intimate relationship between linguistic skill and literacy competence.

It would also have been valuable to include measures of factors that potentially influence whole-word recognition in ASD, specifically visual memory and item specific semantic knowledge. Visual memory has previously been assessed via the Visual Memory subtest of the Test of Visual–Perceptual Skills (Gardner, 1996) but inclusion of this measure was not within current testing constraints. Castles and Crichton (2010) conducted an in depth analysis of semantic knowledge through a spoken-word to picture matching task and by requesting oral definitions. It was not feasible to conduct such analyses with all 40 irregular words of the CC2.

Additionally, although the children's teachers confirmed that they knew all 44 letter-sound correspondences, it may also have been valuable to include a measure of phonological awareness in the test battery. This would have facilitated exploration of factors influencing phonological decoding and enabled determination of whether the ASD children's divergence towards whole-word recognition reading was due to poor phonological skills. However, previous research has reported that the PA skills of children with ASD are associated with language competence rather than ASD status (Lindgren et al., 2009; C. McGee, 2001; Norbury & Nation, 2011), and it is noteworthy that both children with ALN and ALI portrayed weaknesses in phonological decoding relative to whole-word recognition.

Conclusion

In conclusion, the data suggests that reading ability is influenced to a greater extent by language ability than ASD symptomatology, but that reading processes may be associated with ASD phenotype. Children with language impairments are more likely to be poor readers than their non-language impaired peers, regardless of ASD status. However, children with ASD are more likely to have a bias towards whole-word recognition relative to phonological decoding, as evidenced by better irregular word than non-word reading. For children with ASD who are struggling to use phonological decoding strategies to read, whole-word recognition tuition may be a viable route to facilitate development of reading skill and confidence.

Chapter Five: The Influence of Language Competence on Reading Comprehension

Chapter Overview

The first experimental chapter of this thesis focused on word identification. This chapter explores the second component of reading, namely comprehension, and uses the framework of the Simple View of Reading (Hoover & Gough, 1990). To date, the majority of research has explored comprehension at the passage level, whereas there is a paucity of research on sentence comprehension. The level of processing at which comprehension is most vulnerable is therefore unclear.

I explored comprehension at sentence and passage levels across language phenotypes. The sample included 50 children with autism spectrum disorders, 25 with age-appropriate structural language skills (ALN) and 25 with language impairments (ALI) and 30 typically developing peers (TD). The participants read sentences in which syntactic and semantic coherence was manipulated and reading times for sentence stems and final words were analysed. Children with ALN demonstrated similar syntactic and semantic facilitation to TD peers. In contrast, few children with ALI could read beyond the single word level. Those who could read sentences benefited from semantic coherence, but were less sensitive to syntactic coherence. Passage comprehension was assessed through the NARA-II, and the strongest predictor of comprehension was vocabulary knowledge. Thus, reading accuracy and comprehension of connected text aligns with linguistic competence. This indicates that literacy interventions for children with ASD should be tailored to the decoding and language skills of the individual.

The work presented within Chapter 5 is 'in press' in JAAD.

Lucas, R., & Norbury, C. (In press). Levels of text comprehension in children with autism spectrum disorders (ASD): The influence of language phenotype. *The Journal of Autism and Developmental Disorders.*

Introduction

Many children with ASD have poorer reading comprehension than their TD peers (cf. Brown et al., 2013) and have a disproportionate difficulty with comprehension relative to decoding (Henderson et al., submitted; Huemer & Mann, 2010; Jones et al., 2009; Nation et al., 2006; Newman et al., 2007; Ricketts et al., 2013). However, the majority of studies explore comprehension at the passage level. There is considerably less research investigating sentence level comprehension and results are equivocal. The level at which comprehension is most vulnerable is therefore unclear. It is important to identify when in the reading process comprehension difficulties begin to emerge in order to target interventions at the appropriate level; if comprehension is impaired at the sentence level, this should be rectified prior to targeting passage comprehension.

This study explores the sentence and passage comprehension of children with ASD, taking into consideration linguistic phenotype. As discussed in Chapter 2, several aspects of autistic cognitive style have been implicated in the increased rates of poor reading comprehension observed in this population. For example, theory of mind deficits (Baron-Cohen et al., 1985) may impair comprehension as a result of reduced understanding of the mental states of story characters and how these internal states motivate character behaviour. To that end, measures of social symptom severity have been found to predict small, but significant amounts of variance in the reading comprehension scores of individuals with ASD (Ricketts et al., 2013). Furthermore, children with ASD appear to have more difficulty comprehending texts with high social content relative to passage that require low social knowledge (Brown et al., 2013). In addition, children with ASD have been reported to have difficulty integrating information from different sources to achieve holistic meaning (Frith, 1989; Frith & Happé, 1994), leading them to process individual elements of text rather than experiencing the story as a coherent whole (Kanner, 1943). This style of processing, termed ‘weak central coherence’ (WCC) may be especially detrimental to text comprehension because of the need to integrate information both across the text and with general knowledge and experience in order to make appropriate inferences (Jolliffe & Baron-Cohen, 1999).

However, the majority of previous investigations of reading comprehension within ASD have included heterogeneous groups with wide ranging linguistic abilities. In addition, few studies investigating WCC using written materials have incorporated measures of single word reading. Given that reading comprehension in typical development is underpinned by both decoding and oral language competence (Gough & Tumner, 1986), it may be anticipated that linguistic competence may be equally, if not more, influential than ASD diagnosis (cf. Brown et al., 2013). In order to understand the meaning of a text, it is important to have semantic knowledge of the individual words, or at least the majority of them. It has been suggested that adequate reading comprehension is dependent upon the reader having knowledge of at least 90% of the words in the text (Hirsch, 2003). This will facilitate attainment of the 'gist' of the text and readers are likely to be able to make an accurate guess at the correct meaning of unfamiliar words.

In addition to exploring individual factors related to reading comprehension it is also important to identify when in the reading process comprehension difficulties begin to emerge, in order to target interventions effectively. While there is substantial evidence that many children with ASD have difficulties with passage reading comprehension (Frith & Snowling, 1983; Lockyer & Rutter, 1969; Nation, et al., 2006; Norbury & Nation, 2011; Ricketts et al., 2013; Rutter & Bartak, 1973), there is considerably less research exploring sentence-level reading comprehension, and results are equivocal. If comprehension is impaired at the sentence level, this should be rectified prior to targeting passage level comprehension.

Sentence Reading Comprehension

Research exploring sentence reading comprehension in ASD has employed three core paradigms: homograph tasks, sentence to picture matching tasks, and analysis of reading pace. Studies utilising these methodologies will be discussed in turn, followed by discussion of the factors contributing to the conflicting findings.

Homograph Task

The homograph task has been used extensively to measure the extent to which individuals with ASD use contextual information to modify pronunciation of ambiguous words, for example, 'in her *eye/dress* there was a big *tear'.* As discussed in Chapter 2, the homograph task is an explicit test of central coherence. At the sentence level, it has consistently been reported that individuals with ASD use contextual information less effectively than non-autistic peers, exhibiting a tendency to use the most frequent pronunciation, regardless of the context (Frith & Snowling, 1983; Happé, 1997; Jolliffe & Baron-Cohen, 1999; López & Leekam, 2003; M. Snowling & Frith, 1986). Frith and Snowling presented participants with five homographs that were embedded in ten sentences combined to make a short story. The ASD group of eight individuals read the homographs significantly less accurately than the 10 reading-age matched controls, exhibiting a tendency to use the most frequent pronunciation, regardless of the context. However, the age of the ASD participants spanned eight years (ages 9-17) which may mask key developmental changes (Tager-Flusberg, 2004). This, along with the small sample size necessitated further research. The study was replicated by Happé (1997) with a sample of 17 individuals with ASD (aged 8-28), Jolliffe and Baron-Cohen (1999) with 43 adults with ASD and López and Leekham (2003) with 16 adolescents with ASD. In each study, the ASD participants were less likely to provide the contextually appropriate pronunciation when the subordinate pronunciation was required. This difficulty at the sentence level has been taken as evidence of weak central coherence.

However, performance on such tasks may also be influenced by the language and reading skills of the participants. These factors are known to affect contextual processing in other developmental disorders, yet are often not well controlled. For example, frequently the only measure of language ability is verbal IQ. The non-verbal IQ standard scores of Happé's ASD participants ranged from 50-100, thus, the average score of 79.60 masked substantial individual variation. No measure of language ability was administered to the younger TD group and it is therefore uncertain whether they had similar linguistic competence. Similarly, the verbal IQ of Jolliffe and Baron-Cohen's ASD participants ranged from 88-135, although there was similar variability in the TD group (range = 87-127). Additionally, none of these three studies included a measure of reading ability. It is therefore possible that group differences are driven more by associated linguistic and reading factors, rather than aspects of autistic phenotype.

Consideration of language ability is particularly important given the demands of the homograph task. Successful completion of the homograph task requires children to understand that homographs have multiple meanings, to know these multiple meanings and to know that they are associated with different pronunciations, to access the correct meaning/pronunciation and to inhibit the incorrect meaning/pronunciation (even when it is of higher frequency). These skills are all reported to be poorer amongst children with language difficulties (cf. Norbury, 2005), in part due to reduced semantic knowledge. Indeed, Snowling and Frith (1986) found that performance on the homograph task was highly dependent on language ability for individuals with ASD.

Additionally, task characteristics, such as stimuli presentation order, can influence performance. Brock and Bzishvili (2013) administered the homograph task to 40 university undergraduate students. As discussed in Chapter 2, TD individuals become increasingly aware of the nature of the task as it progresses and modify their responses accordingly. As a result, individuals begin to expect that subordinate meanings were likely to be encountered over the course of the experiment, and over time, accuracy for subordinate pronunciations increases. Thus, the homograph task may not exclusively measure immediate and spontaneous use of context, as is commonly assumed. Instead, executive skills such as comprehension monitoring, set shifting and inhibition play a role in task success, skills that some children with ASD may find difficult (Liss et al., 2001; McEvoy, Rogers, & Pennington, 1993; Ozonoff, 1995; Rumsey, 1985; Shu, Lung, Tien, & Chen, 2001).

Sentence-picture matching

A more traditional, but less frequently employed, comprehension assessment is a sentence to picture matching task. Snowling and Frith (1986) used this paradigm to assess the comprehension of eight individuals with ASD. The participants had chronological ages of 11-19, but single word reading ages of 8-10 years, evidencing impairments in reading accuracy. For sentences presented in the written form, the average accuracy of the ASD group was 24 out of 40. The lack of a TD comparison group means it is not possible to determine whether the children were achieving age appropriate comprehension scores, although given their decoding impairments this is unlikely. Nevertheless, the ASD group achieved comparable results to a non-autistic group of children with cognitive impairments, who were of a similar age, cognitive ability and reading ability. This indicates that the children with ASD were achieving scores consistent with their cognitive and decoding ability and factors associated with ASD did not result in quantitative differences. Additionally, when equivalent sentences were presented in the spoken form, accuracy was very similar (23 out of 40). This suggests that reading comprehension aligns with listening comprehension.

Similarly, Åsberg, Dhalgren and Dhalgren (2008) asked participants to match written sentences to the corresponding pictures. The 37 children with ASD (mean age = 9.74) achieved significantly lower accuracy scores than their TD peers (p = .016, η_p^2 = .105), signifying impaired sentence comprehension. However, it is noteworthy than although the groups were matched on age, the ASD group had lower non-verbal cognitive ability, lower verbal cognitive ability and poorer single word reading. It is therefore possible that the group differences are attributable to differential language or decoding ability, rather than ASD. Indeed, for the children with ASD there was a strong positive correlation between decoding and comprehension (r = .72), indicating that this hypothesis is likely to be valid.

Reading pace

A more implicit measure of sentence comprehension, with fewer task demands, involves analysis of reading pace. West and Stanovich (1978) presented participants with a written sentence stem and then displayed the final word of the sentence after a brief delay. Both TD children and adults read the final word quicker when it was semantically congruent as opposed to anomalous, with the sentence stem (i.e. ‘The girl sat on the… chair/cat’). Similarly, Joseph et al., (2008) manipulated the plausibility of sentences and found that both TD children and adults read plausible sentences significantly faster than anomalous sentences.

This methodology was employed by Saldana and colleagues (2007, 2013) to assess the sentence reading comprehension of adolescents and adults with ASD. Saldana and Frith (2007) analysed the reading pace of 16 adolescent males with ASD who had poor text comprehension. Participants read sets of two short sentences followed by a general knowledge question. In 50% of cases, the sentences primed the question. To illustrate: "The Indians pushed the *rocks/cowboys* off the cliff onto the *cowboys/rocks*. The cowboys were badly injured. Can rocks be large?". Both the TD and ASD groups read the primed questions quicker than the non-primed questions indicating that they were generating inferences and integrating information across sentences. The size of the priming effect for the ASD group did not differ from TD peers, who were matched for receptive vocabulary knowledge and word reading ability. Likewise, Tirado and Saldana (2013) found that adolescents and adults with ASD and poor text comprehension read target phrases significantly quicker when the phrase was congruent with information in the preceding sentence.

Thus, at the sentence level, many individuals with ASD can comprehend sentences and make inferences as efficiently their TD peers, even if they experience difficulties with passage comprehension. However, within the samples, and particularly within the ASD groups, there was large variation in language competence, especially with regards to receptive vocabulary. For example, Saldana and Frith (2007) used the BPVS to assess receptive vocabulary and standard scores for the ASD group ranged from 53-147. Thus, the group mean of 98.20 masks substantial variation. It is therefore uncertain whether *all* participants with ASD comprehended the sentences to the same extent or whether those with poor language ability struggled and their weaknesses were masked by the group mean.

Sentence Comprehension Summary

To summarise, the evidence regarding the sentence comprehension of individuals with ASD is equivocal. The results of implicit tasks indicate that individuals with ASD do comprehend text at the sentence level but performance on explicit homograph and word-picture matching tasks suggests that sentence comprehension is challenging for individuals with ASD. The conflicting results may be attributable to differing task demands or participant characteristics. Despite the well-evidenced relationship between language ability and reading comprehension for TD individuals, studies have rarely taken language competence into consideration. In fact, there is a dearth of research considering the influence of language ability on the sentence reading comprehension of individuals with ASD.

It is possible that differences may emerge as a function of language phenotype, as is the case in the verbal domain (Brock et al., 2008; Norbury, 2005a), and at the passage level (Brown et al., 2013).

Passage Comprehension

Research has consistently indicated that, as a group, children with ASD attain lower text reading comprehension scores than their TD peers (Frith & Snowling, 1983; Rutter & Bartak, 1973)(Frith & Snowling, 1983; M. Rutter & Bartak, 1973). Rutter and Bartak administered the NARA (Neale, 1966) to 45 children and adolescents with ASD, who were at least 10 years old. Although 13 of the participants achieved a reading accuracy age $\geq$8 years, only two achieved a reading comprehension age $\geq$8 years. Similarly, Frith and Snowling administered the NARA to eight children aged 9-17 with ASD and the mean reading comprehension age was 6 months behind the mean reading accuracy age (8;9 vs. 9;3). However, early studies included participants with a wide range of language abilities and it is therefore uncertain whether text comprehension deficits are a universal feature of ASD, or only arise for individuals with concomitant language difficulties.

The extent to which reading comprehension aligns with oral language competence in ASD has been investigated in two ways. Firstly, two studies have directly compared reading comprehension in different language phenotypes within ASD. Secondly, several studies have explored the relationship between oral language skill and reading comprehension in heterogeneous samples of participants with ASD. Lindgren et al. (2009) compared the reading ability of children and adolescents with ALN, ALI and LI. The participants in both language impaired groups had a positive history of language delay and/or deficits, and achieved a standard score more than one standard deviation below the mean on either the CELF or a non-word repetition test, both of which are considered to be psycholinguistic markers of LI (Coady & Evans, 2008; Conti-Ramsden, 2003; Conti-Ramsden et al., 2001). Although all three groups achieved mean passage comprehension standard scores greater than 90, the ALN group scored significantly higher than the ALI and LI groups, whose scores did not differ from each other.

Likewise, Norbury and Nation (2011) assessed the reading comprehension of adolescents with ALN and ALI, but utilised a TD rather than LI comparison group. Again, participants with ALI had a history of language delay, but they also had a diagnosis of language impairment from a speech-language therapist, and achieved a standard score at least 1.25 SD below the mean on the Recalling Sentences subtest (RS) of the CELF-4 (Semel et al., 2003), an excellent clinical marker of language impairment within clinical populations (Riches et al., 2010). Norbury and Nation also found that adolescents with ALI achieved lower reading comprehension standard scores than their ALN peers, who did not differ from TD controls. Thus, children with language impairments (regardless of ASD status) achieve lower reading comprehension standard scores than their non-language impaired peers.

A number of studies have explored correlations between language and reading comprehension in larger, unselected cohorts of children and adolescents with ASD. Nation et al. (2006) found a significant, strong, positive correlation between text reading comprehension and both receptive vocabulary and oral language comprehension. Similarly, Åsberg, Kopp, Berg-Kelly and Gillberg (2010) explored reading in girls with ASD and found a significant, strong, positive correlation between reading comprehension and vocabulary knowledge. Vocabulary knowledge was a significant unique predictor of reading comprehension, accounting for 18% unique variance. Likewise, the reading competency of adolescents with ASD has been assessed in several recent studies (Henderson et al., submitted; Norbury & Nation, 2011; Ricketts et al., 2013) and all found that receptive vocabulary was a unique predictor of reading comprehension. The consistency of these findings is underlined by a recent meta-analysis (Brown et al., 2013). The strongest individual predictor of reading comprehension in ASD was vocabulary knowledge, which accounted for 57% of the variance.

Poor Comprehenders

In addition to experiencing comprehension impairments, many children with poor language skills also have deficits in decoding (Lindgren et al., 2009; Norbury & Nation, 2011). It is therefore not necessarily the case that these children have a Poor Comprehender reading profile, in which comprehension lags behind reading accuracy and chronological age expectations. As discussed in Chapter 2, approximately 30% of children with ASD demonstrate a Poor Comprehenders reading profile (Henderson et al., submitted; Nation et al., 2006), relative to 7-10% of TD children (Clarke et al., 2010; Nation et al., 2010; Nation & Snowling, 1997; Stothard & Hulme, 1995; Yuill & Oakhill, 1991). However, studies reporting the percentage of Poor Comprehenders within ASD samples have included a heterogeneous group of ASD participants, and it is therefore uncertain whether the likelihood of a child demonstrating a Poor Comprehender reading profile is associated with a particular language phenotype. As many children with ALN have age-appropriate decoding and comprehension skills (Lindgren et al., 2009; Norbury & Nation, 2011) it may be expected that the majority of ASD Poor Comprehender would have language impairments. Nevertheless, many children with language impairment have deficits in both decoding and comprehension (Lindgren et al., 2009; Norbury & Nation, 2011). It is therefore uncertain whether the likelihood of a child demonstrating a Poor Comprehender reading profile is associated with a particular language phenotype.

The Current Study

The current study explored the sentence reading comprehension of children with ASD and enhances the field by taking into consideration language phenotype. Sentence processing was assessed using on-line techniques which do not require explicit reflection; children read sentences in which the syntactic and semantic structure was manipulated (cf. Joseph, et al., 2008; Saldana & Frith, 2007; West & Stanovich, 1978), whilst passage comprehension was assessed through the NARA-II (Neale, 1997). There were three key questions:

1) Does sentence reading processing align with language ability or ASD diagnosis?

   I anticipated that processing would closely align with language status, rather than autism diagnosis. Thus, children with ALN would read sentence stems that were syntactically coherent more quickly than those that were syntactically scrambled. It was also anticipated that children with ALN would read the final word of the sentence faster when it was semantically coherent with the sentence stem context, relative to the condition in which the final word was anomalous with the sentence stem context. In contrast, I predicted that the reading pace of children with ALI would be less affected by the syntactic and semantic manipulations.

2) Does passage reading comprehension align with language ability or ASD diagnosis? I predicted that reading deficits in ASD might become more pronounced relative to TD peers. Nevertheless, across the group, I predicted that semantic knowledge would be a better predictor of comprehension than autistic symptomatology.

3) Are children with ALN or ALI more likely to demonstrate a Poor Comprehender reading profile? I hypothesised that a Poor Comprehender reading profile would be more evident for children with ALI, than children with ALN.

Method

Participants

Eighty children aged 7-14 years took part in the study. This included 50 children with ASD (ALN n = 25, 23 male and ALI n = 25, 18 male) and 30 TD children (18 male). Fifty-six of the participants (18 TD, 17 ALN and 21 ALI) took part in study 1. All participants met the eligibility criteria outlined in Chapter 3.

All children attempted the sentence reading task, however only 12 of the ALI group had sufficient word reading ability to accurately and fluently complete this task (henceforth referred to as 'ALI sentence readers'). The 'ALI word readers' achieved a TOWRE SWE raw score $\leq$43 which indicated that they were reading at a level equivalent to a child younger than eight years old. Inspection of these children's performance on the TOWRE indicated that they were able to read real words containing 2-3 letters, but struggled to read four letter words. Additionally, they could 'sound out' two letter non-words but had difficulty with longer non-words. The ALI word and ALI sentence readers did not differ in terms of non-verbal cognitive ability or vocabulary knowledge (all t-values < .15 , ps > .10), but ALI word readers attained significantly lower WASI Vocabulary and CELF Recalling Sentences scores (both t < 3.40, p < .005), indicating greater severity of language impairment. There was a trend for the ALI readers to be older (t =1.82, p = .082, but the groups did not differ in autistic symptomatology as represented by SCQ score and ADOS total (both t-values < .37, ps > .72). See Table 5.1.

The TD and ALN groups were matched for chronological age, as well as on cognitive, language and reading measures; in contrast the ALI sentence readers were significantly older, but had lower scores on all cognitive and language measures. The TOWRE SWE standard scores of the ALI group were significantly lower than the TD group and marginally lower than the ALN group (p = .072), but did not differ from the LI group; all three groups were matched on TOWRE PDE standard score. I did attempt to match all groups for non-verbal ability, but similar to other studies, found that non-verbal and verbal abilities are highly correlated (cf. Conti-Ramsden et al., 2012) and lower non-verbal ability scores are associated with ALI group membership (cf. Dennis et al., 2009). Importantly, despite the difference in non-verbal reasoning, the ALN and ALI groups were matched on measures of autistic symptomatology (SCQ and the ADOS; see Table 5.2).

The original study design included an LI comparison group. However, 16 of the 28 participants recruited had insufficient reading skill and the majority of the 12 remaining children were reluctant readers. As a result they were easily distracted during the task, affecting the validity and reliability of the employed reading time measure.

Table 5.1

Participant Ages and Standard Scores for ALI Word Readers and Sentence Readers

Variable		ALI word readers (SD) n=13	ALI sentence readers (SD) n=12	*t* value	*P* value
Chronological age		10.79 (1.31) 8.29–12.51	11.77 (1.38) 9.44-13.07	-1.82	.082
Gender	Male Female	12 1	11 1	χ^2 = .003	.953
WASI matrix reasoning, NVIQ (T-score)		46.75 (8.28)	40.42 (12.02)	1.50	.147
Language ability:					
Receptive one-word picture vocabulary test (Standard score)		74.58 (12.77)	82.08 (9.69)	1.62	.119
Expressive one-word picture vocabulary test (Standard score)		78.25 (13.77)	86.92 (13.77)	1.54	.138
CELF Recalling Sentences (Scaled score)		1.91 (1.58)	4.86 (1.68)	3.77	.002
Reading skill:					
TOWRE SWE	Raw score	25.68 (13.79)	69.28 (10.49)	7.80	< .001
	Standard score	69.28 (10.49)	93.06 (8.10)	5.03	< .001
TOWRE PDE	Raw score	8.73 (7.23)	38.67 (9.06)	8.24	< .001
	Standard score	70.64 (9.09)	98.67 (12.10)	4.75	< .001
Autistic symptomatology:					
SCQ		21.58 (6.10)	20.11 (9.21)	.44	.664
ADOS (Total)		10.50 (3.56)	12.00 (3.46)	.81	.459

Note: When assessment performance was below floor, a score one point below the standardisation ceiling was awarded (to be conservative). For the expressive vocabulary test, this applied to one ALI sentence reader and two ALI word readers. For the TOWRE SWE test, this applied to four ALI word readers, one of whom also scored below floor on the TOWRE PDE test.

Table 5.2

Participant Ages and Standard Scores for TD and ASD Children

Variable	TD (SD) n=30	ALN (SD) n=25	ALI sentence readers (SD) n=12	Test statistic (*F*)	*p* value
Chronological age	10.47[a] (1.01) 8.29–12.51	11.21[a] (1.90) 7.95–14.42	11.80[b] (1.35) 9.44-13.07	4.00	.023
Gender: Male	18	23	8	TD/ALN χ^2 =5.77, p = .016	
Female	12	2	4	TD/ALI χ^2 = 2.68, p = .102 ALN/ALI χ^2 = .00, p = 1.00	
WASI matrix reasoning, NVIQ (T-score)	55.33[a] (7.00)	54.84[a] (11.61)	40.42[b] (12.02)	13.41	< .001
Language ability:					
WASI definitions, VIQ (T-score)	55.33[a] (6.96)	54.84[a] (9.33)	40.42[b] (12.02)	6.14	.004
Expressive one-word picture vocabulary test (Standard score)	120.42[a] (15.12)	115.6[a] (15.90)	86.92[b] (13.77)	21.03	< .001
Receptive one-word picture vocabulary test (Standard score)	115.76[a] (11.27)	112.64[a] (19.59)	82.08[b] (9.692)	23.58	< .001
CELF Recalling Sentences (Scaled score)	11.11[a] (2.42)	10.82[a] (2.77)	4.86[b] (1.68)	17.84	< .001
Reading skill:					
TOWRE SWE (Standard score)	110.38[a] (12.26)	104.06[a] (13.13)	93.19[b] (8.65)	6.51	.003
TOWRE PDE (Standard score)	115.26[a] (14.76)	108.94[a] (14.33)	99.13[a] (12.86)	4.23	.019
Autistic symptomatology:					
SCQ	5.40[a] (4.03)	19.58[b] (7.40)	20.11[b] (9.21)	34.50	< .001
ADOS (Total)	___	10.16[a] (2.95)	12.00[a] (3.46)	.73	.487

Values with the same superscript do not differ when p > .05

Note: When assessment performance was above ceiling, a score one point above the standardisation ceiling was awarded. This applied to two children (one TD, one ALN) for both the receptive and expressive vocabulary test. When assessment performance was below floor, a score one point below the standardisation ceiling was awarded. This applied to one ALI child for the expressive vocabulary test. This procedure was implemented by Nation et al. (2006).

Materials

Sentence Processing

Participants were presented with three sets of 20 sentences to read aloud. These are presented in Appendix C.

1. Plausible – the sentence structure was syntactically correct and the final word semantically congruent with the main sentence content e.g. 'I tied the laces on my... shoe'
2. Anomalous - the sentence structure was syntactically correct but the final word semantically anomalous with the main sentence content e.g. 'I tied the laces on my... wolf'
3. Scrambled – the words in the main sentence were scrambled so syntactic structure was disrupted, however the final word was semantically congruent with the main sentence context e.g. 'The my laces I on tied... shoe'

Stimuli characteristics (Table 5.3) were derived from the N-watch psycholinguistics database (Davis, 2005). The final word of each plausible/scrambled sentence was randomly assigned to an anomalous sentence.

Table 5.3

Characteristics of the Final Words

Characteristic	Mean value	(range)
Length	4.90	(3-7)
Phonemes	4.05	(2-7)
Syllables	1.60	(1-3)
AoA Bristol/ Gilhhooly Logie	285.73	(152-378)
Frequency	56.66	(4.19-459.11)
Imageability	599.60	(483-651)

To ensure the sentences were plausible and the end word was semantically predictable, 20 adults (mean age = 26.73) undertook a sentence completion task. They were asked to provide a final word for the 20 syntactically correct sentences.

Words with 80% accuracy were accepted and 18/20 sentences achieved this. The other two sentences had lower rates of predictability, with semantically related words suggested (e.g. ‘ketchup’ instead of ‘mustard’). Reaction times were therefore compared for these two items with the remaining 18 sentences and in all three sentence conditions the mean reaction times for the two words were within 1.25 SD of the other 18 items, thus these two items were retained in the sentence set.

Passage Comprehension

I attempted to assess the passage comprehension of all individuals with ASD using Form 2 of the NARA-II (Neale, 1997), although three individuals with ALN did not complete the task due to time constraints. Participants completed a practice passage to familiarise them with the assessment and then began formal testing. Due to time and testing constraints in mainstream schools, I was only able to obtain complete NARA-II data from 18 of the TD participants.

Procedure

Participants were tested over two sessions in a quiet room in their school, at home or in the Psychology Department at Royal Holloway, University of London. The test battery took approximately two hours to administer but was broken into shorter segments to avoid participant fatigue. The sentence task was run on a laptop computer and presentation was controlled by E-Prime (Psychology Software Tools, Pittsburgh, PA). Each sentence stem was presented in its entirety for participants to read aloud; the final word of the sentence was presented in isolation 1000ms after onset of the last word of the sentence stem. I selected an interval of 1000ms because previous research has revealed larger differences between ASD and TD groups at the later stages of semantic processing (Henderson, Clarke, & Snowling, 2011). Sentences were blocked by condition to avoid strategic responding (cf. Brock & Bzishvili, 2013); the order in which blocks were presented and the order of sentences within each block were randomised by E-prime.

Sentence stem and final word reading was recorded using version 5.2.37 of Praat (Boersma & Weenink, 2011). Sentence stems were excluded from analysis and considered ‘inaccurate’ if participants made more than one word reading error or the sentence length was increased or reduced by more than one word (e.g. through additions or omissions). Table 5.4 reports details of error rates; there was a total loss of 2.00% of data from the TD group (.83% from plausible sentence stems, 0.83% from anomalous sentence stems and 4.33% from scrambled sentence stems), a total loss of 3.60% of data from the ALN group (1.40% from plausible sentence stems, 2.00% from anomalous sentence stems and 7.40% from scrambled sentence stems) and a total loss of 6.94% of data from the ALI group (5.42% from plausible sentence stems, 3.75% from anomalous sentence stems and 11.67% from scrambled sentence stems). Sentence stem reading time was calculated offline from the audio recording (for accurate sentences) only from voice onset of the first word of the sentence stem to onset of the last word of the sentence stem. Reading times greater than 2.5 SD from the participant's mean were excluded to remove outliers and this resulted in a total of 1.28% lost data from the TD group (2.00% from plausible sentences, 0.67% from anomalous sentences and 1.17% from scrambled sentences), 1.00% from the ALN group (1.00% from plausible sentences, 1.60% from anomalous sentences and 0.40% from scrambled sentences) and 0.42% from the ALI group (0.42% from each sentence type).

Final word reading latencies were excluded from analysis if the word was read incorrectly; see Table 5.4 for details of error rates. There was a total loss of 3.82% of data from the TD group (3.50% from plausible sentence stems, 4.14 % from anomalous sentence stems and 3.83 % from scrambled sentence stems), a total loss of 6.40% of data from the ALN group (6.60% from plausible sentence stems, 6.20% from anomalous sentence stems and 6.40% from scrambled sentence stems) and a total loss of 10.97% of data from the ALI group (9.17% from plausible sentence stems, 10.83% from anomalous sentence stems and 12.92% from scrambled sentence stems).

Vocal response time for the accurately read final words presented in isolation was calculated from presentation of the word to the vocal onset of that word from the audio recording, using Praat software. Response times greater than two seconds or more than 2.5 SD from the participant's mean were excluded to remove outliers. This resulted in a total of 2.38% lost data from the TD group (1.5% from plausible sentences, 3.17% from anomalous sentences and 2.50% from scrambled sentences), 2.27% from the ALN group (1.20% from plausible sentences, 2.60% from anomalous sentences and 3.00% from scrambled sentences) and 2.78% from the ALI group (2.50% from plausible sentences, 2.92% from anomalous sentences and 2.92% from scrambled sentences).

Table 5.4

Accuracy of Sentence Stem and Final Word Reading

	Mean number excluded (SD). Max = 20			
	Average	Plausible sentences	Anomalous sentences	Scrambled sentences
Sentence stems				
TD	0.46	0.17 (0.59)	0.28 (.46)	0.93 (1.23)
ALN	1.17	0.48 (1.23)	1.48 (.77)	1.56 (1.39)
ALI	1.61	1.33 (1.56)	0.92 (.77)	2.58 (2.50)
Final words				
TD	0.77	0.70 (0.75)	0.83 (0.89)	0.77 (0.77)
ALN	1.28	1.32 (1.03)	1.24 (1.05)	1.28 (1.17)
ALI	2.19	1.83 (0.94)	2.17 (0.72)	2.58 (0.52)

Results

For all groups there was wide variation in mean reading time/latency. We conducted log-transformations on the mean scores, but this did not improve the homogeneity of variance. As a result, median times were reported, as these are less sensitive to the skew of the distribution (Baayen & Milin, 2010).

Sensitivity to Syntactic Coherence: Sentence Stem Reading Time

Plausible and anomalous sentences had the same sentence stems, thus we expected the reading times for these stems to be equivalent and they were: TD group (p = .63), ALN group (p = .48) or ALI group (p = .27), see Table 5.5. Reading times were therefore averaged to create a ‘syntactically coherent’ stem reading time.

Table 5.5

Sentence Stem Reading Pace

Group	Plausible stems (ms)	Anomalous stems (ms)	t-value	p-value	Syntactically correct stems (ms)
TD	2054.10 (392.13)	2089.83 (367.67)	.49	.626	2071.96 (323.90)
ALN	1942.86 (525.18)	1998.74 (581.27)	.77	.447	1970.80 (523.63)
ALI	2353.92 (595.88)	2204.29 (532.04)	1.16	.272	2279.10 (518.56)

Figure 5.1 illustrates the estimated marginal mean reading times for syntactically coherent and scrambled stems. A 3 (group: TD vs. ALN vs. ALI) x 2 (sentence type: coherent vs. scrambled) repeated measures ANCOVA was conducted on median sentence stem reading time for accurate responses only, with chronological age as the covariate. Age explained a significant proportion of the variance, $F(1, 63) = 21.11$, $p < .001$, $\eta_p^2 = .25$. However, as illustrated by Figure 5.1, there was also a significant main effect of condition, $F(1, 63) = 334.45$, $p = .001$, $\eta_p^2 = .84$, in which scrambled sentences stems were read more slowly than the syntactically coherent sentence stems. There was no main effect of group, $F(2, 63) = 1.45$, $p = .242$, $\eta_p^2 = .04$, although there was a significant group x sentence type interaction, $F(2,63) = 5.22$, $p = .008$, $\eta_p^2 = .14$. The interaction arose because although there were no group differences in reading time for the scrambled stems, $F(2, 64) = .53$, $p = .594$, there was a trend for the ALI group to read to the syntactically correct stems more slowly than their ALN peers ($p = .156$). The extent of the facilitation derived from a syntactically correct sentence stem was calculated by deducting the median scrambled sentence stem reading time from the median syntactically correct sentence stem reading time, to create a difference score. This is illustrated in Figure 5.2 as a ‘facilitation’ effect.

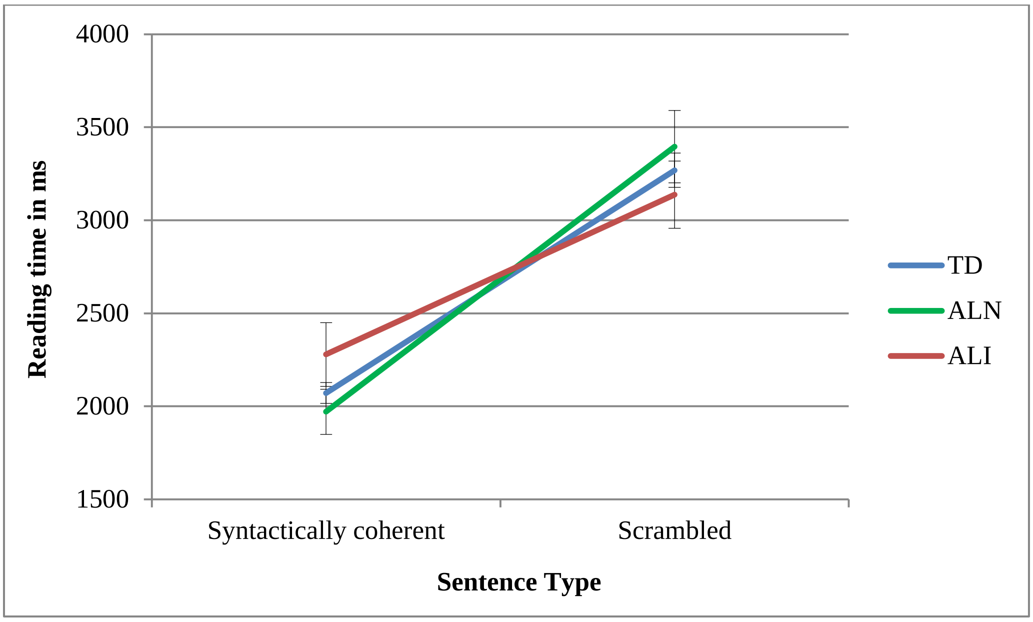

Figure 5.1 *Estimated Marginal Mean Values (Ms) Representing Sentence Stem Reading Time of Accurate Sentences for the TD and ASD Children. Standard Errors are Represented in the Figure by the Error Bars Attached to Each Line.*

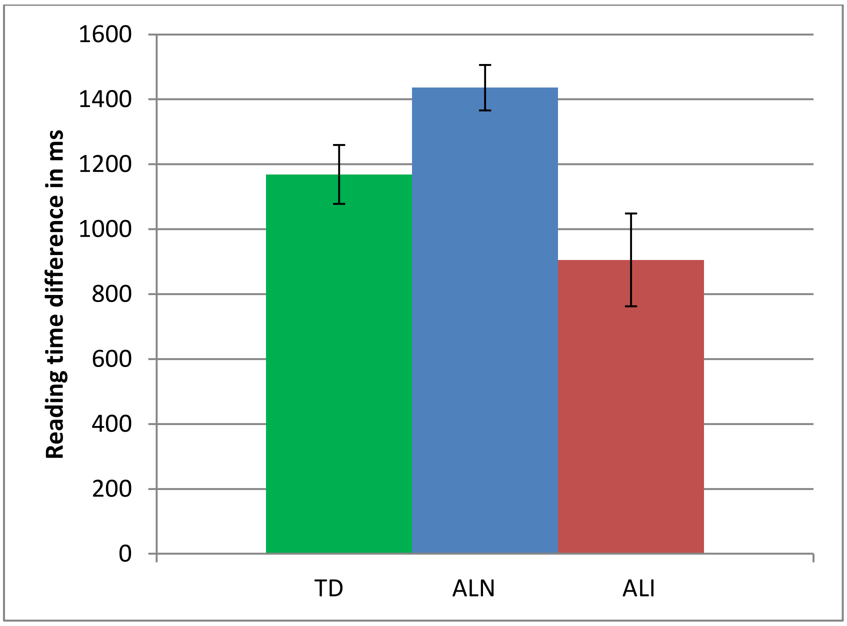

Figure 5.2 *Mean Values (Ms) Representing the Difference in Reading Time of Syntactically Correct and Scrambled Sentence Stems for the TD and ASD Children. Standard Errors are Represented in the Figure by the Error Bars Attached to Each Column.*

Sensitivity to Semantic Coherence: Final Word Reading Time

Condition presentation order was randomised, so approximately 50% of the participants in each group read the plausible final words before the anomalous final words, whist the remaining participants read the anomalous final words first. To determine whether presentation order influenced performance across the two conditions, the semantic facilitation values (difference between anomalous and plausible final word reading latency) of the children who read the plausible final words first were compared to the semantic facilitation scores of the children who were presented with the anomalous final words first. There were no significant differences for the either the TD, ALN or ALI groups (all *p*s > .100).

A 3 (group) x 3 (sentence type: plausible vs. anomalous vs. scrambled) repeated measures ANCOVA was conducted on median final word latency for accurate responses only, see Figure 5.3. Chronological age accounted for significant variance, $F(1,63) = 16.46$, $p < .001$, $\eta_p^2 = .21$. There was also a significant main effect of condition, $F(2, 126) = 48.90$, $p < .001$, $\eta_p^2 = .44$. More specifically, the reading latency was shorter for plausible final words than for anomalous final words ($p < .001$) and for scrambled final words ($p < .001$). There was also a trend for scrambled final words to be read more quickly than anomalous final words final words ($p = .058$). There was not a main effect of group, $F(2, 63) = 2.18$, $p = .122$, $\eta_p^2 = .07$, nor was there a significant group x condition interaction, $F(4,126) = .412$, $p = .800$, $\eta_p^2 = .01$.

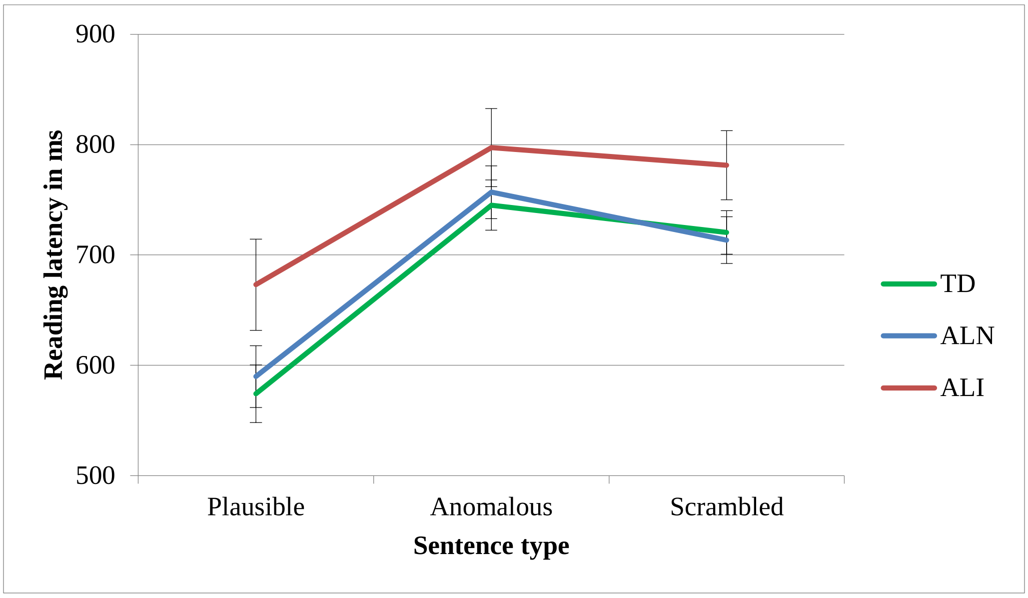

Figure 5.3 *Estimated Marginal Means (Ms) Representing the Final Word Reading Times of Accurate Responses for TD and ASD Children. Standard Errors are Represented in the Figure by the Error Bars Attached to Each Line.*

Passage Comprehension

At the sentence level, and given sufficient processing time, children with ALI were able to benefit from semantic context to the same extent as ALN and TD peers. However, only seven of the ALI children had sufficient reading ability to complete the NARA-II; the other five made more than the permissible number of errors on the first passage, thus the assessment was terminated. Given the very small sample size, statistical analyses were not performed for the ALI group on mean NARA-II scores. Nevertheless, it is notable that even those children with ALI who were able to read connected text accurately, had lower accuracy and comprehension scores than both ALN and TD peers (see Figure 5.4). In contrast, the accuracy scores of the ALN group did not differ from those of their TD peers, $t(38) = .98$, $p = .331$, and neither did their comprehension scores, $t(38) = .83$, $p = .412$. Poor Comprehenders were defined as those with NARA-II comprehension standard scores of less than 85, in the context of TOWRE Total scores above 85, with a score discrepancy of at least 10 standard points. Four children with ALI (57%) and four children with ALN (18%) met these criteria, while none of the TD children did.

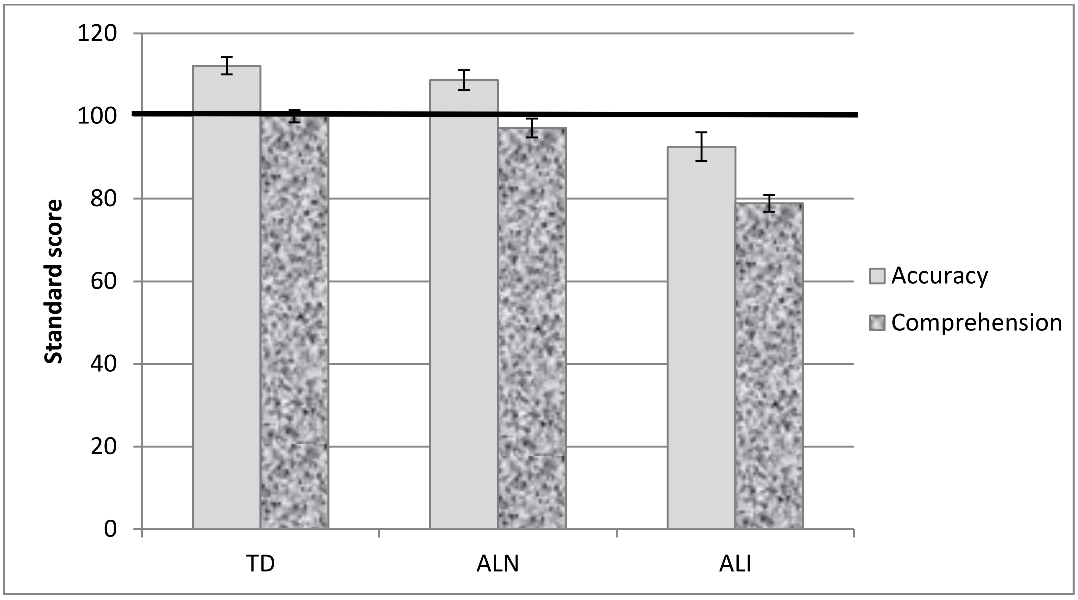

Figure 5.4 *Mean Standard Scores on the Accuracy and Comprehension Components of the NARA-II. Standard Errors are Represented in the Figure by the Error Bars Attached to Each Column*

My analyses so far have considered language status as a categorical variable; clearly language phenotype has a pronounced effect on text reading accuracy, though the effect of phenotype on text comprehension at sentence level is less clear. Given the high attrition rate in the ALI group, the remaining ALI passage readers were combined with their ALN peers to enable me to explore language as a continuous variable that influences reading comprehension. I conducted a regression analysis (n = 47), with the NARA-II standard score as the outcome variable and three predictor variables: vocabulary composite score (average of expressive and receptive vocabulary standard scores), TOWRE Total Score, and Social Communication Questionnaire score (as an index of ASD symptomatology). The strong correlation between expressive and receptive vocabulary standard scores (r = .82, p < .001) justified the use of a vocabulary composite (created by averaging the two standard scores).

The total model was significant, $F(3, 42) = 17.56$, $p < .001$, and explained 57.50% of the variance in reading comprehension (see Table 5.5). Both vocabulary composite (β = .41, t = 4.26, p < .001) and TOWRE Total (β = .23, t = 2.32, p = .026) were significant predictors of reading comprehension. In contrast, SCQ score was not a significant predictor (β = .04, t = .27, p = .790). When ADOS social and communication total score was utilised as the measure of ASD symptomatology, the total model was significant, $F(3, 21) = 9.96$, $p < .001$ and explained 56.10% of the variance in reading comprehension. ASD symptomology remained a non-significant predictor (see Table 5.6). This analysis suggests that when children are fluent passage readers their reading comprehension skills rely on oral language competence, specifically good semantic knowledge, as well as word identification skill.

Table 5.5

Regression Analyses Predicting Passage Reading Comprehension, with SCQ Score as the Index of ASD symptomatology

	β	*t*	*p*	Zero-order correlations	Semi-partial correlations
Vocabulary composite	.41	4.26	<.001	.71	.45
TOWRE Total score	.23	2.32	.026	.60	.24
SCQ score	-.04	.27	.790	-.33	-.03

Table 5.6

Regression Analyses Predicting Passage Reading Comprehension, with SCQ ADOS Score as the Index of ASD symptomatology

	β	*t*	*p*	Zero-order correlations	Semi-partial correlations
Vocabulary composite	.40	2.22	.040	.75	.46
TOWRE Total score	.38	1.522	.145	.64	.34
ADOS score	-.17	.19	.854	-.21	-.04

Discussion

This study investigated the sentence and passage comprehension of children aged 7-14 with ASD. This study contributes to the under-researched field of sentence comprehension and it is the only study to compare the sentence reading comprehension abilities of ASD children with different language phenotypes. The inclusion of children with ASD and age-appropriate structural language skills (ALN), children with ASD and language impairments (ALI) and TD peers enabled me to begin to disentangle the influence of language skill and autistic presentation.

I found that although the children with ALI were able to read large numbers of single words, only 50% of those sampled were able to read accurately and fluently at the sentence level, and only 40% of the ALI sentence readers were able to read passages of text. Children with ALN and the ALI children who were able to read sentences benefited from semantic coherence to the same extent as TD peers, as indexed by faster reading times for semantically coherent final words relative to anomalous final words. However, children with ALI derived less facilitation from syntactic coherence, as indexed by comparison of reading times for syntactically correct and scrambled sentence stems. At the passage level, the influence of language skill was more evident. For the sample as a whole, both vocabulary knowledge and decoding skill predicted reading comprehension. In contrast, autistic diagnosis did not predict any unique variance in comprehension skill.

Decoding Ability

Decoding is a prerequisite skill for successful text comprehension. Despite being able to read single words, 48% of the original ALI sample were unable to accurately and fluently read at the sentence level. Furthermore, despite the ALI sentence readers being at least nine years old (mean age = 11.77), only 40% of the group were able to read the first passage of text, which was aimed at 6 year olds. Henderson et al. (submitted) also found that four of their participants with ASD were able to read single words, but unable to read connected text. Thus, single word decoding is necessary, but not sufficient, for competent text reading accuracy. Inspection of this study's poor readers' TOWRE assessments indicated that many were able to read three letter real words, but struggled with longer real words. The average length of the words in the first passage of the NARA-II is three letters, but 38% of the words contain four or more letters and the longest word (kitten) has six letters. Although 'kitten' is a regular word that many children would be able to sound out, the ALI poor readers also found the PDE subtest of the TOWRE challenging and many were unable to accurately read three letter non-words.

Sentence Reading Comprehension

Previous research has demonstrated that in TD populations, words and sentences are read more quickly if they are syntactically and semantically coherent (H. Joseph et al., 2008; West & Stanovich, 1978). Our results demonstrate that children with ASD also derive benefit from semantic coherence. This is consistent with Saldaña and colleagues (Saldaña & Frith, 2007; Tirado & Saldaña, 2013) who found that individuals with ASD experienced on-line contextual facilitation in a sentence reading task. The current study extends this previous work by including children of a younger age, as well as exploring individual differences in language ability and reading skill.

Our findings are at odds with the results of homograph tasks which indicate that children with ASD have impaired sentence reading comprehension (Frith & Snowling, 1983; Joliffe & Baron-Cohen, 1999; Lopez & Leekam, 2003). This disparity may be attributable to differential task demands and participants characteristics. Successful completion of the homograph task is heavily dependent on linguistic knowledge, thus children with language difficulties are likely to perform more poorly on this task than their non-language impaired peers. However, as is the case with reading skill, language competence is rarely reported or taken into account. Therefore difficulty with the homograph task may be related to linguistic and literacy competence, rather than ASD *per se*.

Using an implicit on-line measure, the current study found no evidence that children with ASD had semantic processing deficits at the sentence level when given a sufficiently long interval in which to process the preceding context. Our results differ to those of Henderson et al. (2011), who did find differences in contextual processing at the same inter-stimulus interval. These differences are likely due to differences in task demands; Henderson et al. (2011) employed a cross-modal task that involved listening to sentences and naming pictures, as well as specifically targeting the subordinate meanings of ambiguous words. Similarly, Brock et al. (2008) found that children with ALI had difficulty using context to inhibit looks to a contextually inappropriate target. Our task did not require inhibitory processes and so may have contributed to improved performance in our ALI readers. Indeed, Brock et al. investigated anticipatory gaze to target pictures in sentences in constraining contexts (i.e. ‘Jon stroked the hamster’ versus ‘Jon chose the hamster’). Participants with ALI and those with specific language impairment benefited as much from the facilitating context as typical peers and peers with ALN. This suggests that in some very structured tasks, individuals with

ALI do benefit from linguistic context, though differences may emerge when task demands increase.

Although the findings pertaining to the ALI group should be interpreted with caution due to the small sample size as a result of attrition, it is notable that the children with ALI derived less benefit than their peers from syntactic coherence. Similar results have been reported from earlier studies exploring recall rates of verbally presented grammatically and semantically coherent sentences relative to recall of meaningless word strings (Aurnhammer-Frith, 1969; Ramondo & Milech, 1984). It is noteworthy that the majority of children with ALI were unable to complete the sentence reading task due to insufficient reading skill, whereas all of the ALN children were fluent readers. Thus, it is necessary to recognise that the results of this study are only applicable to sentence readers. It is likely that children who struggle to read sentences would experience even less facilitation from syntactic and semantic coherence, as even more resources would be dedicated to identifying the words.

Passage Reading Comprehension

Early research exploring the reading skills of individuals with ASD indicated that many children with ASD have impaired passage reading comprehension (Frith & Snowling, 1983; M. Rutter & Bartak, 1973). However, my findings confirm recent work highlighting the vital role of oral language competence in reading comprehension (Lindgren, et al., 2009; Nation, et al., 2006; Norbury & Nation, 2011; Ricketts, et al., 2013).

When considering predictors of reading comprehension, autistic symptomatology did not account for *any* unique variance. This is consistent with the results of Norbury and Nation (2011), but contrasts with Ricketts et al. (2013) who found that ASD symptomatology accounted for 7-8% of unique variance in reading comprehension. To determine whether the discrepancy was associated with the measure of ASD utilised, the regression analysis was repeated solely for the ASD participants, with ADOS communication and social interaction total as the index of ASD (cf. Ricketts et al., 2013). Notably, ASD remained a non-significant predictor. The differential findings could thus be attributable to the measure of reading comprehension. Ricketts et al. administered the WORD whereas the current study utilised the NARA-II, and the two measures differ in the incorporation of literal and inferential questions (Bowyer-Crane & Snowling, 2005). However, as the WORD includes a lower percentage of literal questions it would be hypothesised that ASD would be less associated with performance on the WORD than the NARA-II. Alternatively, the contrasting findings may be attributable to sample characteristics. The participants in the current study were aged 8-12, whereas the Ricketts et al.'s (2013) sample included adolescents aged 14-16. It is possible that ASD symptomatology exerts a greater influence once children are older.

Nevertheless, the findings of the current study are consistent with the meta-analysis of Brown et al. (2013) who conclude that "*having ASD predicts that an individual is more likely than not to have problems with reading comprehension, but whether a given person actually has reading comprehension deficits depends on more factors than ASD diagnosis alone*" (p. 15).

Poor Comprehenders

Reading comprehension was further explored by determining the percentage of children with a Poor Comprehender reading profile, in which comprehension lags behind chronological age and decoding skill. None of the TD children exhibited such a profile, yet 28% of the ASD sample did. This aligns with previous research suggesting that approximately 30% of children with ASD have a Poor Comprehender reading profile (Henderson et al., submitted; Nation et al., 2006). However, unlike other studies, the contribution of language ability was also assessed. The highest percentage of Poor Comprehenders was found amongst the ALI group ($n = 4$, 57%), whereas only 18% ($n = 4$) of children with ALN met the criteria. This suggests children with ALI may be particularly likely to have a Poor Comprehender reading profile, although children with ALN may exhibit this profile more often than their TD peers.

Theoretical Implications

There are two key theoretical conclusions from these results. Firstly, they indicate that decoding and language ability are key predictors of sentence reading competence in autistic populations (cf. Brown et al., 2012). Secondly, they provide evidence that the Simple View of Reading (Gough & Tunmer, 1986) is applicable to passage reading comprehension in ASD as well as TD populations, which is consistent with recent findings (cf. Brown et al., 2013).

Language is of utmost importance for reading comprehension for two key reasons. Firstly, language skill facilitates decoding. Children who struggle to decode must devote the majority of resources to identifying the word, which limits the resources available for comprehension. Additionally, slowed decoding is likely to impair reading fluency, increasing the likelihood that decoded material is forgotten before the meaning of connected words is fully processed (Sedita, 2005). Secondly, understanding the meaning of individual words facilitates understanding of the text as a whole. It has been suggested that adequate reading comprehension is dependent upon the reader having knowledge of at least 90% of the words in the text (Hirsch, 2003). This will facilitate attainment of the 'gist' of the text and readers are likely to be able to make an accurate guess at the correct meaning of unfamiliar words. This is turn can facilitate vocabulary learning; TD children are able to learn the meaning of novel words that are embedded in passages of text (Cain et al., 2001; Nash & Snowling, 2006). The importance of vocabulary knowledge for reading comprehension is further illustrated by the results of intervention studies. Vocabulary training interventions facilitate reading comprehension for both TD children and children with vocabulary impairments (cf. Clarke et al., 2010; Nash & Snowling, 2006).

In addition to considering why language skill is so crucial for comprehension, it is also prudent to consider why autistic symptomatology is less important. The comprehension impairments of individuals with ASD have been attributed to theory of mind (ToM) deficits, which are commonly assumed to be a universal feature of ASD. However, multiple studies have evidenced that this is not the case (Ozonoff et al., 1991; White et al., 2009). This is illustrated by the findings of White et al. who assessed the ToM skills of 45 children with ASD. Only 15 of the children scored more than 1.65 SD below the non-autistic control group mean, suggesting that two-thirds of the children with ASD did not have ToM deficits. Likewise, Ozonoff et al. found that whilst individuals with high-functioning autism had ToM deficits, individuals with Asperger's syndrome were indistinguishable from controls on ToM tasks. Additionally, mentalising competency has been found to only contribute 4-5% of unique variance in the reading comprehension of adolescents with ASD (Ricketts et al., 2013), suggesting that it is not a key predictor of comprehension proficiency.

Educational Implications

In order to target interventions effectively it is important to identify where in the reading process difficulties occur. The results of this study indicate that children with ALN have proficient reading accuracy skills and comprehend text at the sentence level and passage level. In contrast, despite being able to read single words presented in isolation, many children with ALI struggled to read connected text accurately and fluently. Reading fluency creates a link between decoding and comprehension and fluency correlates with performance on comprehension assessments (Fuchs, Fuchs, Hosp, & Jenkins, 2001; Pinnell et al., 1995). This suggests that interventions for children who can read single words but struggle with connected text could target reading fluency, as a prerequisite skill for comprehension. However, Adlof, Catts and Little (2006) conducted a longitudinal study of 604 children aged 7-14 and found that decoding and fluency were highly correlated. Furthermore, decoding and listening comprehension accounted for unique variance in reading comprehension, whereas fluency did not. Thus, it would be more beneficial to target decoding and language competence, rather than training fluency *per se*.

Early research exploring whether vocabulary interventions could facilitate reading skill were often not effective (Mezynski, 1983). However this may have been a result of methodological limitations (Mezynski, 1983). Intervention design and assessment has since been altered and interventions targeting oral language can be effective at increasing reading comprehension. For example, Clarke et al. (2010) conducted a randomised controlled trial to assess the efficacy of three interventions designed to improve the reading comprehension of non-autistic Poor Comprehenders. The 20 week interventions involved text-comprehension training, oral-language training or a combination of both aspects. All three intervention groups showed greater improvements in text comprehension than waiting list controls, however only the group receiving the oral language training continued to show increases in comprehension between the end of the intervention and the 11 month follow-up. This suggests that reading comprehension will be facilitated best by vocabulary interventions.

However, the extent of the improvement in text comprehension may be dependent upon the mode of vocabulary teaching and the language skills of the children. Research has explored whether new vocabulary is learnt and consolidated more effectively from explicit definition training, or when embedded in a short passage of text and meaning is inferred. Both typically developing children and poor readers attain more vocabulary when it is taught in-context, rather than through definition tasks (Gipe, 1978). Three core reasons have been proposed for this finding. Firstly, presenting the word within a context may be more accessible for the children and secondly, it may be more engaging. Alternatively, the context condition may provide more information (semantic, syntactic, pragmatic) enabling a better specified and more durable semantic representation (H. Nash & Snowling, 2006).

With regards to the influence of language ability, children with vocabulary deficits are poorer at learning words from context than their TD peers (Cain, Oakhill, & Lemmon, 2004; McKeown, 1985; M. Nash & Donaldson, 2005). In light of this finding, Nash and Snowling (2006) explored whether children with vocabulary deficits learn better from context or explicit definition training. Immediately after teaching there were no learning style group differences, but three months after training the context learning group attained higher expressive vocabulary scores than the definition training group. Of particular relevance is the finding that text comprehension increased following the vocabulary training. More specifically, text comprehension increased for both groups, but the context training group made greater gains in their ability to answer questions which required knowledge of the target words. The results of this body of research suggest that vocabulary interventions *can* facilitate text comprehension and interventions are particularly effective if the new vocabulary is taught in context, rather than through definition tasks.

There is preliminary evidence that interventions which target vocabulary instruction facilitate the reading comprehension of children with ASD. Dugan et al. (1995) assessed the effectiveness of co-operative learning groups as a means of increasing the reading comprehension for two children (aged 9 and 10) with ASD. Sessions focused on word and fact tutoring and attainment was assessed by definition tasks relating to the target words. Both the children with ASD, and their TD peers, attained higher accuracy scores when the words were taught in the co-operative learning groups rather than the baseline condition (teacher lecturing). However, it is uncertain whether the effect is the result of specific focus on the word, or is a consequence of increased engagement with the session. Engagement was significantly higher in the co-operative learning groups than the baseline condition.

Similarly, Kamps, Locke, Delquadri and Hall (1989) assessed the benefits of peer tutoring sessions focusing on expressive and receptive language for two children aged 9 and 11 with ASD and correct responses to factual questions increased relative to the baseline condition. Likewise, Kamps, Leonard, Potucek, and Garrison-Harrell (1995) reported that co-operative learning groups which reviewed vocabulary words increased accuracy responding to comprehension questions for three children aged 8-13 with ASD. However, both of the interventions by Kamps and colleagues (1995; 1989) included additional components such as passage reading and practice responding to questions. It is therefore uncertain which specific aspects of the interventions were exerting an influence. Indeed, Kamps, Barbetta, Leonard and Delquadri (1994) found that three children with ASD answered comprehension questions more accurately following peer tutoring sessions focusing on story reading and comprehension question answering, relative to the baseline condition of general education. However, they also found that these sessions increased decoding competency. This suggests that improving decoding skill may result in a corresponding increase in comprehension, which would be predicted by the Simple View of Reading (Gough & Tunmer, 1986).

The results of these studies are promising as they suggest that interventions which promote oral language skill and decoding competence can result in improvements in reading comprehension, for both children with ASD and their TD peers. However, the sample sizes for the ASD participants are very small ($n \leq 3$)

and therefore further research is required to confirm these findings. Additionally, the children with ASD were attending mainstream schools and although they exhibited language abnormalities such as use of rote phrases and echolalia, their language skills did not appear to be a major cause for concern (although scores on standardisation language assessments were not reported). It is therefore uncertain whether children with more severe language needs would benefit from similar interventions. This would be an interesting avenue for future research. It is possible that a certain level of expressive and receptive language skill is required for such interventions to be influential. It would be beneficial for future studies to report participant details such as reading and language assessment standard scores at baseline. Characterising the cognitive, linguistic and reading profiles of the participant groups would facilitate clarity regarding the profile of children who may also benefit from such an intervention.

To summarise, interventions will most usefully target vocabulary, as this skill underpins both decoding and comprehension. Interventions should be tailored to the reading and language profiles of the individual; employing a uniform approach for all children with ASD and literacy difficulties will be less beneficial.

Limitations

Due to the fact that this is the first study to explore the influence of language phenotype on the sentence reading comprehension of children with ASD, this study makes a valuable contribution to both the sentence comprehension and ASD literature. However, there are two limitations regarding the participants which should be acknowledged. First, although the original sample size of the ALI group was comparable to the number of participants in the ALN and TD groups, the exclusion of 13 children due to poor reading accuracy resulted in a smaller sample size than desired. Although this in itself is interesting, as it sheds light on the challenges these children experience, it does reduce the strength of the analyses and future research is needed to confirm the findings pertaining to language impaired groups. Nevertheless, the number of ALI participants is consistent with published studies by eminent reading researchers such as Dr Norbury and Professor Nation (e.g. Norbury & Bishop, 2002; Norbury & Nation, 2011).

The second limitation concerns the lack of a non-autistic LI comparison group. Including such a sample would have enabled the relationship between language skill and ASD to be further disentangled. Inclusion of an LI group was attempted, however 16 of the 28 participants recruited had insufficient reading skill and the majority of the 12 remaining children were reluctant readers. Future research could include sentences with simpler vocabulary, in order to make the task accessible for poorer readers and reduce the influence of decoding skill. This would enable to the influence of language ability on sentence comprehension to be explored, without the confounding factor of decoding expertise.

Limitations regarding the task itself are also worthy of consideration. The sentence task utilised was an on-line measure of implicit processing, but it would also have been beneficial to also have included an explicit measure of sentence processing. This would have enabled direct comparison of on-line and off-line task performance in the same participants. An explicit task could involve comprehension questions, or a less-language based assignment such as a written sentence to picture matching task. Indeed, Tirado and Saldana (2013) found that adolescents and adults with ASD were as efficient as TD peers at an implicit comprehension task, but were less able to use the information in the text to respond to explicit questions.

Future Research

It would be beneficial to explore the developmental trajectories of children with ASD, to determine the stage at which children with ALI first start experiencing difficulties. This will enable interventions to be utilised at an early age, thus avoiding Mathew effects. Children who find reading challenging read less and avoid complex texts (Chall & Jacobs, 2003; C. Clark & Foster, 2005). As a result, they encounter and learn less vocabulary than their peers (Cain et al., 2003), which negatively impacts their subsequent reading and learning opportunities further compounding their literacy difficulties (cf. Stanovich, 1986).

In contrast, the current study and previous research suggests that the majority of individuals with ALN do not experience comprehension impairments (Lindgren, et al., 2009; Nation, et al., 2006; Norbury & Nation, 2011; Ricketts, et al., 2013). However, it is possible that autistic symptomology exerts a greater influence on reading comprehension as texts become more complex. Although autistic symptomology did not predict any unique variance in the reading comprehension of the *children* participating in the current study, both Ricketts et al., (2013) and Nation and Norbury (2011) found that ASD status accounted for around 10% unique variance in the reading comprehension of *adolescents* with ASD. It is therefore possible that reading comprehension declines over time.

However, in addition, or as an alternative, to this being attributable to aspects of ASD, this could be the result of decoding proficiency declining. Indeed, Nation and Norbury (2011) found that the real word reading standard scores of their ALN participants declined over a 4 year period, from 98.36 (SD = 10.22) at age 11, to 88.29 (SD = 9.37) when they were nearly 15. As demonstrated many times throughout this thesis, there is an intimate relationship between decoding competency and reading comprehension, for both TD children (Perfetti et al., 1988) and children with ASD (cf. Brown et al., 2013).

Conclusion

In conclusion, this study demonstrates that word reading alone is not a good indication of overall literacy competence in children with ASD. In particular, children with ASD who also experience oral language impairments are likely to experience difficulty with learning to read connected text, despite being able to read single words. Sufficient cognitive and linguistic resources to read accurately and fluently at the sentence level typically results in comprehension, although children with ALI are likely to experience less facilitation from coherence than their non-language impaired peers. At the passage level, the relationship between reading comprehension and language competence is more striking. Therefore decoding and comprehension are intimately associated with oral language skills, and oral language skills explain greater variance in comprehension than autistic presentation. Consequently, future research needs to distinguish between children with different language phenotypes within the autism spectrum and literacy interventions will need to take into consideration decoding and language competence.

Chapter 6: The Influence of Language Competence on Inferencing Skill

Chapter Overview

The study presented in Chapter 5 investigated reading at both the sentence and passage level and found that comprehension aligned with language competence. The current study explores one specific component of reading comprehension, namely, inferencing. This was achieved by comparing the accuracy with which children answered literal and inferential comprehension questions. Forty-two children with ASD (27 ALN, 15 ALI) and 46 non-autistic peers (32 TD, 14 LI) were recruited to the study. The TD and ALN groups answered a similar percentage of literal and inferential questions correctly, whereas both the ALI and LI groups had a disproportionate difficulty with inferencing. These results indicate that inferencing skill aligns with language competence to a greater extent than ASD status. Vocabulary and inferencing interventions may facilitate the reading comprehension of children with language impairments.

Introduction

In addition to identifying individual characteristics (such as language ability and autistic symptomatology) which may increase the likelihood of a child experiencing comprehension difficulties, it is important to ascertain which specific components of comprehension are particularly challenging. One complex aspect of comprehension is inferencing. Making an inference requires an individual to go beyond what is explicitly stated in the text and integrate the text information with prior linguistic and cognitive knowledge. Thus, inferencing may be particularly challenging for individuals with ASD, who have been reported to have a tendency to process individual components, rather than the coherent whole (i.e. weak central coherence; Frith & Happé, 1994). Additionally, ToM deficits may impair the ability to make inferences relating to the internal states that motivate fictional characters' behaviour. Indeed, for individuals with ASD, comprehension is poorer for texts with greater social demands (Brown et al., 2013) and mentalising competency is a small, yet unique, predictor of reading comprehension (Ricketts et al., 2013). However, it is important to note that the ability to make an inference is highly dependent on structural language skill (Norbury & Bishop, 2002). It may therefore be expected that children with ASD and concomitant language impairments would find inferencing particularly challenging, which would make any additional ToM difficulties hard to assess. To support this prediction, the inferencing skills of children with LI will first be discussed.

Inferencing Ability of Children with Language Impairment (LI)

There is a dearth of research exploring the ability of children with LI to make inferences from text, possibly because as many children with LI have difficulty reading connected text. To date, research has focused on the ability of children with LI to generate inferences from orally presented information. The typical paradigm involves researchers reading short stories to their participants and then asking them both literal and inferential comprehension questions. Children with specific language impairment (SLI) and pragmatic impairment[3] (PLI) struggle with both literal and inferential questions; they do not have a selective problem with inferencing (Adams, Clarke, & Haynes, 2009; Bishop & Adams, 1992; Crais & Chapman, 1987; Ellis Weismer, 1985). As inferencing is highly dependent on language skill, this could be perceived as an anomalous outcome. Yet, a successful response to a literal question is also highly dependent on language skill. In particular, semantic knowledge of the words in the question and in the text is required. Therefore, children with language impairments are likely to struggle to understand many aspects of the story, including details that are explicitly stated.

However, when there is heterogeneity within samples, group means may mask individual differences. This is clearly demonstrated by the findings of Norbury and Bishop (2002). They presented participants with five stories auditorily and after each one the children answered six comprehension questions: two literal and four requiring an inference. The performance of children with LI (who had a clinical diagnosis) was compared to TD peers. At a group level, a

[3] Pragmatic language impairment is characterised by difficulties with the social aspects of language and communication. Individuals have problems understanding and producing connected discourse, and conversational responses tend to be socially inappropriate, tangential and/or stereotyped (Bishop, 2000; Conti-Ramsden & Botting, 1999b). PLI was previously referred to as semantic-pragmatic disorder, and is now included in DSM-V as social (pragmatic) communication disorder (American Psychological Association, 2013a).

disproportionate difficulty with inferencing was not evident. Yet examination of individual data revealed that 25% of the children with LI had a disproportionate difficulty answering the inferential questions, relative to only 11% of the control children. This suggests that some, but not all, children with language impairments find answering inferential questions particularly challenging when information is presented orally. When children with good and poor inferencing ability were compared there were no group differences in cognitive or language ability. Instead, the authors suggest that inferencing deficits may be the result of limitations in short-term memory or difficulties suppressing irrelevant information. Indeed, both factors are characteristic of Poor Comprehenders (Gernsbacher, 1990; Oakhill, 1996).

Inferencing Ability of Children with ASD

As discussed in Chapter 2, children and adolescents with ASD have difficulty inferencing in the oral domain (Åsberg, 2010; Norbury & Bishop, 2002). However, research studies exploring text inferencing have reported equivocal results, with implicit tasks indicating that adolescents with ASD can make inferences (Saldaña & Frith, 2007), whilst explicit tasks present greater difficulties (Jolliffe & Baron-Cohen, 1999; Norbury & Nation, 2011). Saldaña and Frith asked 16 adolescents with ASD (mean age = 14;9) to read two connected sentences followed by a question that necessitated an inference, e.g., "The Indians pushed the *rocks/cowboys* off the cliff onto the *cowboys/rocks*. The cowboys were badly injured. Can rocks be large?" When the question was primed by the preceding inference, both the ASD and TD participants (matched for age, single word reading ability and receptive vocabulary) read the question more quickly. Thus, both groups were activating the knowledge necessary to make the bridging inference. The ASD group also answered the questions as accurately as their TD peers. However the performance of both groups was near ceiling and it is therefore possible that differences may have emerged if task complexity was increased. Additionally, as discussed in Chapter 5, there was large variability in the participants' receptive vocabulary and it is uncertain whether all children were effectively making inferences, or whether the group mean masked the difficulties of the children with poorer language skills.

Jolliffe and Baron-Cohen (1999) also assessed the ability of individuals with ASD to make bridging inferences. Participants read aloud a pair of sentences, the first of which described a situation and the other the outcome. They then identified the coherent connecting sentence from a choice of three. Adults with ASD were significantly less accurate than their non-autistic peers who were matched for both verbal and non-verbal cognitive ability. However, the adults with ASD and a history of language delay achieved significantly lower scores than adults with Asperger’s syndrome, who had did not have a delay in early language development. This finding is particularly striking considering that both groups currently had verbal IQ scores within or above the average range. Extrapolation of this finding suggests that children with ALI are more likely to have inferencing deficits than their ALN peers.

This hypothesis is supported by Norbury and Nation (2011). Twenty-seven adolescents (mean age = 14;11) read a story about a beaver and then answered seven literal and seven inferential questions. The TD, ALN and ALI groups correctly answered a similar number of literal questions, but the ALI group were significantly less accurate than their peers at answering inferential questions. As a result, the ALI participants had a disproportionate difficulty with inferencing. When entered into regression analysis, group status (ASD vs. non-autistic) predicted 10% of the variance in inferencing ability, once word reading (which accounted for 6.6% of variance) and oral language comprehension (which predicted 31.7% of the variance) were accounted for. This suggests children with ASD may be more likely to have an inferencing deficit than their peers, but that inferencing skill is highly dependent on language abilities. This emphasises the importance of including children with different language phenotypes as separate groups in research studies.

Interestingly, the results of Norbury and Nation (2011) are contrary to the findings of Snowling and Frith (1986). Sixteen individuals with ASD (aged 12-21) read two short stories (the beaver story, plus another about a hedgehog) and then orally answered 10 literal and 10 general knowledge, inferential questions. The sample was divided into two groups on the basis of verbal ability and children with greater linguistic competence answered more questions accurately than those with poorer linguistic ability. The accuracy of individuals with ASD and lower verbal ability (*n*=11, mean age = 16;0, mean verbal age = 6;1) did not differ as a function of question type; average accuracy for both types was less than 30%. Thus, in addition to finding inferencing challenging, these children were unable to utilise the information in the story to answer the literal questions, potentially as they “read sentence by sentence, but never connected the whole story together” (p. 409). This is consistent with the finding that children with LI struggle to answer both literal and inferential questions about orally presented texts (Adams et al., 2009; Bishop & Adams, 1992; Crais & Chapman, 1987; Ellis Weismer, 1985). The discrepancy between the findings of Snowling and Frith (1986) and more recent work (Jolliffe & Baron-Cohen, 1999; Norbury & Nation, 2011) may be attributable to the language/decoding ability of the participants. The ALI participants in recent studies have substantially better language ability than the participants’ in Snowling and Frith’s study and this may account for their greater proficiency at understanding the literal information provided in the texts.

These findings suggest that whilst many individuals with ASD have difficulties answering comprehension questions which require an inference to be made, inferential questions may be particularly challenging for individuals with ALI. However it is noteworthy that the participants in these studies were adolescents and adults with ASD. It is therefore uncertain whether the same pattern will exist for *children* with ASD. This question will be addressed through Study 3 of this thesis.

The Current Study

The current study investigated whether inferencing skill in the written domain aligns with language ability or ASD diagnosis. To determine this, four groups of participants were included: children with ASD with and without language impairment (ALN and ALI) and non-autistic children with and without language impairment (LI and TD). Based on previous research exploring inferencing in the written, as well as oral domain, there were three possibilities:

1. If difficulty with inferencing is associated with autism spectrum disorders then all children with ASD should have a disproportionate difficulty with

inferencing, regardless of language phenotype. In contrast, non-autistic children (both TD and children with LI) will not show such difficulties.

2. If difficulty with inferencing is associated with language ability then both children with ALI and children with LI will have a disproportionate difficulty with inferencing, relative to TD and ALN peers.
3. If the effects of ASD and LI are additive, inferencing will pose the greatest challenge for children with ALI. This hypothesis was considered most likely.

Method

Participants

Eighty-eight children aged 7-12 years were recruited to the study. The ASD sample included 27 children with ALN (26 male) and 15 children with ALI (14 male). The non-autistic comparison groups included 32 TD children (17 male) and 14 peers with LI (7 male). The sample included 44 of the children who participated in Study 2 (18 TD, 19 ALN and 7 ALI). The remaining children were recruited to this study, with inclusion criteria specifying that the child must be able to read the first passage of the NARA-II without meeting the discontinuation criterion (i.e. making 16 errors). All children also met the eligibility criteria outlined in Chapter 3. The TD sample included a higher percentage of girls than the ASD groups. To ensure this did not influence task performance the TD males and females were compared. There were no group differences in the baseline characteristics of age, cognitive ability, language ability and SCQ score (all $t < 1.13$, $p > .250$). Additionally, there were no group differences in reading ability, as indexed by single word reading accuracy, passage reading accuracy and passage reading comprehension (all $t < 1.10$, $p > .150$). Likewise the LI male and female participants did not differ in terms of age, cognitive ability, language ability or SCQ score (all $t < .90$, $p > .375$). Additionally, there were no group differences in reading ability, as indexed by single word reading accuracy, passage reading accuracy and passage reading comprehension (all $t < .35$, $p > .725$).

All four groups were matched for chronological age. The TD and ALN groups were matched on cognitive, language and reading accuracy measures, as were the ALI and LI groups, with the exception of receptive vocabulary. The ALI group had a poorer expressive vocabulary than their LI peers. A dissociation between expressive and receptive vocabulary is not unusual for children with ASD (Hudry et al., 2010; Kjelgaard & Tager-Flusberg, 2001) and therefore this group difference was not remedied by excluding participants with this profile or by controlling for vocabulary in the analyses. The first procedure would have resulted in an 'unusual' ASD sample and the second would have controlled for language ability – one of the factors the study was designed to explore. As expected, both language impaired groups had significantly lower scores on all cognitive, language and reading accuracy measures than the non-language impaired groups (all $p < .050$). We did attempt to match all groups for non-verbal ability but similar to other studies we found that children with more severe language impairments tended to have lower non-verbal ability scores (cf. Conti-Ramsden et al., 2012; Dennis et al., 2009). Importantly, despite the difference in non-verbal reasoning, the ALN and ALI groups were matched on two measures of autistic symptomatology, the SCQ and the ADOS (Table 6.1). When the four groups were dichotomized into a non-autistic group (TD and LI) and ASD group (ALN and ALI) there were no group differences in age, cognitive ability, language ability or reading ability (all *p*s > .050, Table 6.2).

Table 6.1

Ages and Standard Scores for Each of the Four Groups

Variable		TD (SD) n=32	ALN (SD) n=27	ALI (SD) n=15	LI (SD) n=14	*F* value	*p* value
Chronological age (Years)		10.22[a] (1.01) 8.72–12.51	10.37[a] (1.80) 7.18–12.99	10.95[a] (1.35) 8.32-12.95	10.18[a] (1.44) 8.11-12.50	1.04	.381
Gender:	Male	17	26	11	7	ASD vs. non-ASD:	
	Female	15	1	4	7	x^2 = 20.53, p <.001	
WASI matrix reasoning, NVIQ (T-score)		53.56[a] (7.09)	53.56[ab] (9.20)	47.60[bc] (10.27)	43.79[c] (7.77)	6.09	< .001
Language skill:							
WASI definitions, VIQ (T-score)		57.59[a] (11.71)	53.63[a] (12.54)	36.92[b] (7.62)	42.64[b] (11.17)	17.13	< .001
Expressive one-word picture vocabulary test (Standard score)		112.78[a] (11.71)	114.8[a] (16.13)	84.40[b] (12.07)	90.07[b] (12.94)	26.66	< .001
Receptive one-word picture vocabulary test (Standard score)		110.77[a] (9.25)	110.89[a] (18.45)	75.93[b] (11.52)	88.21[b] (15.89)	28.70	< .001
CELF Recalling Sentences (Scaled score)		10.40[a] (2.27)	10.50[a] (2.63)	3.62[b] (2.90)	3.92[b] (2.54)	38.96	< .001
Reading skill:							
TOWRE SWE (Standard score)		108.50[a] (10.29)	102.46[a] (12.67)	81.68[b] (21.24)	76.29[b] (18.14)	24.80	< .001
TOWRE PDE (Standard score)		111.34[a] (14.51)	106.88[a] (13.70)	85.61[b] (23.72)	84.46[b] (14.53)	18.59	< .001
NARA accuracy (Standard score)		111.34[a] (11.40)	109.11[a] (12.50)	83.87[b] (13.47)	82.14[b] (12.50)	32.19	< .001
NARA comprehension (Standard score)		98.59[a] (8.511)	97.30[a] (11.88)	76.20[b] (7.71)	79.43[b] (9.48)	28.24	< .001
Autistic symptomatology:							
SCQ		3.52[a] (2.38)	19.25[b] (7.33)	22.00[b] (8.99)	12.56[c] (4.46)	35.94	<.001
ADOS (Total)		___	10.50[a] (2.93)	12.40[a] (3.63)	___	2.08	.141

Values with the same superscript do not differ when p < .05

Note: When assessment performance was above ceiling, a score one point above the standardisation ceiling was awarded. This applied to two children (one TD, one ALN) on both the receptive vocabulary test and four children (three TD, one ALN) for the expressive vocabulary test. When assessment performance was below floor, a score one point below the standardisation ceiling was awarded. This applied to one ALI child for the expressive vocabulary test and two ALI children for the accuracy component of the NARA-II. This conservative procedure was implemented by Nation et al. (2006).

Table 6.2

Ages and Standard Scores for Non-autistic and ASD Participants

Variable		Non-autistic (SD) n=46	ASD (SD) n=42	*t* value	*p* value
Chronological age (Years)		10.21 (1.14) 8.72–12.51	10.57 (1.66) 7.18–12.99	-1.20	.234
Gender:	Male	24	40	χ^2 = 20.53	< .001
	Female	22	2		
WASI matrix reasoning, NVIQ (T-score)		50.59 (8.53)	51.36 (9.93)	-.39	.697
Language skill:					
WASI definitions, VIQ (T-score)		53.04 (13.06)	48.20 (13.62)	2.03	.046
Expressive one-word picture vocabulary test (Standard score)		105.80 (15.94)	103.45 (20.87)	.67	.516
Receptive one-word picture vocabulary test (Standard score)		103.76 (15.64)	98.33 (23.38)	1.23	.220
CELF Recalling Sentences (Scaled score)		8.55 (3.76)	7.79 (4.35)	.81	.420
Reading skill:					
TOWRE SWE (Standard score)		98.29 (21.30)	95.55 (17.39)	.80	.424
TOWRE PDE (Standard score)		102.79 (20.62)	100.10 (17.42)	.72	.460
NARA accuracy (Standard score)		103.91 (16.73)	100.10 (17.63)	.61	.542
NARA comprehension (Standard score)		93.73 (11.66)	89.76 (14.64)	.1.01	.316
Autistic symptomatology:					
SCQ		6.08 (5.54)	19.74 (8.13)	-8.89	<.001
ADOS (Total)		___	11.13 (3.25)	___	___

Materials

Passage comprehension was assessed using Form 2 of the NARA-II (Neale, 1997). A sample passage is provided in Appendix D. Participants completed a practice passage to familiarise them with the assessment and then began formal testing. The 40 questions from passages 2-6 of the NARA were analysed by the two authors to identify literal and inferential questions. The authors agreed on the classification of 38 of 40 of the questions and the two discrepant items were categorised through discussion. This resulted in a total of 26 literal questions and 14 inferential questions (Appendix D). Passage 2 included five literal and three inferential questions, passage 3 included six literal and two inferential questions, passage 4 included four literal and four inferential questions, passage 5 included five literal and three inferential questions, and passage 6 included six literal and two inferential questions.

Procedure

Participants were tested over two sessions in a quiet room in their school, at home or in the Psychology Department at Royal Holloway University of London. The test battery took approximately two hours to administer.

Results

To account for individual differences in the number of comprehension questions administered and for the different number of literal and inference questions, the raw accuracy scores were transformed into a percentage of the total questions administered for each question type. In order to ensure that the results were based on the opportunity to answer both literal and inferential questions, analysis commenced at passage 2 (Surprise Parcel). Two children with LI read passage one, but made more than the permissible number of errors on passage two (i.e. > 16). They were excluded from further analysis so 12 children with LI were included in the inferencing analysis.

The TD and ALN groups read a similar number of passages, which were of equivalent complexity (both *p*s > .300). Each group also answered a similar numbers of literal questions and a similar number of inferential questions (both *p*s

> .50). The same was true of the ALI and LI groups. However, both language impaired groups read fewer passages, read less complex passages and were administered fewer questions than their non-language impaired peers, all p < .007 (Table 6.3).

Table 6.3

NARA-II Administration Details

	TD *M (SD)*	ALN *M (SD)*	*t*	*p*	ALI *M (SD)*	LI *M (SD)*	*t*	*p*
Number of passages read (max=5)	4.19 (.74)	3.96 (.98)	1.00	.320	2.40 (1.30)	2.25 (1.44)	.29	.772
Most complex passage (max=6)	5.53 (.76)	5.26 (1.20)	1.02	.313	3.40 (1.40)	3.17 (1.36)	.45	.658
Literal questions administered (max=26)	17.38 (3.93)	16.70 (4.88)	.71	.560	10.53 (5.71)	10.17 (5.99)	.17	.983
Inferential questions administered (max=14)	9.88 (1.85)	9.67 (2.47)	.62	.712	6.00 (3.16)	5.83 (3.40)	.14	.891

A 4 (group) x 2 (question type; literal vs. inferential) repeated measures analysis of variance was conducted on percentage accuracy scores. As illustrated by Figure 6.1, there was a main effect of condition $F(1, 82) = 41.40$, $p < .001$, $\eta_p^2 = .34$, with a higher percentage of literal questions answered accurately relative to inferential questions. There was also a main effect of group $F(3, 82) = 4.43$, $p = .006$, $\eta_p^2 = .14$, with the ALI group answering the lowest percentage of questions correctly. The condition x group interaction was also significant $F(3, 82) = 3.01$, $p = .035$, $\eta_p^2 = .10$. Although the ALI group correctly answered a similar percentage of literal questions as their TD and ALN peers (both $p > .500$), they correctly answered a lower percentage of inferential questions than their TD and ALN peers (both $p < .005$). They also did not differ from their LI peers in terms of inferencing accuracy ($p = .995$), but were less proficient at answering literal questions ($p = .010$).

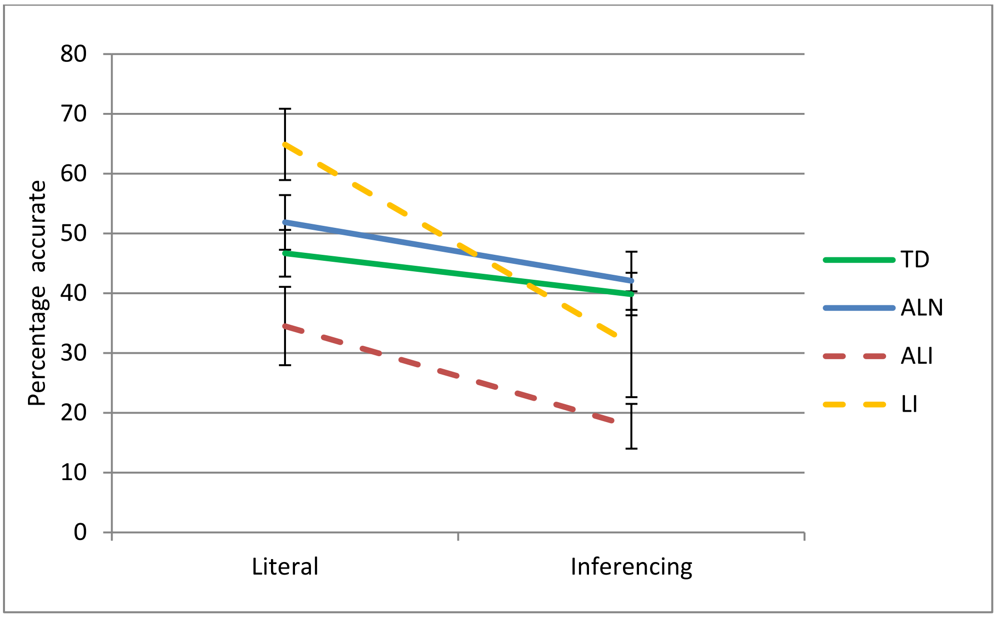

Figure 6.1 *Mean Values Representing the Percentage of Correct Responses for Literal and Inferencing Questions. Standard Errors are Represented in the Figure by the Error Bars Attached to Each Line.*

To determine whether ASD diagnosis accounted for variance in inferencing skill, regression analysis was conducted with the percentage of inferential questions answered correctly as the outcome variable. Four predictor variables were entered into the model, age, vocabulary composite score (average of expressive and receptive vocabulary raw scores), single word reading composite score (average of TOWRE SWE and PDE raw scores), and group (ASD versus TD). The total model explained 34.40% of the variance in inferencing accuracy (see Table 6.4).

Vocabulary composite was the only unique predictor (unique $r^2 = .51$; $p < .001$) and neither age, nor single word reading accuracy nor group predicted additional unique variance. This analysis suggests that the inferencing skill of children is highly dependent on oral language skill, specifically good semantic knowledge, and is not influenced by autistic symptomatology.

Table 6.4
Regression Analysis Predicting Inferencing Skill

Predictor	β	t	p	Unique R^2
Age	.47	.27	.785	.03
Vocabulary knowledge	.79	5.29	< .001	.51
Single word reading	.27	1.45	.151	.16
ASD diagnosis	2.53	.56	.578	.06

To obtain an index of inferencing ability I divided the inferencing score (percentage correct) by the literal score (percentage correct; cf. Nobury & Bishop, 2002) to create an 'inferencing ability' score. A score of 1 indicates that the child answered inferential questions as accurately as literal questions. A score >1 signifies that inferencing is an area of strength, whereas a score <1 denotes an inferencing deficit. Four one-way t-tests were conducted with a reference value of 1. As evident from Figure 6.2, inferencing was particularly challenging for the ALI group, $t(14) = 2.70$, $p = .017$ and the LI group , $t(11) = 3.06$, $p = .011$. In contrast, the TD participants did not have a disproportionate difficulty with inferencing, $t(31) = .38$, $p = .708$ and neither did the ALN children, $t(26) = .68$, $p = .501$.

As group means can mask individual differences the percentage of children within each group who demonstrated a disproportionate difficulty was also calculated. The TD group achieved a mean inferencing deficit score of .96, with a SD of .63. Thus, scores falling below .33 were >1 SD from the TD mean and indicated a disproportionate difficulty with inferencing. Only one TD child scored below this level (3.10% of the TD sample), relative to 14.80% of children with ALN (n = 4), 33.33% of children with ALI (n = 5) and 25% of children with LI (n = 3). Thus, the percentage of children with ASD (ALN+ALI) with an inferencing deficit did not differ from the non-autistic children (TD+LI), $x^2(1, n=86) = 2.41$, $p = .120$, but the language impaired children (ALI+LI) were significantly more likely to have a disproportionate difficulty with inference than the non-language impaired children (TD+ALN), $x^2(1, n=86) = 6.56$, $p = .011$.

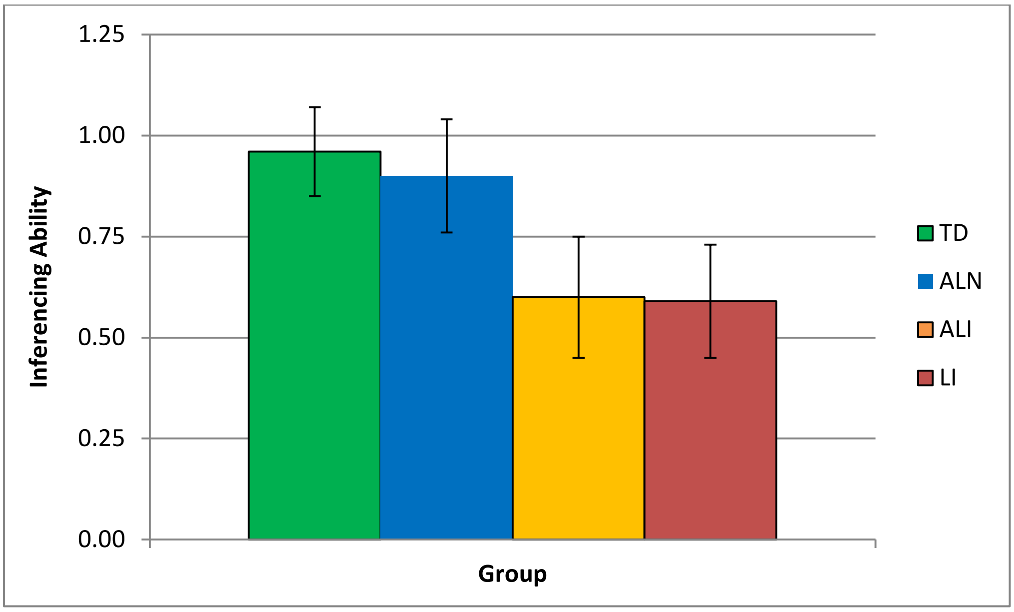

Figure 6.2 *Inferencing Ability Scores by Group. A Score of 1 Indicates that the Child Answered Inferential Questions as Accurately as Literal Questions. Standard Errors are Represented in the Figure by the Error Bars Attached to Each Column.*

Discussion

This study investigated the inferencing ability of children with ASD and compared their proficiency to both TD and LI peers. Children with ALN made inferences as accurately as their TD peers, whereas both children with ALI and LI were significantly poorer. Thus, inferencing skill aligns with language competence, rather than autistic symptomatology.

Does Inferencing Skill Align with Language Ability or ASD Diagnosis?

Previous research indicates that both adults and adolescents with ASD have difficulties making inferences from connected text and that inferencing is particularly challenging for individuals with ALI (Jolliffe & Baron-Cohen, 1999; Norbury & Nation, 2011). The current study explored whether the same deficit was evident amongst *children* with ASD - it is possible that as the length and complexity of texts increases with age, a corresponding increase in processing deficits, such as difficulties making inferences, may be more evident. Indeed, there is preliminary evidence that text comprehension standard scores decline with age for individuals with ASD (Dockrell, Ricketts, Palikara, Charman, & Lindsay, 2012). Uniquely, the current study considered whether non-autistic children with language impairments have a disproportionate difficulty making inferences from text. To date, the inferencing ability of children with LI has been examined in the oral domain but not in the written domain.

The TD and ALN children answered a similar percentage of literal and inferential questions correctly, whereas children with ALI and LI demonstrated inferencing deficits. Individuals with language impairments were significantly more likely to have a disproportionate difficulty with inferencing relative to their non-language impaired peers (29.6% vs. 8.5%) and vocabulary knowledge was the only unique predictor of inferencing ability. This indicates that children's text inferencing ability is highly dependent on language skill, which is consistent with previous research with autistic adolescents and adults (Jolliffe & Baron-Cohen, 1999; Norbury & Nation, 2011). Crucially, this study provides the first research evidence that non-autistic children with LI find inferencing from text particularly challenging, as is the case for inferencing in the oral domain (Norbury, 2002).

Theoretical Implications

Once again, the results of the current study demonstrate that an aspect of reading, in this case inferencing, is associated with language skill, rather than ASD status. Language is so important for inferencing for two key reasons. Firstly, language skill facilitates decoding. Children who struggle to decode may devote the majority of resources to identifying the word, which limits the resources available for inferencing. Additionally, slowed decoding is likely to impair reading fluency, increasing the likelihood that decoded material is forgotten before the meaning of connected words is fully processed (Sedita, 2005). Secondly, in order to successfully make an inference, it is beneficial to understand the meaning of the words. Thus, children with better vocabulary knowledge are able to make inferences more efficiently than children with poorer vocabulary knowledge (Adams et al., 2009; Bishop & Adams, 1992; Crais & Chapman, 1987; Ellis Weismer, 1985; Norbury & Bishop, 2002).

In addition to considering why language skill is so crucial for comprehension, it is also prudent to consider why autistic symptomatology is less important. Inferencing relies on the integration of material, and thus poor inferencing could be associated with weak central coherence (WCC). WCC is commonly considered to be universal in ASD (Frith & Happé, 1994), but in the verbal domain is associated with linguistic competence (Norbury, 2005a).

Educational Implications

One complex skill that influences text reading comprehension is the ability to make inferences (cf. Cain & Oakhill, 1999; Oakhill, 1984; Oakhill et al., 2003). This study confirms that children's text inferencing skill is driven by language competence, as is the case of adolescents and adults with ASD (Jolliffe & Baron-Cohen, 1999; Norbury & Nation, 2011). Thus, interventions targeting inferencing skill may be instrumental in improving reading comprehension and such interventions may be particularly pertinent for children with language impairments. The effectiveness of inferencing interventions for children with ASD is yet to be evaluated and this would be a valuable area for future research. However, given that the inferencing ability of the children with ASD did not differ from that of their non-autistic peers, it would be hypothesised that effective interventions for non-autistic children would also assist children with ASD.

Yuill (1988) compared the efficacy of three reading comprehension interventions for non-autistic Poor Comprehenders. Greater improvements were reported in the comprehension skills of the less skilled comprehenders who received inference skill training, relative to those who received rapid decoding practice, and slightly, but not significantly, more than those given comprehension exercises. However, the small number of participants in each group (n = ca.10) and limited age range (7-8 years) necessitated further research prior to conclusive conclusion. McGee and Johnson (2003) replicated the study with a larger sample and wider age range (6-10 years). The benefit of inference training that they reported was more substantial; comprehension practice increased the performance of less skilled comprehenders by 10 months, yet the inference training raised performance by 20 months. However, as noted in the 'Methodological Issues' chapter of this thesis, age-equivalent scores can be misleading. Of particular relevance here is that the difference between scores is not equivalent, thus the amount of improvement expected within 10 months may be more than half that expected in 20 months. Furthermore, a wide range of scores can refer to attainment within the average range for the child's chronological age. Nevertheless, of the ten

Poor Comprehenders who received the inference training, seven then met criteria for a ‘skilled’ comprehender, relative to four of the ten children who received the comprehension exercises. Thus, inference training may be effective at facilitating reading comprehension.

Limitations and Future Research

One limitation of this study is the final sample size of both the ALI and LI groups. Many children with language impairments find reading connected text challenging, which impeded participant recruitment. Although this in itself is interesting (as discussed in the previous chapter), it does reduce the strength of the analysis and future research is needed to confirm the findings pertaining to these language impaired groups.

An additional limitation is the measure of inferencing skill. This study reports the first evidence that text inferencing deficits are not experienced by all children with ASD and are instead associated with language competence. However, there was no exploration of *why* children with language impairments find inferencing so challenging. A more nuanced assessment would have enabled identification of reasons for inferencing failure. Such a methodology was employed by Cain et al. (2001) who assessed the extent to which the inferencing deficits of Poor Comprehenders were attributable to failure to retrieve the correct premise from the text, failure to recall the relevant item from the knowledge base, failure to integrate the information in the text and the taught knowledge, and failure to generation the correct (as opposed to incorrect) inference. Future research employing such a paradigm will enable identification of the mechanisms contributing to the inferencing deficits experienced by children with language impairments and identification of components that would most usefully be targeted by interventions.

It would be interesting to determine whether training vocabulary could improve inferencing. This suggestion is presented as in order to correctly make an inference it is necessary to understand the vocabulary in the text, and inferencing skill aligns with linguistic competence. Thus, one might predict that training vocabulary could facilitate inferencing for children with language impairments. Indeed, Nash and Snowling (2006) found that teaching new vocabulary increased the ability of children with poor vocabulary knowledge to answer inferential text comprehension questions. More specifically, pre-intervention the children answered an average of 0.92 inferential questions correctly, and post-intervention this increased to 1.75 (max = 4). However, the authors did not report whether this increase is statistically significant.

It is uncertain whether this would also be the case for children with ASD. Children with ASD may be able to learn new words which are explicitly taught (Henderson, Powell, Gaskell, & Norbury, 2014), but whether they can spontaneously transfer this knowledge to facilitate inferencing (which requires knowledge of the trained words) is currently unclear.

Conclusion

This study provided further evidence that text inferencing ability is intimately associated with oral language skill, and inferencing deficits are not a universal feature of ASD (cf. (Jolliffe & Baron-Cohen, 1999; Norbury & Nation, 2011). Consequently, it should not be assumed that all children with ASD require intervention; instead this would most usefully benefit children with ALI. Specific inferencing interventions can facilitate the development of inferencing skill for TD children (A. McGee & Johnson, 2003; Yuill & Oakhill, 1988), yet it is uncertain whether this would also be the case for children with ASD. It is also plausible that vocabulary interventions may facilitate inferencing; this is a potential avenue for future research.

Chapter 7: The Relationship Between the Home Environment and Literacy Development

Chapter Overview

The previous experimental chapters have explored the influence of autistic symptomatology and language competence on reading accuracy and comprehension. In addition to child characteristics, primary caregivers can influence literacy development. This chapter explores the home literacy environment (HLE) of children with ASD. The HLE of children with ASD was compared to the HLE of TD peers, to determine whether there were any quantitative or qualitative differences, and whether this varied as a function of language phenotype.

Sixty-four families participated in the study. Forty-one children with ASD (21 ALN, 20 ALI) and 23 TD children completed standardised assessments of reading ability and their parents completed a questionnaire regarding the HLE. The vast majority of children with ASD had literacy rich homes, with a wealth of literacy resources. Subtle group differences emerged in reading practices. Parents of children with ALI engaged their children in shared book reading and reading discussion more frequently than parents of TD and ALN children. However, both ALN and ALI children read with their parents for a shorter duration than TD children and shared reading duration was negatively associated with ASD severity. Across groups, frequency and duration of time spent reading alone was positively associated with reading ability and enjoyment of reading. Thus, home literacy practices are a reflection of child characteristics. These findings provide a preliminary insight into the home literacy environment of children with ASD.

Introduction

The attainment of proficient literacy skill is dependent upon both nature and nurture. The preceding chapters have examined the influence of individual differences on reading accuracy and comprehension, specifically oral language ability and autism phenotype, both of which are genetically (and environmentally) influenced. This chapter evaluates the role of the home literacy environment (HLE). There is a wealth of research investigating the HLE of TD children, which was summarised in Chapter 1. In contrast, little research has explored the HLE of children with developmental disorders. One developmental disorder that may pose a particularly interesting case is ASD. As a result of the social communication difficulties (Lord & Jones, 2012), language difficulties (Kjelgaard & Tager-Flusberg, 2001) and reading problems (Brown et al., 2013) experienced by many children with ASD, the HLE may differ from that of their TD peers.

ASD is characterised by impairments in social interaction and social communication (APA, 2013a) and these difficulties may impede shared book reading. For example, children with ASD may be less motivated to engage in social activities and derive less enjoyment from shared book reading than their TD peers do. However, ASD is also characterised by a restricted repertoire of interests and behaviour (APA, 2013a). Children with ASD may have an intense preoccupation with reading, or read profusely to support a special interest, and this repeated exposure to text may enhance literacy development (Bryson, 1994; Talero-Gutierrez, 2000). Thus, any differences in the HLE of children with ASD may be due to aspects of autistic symptomology. However, the language skills of children with ASD may also interact with the HLE. Children with ALI may need more support than their ALN peers to access texts; language deficits may impair decoding and comprehension and because of these challenges children with ALI may be less motivated to engage in shared reading and independent reading. Thus for school-aged children with developmental disorders, the HLE may reflect child characteristics, rather than child literacy development being influenced by the HLE, as in the case for young TD children (cf. Bus, van IJzendoorn & Pellegrin, 1995). Insight into whether this is likely to be the case can be provided by consideration of the HLE of children with LI.

The HLE of Children with LI

First, it is important to consider *why* the HLE may differ for TD children and children with LI. As children with LI struggle to read connected text and have deficits in text comprehension, it is plausible that they may be less motivated to read than their TD peers, thus, less willing to spend time engaged in home literacy practices. This reduced reading frequency/duration could result in fewer opportunities to learn and clarify the meaning of words (Cain et al., 2003), which negatively impacts their subsequent reading and learning opportunities, so further compounding their literacy difficulties (cf. Stanovich, 1986).

Indeed, children with language impairments do have lower levels of literacy motivation than their non-language impaired peers (Kaderavek & Sulzby, 1998), and even within samples of children with LI, print interest correlates with oral language skill (Sawyer et al., 2014). For example, Sawyer et al. (2014) assessed the print motivation of 119 children aged 4-5 years with LI. Print interest was assessed through the frequency with which children ask for help reading words and the frequency with which they ask a family member to write their name. On average, children ask for help reading words only twice a month, and for help writing their name four times per month. This would suggest that they have low levels of print interest. This proposition is supported by Lanter, Freeman et al. (2012) who reported that, on average, pre-school TD children ask to be read to at least three times a week. However, the comparison of motivation/enjoyment across studies is challenging because of the different ways print interest or reading enjoyment is conceptualised. For example, some studies use of frequency of activity ratings, whilst others employ categorical or continuous scales of enjoyment rating.

TD poor readers are less motivated to read than proficient readers and TD children who are un-enthusiastic about reading spend less time reading than their more motivated peers (Chall & Jacobs, 2003; C. Clark & Foster, 2005). Perhaps this is also the case for children with LI. Indeed, Sawyer at al. (2014) found that there was a moderate, but significant correlation between linguistic competence and print interest. Conjecture suggests that children with LI would engage in shared book reading practices less than their TD peers, however recent studies have provided conflicting evidence on this subject.

The frequency with which children aged 4-5 with LI are engaged in home literacy practices was explored by Skibbe, Justice, Zucker and McGinty (2008). Parents were presented with nine statements regarding specific activities, such as, ‘How often do you or another family member tell stories with your child’. For each statement they rated the frequency of occurrence on a 5 point Likert scale and these scores were summed to create a total literacy practices score. The LI group had a mean score of 25.69, suggesting each activity took place once-twice a week, whereas the TD comparison group attained a significantly higher mean score of 29.00, indicating that most activities occurred at least twice a week. This difference was statistically significant, with a moderate effect size. Child enjoyment of literacy was not assessed and therefore it is unknown whether the discrepancy is due to differential levels of child motivation. However, mothers of children with LI reported fewer positive feelings during shared book reading than mothers of TD children. This suggests that the mothers of children with LI enjoy shared book reading activities less than mothers of TD children, which could contribute to the differences in the frequency with which the children are engaged in literacy practices.

In contrast, Sawyer et al. (2014) reported that parents read to their children with LI five times a week, which is slightly higher than the frequency with which parents read to their non-language impaired children (Foy & Mann, 2003; Roberts et al., 2005). With regards to literacy teaching, parents of children with LI, on average, reported teaching their child about letters and words three times per book reading session (Sawyer et al., 2014). It is difficult to determine whether this differs from the frequency with which parents of TD children teach their children about letters and words as other studies generally do not constrain the context of literacy teaching to within book reading. Instead, they report the frequency of literacy teaching in any context, and for children aged 4-5 this averages three times per week (Stephenson, Parrila, Georgiou, & Kirby, 2008). The disparate results of Skibbe et al. (2008) and Sawyer et al. (2014), may therefore be attributable to the different measures; whilst Skibbe et al. reported a composite of general facilitatory literacy practices, Sawyer et al. focused on two specific factors, namely shared book reading and literacy tuition.

There is limited research exploring the relationship between the HLE of children with LI and their language and literacy attainment. Furthermore, the results of the extant research are not consistent. For example, Skibbe et al. (2008) found that there was no relationship between maternal literacy practices and the print related knowledge of 56 4-5 year children with LI although there was a relationship between these factors for their 52 TD peers. The authors suggest that LI may attenuate the effects of environmental influences (such as engagement in literacy practices) on literacy attainment.

In contrast, McGinty and Justice (2009) explored the relationship between the HLE and print knowledge for 41 children aged 3-5 with LI and found that the quality of shared book reading (as assessed by researcher observation scales) was a significant predictor of print knowledge, although the frequency of home literacy practice was not. Likewise, Sawyer et al. (2014) found that there was a small, but significant relationship between reading frequency and print knowledge for pre-school children with LI, and that reading frequency predicted 4% of the variance in print knowledge once maternal education and non-verbal cognitive ability were accounted for. However, frequency of literacy teaching was not associated with print knowledge. These studies suggest that for children with LI there is a relationship between shared book reading and literacy competence, but no relationship between literacy teaching and level of skill.

Further support for the efficacy of shared book reading for children with LI is provided by shared book reading interventions. Crain-Thoreson and Dale (1999) assessed the impact of shared book reading interventions (focussing on quality rather than quantity) for children aged 3-5 years with LI. From pre- to post-test there were significant increases in the participants' number of utterances and the number of different words used, although performance on standardised receptive and expressive language assessments did not increase. This is promising as it suggests that a supportive HLE can facilitate some aspects of language development of children with special educational needs. Furthermore, it is likely that increasing language would result in corresponding improvements in literacy. There is a strong relationship between vocabulary knowledge and both decoding and comprehension (cf. Nation & Snowling, 2004) and vocabulary interventions for children with language weaknesses can facilitate reading comprehension (H. Nash & Snowling, 2006).

This research provides evidence that parents engage their LI children in facilitatory literacy practices and that activities such as shared book reading can, but do not consistently, facilitate linguistic and literacy development. However, it is possible that children with LI do not benefit as much from home literacy practice as their TD peers (potentially due to poorer requisite skills) and therefore the impact of such activities may be attenuated. Support for this notion is provided by the results of Kaderavek and Sulzby (2000) who found that children with weaker language skills benefitted less from literacy experiences than their peers with stronger language skills. Similarly, Justice et al. (2003) found oral language skill predicted the amount of gain made during a literacy intervention. Thus, shared literacy practices may be beneficial for children with LI, but gains might be smaller than those of non-language impaired peers.

The HLE of Children with ASD

There is limited research exploring the HLE of children with ASD. Lanter (2009) recruited a sample of 45 children with ASD aged 4-8 years and the results are disseminated in Lanter, Freeman, and Dove (2012) and Lanter, Watson, Erickson, and Freeman (2012). Additional information is provided by Watson, Andrews and Orovitz (1996).

Provision of Resources

Watson et al. (1996) asked parents of 31 pre-school children aged 2-5 with ASD to complete a questionnaire regarding the provision of literacy resources in their home and found that there was an abundance of books and a similar quantity to TD peers. Similarly, Lanter (2009) attained data on the HLE of 45 children aged 4-8 with ASD. All of the parents reported that their children owned at least 30 books, with 92% having at least 55 books. It is difficult to ascertain whether this is similar to the number of books TD children have, as a direct comparison with peers was not made. However, the National Literacy Trust conducted a survey of book ownership with a sample of over 18,000 children aged 8-17, and 50% of the children had more than 50 books in their home, with 9% having access to more than 500 books (C. Clark & Poulton, 2011). Lanter (2009) also reported that 78% of parents stated that their child had at least six different types of reading materials, although the different types were not specified. However, as previously discussed, access to text does not guarantee reading development. Instead, active engagement is required.

Home Literacy Practices

There is evidence to suggest that parents of children with ASD read to their children as frequently as parents of TD children read to their children (Lanter, Freeman, et al., 2012; Watson et al., 1996). Eighty per cent of the parents in Lanter's (2009) sample reported that they read to their child with ASD at least three times a week and 71% reported that they teach their child to read, outside of shared reading situations, at least three times a week. Lanter, Freeman et al. (2012) found that were no differences between the frequency with which these children with ASD were read to and the frequency with which TD children were read to. In contrast, the TD children were taught to read less frequently than the children with ASD (average of weekly, versus twice a week). However, it is important to consider that the TD children were younger (mean age = 33 months) than the children with ASD (mean age = 67.4 months) and only 31% of the TD children were enrolled in formal education relative to 100% of the children with ASD. Therefore it is likely that the TD children were engaged in reading tuition less frequently than the children with ASD as it was not developmentally appropriate for them to receive such instruction. In addition to frequency of reading activities, the duration of such exercises may be of importance. Watson et al. (1996) reported that parents of children with ASD read to their children as frequently as parents of TD children, but the duration of the shared readings sessions was shorter.

For TD children, shared book reading is particularly beneficial if accompanied by discussion and questioning (cf. Bus, van IJzendoorn & Pellegrini, 1995). Of the parents of children with ASD in Lanter, Watson et al.'s (2012) sample, 97% reported asking their children identification questions, such as 'Can you find X?' and 57% of the sample reported asking this type of question most frequently. Ninety percent of parents posed questions about their child's ability to relate to the book and 89% asked questions about the characters' feelings. Fewer parents (71%) asked their child prediction questions, such as 'What do you think will happen next?' and only 11% of parents reported asking this question most frequently.

However, it is unclear whether these questions were posed on *most* reading occasions, or whether they had *ever* been asked. Furthermore, although the study included 11 participants with ASD and typical language development, nine children with moderate language impairments and 15 children with severe language impairments, analysis exploring the relationship between language phenotype and questioning was not reported. It is therefore uncertain whether parental posing of questions is associated with linguistic competence. Additionally, as there was no comparison group, it is uncertain whether the frequency or style of questioning is specific to families with a child with ASD.

The work of Watson et al. (1996) and Lanter and colleagues (Lanter, 2009; Lanter, Freeman, et al., 2012; Lanter, Watson, et al., 2012) suggests that many children with ASD are engaged in facilitatory literacy practices. However, there is a lack of research exploring the relationship between the HLE and literacy attainment for children with ASD. Watson et al. (1996) attained data regarding the HLE and assessed both procedural print-related achievements (such as alphabet knowledge and reading skill) and conceptual print-knowledge (i.e. understanding of the nature and purpose of print). Similarly Lanter and colleagues (Lanter, 2009; Lanter, Freeman, et al., 2012; Lanter, Watson, et al., 2012) collected details regarding the HLE and assessed the children's emergent literacy skills (e.g. alphabetic knowledge and print concepts knowledge). However, none of these studies explored the relationship between shared book reading and word reading skills. It is therefore unknown whether shared book reading can facilitate the literacy skills of children with ASD.

Reading Enjoyment

Lanter (2009) asked parents to report how much their child enjoys shared book reading. The overwhelming majority indicated that their child did enjoy reading, with only 5.7% tolerating it and 2.9% not enjoying it. When enjoyment was rated on a five-point scale from 1 (does not enjoy reading at all) to 5 (enjoys a lot), the average score for children with ASD was 4.40 (enjoys somewhat) which was significantly lower than the mean score of 4.80 for the younger language-matched TD children (Lanter, Freeman, et al., 2012). This suggests that the vast majority of pre-school children with ASD enjoy shared book reading, although they may derive slightly less enjoyment from this activity than TD children.

Lanter, Freeman et al. (2012) also investigated print motivation by assessing the frequency with which the child asks to be read to and the frequency with which they independently read/browse texts. Parents rated the frequency of these two activities using a five point rating scale ranging from 1 (less than monthly) to five (three or more times per week). The children with ASD asked to be read to significantly less frequently than the TD comparison group (ASD mean = 3.9, TD mean = 4.9). This finding could be attributable to the difficulties children with ASD have with social interaction. However, it is also important to consider that the ASD group were older and a higher percentage had begun formal education. It is therefore possible that the discrepancy could partially be attributable to the children with ASD being better equipped to access resources independently. There were no group differences in the frequency of independent reading of children with ASD relative to TD peers, however, the mean scores of both groups were at ceiling. It is therefore possible that differences may have emerged if additional categories were introduced (e.g. five or more times per week, daily). Indeed, the scores of the TD group ranged from 3-5, whereas all ASD children were reported to read independently several times per week. Likewise, Watson et al. (1996) found that children aged 2-5 with ASD enjoyed shared book reading less than their TD peers, but they enjoyed looking at books and print independently.

This data suggests that children with ASD may derive less enjoyment from shared book reading than their TD peers. However, the extent to which children with ASD enjoy reading may be associated with language and or literacy competence. Indeed, TD children’s interest and motivation to participate in literacy-related activities is associated with their literacy accomplishments (Frijeters, Barron, & Brunello, 2000) and non-autistic children with language impairments show low levels of literacy motivation (Kaderavek & Sulzby, 1998). Lanter, Watson et al., (2012) detailed the extent to which the same group of children reported by Lanter, Freeman et al. (2012) enjoyed shared-reading, but presented the scores by language phenotype. Just over two-thirds of the sample were ALI; half with severe language impairments who attained an expressive and receptive vocabulary composite standard score less than 50, and the other half had moderate impairments and attained a score between 50 and 69. The remainder of the sample were ALN, and achieved a vocabulary composite standard score between 70 and 115. For parental perception of child enjoyment during shared book reading (rated from 1-5), children with ALN received an enjoyment score of 4.8, whilst children with ASD and moderate language impairments attained a score of 4.4 and children with ASD and severe language impairments received an enjoyment score of 4.1. Statistical analysis exploring group differences was not reported, but the data suggests that children with ALI derive less enjoyment from reading than children with ALN.

Additionally, Lanter, Watson et al. (2012) reported that, on average, children with ALN ask their parents to read with them at least twice a week, whereas children with ALI request shared book reading on a weekly basis. Children with ALI may derive less enjoyment than their non-language impaired peers as they find decoding arduous. Even when the child is solely listening to a text being read, children with ALI may find the activity more challenging due to impaired comprehension (Norbury & Bishop, 2002; Wagner, Sahlén, & Nettelbladt, 1999). Thus, they may derive less enjoyment than their ALN peers from listening to stories that are read to them. However, listening to stories can facilitate vocabulary learning, especially if a definition is provided of key/novel words (Brett, Rothlein, & Hurley, 1996; Feitelson, Kita, & Goldstein, 1986; Stahl, Richek, & Vandevier, 1991). Thus, if parents are aware that their child is struggling to learn to read, it is possible that they may place more emphasis on home reading tuition in order to give them an extra boost.

Literature Preferences

Children with ASD may also differ from TD children with regards to the type of literature they enjoy. Relative to factual books, comprehension of the content in fictional books requires more abstraction and draws on social cognitive skills, such as the ability to make inferences, identify causal attributes, understand character motivations and make predictions and conclusions. It may therefore be anticipated that the individuals with ASD would have a preference for factual books. Indeed, Randi, Newman and Grigorenko (2010) reported that "In our experience, children with ASDs typically prefer expository text, such as science texts. This may be because they find narrative text especially challenging because of its more abstract (and social) reasoning demands" (p. 895). However, the parents in Lanter's (2009) sample indicated that the majority of their children with ASD preferred stories (60%), whilst only 26% preferred factual books, which focused on topics such as dinosaurs, planets, and trains or trucks. Of the remaining 24%, 14% stated that non-traditional reading material (such as specialist magazines and field guides) was their child's favourite, and less than 10% of the children had a preference for activity or comic books. These figures closely correspond to the percentage of TD children who enjoy such literature. The National Literacy Trust surveyed approximately 2,500 primary schools pupils and 62% reported that they enjoy fiction, whilst only 35.7% reported that they enjoy factual books (C. Clark & Foster, 2005).

The Current Study

It is evident that children with ASD have similar access to literacy resources as their TD peers and that the majority of parents frequently read to their children and pose questions about text. However, it is currently unclear whether this varies as a function of language phenotype and whether there is a relationship between shared book reading practice and language and / or literacy development. The limited available evidence concentrates on early childhood, and there is a dearth of research on the HLE of older children. The current study was conducted in order to fill these critical gaps in the literature and investigated whether there were any quantitative and / or qualitative differences in the HLE of children with ASD and whether this varies by language phenotype. This was explored with regards to the provision of resources, shared book reading frequency and duration, and reading enjoyment.

The provision of resources was expected to be similar for TD and ASD children. However, it was hypothesised that the frequency and/or duration of shared book reading would be reduced for children with ASD due to social interaction reluctance. It was anticipated that children with ALN would read independently instead, although children with ALI would be less able to do so due to their poorer reading skill. Furthermore, as a result of their expected reading difficulties children with ALI were expected to enjoy reading less, reducing motivation. Thus, children with ALI would potentially have less exposure to text, further compounding their language and literacy difficulties.

Method

Participants

Parents whose children had participated in studies 1-3 and study 5 between September 2011 and September 2012 were invited to complete the HLE questionnaire. Of the 85 families contacted, 64 returned the questionnaire (75.29% response rate). There were no differences in the socio-economic status of responders and non-responders, in the age of their children, or in the gender composition (*p*s > .100). There were also no differences in the cognitive, language or reading skills of the children whose parents did and did not respond (all *p*s > .150; see Table 7.1).

Child details are presented in Table 7.2 and parental characteristics are presented in Table 7.3 for the 64 families who took part in the study. Children aged 7-13 years completed reading assessments and their primary caregiver completed the HLE questionnaire. Only one father completed a questionnaire, the remainder were completed by the child's mother (91.80) or an unspecified parent (n=3). Forty-one of the children had an existing diagnosis of ASD and met the inclusion criteria outlined in Chapter 3. Of these children, 21 had age-appropriate structural language skill (20 male) and 20 had language impairments (19 male). TD children (*n* = 23, 15 male) were recruited from local schools and communities and did not have any reported special educational needs, a history of ASD or language delay.

All three groups were matched on chronological age, however the TD group had a differential gender distribution to the ASD group. To determine whether this had any bearing on the HLE and associated factors, the TD males and females were compared on the five parental factors reported in Table 7.3, reading enjoyment (yes vs. no), frequency (daily vs. not daily), encourages child to read (daily vs. not daily), number of books (>100 vs. ≤100) and SES. There were no group differences (all *p* > .050).

The TD and ALN groups also were matched on all cognitive and language measures, whereas the ALI group had significantly lower scores on these assessments. Nevertheless, the ALN and ALI groups were matched on autistic symptomatology as indexed by ADOS and SCQ scores; the TD group had significantly lower SCQ scores than both of the ASD groups. For the children with ASD there was substantial overlap between language and literacy competence. The children with ALI attained significantly lower single word reading accuracy standard scores, as well as significantly lower passage reading accuracy and comprehension standard scores. Seventy percent (n = 14) of the children with ALI attained TOWRE Total standard scores less than 85, indicative of single word reading impairments, compared to only 14% (n = 3) of children with ALN. Additionally, three of the children with ALI had insufficient reading skill to read passages of connected text, and 62% of the ALI children who could complete the task attained an accuracy standard score below 85, whereas none of the TD and ALN children did. Only 15% of the children with ALI attained a comprehension standard score above 85, relative to 88% of the ALN group and the entire TD group.

Table 7.1
Comparison of Families who Did vs. Did Not Complete the HLE Questionnaire

Variable		Responders *M* (SD) n=64	Non-responders *M* (SD) n=21	t-value	p-value
Chronological age (Years)		10.85 (1.42)	10.34 (1.80)	1.35	.180
Gender	Male	54	16	χ^2 = .74	.600
	Female	10	5		
Socio-economic status (IDACI rank)		21821 (6834)	19203 (7923)	1.37	.175
Matrix Reasoning, WASI, NVIQ (T-score)		52.48 (9.21)	54.14 (7.51)	1.10	.275
Language ability:					
Vocabulary Definitions, WASI VIQ, (T-score)		52.48 (12.62)	50.38 (14.17)	.64	.526
Expressive one-word picture vocabulary test (Standard score)		117.58 (14.50)	112.67 (13.09)	.48	.627
Receptive one-word picture vocabulary test (Standard score)		104.70 (20.18)	107.35 (18.34)	.91	.365
Recalling Sentences CELF (Scaled score)		8.28 (4.19)	8.44 (4.24)	.13	.898
Reading skill:					
TOWRE SWE (Standard score)		97.69 (18.37)	103.55 (12.58)	1.35	.182
TOWRE PDE (Standard score)		100.80 (19.12)	107.36 (13.71)	1.44	.154
Autistic symptomatology:					
SCQ		10.43 (3.27)	11.54 (8.81)	1.01	.316
ADOS (Total)		10.43 (3.27)	11.13 (4.26)	.45	.621

Table 7.2
Child Details by Group

Variable	TD *M* (SD) n=23	ALN *M* (SD) n=21	ALI *M* (SD) n=20	F-value	p-value
Chronological age (Years)	10.40[a] (1.08) 8.72-12.51	10.91[a] (1.75) 7.93-13.30	11.31[a] (1.23) 8.32-13.22	2.31	.108
Gender Male	15	20	19	TD vs. ASD	
Female	8	1	1	χ^2=(1, n=64) = 7.86, *p* = .005	
Matrix Reasoning, WASI, NVIQ (T-score)	53.88[a] (6.76)	53.77[a] (10.00)	47.05[b] (9.49)	4.08	.022
Language ability:					
Vocabulary Definitions, WASI VIQ, (T-score)	58.09[a] (7.34)	57.43[a] (9.20)	37.94[b] (11.22)	27.62	<.001
Expressive one-word picture vocabulary test (Standard score)	112.67[a] (13.09)	117.58[a] (14.50)	84.10[b] (14.23)	33.44	<.001
Receptive one-word picture vocabulary test (Standard score)	110.09[a] (11.61)	116.90[a] (17.02)	78.85[b] (14.54)	39.89	<.001
Recalling Sentences CELF (Scaled score)	10.11[a] (2.11)	10.81[a] (3.04)	4.11[b] (3.58)	27.45	<.001
Reading skill:					
TOWRE SWE (Standard score)	109.10[a] (11.23)	100.97[a] (12.79)	79.94[b] (17.93)	21.10	<.001
TOWRE PDE (Standard score)	110.38[a] (15.63)	105.13[a] (13.61)	84.12[b] (18.11)	14.07	<.001
NARA accuracy (Standard score)	110.44[a] (10.82)	109.24[a] (13.34)	83.77[b] (13.10)	21.09	<.001
NARA comprehension (Standard score)	97.67[a] (7.76)	97.65[a] (11.52)	75.77[b] (7.37)	26.89	<.001
Autistic symptomatology:					
SCQ	4.00[a] (4.17)	19.68[b] (8.05)	22.22[b] (8.65)	38.45	< .001
ADOS (Total)	______	9.50[a] (2.85)	11.83[a] (3.46)	-2.02	.054

Values with the same superscript to do not differ when p < .05

Materials

The children's single word reading ability was assessed using the sight word efficiency (SWE) and phonemic decoding efficiency (PDE) subtests of the Test of Word Reading Efficacy (TOWRE; Torgesen, Wagner & Rashotte, 1999). Information regarding the HLE was gathered through parental questionnaire. Please see Appendix E for a list of the questions.

Socio-Economic Status

Socio-economic status was indexed by The Income Deprivation Affecting Children Index (IDACI, Department of Education, 2010) rank scores. Higher scores indicate higher SES status.

Parental Reading

Parental reading enjoyment was ascertained through the question "Do you enjoy reading?". The response options of 'no', 'yes, a little' and 'yes, a lot', were dichotomised into 'no' and 'yes' for analysis. Parents were also asked how frequently they read and could select either 'rarely or never', 'a few times a month', 'every week' or 'almost every day'.

Provision of Resources

The provision of literacy materials was quantified through specification of the number of books in the family home, with response options including '0-10', '11-25', '26-50', 51-100' or '101+'. In order to enable consistent comparison in the analysis, responses for the first two categories were combined to form a <50 category. Only 3.2% of families had less than 26 children's books in their home but all of these families had children with ALI.

Child Reading

Parents indicated whether their child enjoyed reading, by selecting the applicable response from three options, 'no', 'yes, a little' or 'yes, a lot', which for analysis was dichotomised into 'no' and 'yes'. To assess the frequency with which parents engage children with facilitative reading practices they were asked "How often do you do the following things?" and the items listed were: 'read to your child', 'read with your child', 'listen to your child read', 'ask your child questions whilst you/they are reading', 'talk to your child about what he/she has read', and 'encourage your child to read materials that are not part of work for school (i.e. books, magazines)'. Additionally, parents were asked how often their child reads alone at home. The response options provided were 'rarely or never', 'a few times a month', 'every week' and 'almost every day'.

For the two questions relating to reading discussion, i.e. 'how often do you ask your child questions whilst you/they are reading', and 'how often do you talk to your child about what he/she has read', the four response options were dichotomised into weekly and not weekly for analyses.

To assess reading duration, parents were asked 'How long do you usually spend reading with your child?" and "How long does your child read for?". Three time categories were devised; <15minutes, 15-30 minutes and >30mins. Of the 44 parents who answered the question regarding shared book reading duration, 10 (23%) answered with time periods (e.g. 5-10mins) rather than specific periods of time (e.g. 30mins). However, only two parents responded with time periods that crossed these boundaries. Specifically, one ALI parent specified 10-20 minutes which was categorised as <15 minutes to be conservative, and another ALI parent reported 20-60 minutes which was categorised as >30 minutes, as there was greatest overlap with this category.

Of the 55 parents who answered the question regarding independent book reading duration, 15 (27%) answered with time periods rather than specific times. Of these, four parents responded with time periods that crossed the category boundaries. Two parents (one TD, one ALN) specified 10-30 minutes which was categorised as 15-30 minutes as there was greatest overlap with this category. As above, one ALI parent specified 10-20 minutes and another 20-60 minutes. These were respectfully categorised as <15 minutes and >30 minutes.

Procedure

Children completed the reading assessments, and where relevant, the ADOS, whilst participating in studies 1-3 or study 5. They were tested in a quiet room in their school or in the Psychology Department at Royal Holloway University of London. Following participation, parents were invited to complete the HLE questionnaire.

Results

Parental Characteristics

To determine whether parental characteristics were similar across groups, five factors were inspected. Namely, parental enjoyment of reading, the frequency with which parents read, the frequency with which parents encourage their child to read, the number of children's books in their homes and socio-economic status (Table 7.3).

Ninety-one percent of TD parents reported that they enjoy reading, as did 85% of the ALN and ALI parents. There were no differences in parental enjoyment of reading between the TD and ALN groups, $\chi^2(1, N=42) = .013$, $p = .910$, or TD and ALI groups, $\chi^2(1, N=42) = .013$, $p = .910$. Nearly 70% of parents in each group read almost every day and encourage their child on a weekly basis. This suggests that the majority of parents consider reading to be important. Parents also provided literacy rich environments for their children, with 87.30% of families having more than 50 children's books in their home. A one-way ANOVA was conducted on IDACI SES rank and there was a significant main effect of Group $F(2, 58) = 3.95$, $p = .025$. The ALI group did not differ from either their ALN ($p = .179$) or TD ($p = .880$) peers. However, the TD group had a lower SES score than the ALN group ($p = .007$).

Table 7.3
Parental Characteristics

Variable	TD n=23	ALN n=21	ALI n=20
Percentage of parents who enjoy reading	91.30%	85.00%	85.00%
Frequency with which parent reads at home			
Monthly	8.70%	0%	0%
Weekly	21.70%	9.50%	25.00%
Daily	69.60%	90.50%	75.00%
Frequency with which parent encourages their child to read			
Rarely	17.40%	0%	0%
Monthly	13.00%	15.80%	15.00%
Weekly	52.20%	36.80%	45.00%
Daily	17.40%	47.40%	40.00%
Number of children's books in the family home			
< 50	4.30%	10.00%	25.00%
51-100	43.50%	35.00%	25.00%
>100	52.20%	55.00%	50.00%
IDACI SES Rank	*M* = 19714 (SD = 5032)	*M* = 25213 (SD = 5791)	*M* = 20815 (SD = 6834)

Reading and Reading Discussion Frequency

The frequency of reading related activities is detailed in Table 7.4. Although over 50% of TD and ALN children read alone on a daily basis, only 25% of children with ALI did so. To explore whether independent reading frequency was related to reading ability, reading alone frequency was dichotomised into 'daily' and 'not daily'. Children with ASD (ALN and ALI) who read alone daily (n= 21) achieved significantly higher standard scores on both the TOWRE SWE, $t(33) = 2.96$, $p = .006$, and PDE $t(33) = 2.59$, $p = .014$, than children with ASD who do not read alone daily (n=14), providing support for this hypothesis.

A shared-reading frequency composite was created by determining whether parents read to their child or read with their child (reading is shared) or listened to their child read on a daily basis. Ninety percentage of children with ALI engaged in shared reading on a weekly basis, which is significantly higher than the 59% of TD children, $\chi^2(1, n=42) = 3.70$, $p = .054$ and 47% of ALN children $\chi^2(1, n=39) = 6.43$, $p = .011$.

Similarly, although 85% of parents asked their ALI children questions during shared reading, significantly fewer parents of TD children, $\chi^2(1, n=43) = 4.97$, $p = .026$ and ALN parents do $\chi^2(1, n=40) = 10.23$, $p = .001$. Additionally, 90% of parents asked their ALI children questions about what he/she has read, which does not differ from TD families, $\chi^2(1, n=43) = 1.61$, $p = .205$, but is significantly higher than the percentage of ALN families that did, $\chi^2(1, n=41) = 8.14$, $p = .004$.

Table 7.4

Frequency of Reading Related Behaviours

Activity		TD (%)	ALN (%)	ALI (%)
Child reads alone	Rarely	4.30	15.00	20.00
	Monthly	13.00	10.00	20.00
	Weekly	13.00	20.00	35.00
	Daily	69.00	55.00	25.00
Engaged in shared reading on a weekly basis		59.10%	47.40%	90.00%
Asked questions during shared reading on a weekly basis		57.80	30.00	85.00
Ask questions about reading on a weekly basis		69.60	42.90	90.00

Reading Duration

The length of time children spent reading with a parent and the amount of time spent reading alone was coded into three categories; <15minutes, 15-30 minutes and >30mins. As illustrated by Figure 7.1, 23% of TD children spent more than 30 minutes reading with a parent, compared to very few children with ASD. This may reflect difficulties with social interaction, thus I explored whether the amount of time spent reading with parents was associated with severity of ASD. Children with ASD who engaged in shared reading for <15 minutes had significantly higher SCQ scores ($M = 25.62$, SD = 7.80) than the children with ASD who engaged in shared reading for >15 minutes ($M = 19.54$, SD = 6.76), $t = 2.12$, $p = .044$, although the effect size was small, Cohen's $d = .083$.

Figure 7.2 illustrates that more than 50% of the children in the TD group and nearly 40% of the children in the ALN group read alone for more than 30 minutes, compared to just 11% of the children in the ALI group. The shorter reading alone time of the ALI participants may be due to their reduced competency level – if the ALI children are struggling to read, or do not comprehend what they read, then they may be less able to read for long periods on their own. There was substantial within group variation, although the ASD children who spent less 15 minutes reading alone did achieve lower TOWRE total standard scores (M = 82.93, SD = 22.34) than the ASD children who spent 15 minutes or more reading alone (M = 95.45, SD = 20.62). However, the difference was not statistically significant, t = 1.44, p = .164, although there was a moderate effect Cohen's d = .58.

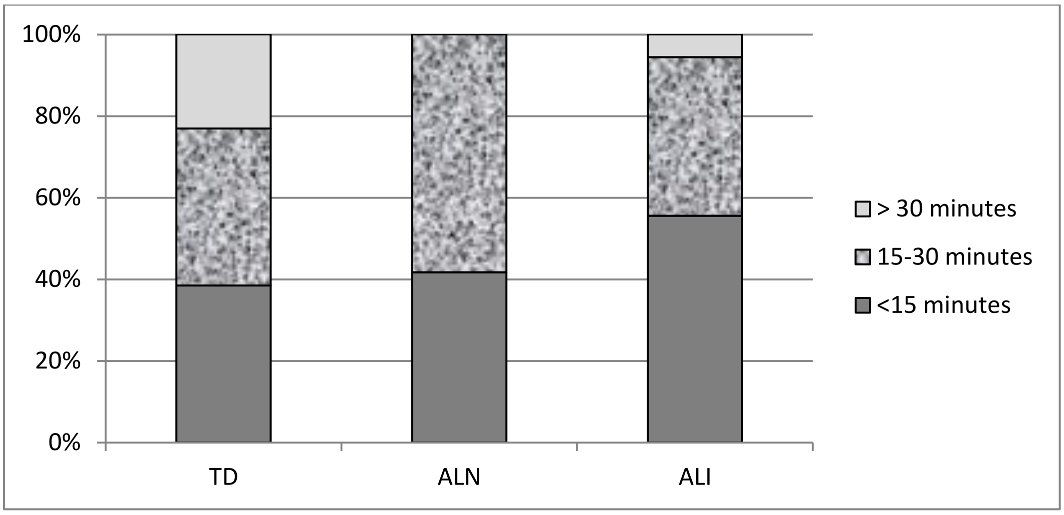

Figure 7.1 *Amount of Time Spent Reading with Parent*

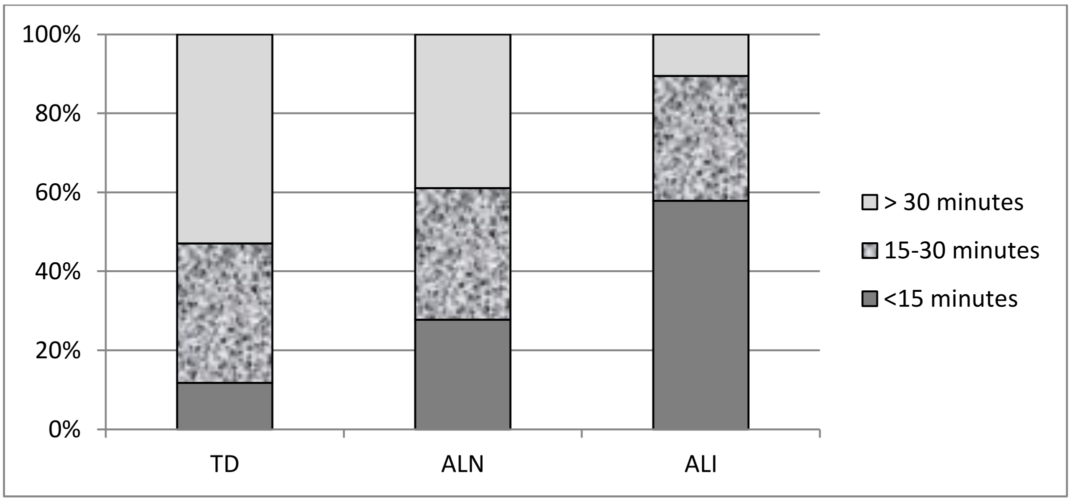

Figure 7.2 *Amount of Time Spent Reading Alone*

Reading Enjoyment

According to parental report, 73.90% of TD children enjoy reading, as do 80% of children with ALN, but only 45% of children with ALI do so. The TD and ALN groups did not differ in terms of reading enjoyment, $\chi^2(1, n=43) = .04$, $p = .849$, and neither did the TD and ALI groups, $\chi^2(1, n=42) = 2.29$, $p = .130$. However, the difference between the two ASD groups was significant, with a higher percentage of children with ALN than ALI enjoying reading, $\chi^2(1, n=40) = 3.84$ $p = .050$.

Parents also indicated whether their child does, or does not, enjoy reading certain types of literature (Figure 7.3). Across all three groups, enjoyment of fiction and factual books was similar. However, there was a trend for children with ALI to enjoy periodicals less than their non-language impaired (TD and ALN) peers, $\chi^2(1, n=60) = 3.48$, $p = .062$, yet to enjoy comics more $\chi^2(1, n=50) = 3.55$, $p = .060$.

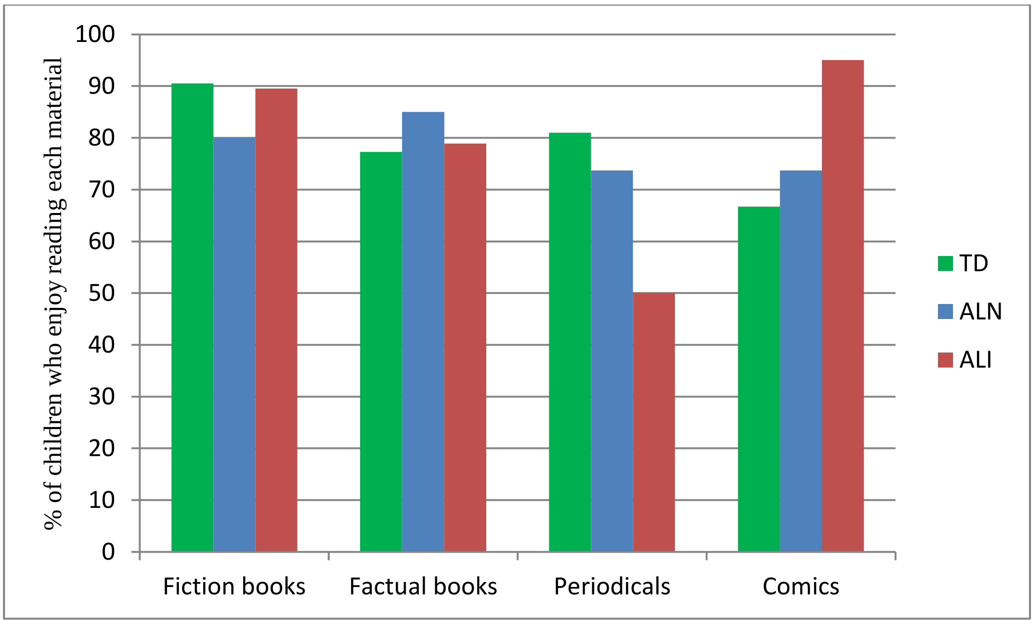

Figure 7.3 *Percentage of Children who Enjoy Each Type of Literature*

Discussion

This study explored the home literacy environments of children with ASD, taking into consideration language phenotype. The vast majority of children with ASD had literacy rich homes, with a wealth of literacy resources. However, there were subtle differences in the HLE of children with ASD and their TD peers. Children with ALI, who were also more likely to be poorer readers, were engaged in shared book reading activities and reading discussions more frequently than non-language impaired peers. However, both ALN and ALI children read with their parents for a shorter duration than TD children and shared reading duration was negatively associated with ASD severity. Across groups, frequency and duration of time spent reading alone was positively associated with reading ability, as was enjoyment of reading.

Provision of Resources

Previous research has indicated that parents of pre-school children with ASD provide literacy rich environments for their children. This study demonstrates that this is also the case for children in middle childhood. Over three-quarters of the children with ASD in the current sample reside in homes with more than 50 children's books. Furthermore, the children with ASD had access to a similar number of books as their TD peers. These results are consistent with Lanter (2009) and Watson et al. (1996) who reported that younger children with ASD have an abundance of books and a similar quantity to their TD peers.

Reading Frequency and Duration

To date, the limited research on the HLE of children with ASD has focused on early childhood and indicates that the majority of parents read to their child, and teach their child to read at least twice a week, which is similar to the frequency with which parents read to their TD children (Lanter, Freeman, et al., 2012; Watson et al., 1996). However, in the current study, the TD and ALN children (aged 7-13) engaged in shared book reading activities less frequently, with approximately 35% of TD and 25% of children with ALN engaging in shared book reading activities on at least a weekly basis. However, 80% of children with ALI participated in shared book reading activities on a weekly basis. These children had significantly poorer reading ability, with some children achieving real and non-word reading raw scores that would be expected of TD children younger than age eight and experiencing difficulty reading passage of texts accomplished by children age six. Perhaps once children become more proficient readers, they are less likely to engage in shared book reading practices with their parents as they have the resources to read independently. Indeed, a recent survey of over 1000 families found that 65% of parents read to their 6–8 year old children on a weekly basis, yet only 37% of parents read to their 9–11 year old children. Furthermore, only 6% of 6-8 year olds are never read to, compared to 29% of children aged 9-11 (Scholastic, 2013). Poorer readers and children in the early stages of literacy development will need more support to enable them to access reading materials. Additionally, parents of children with ALI may be aware of their children's difficulties, thus ensuring engagement in facilitatory activities as a means of fostering their language and literacy development. Further exploration of these potential explanations is warranted.

These results suggest that once children reach late childhood, shared book reading frequency is negatively associated children's literacy attainment, whereas in early childhood, a positive relationship is evident (Bingham, 2007; Bus et al., 1995; Rowe, 1991; Scarborough et al., 1991; Share et al., 1983). Yet this does not mean that reading frequency diminishes from early to late childhood. Whilst proficient readers may rarely engage in shared-book reading, they frequently read on their own. More than 50% of children with ALN and their TD peers read on their own most days. However, fewer than 30% of ALI children read on their own most days, and these children read for a shorter duration than the ASD proficient readers. This is consistent with the proposition that children with ALI may be less able to read independently, potentially due to difficulties with decoding and comprehension.

Whilst shared reading *frequency* was influenced by language status, shared book reading *duration* was associated with ASD status. Although 22% of TD children usually spent more than 30 minutes reading with parents, only one child with ASD did so. This may reflect difficulties with social interaction. Indeed, for the children with ASD, duration of shared reading was negatively associated with ASD severity, as indexed by SCQ score.

Reading Discussion

When shared book reading is accompanied by discussion and questioning it can facilitate language development (cf. Bus, van IJzendoorn & Pellegrin, 1995). It could therefore be suggested that parents of children with ALI may engage their child in reading discussion less frequently than parents of ALN and TD peers. Yet in the current study, over 85% of parents of children with ALI engaged their children in reading discussions on at least a weekly basis, but only 48% of TD and 29% of ALN families do so. Similarly, parents of ASD poorer readers engaged their children in discussion more frequently than parents of proficient readers. It would be interesting to explore this further to determine whether this is because parents of ALI children and poorer readers feel they have more opportunity to ask questions (as they engage in shared reading more frequently) or because they feel their children need more text comprehension and language practice.

Future research could also explore whether TD and ASD parents ask qualitatively similar questions; it is possible that the nature of parents' questions differs as a function of autistic symptomatology or language phenotype. For example, Lanter (2009) reported that 90% of parents asked their child with ASD questions about the characters' feelings. It would be interesting to see if this figure is comparable to questions asked to TD peers, or whether parents of children with ASD target this concept specifically as it is an area of particular difficulty (Baron-Cohen, 1991). Likewise, it would be interesting to determine whether parents of children with language impairments refrain from asking their children complex questions, instead opting for closed questions. Asking simpler questions may increase the likelihood of a correct response, thus increasing the child's self-efficacy and confidence, and potentially resulting in increased literacy attainment (Schunk & Rice, 1993; Shell, Colvin, & Bruning, 1995; Shell, Murphy, & Bruning, 1989). However, avoiding complex language may in turn impede language development, by limiting exposure to novel vocabulary and sentence structures. Open questions may facilitate language by providing experience of responding appropriately to such questions, and practice using language skills (Dickinson & Smith, 1994; Whitehurst et al., 1994). Dickinson and colleagues (Dickinson & Tabors, 2001; Dickinson, 2011) conducted a longitudinal study examining teacher–child conversations during free-play and shared book reading, and high-quality conversations were linked to gains in both language production and language comprehension.

Reading Enjoyment

Previous research has indicated that children aged 4-8 with ASD do enjoy shared book reading (Lanter, 2009), albeit less than TD children (Lanter, Freeman, et al., 2012; Watson et al., 1996). TD children's interest and motivation to participate in literacy-related activities is associated with their reading competence (Frijeters et al., 2000); children with reading impairments have low levels of literacy motivation (Chall & Jacobs, 2003; C. Clark & Foster, 2005), as do non-autistic children with language impairments (Kaderavek & Sulzby, 1998). It was therefore expected that children with ALI would be less enthusiastic about reading than their ASD peers. Indeed, although 80% of the ALN participants in the current study enjoy reading, fewer than 50% of ALI children do so.

Parents also indicated that their children enjoy reading a range of materials. Enjoyment of factual vs. fiction books was a key comparison; it was hypothesised that children with ASD may be more likely to enjoy factual books (cf. Randi et al., 2010). However, over 80% of children with ASD enjoyed fiction and factual books, regardless of language phenotype. Nevertheless, subtle group differences did emerge in enjoyment of periodicals and comics. Relative to TD and ALN children, fewer children with ALI enjoy periodicals, yet more enjoy comic books. Comic books typically have fewer words than story books and less experienced readers may find them easier to access. Indeed, 70% of primary school pupils enjoy comics, relative to only 44% of secondary school pupils (C. Clark & Foster, 2005). As different types of texts contain different types of vocabulary, children should be encouraged to maintain their interest in a variety of texts in order to facilitate vocabulary development.

Implications

The results of this study indicate that children with ASD grow up in literacy rich environments and their parents promote both language and literacy development. Despite engaging in shared reading practices and discussion more often than their non-language impaired peers, children with ALI attained lower language and literacy scores. This raises the question of *why* these children lag behind their peers, despite additional input. Two possibilities were identified.

First, children with ALI may receive poor quality literacy input. The quality of facilitatory literacy practices is clearly important for effectiveness, with higher quality interactions predicting higher literacy skill (NICHD, 1999, 2002; Roberts et al., 2005). However, there is no evidence that the language and literacy difficulties experienced by children with LI are the result of parental input. Nevertheless, there is evidence that parents of children with ASD are more likely to demonstrate speech and pragmatic language deficits than the parents of TD children, as well as being more likely to be aloof and undemonstrative (Landa et al., 1992; Piven et al., 1997). In particular, parents of children with ALI may have language and literacy deficits (cf. Lindgren et al., 2009). These characteristics could affect the quality, as well as the frequency and duration of shared book reading sessions. This was not explicitly assessed in the current study, although it is acknowledged that it would have been beneficial to have attained a measure of parental personality, perhaps through administering the Broad Autism Phenotype Questionnaire (Hurley, Losh, Parlier, Reznick, & Piven, 2007). level of education and reading ability and incorporated this into the analyses.

An alternative proposition is that children with ALI derive less benefit from home literacy practices than their non-language impaired peers and therefore the impact of such activities may be attenuated. This notion aligns with the literature exploring the effectiveness of literacy experiences for children with LI. Shared literacy practices are beneficial for children with LI, but the extent of the benefit is associated with language competence, in that children with weaker language skills derive less benefit than children with greater linguistic competence (Justice, Chow, Capellini, Flanigan, & Colton, 2003; Kaderavek & Sulzby, 2000). However, it is uncertain why this is the case. One potential explanation is that children with language impairments do not have the requisite skills to ascertain the maximum benefit. Alternately children with LI may need more explicit, rather than implicit teaching. Although Sawyer et al. (2014) reported that direct literacy instruction delivered by parents was not associated with their LI children's literacy competence, the components of the literary instruction were not well documented, thus the nature of this teaching i.e. implicit vs. explicit is not clear. Teaching explicit definitions of words is beneficial for children with weaker language skills (Penno, Wilkinson, & Moore, 2002), although children with poor vocabulary learn new words better when presented in context than when taught in isolation (H. Nash & Snowling, 2006). However, it is uncertain whether this is also the case for children with ALI. Nevertheless, parents of children with ALI appear to be sensitive to their children's additional needs and prepared to spend additional time engaging them in facilitatory literacy practices. They may therefore be ideally placed to assist with/deliver interventions.

Limitations and Future Directions

Although the current study contributed to the scarce literature on the HLE of children with ASD, there are limitations, which need to be taken into consideration. For example, data obtained regarding the nature of the HLE environment was obtained through parental report. The importance of caregivers reading with children is well-reported within the media (e.g. Burns, 2013) which could bias caregivers into reporting elevated levels of literacy activities with their children. However, parents in the current study reported the full range of responses, with some caregivers indicating that they 'rarely' engage their children in any literacy activities. Validation via researcher observations was not within the financial and time constraints of this study but could be incorporated into future research. It may have been possible to collect data from the children themselves regarding how much they enjoy reading and using a 5-point Likert scale would have provided a larger range of responses. The children could also have been questioned about their literature interests, which may result in more accurate data regarding the literature they enjoy reading. Furthermore, children could have been asked to rank the literature types, to identify literature preferences. This may have resulted in greater group differences than simply asking whether texts are enjoyed, with a dyadic response option.

It would also have been desirable to include a language matched control group for the children with ALI. This could either have been a group of younger TD children, or a sample of LI peers. This would indicate whether the additional input the ALI children were receiving was consistent with their developmental level. I did attempt to include a comparison group of LI peers, however the response rate was very low. One potential reason for this is that non-autistic LI is hereditary (Barry et al., 2007; Bishop et al., 2006; Bishop et al., 1996; Lindgren et al., 2009; Whitehouse et al., 2007), thus many parents of children with LI may also have language and literacy problems (cf. Lindgren et al., 2009), which may affect their willingness to complete a written questionnaire. This could have been circumvented by conducting individual parental interviews, but this was not feasible for this thesis.

Additionally parental difficulties may affect the extent to which they engage their children in literacy practices, which could diminish the usefulness of a LI comparison group for the children with ALI. It may therefore have been better to include a group of younger TD children matched for language ability. However, as discussed in Chapter 3, language is a multi-faceted construct and it is debateable which aspects of language should be ‘matched’ and how this should be determined (Plante et al., 1993). For example, even when groups are matched for vocabulary, children with LI may have poorer production and/or comprehension of connected prose and text than younger TD children. Another alternative would have been to include a reading matched group of young TD children. However, using younger children is not without its problems. For example, attention span increases with age (cf. Ruff, Lawson, Parrinello, & Weissberg, 1990) and therefore it would not be meaningful to compare variables such as shared and independent reading duration.

Future research will most usefully adopt a longitudinal approach. Documenting the HLE of children from pre-literacy instruction to late childhood and beyond will enable the relationship between the HLE and literacy development to be assessed at multiple time points. This could determine whether differences in the HLE of children with different linguistic and literacy profiles are a cause or consequence. This information could be utilised to target interventions effectively.

Conclusion

This study contributes to the minimal literature on the HLE of children with ASD. Children with ALI, who are poor readers, participate in facilitatory literacy practices such as shared book reading and reading discussion more frequently than their ALN and TD peers. This suggests that parents are sensitive to their children’s needs and may therefore be well-placed and willing to assist with interventions. However, duration of shared reading is negatively associated with ASD symptomatology. Once children with ASD become competent readers, they read alone as frequently as their TD peers and for a similar duration. However, it is uncertain whether children with ASD read for the same purposes as TD children and are able to implicitly learn from texts. When considering the literacy development of children with ASD, language profile, reading competence and autistic characteristics should all be considered.

Chapter 8: The Influence of Orthography on Oral Vocabulary Learning

Chapter Overview

The thesis now transitions from how children with ASD ‘learn to read’, to whether they can ‘read to learn’. This chapter investigates whether children with ASD can use orthography to facilitate vocabulary learning, as is the case for typically developing children. Forty-one children aged 7-12, 20 with a formal diagnosis of ASD and 21 TD peers, were taught 16 low frequency concrete science words, such as ‘breccia’. Half of the stimuli had the written word presented alongside a picture of the target item (orthography present, OP); the remaining items were taught with orthography absent (OA). During the learning phase eye-movements were recorded; there were no group differences in the time spent fixating the written form. Production, comprehension and recognition of orthographic forms of new words were assessed immediately after learning and again after a 24 hour delay. The vocabulary learning of both groups was facilitated by the presence of orthography. Overall, the groups did not differ in comprehension of new words or recognition of new orthographic forms, although the children with ASD demonstrated superior phonological learning (as measured by a picture naming task) relative to TD peers. Additionally, both groups retained or increased new knowledge after 24 hours. The results suggest that presenting the written form during oral vocabulary teaching will enhance learning and provide a mechanism for children with ASD to increase word knowledge despite potential limitations in social learning.

The work presented within Chapter 8 has been published in QJEP:

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Introduction

Typically developing children are able to use the written form of words to facilitate learning of vocabulary which is explicitly taught. More specifically, the presence of orthography can aid phonological, semantic and orthographic learning (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008) and the rationale behind this phenomenon is detailed in Chapter 1. To date, it is uncertain whether children with ASD benefit from the presence of orthography during oral vocabulary learning, as discussed in Chapter 2. This provided the motivation for the current study, which investigated whether children with ASD are able to use orthography to facilitate oral vocabulary learning, and whether they benefit to the same extent as their TD peers.

Many studies exploring word learning only assess knowledge immediately after teaching (e.g. Reitsma, 1983; Ricketts, Bishop, & Nation, 2009; Rosenthal & Ehri, 2008). However, in order to be beneficial, knowledge must be retained after a delay. As a result, the study presented in this chapter assessed the recall and recognition of knowledge immediately after learning *and* following a delay (cf. Henderson et al., 2013; Norbury et al., 2010). In order to situate the hypothesis and rationale for this component, the introduction to this chapter will discuss the literature regarding retention of phonological, semantic and orthographic knowledge.

Phonology

Research has demonstrated that recognition and recall of non-words improves after a period of consolidation (typically involving sleep) for both TD children and adults (Brown, Weighall, Henderson & Gaskell, 2012, 2013; Henderson, Weighall, Brown & Gaskell, 2012; Dumay & Gaskell, 2007; Tamminen, Payne, Stickgold, Wamsley & Gaskell, 2010). However, recent research suggests that this phenomenon may be dependent on the accompanying information provided. Henderson et al. (2013) demonstrated that the phonological recall for new words was superior seven days after learning (relative to immediately after learning) when the words were taught accompanied by semantic information, but not solely orthographic information.

There is little evidence regarding consolidation of phonological knowledge for children with ASD. However, Norbury et al. (2010) taught 6-7 year old children with ASD non-word names for novel items and tested retention after four weeks. Initially, the children with ASD achieved greater accuracy on a picture naming task than the TD children, and their performance remained stable four weeks later. In contrast, naming ability increased significantly for TD children despite no further exposure to the novel words. This suggests that following a delay, knowledge is retained for children with ASD, but increases for TD children.

Semantics

There are contradictory findings regarding the consolidation of semantic knowledge. Nation et al. (2007) and Ricketts et al. (2008) taught TD children non-words and assessed semantic knowledge through a word to picture matching task. Performance remained stable over time, indicating that knowledge was retained but did not increase. In contrast, Henderson, Weighall and Gaskell (2013) found that the quality of definitions for taught science words was greater 24 hours after training relative to immediately after training, and further increased after 7 days. The discrepancy between studies could be attributable to differences in task demands or the use of real-word versus non-word stimuli.

Poor Comprehenders are significantly worse than TD peers at retaining new semantic information (Cain et al., 2001; Nation et al., 2007; Ricketts et al., 2008). For example, Ricketts et al. taught non-words embedded in a ‘helpful’ context which provided cues to the non-word’s exact meaning (e.g. zebra) and found that performance on a non-word to picture matching task (an index of semantic learning) declined from 40% to 30% after a six day delay. Deterioration in knowledge is also evident when semantic information is explicitly taught. Nation et al. taught 8-9 year old children four non-words and assessed semantic learning through a definition naming task (max score = 4). The performance of the Poor Comprehenders declined from 2.50 on day one to 1.42 on day seven, thus an average of one item was forgotten over the week. Like Ricketts et al., Nation et al. also administered a non-word to picture matching task; however performance for both groups was close to ceiling, thus limiting the interpretability of the results.

Further evidence that Poor Comprehenders are significantly worse than TD peers at retaining new semantic information is provided by Cain et al. (2001), who taught 7-8 year old children 12 facts about an imaginary planet called ‘Gan’. The facts fell into three categories, those regarding people/animals (e.g. “Bears on Gan have bright blue fur”), facts about the environment, and those referring to a common object. The experimenter read aloud the sentences, repeating them until the children had perfect verbal recall of the items and achieved 100% accuracy on a forced-choice picture recognition task, which contained the target and three distractor items. For both groups, the majority of items were correctly recalled on the first trial. However, there was a trend for the skilled comprehenders to learn the items more quickly than the poorer comprehenders (recall task $p = .062$, recognition task $p =.067$). The children were then read six stories containing these facts and answered comprehension questions. Following this, they were retested on the verbal recall task and there were no group differences in accuracy. However, when the test was administered again seven days later, the skilled comprehenders achieved significantly higher scores than the poorer comprehenders ($p < .05$). Therefore the poorer comprehenders found learning the new information more challenging and were significantly worse at retaining the information.

As many individuals with ASD have a Poor Comprehender profile (cf. Henderson et al., submitted; Nation et al., 2006; Ricketts et al., 2013), it may be expected that retaining semantic information may also be problematic for children with ASD. Indeed, Norbury et al. (2010) found that immediately after learning children with ASD provided fewer semantic details about novel items than their TD peers and group differences were more pronounced four weeks later, although in this study semantic details were learned incidentally, rather than explicitly presented. Therefore, although phonological information may be retained for children with ASD, this may not be the case for semantic information.

Orthography

To date little is known about consolidation of orthographic learning. The most relevant research was conducted by Henderson et al. (2013) who taught TD children aged 5-9 years new science words accompanied by orthographic information. On an explicit measure of orthographic learning (a two-alternative forced-choice task), the ability to recognise the new written forms was maintained over seven days, but did not significantly improve over time. However, in this case, the lack of a consolidation effect may be due to ceiling effects in the orthographic choice task immediately after learning. To my knowledge, no research has explored retention of orthographic forms for children with ASD.

Study Limitations

One limitation of previous work is that, in the majority of cases, children have been asked to learn non-words (e.g. biscal), often presented as 'alien' words. Although this ensures that the stimuli are unfamiliar to all participants and allows stimulus characteristics to be rigorously controlled, it is questionable whether participants generally, and children with developmental disorders specifically, treat non-words in a similar fashion to words which have some relevant meaning (Potts, John, & Kirson, 1989). It may be that retention of information is improved when there is potential for longer term benefit of knowing the words for scholastic purposes. The inclusion of curriculum based vocabulary could also provide a test for word learning in more ecologically valid contexts. Indeed, Henderson et al. (2013) found improvements in the recall and recognition of newly learned science vocabulary in typically developing children 24 hours after instruction, with improvement continuing seven days later in the absence of further instruction. This contrasted with the findings of Nation et al. (2007) and Ricketts et al. (2008) who used non-word stimuli and found that TD children's semantic knowledge was retained but did not increase. The current study focuses on learning science vocabulary as I felt that a focus on factual, curriculum based content would be more accessible and motivating for children with ASD and their TD peers.

The Current Study

The current study investigated whether orthography facilitates oral vocabulary learning for children with ASD, as it does for typically developing children and children with neurodevelopmental disorders such as Down syndrome. The study advances current research on word learning in ASD in a number of key ways. First, I tested the extent to which children with ASD use relative strengths in phonological processing and single word reading, to learn new information. Second, I tested word learning in a non-social yet ecologically relevant context.

Third, I measured both initial learning and retention of knowledge in three domains, production (phonological learning), comprehension (semantic learning) and written form recognition (orthographic learning). Fourth, I presented children with real, low frequency science words from the UK National Curriculum. I anticipated that science topics would be particularly motivating for children and would be important for establishing evidence-based strategies for teaching and learning in ASD (cf. Henderson, et al., 2013). Finally, I included an objective measure of the extent to which children visually focus on the orthographic form, in order to better understand any potential group differences in how children use orthography to support word learning. The study allowed me to answer three key questions:

1. Does the presence of orthography facilitate the oral vocabulary learning of children with ASD? It was hypothesised that phonological, semantic and orthographic learning would be supported by OP in both groups. However, I anticipated group differences on overall task accuracy. I predicted that children with ASD would be more proficient at picture naming than their TD peers (cf. Norbury et al., 2010), but poorer at semantic learning relative to TD peers (cf. Nation et al., 2007; Ricketts et al., 2008). Group differences regarding orthographic learning were less certain, as orthographic learning has not previously been assessed in ASD.

2. Is newly learned information retained over a 24 hour period? Based on previous research, I anticipated that newly learned information would be maintained over a 24-hour period across all three tasks (Henderson et al., 2013). Henderson and colleagues did not observe improvements in word form recognition (orthographic choice) at 24-hours or seven days for TD children. However, after 24 hours there was an increase in semantic knowledge, as assessed by both spoken word to picture matching and definitions tasks. Additionally, previous studies have reported improvements in picture naming (an index of phonological learning) over time for TD children, but not for children with ASD (cf. Norbury et al., 2010). I therefore expected similar improvements in naming for TD children over 24 hours that would not be evident in participants with ASD.

3. Are any group differences in learning and retention due to initial differences in visual attention to the orthographic form? Recent studies have highlighted both enhanced perceptual capacity in individuals with ASD (Remington, Swettenham, & Lavie, 2012) and differences in top-down control of visual attention (Kelly, Walker, & Norbury, 2013), either of which may contribute to group differences in visual fixations to orthographic forms. I therefore recorded eye-movements during learning trials to index the amount of time spent looking at the printed word relative to the image.

Method

Participants

Forty-seven children aged 7-12 years were recruited to the study. Children with ASD (n = 26, 19 male) all held an existing diagnosis based on DSM-IV/ICD-10 criteria from a multi-disciplinary team external to the research group and were currently in receipt of a statement of special educational need for placement in a specialist school or unit serving children with ASD. In addition, they met criteria for ASD on module 3 of the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, (2000). Twenty-one TD children (12 male) were recruited from local schools and communities and did not have any reported special educational needs or a history of ASD, language delay or literacy difficulties. The study protocol was approved by the Research Ethics Committee at Royal Holloway, University of London. Informed, written consent was obtained from all parents and verbal assent was obtained from all children prior to assessment.

In order to ensure that all children had sufficient reading skill to use the written form for learning, inclusion criteria stipulated that children achieved a minimum raw score of 10 (age equivalent of 7 years) on the PDE subtest of the TOWRE. This resulted in the exclusion of six children with ASD. Thus, 20 participants with ASD (15 male) were included in the study. Groups were matched on raw and standard scores of the PDE. I selected non-word, as opposed to real-word, reading because non-words provide a ‘purer’ measure of phonological decoding, less subject to the influences of existing vocabulary and reading comprehension abilities (Nation & Snowling, 1998). Indeed, although the groups did not differ significantly on chronological age or cognitive ability, they differed significantly on measures of expressive and receptive vocabulary and sight word reading, though mean scores were within the average range (see Table 8.1).

Table 8.1

Descriptive Statistics for TD Children and Children with ASD

Variable		TD n=21	ASD n=20	*t* value	*p* value
Chronological age (years)		10.46 (.92)	10.57 (1.37)	-.30	.766
Gender:	Male	12	15	χ^2 = 1.45	.228
	Female	9	5		
WASI matrix reasoning (T-score)		50.29 (6.04)	51.75 (8.89)	.62	.542
Language:					
Vocabulary definitions WASI (T-score)		54.05 (10.41)	57.85 (13.10)	1.68	.101
Expressive one-word picture vocabulary test (Standard score)		110.05 (9.64)	98.52 (14.54)	2.93	.006
Receptive one-word picture vocabulary test (Standard score)		110.19 (11.68)	95.60 (20.01)	2.83	.008
CELF Recalling Sentences (Scaled score)		9.76 (2.02)	7.44 (4.15)	2.16	.041
Reading:					
TOWRE SWE	Raw score	69.88 (6.18)	63.10 (15.25)	1.85	.076
	Standard Score	104.10 (9.61)	95.48 (13.11)	2.41	.022
TOWRE PDE	Raw score	38.00 (8.32)	34.53 (11.41)	1.19	.270
	Standard Score	105.69 (12.48)	101.13 (16.94)	.99	.335
Autistic symptomatology:					
SCQ (Total)		3.47 (2.67)	22.27 (5.91)	11.83	< .001
ADOS (Total)			11.92 (3.84)		

Materials

Two lists of eight low-frequency words associated with secondary school (ages 11-16) science curriculum were constructed from stimuli created by Henderson et al. (2013; see Appendix F for complete list of stimuli). Each list contained three words relating to animals (e.g. ‘smolt’), two words relating to plants (e.g. ‘lantana’) and three words relating to neither animals nor plants (other category, e.g. ‘breccia’). Lists were counterbalanced across participants. Words were rated for age of acquisition, familiarity, and imageability by 18 educational professionals (teachers, teaching assistants) and researchers who work with children (mean age 26.4 years; SD = 4.82 years; 4 males, 14 females; Henderson, et al., 2013). As summarised in Table 8.2, the words in Set A and B were closely matched for age of acquisition (AOA), familiarity, imageability and length (number of letters and number of syllables). The images were coloured photographs obtained from www.clipart.com and www.fotosearch.com/clip-art, as children are able to generalise word meanings from picture books better if the books contain realistic photographs or colour drawings rather than simple line drawings (e.g., Simcock & DeLoache, 2006, 2008; Tare, Chiong, Ganea, & DeLoache, 2010).

Table 8.2

Stimuli Characteristics: Mean (SD) and Range

	Set A	Set B	*t* value	*p* value
Age of Acquisition	17.15 (2.66) 14.20-23.00	16.08 (1.93) 14.00-19.50	.92	.375
Familiarity	2.55 (2.67) 0.27-8.83	2.75 (2.21) 0.30-5.40	-.16	.873
Imageability	1.64 (1.16) 0.20-3.40	2.11 (1.93) 0.70-5.40	-.59	.567
Number of letters	7.38 (1.85) 5-11	6.88 (1.46) 4-9	.60	.557
Number of syllables	2.50 (.76) 1-3	2.50 (.54) 2-3	.00	1.00

Procedure

The experiment had a 'learning' phase and a 'test' phase and was programmed using E-Prime (Psychology Software Tools, Pittsburgh, PA). Prior to the learning phase, each word was heard once by the children and they were asked whether they knew the word. Any YES responses were probed further (i.e.by asking children to provide a definition 'what is an X; what do you know about an X'). None of the children provided an accurate definition for any of the words. In addition to ensuring that the stimuli were unknown, this procedure familiarised the children with the words prior to learning (cf. Ricketts et al., 2009).

Learning phase

During the learning phase, eye-movements were recorded binocularly using a Tobii T120 eye tracker, which has an average gaze position error of 0.5° and a spatial resolution of 0.2°. Although the T120 can sample at a maximum rate of 120 Hz, it is less tolerant of the extreme head movements observed in some ASD participants. Consequently, a 60 Hz sampling rate was utilised for this study. Children viewed the screen from a distance of 60 cm. Prior to testing, a 5-point calibration and validation procedure was conducted in Tobii Studio software and repeated throughout the testing session as required. Raw data were extracted and analysed using custom written Matlab (The Mathworks, MA) code. Two regions of interest (ROIs) were identified: the picture region measuring 10.5° x 10.7° visual angle and the word region measuring 7° x 2.8°. Fixations were defined as stable looking (±0.5°) for a minimum of 100 ms. Eye-tracking data was unavailable for one TD participant due to technical error.

During the learning phase, children heard a word paired with the corresponding picture. The picture remained on the screen for 500 ms. The 16 stimuli (eight presented with OP and eight OA) were presented in random order. During the first exposure, children listened to the words whilst viewing the pictures on the computer screen. On the second exposure, trials were followed with the question 'Is this to do with animals or plants or neither?' Children responded by pressing the relevant keyboard key (marked a, p, o with stickers). Visual feedback regarding accuracy was provided. During the learning phase children were exposed to each stimulus twice, as piloting with four exposures yielded ceiling effects on two of the three post-tests for TD children.

Test phase

Phonological, semantic and orthographic learning were assessed through three tasks, which were administered in the following order.

1. Picture naming: Children were presented with a picture and asked to name it, providing an index of phonological learning. Presentation order was randomised and accuracy recorded.
2. Spoken word-picture matching: Children heard a spoken word accompanied by four images. One of these was the target stimulus and the other three items were distracter items from the stimulus set. Children were asked to identify the relevant picture by pressing the appropriate keyboard key (marked 1, 2, 3 or 4 with stickers). Presentation order was randomised and accuracy recorded. This task measures comprehension of newly learned words and taps very basic semantic knowledge of new forms.
3. Orthographic choice task: Children heard a word accompanied by the written form and a foil (e.g. *'catalyst'* and *'catalist'*). They were instructed to identify the correct spelling by pressing the corresponding key on the keyboard. Presentation order was randomised and accuracy recorded.

On Day 1, there was a 5-10 minutes break between the learning and the test phase during which time children completed the matrix reasoning task. The three learning outcome measures were re-administered the following day.

Results

Do Children with ASD Fixate on Orthography to the Same Extent as TD peers?

The average duration of fixations to each of the word and picture ROIs, as well as the percentage of total fixations to each of these regions was examined (Table 8.3). In the orthography present condition, there were no significant group differences in average fixation duration or percentage of total fixations to the word region, ts < 1. There were, however, marginal differences in the duration of looking time to the picture, with the TD group gazing on average 300 ms longer than ASD peers, *t*(38) = 1.96, *p* = .057. The percentage of total fixations made to the picture region was similar between groups in the OP condition, *t*(38) = .19, *p* = .850. In the OA condition, both groups spent considerably more time fixating the picture region (than in the OP condition) and there were no group differences in total fixation time, *t*(37) = 1.70, *p* = .100, or percentage of fixations to the picture region, *t*(37) = 1.56, *p* = .127. There were marginal differences in the duration, *t*(37) = 2.00, *p* = .053 and percentage of looking times, *t*(37) = 1.96, *p* = .058, to the word region. The ASD group looked slightly more frequently to this region, even though there was nothing in it.

Table 8.3

Mean Percentage of Fixations to Word and Picture Regions of Interest (ROI), and Mean Fixation Duration (in seconds) to Each ROI During the Learning Phase

	TD	**ASD**	***t*-value**	***p*-value**
Orthography present:				
Percent fixations to word region	30.09 (8.29)	30.66 (8.08)	.07	.793
Percent fixations to picture region	66.08 (7.00)	65.62 (8.40)	.19	.850
Duration of fixations on the word region (seconds)	.86 (.29)	.83 (.35)	.24	.514
Duration of fixations on the picture (seconds)	2.23 (.50)	1.92 (.47)	1.96	.057
Orthography absent:				
Percent fixations to word region	3.84 (2.56)	6.59 (5.58)	1.96	.058
Percent fixations to picture region	89.02 (6.05)	85.91 (6.41)	2.44	.127
Duration of fixations on the word region (seconds)	.17 (.11)	.29 (.23)	2.00	.053
Duration of fixations on the picture (seconds)	3.91 (.68)	3.43 (1.03)	2.90	.097

Does Orthography Facilitate Vocabulary Learning, and is Knowledge Retained?

Picture Naming

This was a challenging task, with mean accuracy rates of less than 12% on Day 1, rising to 38% on Day 2. Four children (two TD and two with ASD) were unable to name any pictures correctly. Nevertheless, as illustrated in Figure 8.1, the presence of orthography did support picture naming accuracy in both groups. Raw scores were entered into a 2 (group: TD versus ASD) x 2 (orthography: OP versus OA) x 2 (day) repeated measures analysis of variance. There was a main effect of orthography by participants $F_1(1, 39) = 32.08$, $p < .001$, $\eta_p^2 = .45$ and by items $F_2(1, 15) = 16.43$, $p = .001$, $\eta_p^2 = .52$, confirming that items learned in the OP condition were named more accurately than the items in the OA condition. There was also a main effect of day $F_1(1, 39) = 34.69$, $p < .001$, $\eta_p^2 = .47$; $F_2(1, 15) = 12.48$, $p = .003$, $\eta_p^2 = .45$, with higher accuracy scores attained on Day 2. There was a small, but significant main effect of group by participants, $F_1(1, 39) = 4.14$, $p = .049$, $\eta_p^2 = .10$, but this was not significant by items, $F_2(1,15) = 1.74$, $p = .210$, $\eta_p^2 = .10$. Children with ASD tended to name more pictures accurately than TD peers, although the effect size was small. There was a day x orthography interaction by participants, $F_1(1, 39) = 4.76$, $p = .035$, $\eta_p^2 = .11$, but not by items, $F_2 < 1$. In general, the effect of OP was more pronounced on Day 2 (t(40)=5.94, p <.001, Cohens *d* = .90) than Day 1 (t(40)=3.68, p = .001, Cohens *d* = .76). None of the other interaction terms were significant, all *F*s < 1.

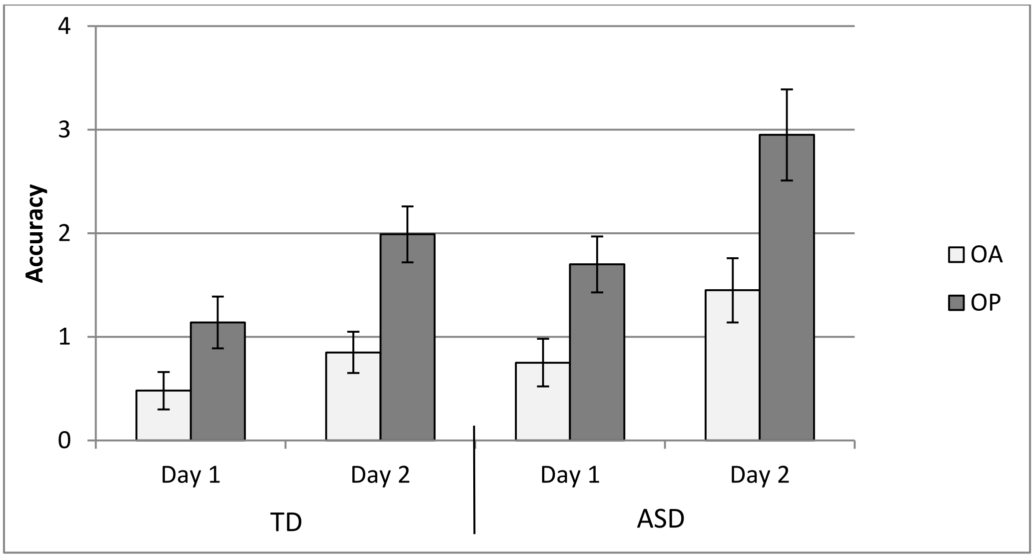

Figure 8.1 *Mean Accuracy on the Picture Naming Task for TD and ASD Children (Maximum Score = 8). Error Bars Represent Standard Error.*

Spoken Word to Picture Matching

Overall, accuracy scores averaged between 62% and 81% correct for both groups, indicating that despite relatively few exposures, children were able to learn the words well enough to distinguish them from other items to which they had been exposed. A 2 (group) x 2 (orthography) x 2 (day) repeated measures ANOVA was conducted on word to picture matching accuracy scores (maximum score = 8). As illustrated by Figure 2, there was a main effect of orthography by participants $F_1(1, 39) = 6.33$, $p = .016$, $\eta_p^2 = .14$ and by items $F_2(1, 15) = 5.04$, $p = .040$, $\eta_p^2 = .25$, with higher accuracy scores for items learned with OP. There was no main effect of day $F_1(1, 39) = 1.69$, $p = .204$, $F_2(1, 15) = .34$, $p = .570$, and no main effect of group $F_1(1, 39) = .09$, $p = .779$, $F_2(1, 15) = .51$, $p = .490$. There was a significant orthography x group interaction by participants, $F_1(1, 39) =5.01$, $p = .031$, $\eta_p^2 = .14$, but not by items, $F_2 < 1$. Paired samples t-tests demonstrated that there was not a significant difference between the OP and OA accuracy scores for the TD group, $t(20) = .22$, $p = .825$. The ASD group, however, achieved significantly higher scores for words learned in the OP condition relative to the OA condition, $t(20) = 3.00$, $p = .007$, $\eta_p^2 = .32$.

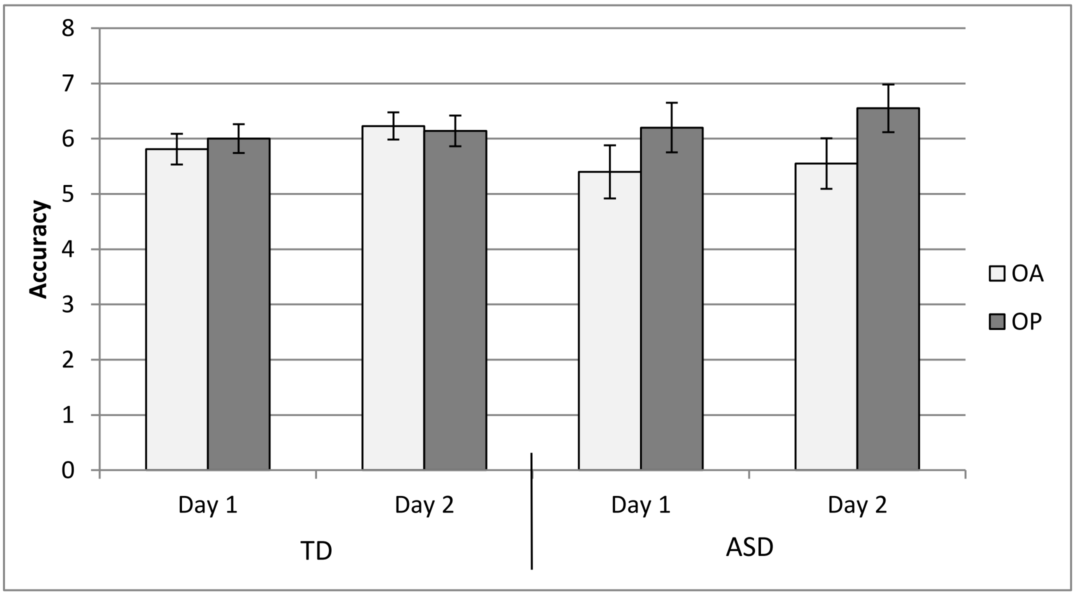

Figure 8.2 *Mean Accuracy on the Spoken Word to Picture Matching Task for TD and ASD Children. Error Bars Represent Standard Error.*

Orthographic Choice

As with the word to picture matching task, accuracy on the orthographic choice task was uniformly high, averaging between 62% and 87% correct. A 2 (group) x 2 (orthography) x 2 (day) repeated measures ANOVA revealed a main effect of orthography by participants $F_1(1,39) = 20.27$, $p < .001$, $\eta_p^2 = .34$ and by items $F_2(1, 15) = 9.09$, $p = .009$, $\eta_p^2 = .38$, such that items learned with OP were more accurate than the items learned without orthography. There were no main effects of day, F_1 and $F_2 < 1$. The main effect of group approached significance, $F1(1, 39) = 3.52$, $p = .068$, $\eta_p^2 = .08$; $F_2(1, 15) = 4.13$, $p = .060$, $\eta_p^2 = .22$, with tendency for the TD group to achieve higher accuracy scores than the ASD group. None of the interaction terms were significant by participants or by items, all *F*s < 1.00.

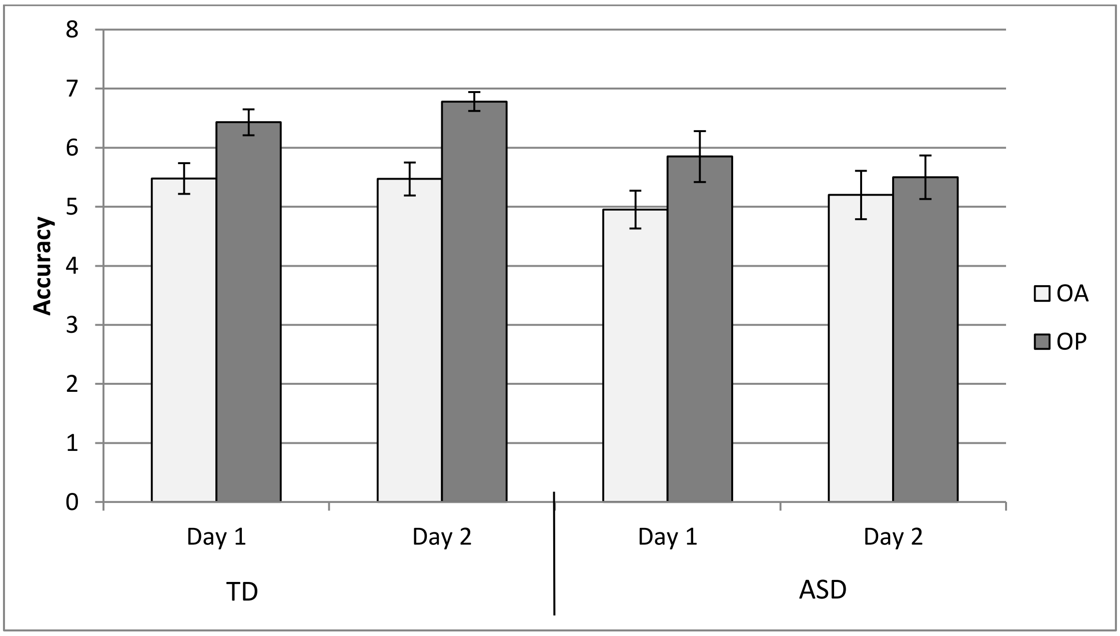

Figure 8.3 *Mean Accuracy on the Orthographic Choice Task for TD and ASD Children. Error Bars Represent Standard Error.*

Summary

Orthography facilitated the learning of phonological, semantic and orthographic characteristics of new words for children with ASD and their TD peers. Both groups benefited from the presence of orthography during learning, but children with ASD learned phonological information more readily than their

TD peers. While there were no group differences in terms of semantic learning, children with ASD benefitted more from the presence of orthography than their TD peers TD group to show superior semantic learning overall. There was a trend for the TD groups to learn the orthographic form better than their ASD peers, although both groups benefited from the presence of orthography during learning. Both groups retained semantic and orthographic knowledge from Day 1 to Day 2, and naming accuracy (an index on phonological learning) increased overnight for both groups.

Discussion

This study investigated whether orthography facilitates oral vocabulary learning for school-aged children with ASD who, as a group, had age-appropriate decoding skills. Children were taught 16 low-frequency science words and learning was assessed via three post-tests; picture naming, spoken-word to picture matching and orthographic choice. The key finding is that orthography facilitated learning for both groups of children, particularly phonological and orthographic details of new words, and that new information was retained over a 24-hour period. In the remainder of this paper I return to the questions posed in the introduction.

Does Orthography Support Oral Vocabulary Learning for Children with ASD?

Vocabulary learning is facilitated by the presence of orthography for TD children (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008) and children with Down syndrome (Mengoni et al., 2013). The present study extends these findings by demonstrating for the first time that this is also the case for children with ASD who had developed proficient phonological decoding and single word reading skills.

There were, however, subtle differences between children with ASD and their typically developing peers. Consistent with previous research (Norbury, et al., 2010), children with ASD learned the names of the new items more readily than their TD peers, suggesting that immediate phonological learning may be an area of strength for some children with ASD and may circumvent social-cognitive limits to word learning. However, the performance of the children with ASD was significantly poorer than the TD group on standardised measures of vocabulary knowledge and single, sight-word reading proficiency. Thus, there is a disparity between children with ASD's ability to acquire information about new word forms and meanings, and the storage, integration and retrieval of this lexical information over a longer period of time. In addition, while recognition of new words was very good, overall rates of naming accuracy in this study were disappointingly low in both ASD and TD groups (cf. Mengoni et al., 2013). It is likely that this reflects the relatively large number of words to be learned (n = 16) and the limited number of exposures children received (one pre-learning exposure and two exposures during the learning phase). Future research will need to vary both the number of new words to be learned and the number of exposures required for each word in order to determine an optimal learning environment.

Orthography was particularly beneficial for children with ASD when learning novel orthographic forms, more so than for TD peers. Analyses suggested that this was because TD children outperformed children with ASD in the OA condition, and thus did not need to make use of orthography in the same way. The TD children had greater existing orthographic knowledge, as indexed by higher TOWRE SWE scores; it is therefore possible that they were able to generate the orthography independently, whereas children with ASD were less likely to do so. A more direct test of this hypothesis would be to ask children to spell words that had been learned in OA and OP conditions. An alternative strategy would be to see whether actively engaging orthographical learning, for example by instructing the children to read aloud the written form, would generalise to the OA condition.

One could ask whether it is the orthography specifically that supports learning, or just the presence of additional information or cues that supports representations of new words. Mengoni et al.(2013) attempted to distinguish these two possibilities by including unfamiliar symbols in the 'OA' condition and found that indeed, only the presence of meaningful orthography facilitated vocabulary learning. I chose not to include such a control in my experiment. First, it is not apparent that having additional visual stimuli is necessarily helpful, and is arguably only helpful if children can implicitly form associations between these visual symbols and the new words. There is considerable debate as to whether or not associative learning mechanisms develop appropriately in ASD and little evidence that such mechanisms would be employed implicitly. Furthermore, there is evidence that at least some individuals with ASD may attend more to visual items in the periphery (Remington et al., 2012) and this could serve to distract children with ASD from the task at hand (cf. Kelly, et al., 2013). Future studies could usefully contrast learning with orthography to learning in other conditions in which meaningful information (i.e. definitions or semantic cues) are also provided (cf. Henderson et al., 2013).

Orthography is thought to support oral vocabulary learning because the written form provides cues to pronunciation. On this view, orthography should be particularly beneficial when the words to be learned have consistent grapheme-phoneme correspondences. Indeed, previous research has demonstrated that regular words are learned more readily than irregular words (Wang, Castles, & Nickels, 2012), though orthography is most beneficial for learning new words with irregular spellings (Ricketts et al., 2009, but see Rastle, McCormick, Bayliss & Davis, 2011). I did not control for regularity in the present study; to provide such a control would require use of non-word stimuli, as employed by Ricketts et al. (2009) and Mengoni et al. (2013). Given the educational challenges children with ASD face, I felt it would be more beneficial to see if I could support learning of words that had scholastic relevance. In addition, it is questionable whether participants generally, and children with developmental disorders in particular, treat non-words in a similar fashion to words which have some relevant meaning (Potts et al., 1989). I felt that science words in particular would be motivating to school-aged children and tap an area of interest for many individuals with ASD.

Is Newly Learned Information Retained?

The ultimate goal of learning is to provide long term, stable representations of new word knowledge, something that requires a prolonged process of memory consolidation. Few previous studies of word learning in ASD have measured longer term retention of newly learned words. Norbury et al. (2010) reported that in ASD, phonological learning, as indexed by a picture naming task, remained stable over a four-week period. In contrast, the performance of TD peers improved over the same period. In the current study, naming performance improved for both groups over a 24-hour period, and this improvement was particularly evident if the word was learned with orthography present. It is therefore possible that orthography influences consolidation processes, which may be qualitatively different in children with ASD (Henderson et al., 2014). A more stringent test of consolidation would be to measure the extent to which newly learned words engage in lexical competition with similar known words (cf. Henderson et al., 2012; Henderson, Powell, et al., 2013). Exploration of knowledge retention over a longer period is also necessary.

In contrast, though consistent with previous research (Cain et al., 2001; Nation et al., 2007; Norbury et al., 2010; Ricketts et al., 2008), in the current study there was no improvement in either group on the word to picture matching task or the orthographic choice task, but neither did children ‘forget’ newly learned material.

Are there Any Group Differences in Visual Attention to the Orthographic Form?

Unlike previous studies, I used eye-tracking methods to ensure that participants at least inspected orthographic forms to a similar degree. The inclusion of eye-tracking during learning revealed that both groups of children fixated the written form to a similar extent. In the orthography absent condition, children with ASD looked longer to the word region, perhaps suggesting that they actively sought this additional cue to learning. There were small, but significant differences in fixation duration to the picture, with the TD group gazing longer at the image. Subtle differences in the allocation of visual attention to different sources of information during the learning process did not interfere with performance in this task, but may contribute to the quality of representations acquired over time.

Limitations and Future Directions

The results are encouraging in demonstrating that providing orthography supports learning of complex concepts for children with ASD. However, the participants were a relatively able group with word and non-word reading scores within the normal range. A significant proportion of children with ASD are not proficient at decoding text (Nation et al., 2006) and it is therefore unlikely that presenting orthography alone would facilitate word learning in the same way. An important question for future research is whether presenting the orthographic form supports learning or actually hinders vocabulary development by diverting attention and processing resources from other aspects of word learning. For example, a child struggling to read may spend more processing effort trying to decode a word and not attend to the referent or link the referent with the spoken phonological form. Application of eye-tracking measures in word learning tasks aimed at a more diverse group of learners with ASD should elucidate this matter. However, my research does suggest that there are potential alternative routes to word learning in ASD. Thus, in order to understand the heterogeneity that exists in vocabulary development within this population, it is necessary to consider individual differences in a range of cognitive skills, including social-cognitive abilities (Luyster & Lord, 2009), phonological skill (cf. Jones et al., 2009) and reading competence (Nation et al., 2006).

It is also important to note that a primitive measure of semantic learning was utilised, that is, a written word to picture matching task. There was not a significant main effect of group, although differences may have been evident if a more nuanced measure of semantic learning, such as a definitions task, was employed. Using such a measure, Norbury et al. (2010) found that children with ASD recalled fewer semantic details of novel stimuli than their TD peers. However, such a task has high language demands and this should be taken into consideration if administered to children with language impairments.

I did not measure text comprehension in this study but this is an important skill that may also assist vocabulary development; typically developing children infer new word meanings from written contexts (Carnine, Kameenui, & Coyle, 1984; Herman, Anderson, Pearson, & Nagy, 1987; Jenkins, Stein, & Wysocki, 1984; Nagy et al., 1985). Many verbally able children with ASD have difficulties comprehending texts and are particularly poor at making inferences, despite age-appropriate decoding skills (Norbury & Nation, 2011). This suggests that children with ASD may be able to learn vocabulary that has been explicitly taught, but have difficulty spontaneously using text to learn new words. There is some indication in the data that this is indeed the case; although groups were matched for decoding skill, the children with ASD had significantly poorer overall vocabulary scores.

Developmental and Clinical Implications

Early in development, children's exposure to new words comes almost exclusively through their interactions with other people, and the ability to 'tune-in' to the social cues and intentions of the conversational partner is paramount to learning meaning and uncovering the structural regularities of speech (Kuhl, 2007; Kuhl, Coffey-Corina, Padden, & Dawson, 2005). The social differences that characterise ASD are therefore likely to contribute to the significant delays in acquiring first words and phrases and the often protracted rate of vocabulary development in this group (Kristelle Hudry et al., 2010). In the pre-school years, individual differences in vocabulary growth are likely to be associated with individual differences in social behaviour (Luyster & Lord, 2009; Smith, Mirenda, & Zaidman-Zait, 2007) and phonological and perceptual aptitude (cf. Jones et al., 2009). As children get older, their ability to learn independently from context grows. Here, children with ASD are also likely to be disadvantaged. However, the results suggest that those children who can read will have some facility for learning from print. The National Institute of Child Health and Development (NICHHD, 2010) has argued that at least some vocabulary should be explicitly taught, particularly concepts that are complex and not part of a child's everyday experience. Direct instruction, supported by orthography, is likely to strengthen phonological, semantic and orthographic connections within the lexicon and support longer term retention of new information. In ASD, orthography represents an opportunity to capitalise on strengths in phonology and word reading, to compensate for weaknesses in semantic and social learning. Future research should include classroom-based studies that vary the social context, the number of exposures and the amount of semantic and orthographic information provided to determine the optimal learning contexts for children with ASD.

Conclusion

To summarise, this study explored whether children with ASD can use orthography to facilitate vocabulary learning. The presence of orthography during learning facilitated production, comprehension and recognition of orthographic forms of new words and new knowledge was retained or increased after 24 hours. However, the participants had proficient language and literacy skills and it remains uncertain whether ASD children with poorer reading ability would ascertain similar benefit from the printed form. The results suggest that presenting the written form during oral vocabulary teaching will enhance learning and provide a mechanism for children with ASD to increase word knowledge despite potential limitations in social learning.

Chapter 9: Discussion and Conclusions

The primary aim of this thesis was to explore the reading skills of children with autism spectrum disorders, taking into consideration language phenotype. Researchers have noted that language competence exerts a major influence on the decoding skills of TD children (e.g. Catt et al., 2002) and both oral language competence and decoding skill are associated with text comprehension, in accordance with the Simple View of Reading (Gough & Tunmer, 1986). The studies in this thesis investigated whether this is also the case for children with ASD. It is possible that aspects of autistic phenotype may influence reading comprehension to a greater extent than language skill. For example, it has been suggested that children with ASD have theory of mind deficits (Baron-Cohen et al., 1985), executive dysfunction (Hill, 2004) and weak central coherence (Frith & Happé, 1994), all of which may impair comprehension. However, ASD is also characterised by a restricted range of interests and repetitive behaviours (APA, 2013a), which could facilitate reading development (Bryson, 1994; Talero-Gutierrez, 2000), through greater focus on reading activities.

Chapters 4-6 systematically explored the influence of language phenotype on reading at the single word, sentence and passage level. It was hypothesised that language skill would exert a greater influence than ASD diagnosis on single word, sentence and passage reading accuracy, and on text comprehension. This prediction was confirmed; at each level, reading competence aligned with language phenotype, rather than ASD status. For young TD children, reading skill is also influenced by the home literacy environment (HLE; e.g. Bus et al., 1995). However, it is equivocal whether this is also the case for older children (Halle et al., 1997) and for children with LI (McGinty & Justice, 2009; Sawyer et al., 2014; Skibbe et al., 2008), and the relationship between the HLE and literacy attainment for children with ASD is unexplored. Chapter 7 detailed the HLE of children with ASD and different language phenotypes. It was hypothesised that children with ASD would engage in shared book reading less frequently and/or for a shorter duration, due to difficulties with social interaction. Indeed, the duration of shared book reading was associated with autistic symptomatology. However, frequency was related to language phenotype; parents of children with ALI engaged their children in shared book reading and reading discussion more frequently than parents of TD and ALN children.

The thesis then transitioned from how children with ASD learn to read, to whether they can use their reading skills to learn new information. TD children use orthographic forms to facilitate vocabulary learning (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008). I found that this is also the case for children with ASD who were proficient readers; they were able to use the written form to facilitate oral vocabulary learning as effectively as their TD peers.

This chapter begins by summarising the main findings of this thesis and examining the extent to which they align with previous research. The limitations of the current work are then considered. The next sub-section discusses the theoretical and educational implications of this research programme. This is followed by directions for future research and the thesis conclusions.

Summary of Findings

Reading Development

Numerous research studies have reported the word and non-word reading skills of children with ASD (e.g. Castles et al., 2010; Henderson et al., 2011; Heumer & Mann, 2010; Minshew et al., 1994; Jones et al., 2009; Nation & Norbury, 2011; Newman et al., 2007) in order to characterise their samples. However, very few published studies have explicitly compared word and non-word reading in order to examine the single word reading strategies implemented by children with ASD. The few exceptions include an assessment which combines regular and irregular word reading (Henderson et al., submitted; Minshew et al., 1994; Norbury & Nation, 2011) which is not a pure measure of whole-word recognition. Furthermore, studies tend to include a heterogeneous sample of participants, without taking into consideration the influence of language impairment on literacy development (Henderson et al., submitted; Minshew et al., 1994). Study 1 attempted to overcome these limitations.

The research presented in Chapter 4 assessed whether children with ASD utilise both phonological decoding and whole-word recognition to read single words, and whether a bias towards a particular strategy is evident. This was achieved by administration of non-word reading and irregular word reading tasks. It was hypothesised that overall reading accuracy would align with language skill, rather than ASD diagnosis, whilst reading mechanisms may be associated with autistic phenotype. Indeed, the TD and ALN children demonstrated age-appropriate word reading skills, whereas the ALI and LI children attained standard scores that were on average 1.25 SD below population norms. Additionally, although the majority of children with ASD had equivalent non-word and irregular word reading, nearly 40% of the children with ASD exhibited a bias in favour of whole-word recognition (45% of the ALN sample and 33% of ALI participants), compared to only 14% of non-autistic children. These results suggest that word reading ability is influenced to a greater extent by language ability than ASD symptomatology, but that reading processes may be associated with ASD diagnosis. This finding aligns with the results of Henderson et al. (submitted) who also found that children aged 7-15 with ASD have poorer non-word reading than word reading, and extends them by demonstrating that is the case for both children with ALN and children with ALI.

The second component of reading is comprehension. The majority of research investigating the text comprehension of children with ASD has focussed on the passage level. The limited research exploring comprehension at the sentence level has reported conflicting results, which may be a consequence of the different study designs. For example, studies employing implicit paradigms indicate that the sentence processing of individuals with ASD is intact (Saldaña & Frith, 2007; Tirado & Saldaña, 2013), whereas the results of homograph tasks suggest that individuals with ASD use contextual information less effectively than non-autistic peers, exhibiting a tendency to use the most frequent pronunciation, regardless of the sentence context (Frith & Snowling, 1983; Jolliffe & Baron-Cohen, 1999; López & Leekam, 2003). However, discrepancies may also be attributable to the language and reading competence of the participants. Many studies have included heterogeneous samples and the language skills of the groups are not well characterised.

Chapter 5 examined the implicit sentence processing of children with ASD. The participants read sentences in which the syntactic coherence of the stem and the semantic coherence of the final word was manipulated (cf. Joseph et al., 2008; West and Stanovich, 1978). Uniquely, language phenotype was taken into consideration by including two groups of ASD participants, those with ALN and peers with ALI. Despite being able to read single words, 48% of the children with ALI had insufficient resources to read accurately and fluently at the sentence level. Children with ALN and the ALI children who were able to read sentences benefited from semantic coherence to the same extent as TD peers, as indexed by faster reading pace for semantically coherent, as opposed to incongruous final words. However, the children with ALI derived less facilitation from syntactic coherence than the TD and ALN groups. Thus, language ability exerted an influence on reading accuracy and a subtle influence on sentence processing.

The influence of language ability on comprehension was more evident at the passage level. Passage reading competence was assessed through the NARA-II; children read aloud short stories and then answered comprehension questions. It was expected that reading accuracy and comprehension would align with language ability, rather than ASD status. However, it was anticipated that a Poor Comprehender reading profile would be more prevalent amongst children with ASD. The children with ALN were as accurate as their TD peers in terms of accuracy and comprehension, and both these groups were more accurate than their ALI and LI peers, who did not differ from each other. However, children with ALI were most likely to exhibit a Poor Comprehender' reading profile. Approximately 57% of children with ALI had a disproportionate difficulty with comprehension relative to decoding, compared to only 18% of children with ALN (and none of the TD children). This extends the results of previous studies which have shown that children with ASD are more likely to have a Poor Comprehender reading profile, by demonstrating that this is particularly the case for children with ALI. In contrast, children with ALN tend to be proficient comprehenders, at least using the standard materials presented here.

The NARA-II includes both literal and inferential questions; it is therefore possible that the overall score masks differences in the relative ability of each group to answer qualitatively different questions. Chapter 6 explored the ability of children with different language phenotypes to make inferences from text. Inferencing is a multi-faceted skill which requires an individual to go beyond what is explicitly stated and integrate textual information with prior linguistic and socio-cognitive knowledge. Based on aspects of autistic symptomatology (i.e. difficulties with social interaction and communication) and aspects of autistic cognition (such as WCC and ToM deficits), it has been suggested that inferencing may be particularly challenging for children with ASD. However, inferencing is also highly dependent on language skill (Jolliffe & Baron-Cohen, 1999; Norbury & Bishop, 2002; M. Snowling & Frith, 1986), so children with language impairments were expected to have difficulties with inferencing. Whilst children with ALI and LI did have disproportionate difficulty answering inferential questions relative to literal ones, TD and ALN children did not. Once again, the results demonstrate that an aspect of reading, in this case inferencing, is associated with language skill, rather than ASD status. Additionally, it indicates that the poorer text comprehension of children with language impairments (ALI and LI) may be partially attributable to difficulty with inferencing. This study provides the first evidence that *children* with ALI find inferencing particularly challenging and the first evidence that children with LI struggle to make inferences from *text*.

The results of these three studies indicate that language ability exerts a greater influence on decoding and comprehension skill than ASD symptomatology. However, ASD status is associated with a different pattern of single word reading and an increased likelihood of a Poor Comprehender reading profile.

The Home Literacy Environment (HLE)

The first three studies of this thesis focused on individual child characteristics, but the environment also exerts an influence on reading development. Very few published studies have detailed the HLE of children with ASD and the majority of research focuses on the HLE in early childhood. There is a dearth of research considering the HLE of older children and whether there is a relationship between shared book reading practices and language and / or literacy attainment for children with ASD, as is the case for TD peers (e.g. Bus, et al., 1995). Data regarding the HLE was collected via parental questionnaire and the findings are presented in Chapter 7.

Children with ALN did not differ from their TD peers with regards to enjoyment of reading, shared book reading frequency, reading discussion frequency, independent reading frequency or independent reading duration. In contrast, children with ALI, who were less proficient readers, enjoyed reading less and read independently less frequently and for a shorter duration than their TD and ALN peers. However, they participated in shared book reading and reading discussion with their caregivers more frequently than their non-language impaired peers. This is contrary to the literature on younger TD children, which indicates a positive relationship between shared home literacy practices and language and literacy skill (cf. Bus, et al., 1995). However, for older TD children, parental instruction does not significantly correlate with reading attainment (Halle et al., 1997). Children with ALI may have engaged in shared home literacy practices more frequently than peers because their parents perceived they needed the extra support and they were less able to read alone.

Thus, frequency of shared book reading was *negatively* associated with reading proficiency, and was not related to ASD status. In contrast, duration of shared booked reading did align with ASD symptomatology. Although 23% of TD children usually spend more than 30 minutes reading with a parent, very few children with ASD do so. This may reflect difficulties with social interaction, as children with ASD who participated in shared booked reading practices for less 15 minutes had significantly higher SCQ scores than those who engaged for more than 15 minutes. These findings provide a preliminary insight into the home literacy environment of children with ASD.

Reading to Learn

Whilst previous investigations have highlighted precocious reading skills in children with ASD, it is not clear whether proficient readers use their literacy skills in functional ways. TD children are able to use their reading skills to learn new explicitly taught oral vocabulary (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008) and this is also the case for children with developmental disorders such as Down syndrome (Mengoni et al., 2013). Chapter 8 reports the first study exploring the extent to which children with ALN, who were proficient readers, can use the written form of a word to aid vocabulary learning. Children were taught low-frequency Science words by presenting the spoken word and a pictorial representation, which was accompanied by the written form for 50% of the stimuli. The vocabulary learning of children with ASD who were proficient readers and their TD peers was facilitated by the presence of orthography. Overall, the groups did not differ in comprehension of new words or recognition of new orthographic forms, although the children with ALN demonstrated superior phonological learning (as measured by a picture naming task) relative to TD peers. Additionally, both groups retained or increased new knowledge after 24 hours. The results suggest that presenting the written form during oral vocabulary teaching will enhance learning and provide a mechanism for children with ALN to increase word knowledge despite potential limitations in social learning.

Limitations and Considerations

Sample Characteristics

The Number of Participants

An inherent problem with working with children from clinical populations is the issue of sample size. At least 20 participants with ALN participated in each study, but the number of participants with ALI ranged from 12-21. Although at least 20 participants with ALI were typically recruited for each study, many children were unable to read connected text. They therefore could not complete the tasks and so were excluded from the study. Nevertheless, the number of participants included in the analyses was similar to the number of participants included in previous work (e.g. Nation & Norbury, 2011). However, there are consequences for the statistical analyses. For example, the small sample size restricted the number of predictor variables that could be entered into the regression analysis. Additionally, unequal group sizes increases the chance that two independent variables may be confounded. Unequal group sizes increase the chance that assumptions of homogeneity and sphericity are violated and therefore these were always stringently checked and Greenhouse Giesser corrected values were reported where relevant. The specific post-hoc test utilised was dependent upon the variability within/between conditions, the equality of the sample sizes and the number of comparisons being made.

The Age Range of the Participants

Children aged 7-14 participated in the studies reported in this thesis. Although the groups included in each study were matched for age, the large age range may have affected the results; the inclusion of children with a large range of ages predisposes variation in performance. This variability, which is attributable to developmental differences, may reduce the power to detect group differences. This was circumvented in study 1 (exploring single word reading) and study 2 (passage reading) by the use of standard scores from standardised assessments (CC2 and NARA-II) which take age into account. However, the sentence reading time paradigm employed in study 2 was an experimental measure and thus standard scores were not available. Nevertheless, there was no significant correlation between age and either sentence stem reading pace or final word reading latency for the TD group (all $p > .150$), with the exception of anomalous sentence stems, $p = .012$. However, there were significant negative correlations between age and reading pace for each type of sentence stem and two of three final words (namely plausible and anomalous), all $p < .01$, suggesting that age accounted for a large amount of variation in ASD children's reading times.

As ASD symptom severity can decline in adolescence (McGovern & Sigman, 2005), the influence of ASD symptomatology may vary at different developmental points. Future work should take a developmental approach and examine the relationship between ASD symptomatology and measures of reading competence (both decoding and comprehension) at different time points, ideally in a larger, representative sample. This would enable any changes in relationships over-time to be identified. It would also be interesting to determine whether the relationship between language ability and reading skill varies at different time points. It may be that as time increases the relationship diminishes. If children with ASD are not learning new words from texts, this could affect their decoding skill. Thus, they may have better language ability than single word reading skill. For instance, Norbury and Nation (2011) found that at age 11, there were significant group differences in the single word and non-word reading ability of children with ALN and ALI. At age 14, the ALN group still achieved slightly higher single word and non-word reading scores, however there was not a significant group difference. This resulted from the greater decline in standard scores of the ALN group. Nevertheless the groups still differed significantly in terms of language ability, as indexed by the scores of five language measures.

Additionally, the direction of the relationship between language ability and reading competence for children with ASD could be examined. Proficient reading may facilitate the vocabulary development of children with ASD, as is the case for TD peers (Verhoeven et al., 2011). Indeed, Study 5 found that children with ASD can use their reading skills to facilitate learning of vocabulary which is explicitly taught, and it would be interesting to see whether they can also do so implicitly or when the words are embedded in context.

The Range of ASD Severity

Expression of ASD symptomatology is incredible heterogeneous. In order to reduce variability in the expression and severity of ASD of children who participated in the studies detailed in this thesis, all participants attended either specialist schools or specialist units. Whilst ensuring that the ASD sample was as homogeneous as possible, this may restrict generalizability. Around 70% of children with ASD are now educated in mainstream schools (Keen & Ward, 2004) and the reading development of these children may follow a different trajectory, either as a result of their less severe needs, or as a result of their educational experiences. Children with ASD who have a severe learning disability are more likely to attend a specialist unit than mainstream school (Keen & Ward, 2004).

In addition to excluding children with more minimal symptomatology, children with severe deficits in non-verbal and verbal social communication and behaviours which markedly interfere with functioning were not included in the sample. However, around 30% of children with ASD are unable to produce three words phrases (Hus et al., 2007; Lord, Risi, & Pickles, 2004), thus the sample utilised is not representative of all children with ASD. There is a dearth of research exploring the reading skills of minimally verbal children and the majority of research is in the form of case-studies of children with hyperlexia (e.g. Atkin &

Lorch, 2006; Bryson, Landry, & Smith, 1994; Talero-Gutierrez, 2006). These indicate that children with ASD can learn to read, and often their skill exceeds their cognitive and / or language ability. However, in my experience, these children are likely to be the exception, rather than the norm. I did recruit a group of 16 children aged 8-14 with severe ASD who also had minimal language skills. However the majority of these children struggled to read single words and only six of the children were able to read more than 10 words of the CC2, therefore the rest met the CC2 exclusion criteria. Thus, the data from these children are not reported within this thesis. Children were required to have measurable reading skills and be able to sustain attention in order to complete the tasks, consistent with previous reports (e.g. Henderson et al., submitted; Nation et al., 2006).

Categorisation of Language Impairment

Participants were categorised as either having age-appropriate structural language skills (TD / ALN) or language impairments (ALI / LI). Previous studies which have informed our understanding of reading development consider ‘normal’ language and ‘language impairment’ to be discrete categories (e.g. Lindgren et al., 2009; Norbury & Nation, 2011). Using a categorical approach enables direct comparison with the findings of such studies. However, using this approach also artificially dichotomises the continuous distribution of language skills. It is likely that a child who attains a language assessment standard score of 86 (i.e. one standard point above the impairment cut-off) would perform more similarly on reading measures to a child who achieves a standard score of 84 (indicating impairment), than a child who receives a standard score of 100 (population mean). Additionally, language is multi-dimensional, and there is not a consensus for which aspect of language, or which test of language, is most appropriate for matching groups (Plante et al., 1993).

Thus, in many respects the divide is arbitrary. Nevertheless, the results of neuroimaging studies do indicate that children with LI differ from the TD peers with regard to brain structure. More specifically, TD individuals have larger cortical regions in the left hemisphere than the right hemisphere, especially in key language areas such as the perisylvian region, planum temporale and Heschel’s gyrus. However, for individuals with LI or language-based learning disorders (such as dyslexia) there is reduced or reversed asymmetry in these areas (M. Clark & Plante, 1998; Galaburda, 1989; Gauger et al., 1997; Jernigan et al., 1991; C. Leonard et al., 1996; Plante et al., 1991).

It is also important to consider the long-term stability of language impairment. The presence of LI remains relatively stable from school entry to adulthood (Conti-Ramsden & Botting, 1999a; Johnson et al., 1999; Tomblin, Freese, & Records, 1992; Tomblin, Zhang, Buckwalter, & O'Brien, 2003; Young et al., 2002). However, there are currently no longitudinal studies of different language phenotypes within ASD and so it is unclear how stable the language distinctions are.

To account for these factors, correlational and regression analysis were conducted (where appropriate), as advocated by Jarrold and Brock (2004). In some cases, the whole sample was combined, and ASD symptomatology was entered as a variable. In other instances, the ALN and ALI groups were combined to create an ASD group and the amalgamation of the TD and LI groups created a non-autistic group. This provided a range of scores and larger sample sizes. However, it should be noted that the correlational analysis can determine whether a relationship between two variables is present, but does not specify causation. Nevertheless, the regression analyses enables predictors of variables to be determined.

Group Matching

For each of the studies the TD and ALN groups were stringently matched for age, non-verbal cognitive ability, verbal cognitive ability, language ability and vocabulary knowledge. By nature of the classification, the children with ALI had lower scores on all language assessments. However, they also attained lower scores on the non-verbal cognitive ability task (the Matrix Reasoning sub-test of the WASI; Wechsler, 1999). I did attempt to match all groups for non-verbal ability, but similar to other studies, I found that non-verbal and verbal abilities are highly correlated (cf. Conti-Ramsden, St. Clair, Pickles & Durkin, 2012; Reilly, 2013) and lower non-verbal ability scores are associated with LI and ALI group membership (cf. Dennis, Francis, Cirino, Schachar, Barnes & Fletcher, 2009). It could be suggested that non-verbal reasoning ability should be controlled for in statistical analysis. However, Dennis et al. (2009) present arguments demonstrating that this is theoretically and statistically inappropriate. By including non-verbal reasoning ability as a covariate in the analysis I would be controlling for language ability, the very variable that I am most interested in. Therefore I did not co-vary non-verbal IQ in the analyses. An alternative, would be to only include children with ALI who were of a similar non-verbal ability to their ALN peers, however this would have resulted in an unrepresentative sample and have considerably reduced the generalisability of the findings (Brock & Jarrold, 2004).

Where feasible, and of interest, the ALI group were matched to non-autistic LI peers of a similar cognitive and language ability. Both Burack et al. (2002) and Bishop and Norbury (2005a, 2005b) highlight the benefits of including children with LI as a comparisons for children with ASD; this illuminates which aspects (in this case of reading ability) are associated with ASD diagnosis, and which occur in the context of LI. However, as previously acknowledged there is no accepted prescription for which aspects or tests of language are the most appropriate for matching groups (Plante et al., 1993). In consideration of this, both expressive and receptive vocabulary assessments were administered, as well as the Recalling Sentences subtest of the CELF (Semel et al., 2003), which is a sensitive psycholinguistic marker for LI, for both autistic and non-autistic children (Botting & Conti-Ramsden, 2003; Conti-Ramsden et al., 2001; Riches et al., 2010).

It could be argued that a more appropriate comparison group would comprise younger TD children, matched on either language ability, single word reading ability or reading comprehension. Matching for skills such as these can help to determine whether a strength in one skill is the cause or consequence of a strength in a different skill. Thus, in the current sample such a design could elucidate whether vocabulary deficits can contribute to decoding impairments, or whether they result from reading difficulties. Although in this case, the relationship is likely to be bi-directional. It is necessary to consider the practical aspects of such a design. If groups are matched for language ability, it is likely that the younger children would be at the very earliest stages of learning to read and would have had less reading instruction. Additionally, if groups are matched for reading ability, they may have similar single word knowledge, but different discourse construction or comprehension. Thus, it is not possible to make clear conclusions regarding the role of language skill. Furthermore, TD children are likely to have had different life experiences to children with developmental disorders, as are children of different ages (Burack et al., 2004).

It could also be suggested that the participants should have been matched pair-wise/triplet-wise, rather than at a group level. However, it is uncertain which variables they would be matched on. Children with ASD show a different profile of reading and vocabulary to TD children and therefore matching on one variable, would almost certainly lead to a discrepancy on another variable. For example, some children with ASD have superior expressive language, relative to receptive language (Bartak et al., 1975, 1977; Hudry et al., 2010; Loucas et al., 2008; Lloyd et al., 2006).

The Measures

All of the children with language impairments had a clinical diagnosis of the disorder and were receiving specialist educational support for language impairment. Current language competence was quantified through the Recalling Sentences subtest of the CELF (Semel et al., 2003), rather than a range of CELF tasks. This subtest was selected from the CELF battery as it is a sensitive diagnostic marker of language impairment for both non-autistic children and children with ASD (Botting & Conti-Ramsden, 2003; Conti-Ramsden et al., 2001; Riches et al., 2010). All children had a pre-existing clinical diagnosis of LI and it was not considered necessary to administer the complete CELF. Ethically it is questionable to subject participants to an extensive battery of language assessments that they would find challenging and time consuming, and practically it was difficult to accommodate in the testing schedule.

However, it is acknowledged that administration of multiple components *could* have enabled the relationship between specific aspects of language competence to be explored. For example, the CELF total language score is derived from performance on four core subtests. For children aged 9-12 these are Concepts and Following Directions, Recalling Sentences, Formulated Sentences and Word Classes 2-Total. Nevertheless, there is considerable overlap in the skills required to complete each task, for example receptive language skills, expressive language skills and grammatical knowledge, and therefore performance on the assessments is correlated (all *r*s > 50; Semel, et al., 2003).

Additionally, it would have been prudent to have included a measure of phonological awareness in the test battery. However, previous research has reported that the PA skills of children with ASD are associated with language competence rather than ASD status (Lindgren et al., 2009; C. McGee, 2001; Norbury & Nation, 2011), and that PA ability is positively related with decoding skill (Åsberg & Dahlgren Sandberg, 2012; Jacobs & Richdale, 2013; White et al., 2006). Additionally, for TD children at least, reading proficiency can enhance PA (Nation & Hulme, 2011). Thus, it is therefore likely that the children with ALN who participated in the current study would have better PA than ALI peers.

The ADOS was administered to all participants with ASD. It was not administered to the TD participants in order to 'rule out' the presence of ASD, as it was deemed inappropriate to subject these children to a time-consuming assessment that would not contribute any beneficial information. There is often substantial overlap between LI and ASD symptomatology (Bishop & Norbury, 2002), so it could be argued that all children with LI should have been administered the ADOS in order to ensure that they were not exhibiting autistic tendencies that may have affected their reading development. However, all of the children were in specialist units and I confirmed with educational staff that these children were not suspected of, or previously diagnosed with any ASD diagnosis.

It may have also been beneficial to include measures of autistic cognition such as ToM and WCC. However, the difficulty with such measures is differentiating autistic symptomatology and language ability. Although children with ASD appear to do worse on measures of ToM (Baron-Cohen et al., 1985) and WCC (Frith & Snowling, 1983), assessments of these domains have high language demands. For example, one task frequently used to assess appreciation of mental states is the Strange Stories task (Happé, 1994) and success in dependant on understanding of metaphors, idoms and jokes. This assertion is supported by the finding that children with LI perform worse on this task than their TD peers (Farmer, 2000). Norbury (2005b) further explored ToM task performance and found that children with ALN achieve similar scores to their TD peers, whilst only children with ALI attain lower scores, and perform at a level commensurate with their LI peers. This suggests that ToM tasks tap linguistic skill, more than autistic symptomatology.

Likewise, one frequently employed measure of WCC, namely the homograph task, is highly dependent on language ability. Successful completion of this task requires the understanding that homographs have multiple meanings, to know these multiple meanings and to know that they are associated with different pronunciations, to access the correct meaning/pronunciation and to inhibit the incorrect meaning/pronunciation (even when it is of higher frequency). These skills are all reported to be poorer amongst children with language difficulties (cf. Norbury, 2005), in part due to reduced semantic knowledge. Concordantly, performance on the homograph task aligns with language skill (M. Snowling & Frith, 1986). As a result, it can be difficult to determine whether poor performance on ToM and WCC tasks is attributable to autistic cognition or language difficulty.

Due to the relationship between the HLE and reading ability, it would have been prudent to have collected data regarding parental education level. This would have enabled group matching on an additional factor known to influence reading ability (Bracken & Fischel, 2008; Christian et al., 1998). Instead, a measure of socio-economic status was utilised, which has also been reported to differentiate reading outcomes (Fitzgerald et al., 1991; Sénéchal et al., 1998), and is itself associated with parental education (American Psychological Association, 2013b).

Study Continuity

It would have been ideal to have the same participants partake in all five studies, or at the very least, in studies 1-3. This would have enabled exploration of the relationship between single word, sentence and passage level reading in the same group of participants. Sixty-nine participants were included in at least two of the studies (30 TD, 20 ALN, 19 ALI), of whom 33 participated in all three studies (9TD, 9 ALN and 15 ALI). The majority of children were tested at school and due to time constraints it was not feasible for all children to complete each of the reading tasks, as well as the standardised cognitive and language assessments.

Theoretical Implications

The theoretical implications of the studies reported in this thesis relate to the Simple View of Reading (Gough & Tunmer, 1986) and to theories of autistic cognition, primarily ToM and WCC.

The Simple View of Reading proposes that reading is driven by decoding skill and language competence. The results of studies 1, 2 and 3 demonstrate the intimate relationship between language ability and both decoding and comprehension for both autistic and non-autistic populations. More specifically, in all three studies children with ALN had similar reading accuracy and comprehension to their TD peers. In contrast, children with ALI had significantly poorer reading accuracy, with many participants struggling to read connected text, and comprehension deficits were common. The reading accuracy and comprehension of these children was in line with their LI peers. Furthermore, vocabulary knowledge was a unique and significant predictor of both reading accuracy and comprehension. This provides evidence that the Simple View of Reading is applicable to children with developmental disorders (as well as TD children), strengthening the model. This aligns with and extends the findings of Brown et al. (2013). They conducted a meta-analysis of 36 studies of reading comprehension, including studies in which participants either read, or were read, sentences or texts and all studies included a group of individuals with ASD and a comparison group. They found that 57% of the variance in reading comprehension across the studies was accounted for by semantic knowledge. Similarly, 55% of the variance in reading comprehension across the studies was accounted for by decoding skill.

I also explored the extent to which autistic symptomatology contributed to both reading accuracy and comprehension. Across the first three studies, reading ability aligned with language ability, rather than ASD status. Furthermore, autistic diagnosis did not contribute any variance in regression analysis and neither did autistic symptomatology, whether indexed by the SCQ or the ADOS. This aligns with the results of Brown et al. (2013) who concluded that "having ASD alone does not predict reading comprehension deficits" (p.932).

This calls into question the extent to which cognitive theories of ASD can account for the reading development of children with ASD, although, it is acknowledged that the relationship between cognitive theories of ASD and reading proficiency was not explicitly assessed in the studies reported in this thesis. Nevertheless, some researchers have found that certain aspects of autistic symptomatology do account for unique variance in reading comprehension. For example, Ricketts et al. (2013) found that mentalising competency contributed 4-5% of unique variance in the reading comprehension of adolescents with ASD. Despite this small percentage, Ricketts et al. propose that the Simple view of Reading should be "extended to include variables other than word recognition and oral language" (p. 813) and appear to suggest that social behaviour and mental state should be taken into consideration. However, as previously discussed, success on ToM tasks is highly dependent on language ability (Farmer, 2000; Norbury, 2005b), and Ricketts et al. did not take this into consideration. Additionally, it is important to note that ToM deficits are not a universal feature of ASD (Ozonoff et al., 1991; White et al., 2009). At first glance, it may appear that Brown et al.'s (2013) finding that individuals with ASD struggle to comprehend texts with high social demands, yet are more proficient with low social texts, provides support for Ricketts et al.'s proposition. However, closer examination reveals that high social texts tend to be more complex, although this may not be the case with newer materials (cf. White et al., 2009).

To conclude the results of the studies reported in this thesis indicate that the reading accuracy of children with ASD is associated with language competence, and many children with ALI struggle to read connected text. Reading comprehension is underpinned by both decoding and language skill. In contrast, neither reading accuracy or comprehension is influenced by autistic symptomatology. Thus, these findings are commensurate with the Simple View of Reading and do not provide evidence that this model should be extended to incorporate social skill. This conclusion aligns with Brown et al. (2013) who state that

"*…having ASD alone does not necessarily predict that such an individual will have reading comprehension deficits. Instead, more information about the individual needs to be considered, especially language ability, before one can* *accurately predict whether a given individual with ASD will experience significant difficulties with reading comprehension*."(p. 932).

Educational Implications

The educational implications of the studies presented in this thesis shall be divided into three categories, namely, learning to read, the home literacy environment and reading to learn. The educational implications have previously been discussed in each experimental chapter and therefore shall be synthesised here.

Reading Development

In order to target interventions effectively it is important to identify where in the reading process difficulties occur. To this end, this thesis systematically explored reading at the single word, sentence and passage level. The results of this investigation suggested that the reading skills of children with ASD are influenced by language ability to a greater extent than by ASD symptomatology. As a result, interventions should be tailored to the reading and language profile of the individual. Despite being able to read single words presented in isolation, many children with language impairments (both LI and ALI) struggled to read connected text accurately and fluently. Reading fluency creates a link between decoding and comprehension and fluency correlates with performance on comprehension assessments (Fuchs et al., 2001; Pinnell et al., 1995). This suggests that interventions for children who can read single words but struggle with connected text could target reading fluency, as a prerequisite skill for comprehension. However, Adlof, Catts and Little (2006) conducted a longitudinal study of 604 children aged 7-14 and found that decoding and fluency were highly correlated. Additionally, decoding and listening comprehension accounted for unique variance in reading comprehension, whereas fluency did not. Thus, it would be more beneficial to target decoding and listening comprehension, rather than training fluency per se. At the passage level, it is also evident that reading comprehension is driven by decoding ability and vocabulary knowledge, rather than ASD phenotype.

Children with comprehension deficits may also benefit from interventions which target oral language skills, especially vocabulary (Clarke et al., 2010; Whalon, Al Otaiba, & Delano, 2009). Clarke et al. (2010) conducted a randomised controlled trial to assess the efficacy of three interventions designed to improve the reading comprehension of Poor Comprehenders, namely text-comprehension training, oral-language training and a combination of both aspects. Although all three intervention groups showed greater improvements in text comprehension than waiting list controls, only the group receiving the oral language training continued to show increases in comprehension between the end of the intervention and the 11 month follow-up. The impact of vocabulary interventions may be two-fold. First, vocabulary knowledge can facilitate decoding. Having phonological knowledge of words will enable words to be ‘guessed’ based on the morphological units. Second, improving vocabulary knowledge will aid understanding of the words which are decoded, and facilitate ‘educated guesses’ of unknown words based on the context. One specific aspect of reading comprehension which children with language impairments (both LI and ALI) found challenging was inferencing. Research has shown that interventions specifically targeting inferencing can facilitate comprehension (McGee & Johnson, 2003; Yuill & Oakhill, 1988). However, it is plausible that vocabulary interventions could also facilitate inferencing skill. This proposal was discussed in more detail in Chapter 6.

Nevertheless, subtle differences associated with ASD diagnosis did emerge at the single word level; children with ASD were more likely than their TD peers to exhibit a bias towards irregular word reading over non-word reading. For children with ASD who are struggling to use phonological decoding strategies to read, whole-word recognition tuition may be a viable route to facilitate development of reading skill and confidence. As whole-word recognition skills develop, knowledge of orthographic-phonemic connections may progress, enabling skill at translating orthography to phonology to evolve. Indeed, research with individuals with Down syndrome has demonstrated that non-word reading can be facilitated by whole-word reading (Roch & Jarrold, 2012). Determining whether this is also the case for children with ASD is an avenue for future research.

The Home Literacy Environment

In addition to individual characteristics (such as language competence), the reading development of young TD children is associated with environmental influences such as the HLE (cf. Bus et al., 1995). Parent-child shared-book reading interventions can facilitate the development of language (Arnold, Lonigan, Whitehurst, & Epstein, 1994; Hargrave & Sénéchal, 2000; Whitehurst et al., 1994; Whitehurst et al., 1988), although they do not always produce the anticipated benefits (Wake et al., 2013). Likewise, parent-child shared-book reading interventions can facilitate literacy orientation (High, Hopmann, LaGasse, & Linn, 1998; Needlman, Freid, Morley, Taylor, & Zuckerman, 1991), although they do not always result in increases in literacy skill (Goldfeld et al., 2011; Goldfeld et al., 2012).

These findings are promising as these studies suggest that parents may be willing tutors to support targeted interventions. This is emphasised by the results of Study 4. Ninety percent of parents of children with ALI engaged their children in shared book reading activities on a weekly basis, with 55% doing so on an almost daily basis. Similarly, 85% of parents engaged their children in reading discussions on a weekly basis, with 45% of parents doing so most days. This suggests that parents are sensitive to their children’s literacy needs, and they may therefore be well-placed to provide shared-book reading interventions.

Indeed, parent-led shared book reading interventions can facilitate the language development of children with LI (Crain-Thoreson & Dale, 1999), which in turn may result in improvements in literacy. There is a strong relationship between vocabulary knowledge and both decoding and comprehension (cf. Nation & Snowling, 2004) and vocabulary interventions for children with language weaknesses can facilitate reading comprehension (Nash & Snowling, 2006).

Reading to Learn

Study 5 investigated whether children with ASD could use the printed form of the word to facilitate vocabulary learning, as is the case for TD peers (Reitsma, 1983; Ricketts et al., 2009; Rosenthal & Ehri, 2008). The vocabulary learning of both children with ASD, and their TD peers was facilitated by the presence of orthography and phonological, semantic and orthographic knowledge was retained or increased over 24 hours. Therefore presenting the written form during oral vocabulary teaching is likely to enhance learning. This could be implemented by teachers writing new words on the white board, or parents writing novel words on flashcards or magnetic letters on appliances. However, this study focussed on explicit teaching and words were presented individually. It is uncertain whether children with ASD are able to implicitly learn words from texts.

Avenues for Future Research

The language skills of children with ASD are heterogeneous. It is therefore important for authors to clearly define the language skills of their samples, in order to know the population that the results relate to and to facilitate cross-study comparisons. All too often, participants' verbal IQ is reported, but specific measures assessing vocabulary knowledge and structural language skills are not included in the test battery (e.g. Jones et al., 2009).

Additionally, many studies exploring the reading skills of children with ASD include a heterogeneous sample of participants. As a result, there is large variation in the results of standardised assessments and the mean score may not be representative. It is therefore recommended that future research should divide the ASD sample on the basis of language phenotype. However, the stability of these phenotypes is worthy of future consideration. It is uncertain whether stability of language phenotype increases during middle-late childhood. The results of Norbury and Nation (2011) provide initial insight. They assessed the language and literacy skills of children with ASD when they were around age 11 and again three years later. At time 1, the group of students with ALN had significantly higher receptive vocabulary and recalling sentences assessment scores than their ALI peers, although the groups did not differ in terms of phonological skill. At time 2, the ALN and ALI groups differed on all three measures, as well as on spoken sentence comprehension. This suggests that language phenotype is stable during adolescence.

There is also a dearth of longitudinal research exploring the literacy skills of children with ASD. Longitudinal research would enable the developmental trajectories of the reading skills of children with ASD to be determined. To date, there is some evidence that single word reading accuracy standard scores of children with ASD decline in adolescence (Norbury & Nation, 2011). Norbury and Nation reported that 14 students with ALN attained a mean standard score of 98.36 (SD = 10.22) on the Sight Word Efficiency subtests of the TOWRE (Torgesen et al., 1999) at age 11, but four years later the same participants attained a mean standard score of 88.29 (SD = 9.37), a statistically significant decrease. The authors propose that poor text comprehension and inferencing deficits have a negative effect on word reading over time. The results of studies 2 and 3 reported in this thesis do not support the notion that individuals with ALN have comprehension and inferencing deficits, but it is important to note that the participants in these studies were younger. Difficulties may only arise once texts become more complex and task demands exceed capacity. Longitudinal research could determine whether text comprehension does decline over time and whether this results in a corresponding decrease in reading accuracy.

It is also noteworthy that although the single word reading accuracy of the adolescents with ALI declined from at age (M = 83.31 , SD = 14.84) to age 14 (M = 81.23, SD = 11.16) the decline is not steep. It would be interesting to determine whether the continuation of shared book reading activities for children with ALI in middle childhood, and potentially into adolescence, protects against a decrease in relative ability.

Conclusion

The findings of this thesis demonstrate that the heterogeneity in the reading skills of children with ASD mirrors the heterogeneity of the disorder. Indeed, Towgood, Meuwese, Gilbert, Turner and Burgess (2009) suggest that variability is the most defining feature of ASD. Although the common perception is that *all* children with ASD are proficient decoders and poor comprehenders, such a reading profile is not universal. Instead, it is has been demonstrated that language competence exerts a greater influence on reading competence than autistic symptomatology, in line with the Simple View of Reading (Hoover & Gough, 1990). More specifically, children with ASD and age-appropriate language skills were proficient at both word identification and comprehension (at least on the measures utilised). In contrast, children with ASD and language impairments have both decoding and comprehension deficits, the latter of which are partially attributable to difficulties with inferencing. Children with ALN read independently at home as frequently as their TD peers, and they are able to use their reading skill to facilitate vocabulary learning. It is yet to be seen whether children with ALI are able to utilise the reading knowledge they have acquired. However, as they are poorer readers they are likely to need more help to access texts. Indeed, children with ALI participate in shared book reading with their parents more frequently than their non-language impaired peers. This indicates that parents could be key agents in delivering interventions. The results of these studies indicate that interventions could most usefully target language skills, as these underpin both decoding and comprehension. Critically, literacy interventions should be tailored to the reading and language profile of the individual. On the basis of the results of the current thesis, and the pre-existing literature, it is indubitable that “we should not associate autism with any one particular reading profile” (Nation & Norbury, 2005, p. 28).

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Appendix A: CC2 Stimuli (Chapter 4)

Regular words	Irregular words	Non-words
bed	good	norf
long	wolf	gop
mist	work	hest
free	eye	roft
take	give	blick
need	shoe	peng
drop	friend	peef
hand	come	spatch
plant	break	drick
life	blood	crat
middle	island	delk
luck	bowl	farl
chicken	couple	pite
tail	soul	framp
market	sure	brinth
chord	iron	borp
pump	lose	trobe
wedding	cough	gurve
marsh	choir	beft
chance	ceiling	pofe
check	deaf	jeaph
navy	brooch	pleech
flannel	yacht	salpy
stench	tomb	grenty
nerve	routine	stendle
curb	gauge	tapple
context	meringue	seldent
brandy	colonel	brennet
weasel	bouquet	bormil
sleek	shove	bleaner
peril	mauve	ganteen
vista	depot	shoathe
crux	cello	tharque
caddy	gist	morshab
grail	crepe	thurnlurse
inset	genre	phleptish
quaver	chamois	gwextoint
magnate	chassis	spoltchurb
mustang	zealot	floatchtwail
creole	soiree	streanshelth

Appendix B: Tables Reporting Key Data for the Children Within the CC2 Standardisation Range (Chapter 4)

CC2 Raw Scores

Group	Total attempted *M (SD)* *Max=120*	Total accurate *M (SD)* *Max=120*	Irregular accurate *M (SD)* *Max=40*	Non-words accurate *M (SD)* *Max=120*
TD	116.78[a] (4.60)	97.33[a] (12.83)	25.74[a] (4.90)	33.81[a] (6.13)
ALN	114.62[a] (6.12)	86.08[a] (12.49)	22.92[a] (5.09)	28.62[a] (4.89)
ALI	93.00[b] (26.27)	60.08[b] (25.36)	15.77[b] (5.31)	17.38[b] (11.65)
LI	78.58[b] (28.04)	46.00[b] (30.80)	11.17[b] (7.54)	14.50[b] (11.57)

Values with the same superscript to do not differ when p < .05

Regression Analyses Predicting Reading Accuracy

Predictor	β	t	Unique R^2
Total accuracy			
Age	-.29	-3.07	-.43*
Vocabulary	.88	8.34	.79**
SCQ score	-.00	0.23	.00
Irregular word reading			
Age	-.15	-1.47	-.23
Vocabulary Composite	.88	7.67	.76**
SCQ score	.13	1.19	.18
Non-word reading			
Age	-.38	-4.36	-.56**
Vocabulary composite	.88	9.14	.82**
SCQ score	-.06	-.62	-.10

*$p < .05$ **p<.001

CC2 Standard Scores

	TD	ALN	ALI	LI
Irregular SS	108.47[a] (13.81)	107.82[a] (11.71)	80.83[b] (8.77)	77.37[b] (14.57)
Non-word SS	108.73[a] (18.84)	100.62[a] (11.32)	81.34[b] (15.85)	84.13[b] (15.11)
Difference	p = .915	p = .009	p = .880	p = .030

Values with the same superscript to do not differ

CC2 Discrepancies

	TD (%)	ALN (%)	ALI (%)	LI (%)
Non-words = irregular words	59.30	57.10	46.2	66.70
Non-words > irregular words	18.50	7.10	23.10	33.30
Non-words < irregular words	22.20	35.70	30.80	0

Appendix C: Sentence Stimuli (Chapter 5)

Syntactically correct sentence stems	Plausible final word	Anomalous final word
I was tired so went to	bed	chicken
I checked if an egg had been laid by our	chicken	navy
To write I hold a pen in my	hand	brandy
To light the christmas pudding I make it with	brandy	iron
I like submarines so I joined the	navy	wedding
I was bridesmaid at my best friend's	wedding	bowl
I poured my cereal into a	bowl	bouquet
I tied the laces on my	shoe	wolf
Little Red Riding Hood's granny was eaten by a	wolf	shoe
The florist arranged the flowers into a	bouquet	choir
I sang in the church	choir	hand
My shirt was creased so I needed an	iron	yacht
The rich man went sailing in his	yacht	mustard
My engagement ring has a big	diamond	hero
The soldier who fought for his country is a	hero	bed
The robber was armed with a	gun	butter
The murderer was sent to	jail	diamond
I used a knife to spread my toast with	butter	gun
I fed the horse some	hay	jail
On a hot dog I like to have	mustard	hay

Scrambled sentence stems	Final word
Tired I to went so was	bed
An our laid checked by if been egg I had	chicken
In hold my I pen a write to	hand
Pudding we with christmas make to light the it	brandy
The I submarines I like so joined	navy
At best was I friend's bridesmaid my	wedding
Into poured my a I cereal	bowl
Tied my the on laces I	shoe
A eaten granny was Little Red Riding Hood's by	wolf
Florist a the flowers arranged into the	bouquet
I in church the sang	choir
Needed so was my creased an shirt I	iron
Man sailing the went in rich his	yacht
Ring my big has engagement a	diamond
Who a country is fought his the soldier for	hero
A was with robber the armed	gun
Sent murderer to was the	jail
Toast to used spread with a my knife I	butter
Some the horse fed I	hay
On like hot have I a to dog	mustard

Appendix D: NARA-II Details (Chapters 5 and 6)

Sample passage from the NARA-11 'Dragon' (Level 4)

The fearful roaring of the dragon guided the Knight to the monster's territory. As the intruder crossed the dreaded marshes, the dragon charged furiously, whipping its enormous tail around the legs of the knight's steed. Horse and rider collapsed. The knight how realised that he must attack when the creature was off-guard. He crouched as though wounded. The monster, accustomed to speedy victory, prepared to seize its prey. Then the knight struck powerfully beneath the beast's outstretched wing. A despairing groan told the villagers that they would be troubled no more.

Questions and answers from Form 2 of the NARA-11

Surprise Parcel (Level 2)

1. On what day did the parcel arrive? *(Literal)*
    a. Saturday
2. How do you know that Jane and Peter were not expecting the parcel? *(Inferential)*
    a. It was a surprise / It says it was a surprise
3. Who undid the string? *(Literal)*
    a. Jane
4. How do you know that the parcel came from another country? *(Inferential)*
    a. It has strange stamps
5. Who had sent the parcel? *(Literal)*
    a. Their uncle
6. What was in the parcel for Jane? *(Literal)*
    a. Skates
7. What was in the parcel for Peter? *(Literal)*
    a. An electric train
8. Why were the children so pleased to receive the present? *(Inferential)*
    a. They had wanted these things for a long time

Circus (Level 3)

1. Where did this story take place? *(Literal)*
    a. Circus / Tent / Big top / Circus ring
2. Were the lions near the beginning, near the middle or near the end of their act? *(Literal)*
    a. End
3. What was Jack waiting for? *(Literal)*
    a. To clear the ring / To take the lions away
4. Why were the lions restless? *(Literal)*
    a. Thunder had frightened them / Because of the thunder
5. What happened to Tina? *(Literal)*
    a. She stumbled/fell over / she lost her whip / A lion jumped at her
6. What did Jack do? *(Literal)*
    a. He cracked the whip / He saved Tina / He controlled the lions
7. Who finished the act? *(Inferential)*
    a. Jane
8. What did Jack decide after this adventure? *(Inferential)*
    a. That he would be a lion tamer / On his future work… *(explanation required)*

Dragon (Level 4)

1. How did the Knight know exactly where to find the dragon? *(Literal)*
    a. By the roaring of the dragon
2. What kind of land did the Knight have to cross? *(Literal)*
    a. Marsh land / or *similar response*
3. How did the dragon knock the Knight down? *(Inferential)*
    a. By whipping its tail around the horse's legs
4. What did the Knight realise would be a good moment to attack the dragon? *(Literal)*
    a. When the dragon was off-guard/wasn't looking
5. What did the Knight pretend? *(Inferential)*
    a. That he was wounded/hurt/dead

6. Why did the dragon think that its very first blow could kill the Knight? *(Inferential)*
    a. He was used to quick victories / He was very powerful
7. What part of the dragon's body did the Knight strike? *(Literal)*
    a. Under his wing
8. Why were the people in the village pleased? *(Inferential)*
    a. Because they would not be troubled again (by the dragon)

Brigantine (Level 5)

1. What historical voyage were they recreating in this story? *(Literal)*
    a. The voyage of Sir Francis Drake
2. What were the two main aims of the voyage? *(Literal)*
    a. *Both of:* To carry out scientific projects ***and*** provide community services
3. How were the young explorers selected? *(Literal)*
    a. Selected from different nations / Selected for their enthusiasm and different abilities
4. How do you know that the expedition was a great success? *(Inferential)*
    a. Because the voyage had outstripped their dreams / they did more than they had expected / *etc.*
5. How did the young explorers know how to carry out the projects? *(Inferential)*
    a. They were supervised by scientists / Scientists helped them
6. Name two activities undertaken on the voyage *(Literal)*
    a. *Any two of:* They salvaged ancient wrecks / Rebuilt houses / They mapped jungle trail / They studied forests / They did relief work
7. Why did some of the young people have a greater test of their courage than others? *(Inferential)*
    a. They had to overcome disabilities
8. What qualities did the young explorers in general show in this expedition? *(Literal)*
    a. *Both of:* Courage and adaptability ***and*** a spirit of adventure

Everest (Level 6)

1. What did the leader realise the team needed? *(Literal)*
    a. Rest
2. What did the leader decide to do? *(Literal)*
    a. Pitch (an intermediate) camp
3. How did the team feel about the leader's decision to stop climbing? *(Literal)*
    a. They were pleased/relieved
4. What incident had hampered their progress? *(Literal)*
    a. One team member fell into a crevasse
5. What had made them slacken their pace of climbing to a crawl? *(Literal)*
    a. Incessant winds of varying violence
6. What lay ahead of them? *(Literal)*
    a. An unforeseen rise
7. What piece of bad luck had the team noticed? *(Inferential)*
    a. All the tracks of the advance party had disappeared
8. Why would it be exciting to reach the peak? *(Inferential)*
    a. It was unconquered – they would be the first to do so

Appendix E: Home Literacy Environment Questionnaire (Chapter 7)

Demographic details

What is your child's date of birth? _____ / _____ / _____

What sex is your child? Male ☐ Female ☐

What is your relationship to your child?

____

Is English your child's first language? Yes ☐ No ☐

Does your child speak/read in any other languages? Yes ☐ No ☐

If yes: What languages? ____________________________

What language is mainly spoken at home? ____________________

Does your child have a diagnosis? Yes ☐ No ☐
E.g. Autism, language impairment

If yes, please provide more details e.g. diagnosis and age at time of diagnosis

____

Literacy provision

How many children's books are there in your home?
(Do not count children's magazines or school books)

0-10	11-25	26-50	51-100	101+
☐	☐	☐	☐	☐

How often do you borrow children's books from the library for this child?

Rarely or never	About once a month	About twice a month	Most weeks	OR	Don't know
☐	☐	☐	☐		☐

Reading enjoyment

	No	Yes, a little	Yes, a lot
Do you enjoy reading?	☐	☐	☐
Does your child enjoy reading?	☐	☐	☐

Does your child enjoy being read/reading any of the following?

	Yes	No	Don’t know
Fiction books	☐	☐	☐
Factual books	☐	☐	☐
Religious books	☐	☐	☐
Newspapers	☐	☐	☐
Comics	☐	☐	☐
Magazines	☐	☐	☐
Instruction manuals	☐	☐	☐
Websites / computer	☐	☐	☐
Other, please specify	☐	☐	☐

Reading at home

Is there a regular time when you read to your child/ your child reads?

Yes ☐ No ☐

If yes: When is this? ____________________

How long do you usually spend reading with your child? ____________________

How long does your child usually read for? ____________________

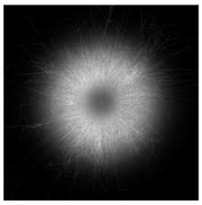
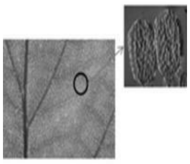
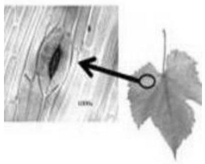
How often do you do the following things?

	Rarely or never	A few times a month	Every week	Almost every day	OR	NA
Read at home (e.g. books, newspapers, magazines)	☐	☐	☐	☐		☐
Read to your child	☐	☐	☐	☐		☐
Read with your child	☐	☐	☐	☐		☐
Listen to your child read	☐	☐	☐	☐		☐
Talk to your child about what he or she has read	☐	☐	☐	☐		☐
Ask your child questions whilst you/they are reading	☐	☐	☐	☐		☐
Encourage your child to read materials that are not part of work for school (e.g. books, magazines)	☐	☐	☐	☐		☐
How often does your child read alone at home?	☐	☐	☐	☐		☐

If you responded NA to any questions, please provide more detail here (continue on the last page if necessary)

Is there anything else that would be useful for me to know about either yours or your child's reading, or about your family's lifestyle? If so, please provide details here. *(Note: A5 side with text box for comments)*

Appendix F: Vocabulary Stimuli (Chapter 8)

Set A		Set B	
Catalyst		Breccia	
Gadfly		Crawdad	
Lantana		Mastodon	
Miscible		Photon	
Palisade		Pupa	
Ratite		Quartzite	
Smolt		Stomata	

Troposphere		Tropism	

Stimuli Characteristics

Stimuli	Age of acquisition	Familiarity	Imageability	Syllables
Set A				
catalyst	15.70	8.53	3.40	3.00
gadfly	18.00	2.47	2.07	2.00
lantana	17.67	0.27	0.20	3.00
miscible	14.20	2.40	1.87	3.00
palisade	15.50	2.47	1.60	3.00
ratite	16.25	0.33	0.60	2.00
smolt	23.00	0.70	0.50	1.00
troposphere	16.86	3.20	2.90	3.00
Average	17.15	2.55	1.64	2.50
Set B				
breccia	14.00	0.30	2.90	3.00
crawdad	17.67	0.50	0.20	2.00
mastodon	19.50	2.40	0.60	3.00
photon	15.20	5.40	1.60	2.00
pupa	14.86	5.10	2.80	2.00
quartzite	16.43	2.10	5.40	2.00
stomata	17.00	5.30	2.00	3.00
tropism	14.00	0.87	4.20	3.00
Average	16.08	2.75	2.11	2.50