ANALYSIS OF PHONOLOGICAL DEVELOPMENT AND READING ACQUISITION IN CHILDREN WITH AUTISM SPECTRUM DISORDER: WHERE DOES COMPREHENSION GET LOST?

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Analysis of Phonological Development and Reading Acquisition in Children with Autism Spectrum Disorder: Where Does Comprehension get Lost?

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Abstract

Reading comprehension in children is often limited by weak decoding skill. Decoding is the transfer or translation of letters into units of meaning, i.e. the understanding of letter strings into words. Children with Autism Spectrum Disorder (ASD) have shown a different pattern in that they have poor reading comprehension but good decoding skill. The aim of this study was to examine some of the possible sources of reading comprehension problems in children with ASD. The target population was children with a diagnosis of ASD who were between the ages of 4 and 9 and who lived in the St. John's, NL area. Ten participants completed tests assessing spelling, vocabulary, non-verbal reasoning, phonological awareness, word decoding as well as word, passage, and listening comprehension. Word decoding was assessed to confirm previous research and as a comparison tool. The children's decoding ability was similar to population means, $t(9) = .44$, $p = .67$, but within the groups sentence comprehension and listening comprehension were found to be poorer than word comprehension, $t(9) = 4.08$, $p < .01$; $t(9) = 3.08$, $p = .01$, respectively. This pattern of findings suggested that problems in reading comprehension that have been observed in children with ASD were likely due to factors other than decoding and could be due to more general difficulties with language processing.

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Table of Contents

Page

Abstract........II

Acknowledgements........III

Table of Contents........IV

List of Tables........V

List of Figures........VI

Introduction........1

Method........24

Results........31

Discussion........44

References........56

Appendices

A........62

B........63

C........64

D........65

E........66

F........67

G........68

H........69

I........70

List of Tables

Table 1 Descriptive statistics for reading and phonological tests. p. 32

Table 2 Comparison of means and standard deviations of Minshew, Goldstein, Taylor, and Seigel (1994) to the findings presented here. p. 35

Table 3 Inter-correlations for tests of reading, listening comprehension, and spelling. p. 38

List of Figures

Figure 1 Mean scores for reading and comprehension tests with a line representing population average showing that Word ID and Word Comprehension are both above population means while Passage Comprehension and Listening Comprehension are below. p. 34

Figure 2 Means and Standard Deviations for Identity tests showing that Vowel ID is lower than both Onset ID and Coda ID. p. 40

Figure 3 Scores for each of the individual participants across standardized reading tests for Word ID, Word Attack, Word Comprehension, Passage Comprehension, and Listening Comprehension. p. 43

Analysis of Phonological Development and Reading Acquisition in Children with Autism Spectrum Disorder: Where Does Comprehension get Lost?

The Diagnostic and Statistical Manual of Mental Disorders (DSM – IV-TR; American Psychiatric Association, 2000) classifies individuals as having Autism Spectrum Disorder (ASD) if they show a total of six or more symptoms from a list of qualitative deficits or impairments in social interaction (e.g. impairment in eye-to-eye gaze, and facial expression; lack of sharing in enjoyment) , communication (e.g. delay in or lack of spoken language; impairment in the ability to sustain conversation), and who may also show repetitive and stereotyped patterns of behaviour (e.g. adherence to non-functional routines). ASD is a spectrum of disorders and may include severe to mild symptoms of autism, Asperger Syndrome or other forms of Pervasive Developmental Disorder (PDD). The fact that the disorder can be classified on a spectrum indicates that each child with autism is unique and will show variation within the criteria of the DSM-IV. As identified with the diagnosis they are later to develop communication skills and often use language inappropriately (Jarrold, Boucher, & Russell, 1997; Wilkinson, 1998). Children with ASD also have poor social and interactive play skills. For example, they often prefer to complete activities on their own time and in their own way, regardless of the usual accepted norm. As well, they often display behaviours that could be characterized as ritualistic or obsessive. They prefer a predictable and unchanging environment and may develop compulsive interests such as a precocious interest in letters and words (Aaron, Frantz, & Manges, 1990). The symptoms of autism can be commonly noticed around the age of 18 to 24 months at which time children typically begin to develop social, communication, and language skills (Mandell, Thompson, Weintraub, DeStephano, & Blank, 2005).

Children with ASD show widespread deficits in many aspects of language including pragmatics, semantics, phonological skills, and syntactic skills (Wilkinson, 1998). These impairments likely lead to deficits in other areas of learning, particularly reading (Jones, 2007). To read, children have to learn to decode words. Decoding involves processing the visual aspects of print and activating the auditory-phonetic characteristics of the speech sounds represented by the print (Martino & Hoffman, 2002). The basis of decoding is the mastery of a cipher in which the reader has learned to form connections between the letters in written words and the phonemes associated with the pronunciation of the letters (Ehri, 1994; Gough & Wren, 1999). When errors in decoding occur in typically developing individuals, reading comprehension may be impaired, and this is what occurs for children with dyslexia (Martino & Hoffman, 2002). In contrast, children with ASD appear to have decoding skills that are as good as those of typically developing children of average reading ability (Frith & Snowling, 1983; Minshew, Goldstein, Taylor & Seigel 1994; Nation, Clarke, Wright & Williams, 2006; Snowling & Frith, 1986), and they have better decoding skills than children with dyslexia (Newman, Macomber, Naples, Babitz, Volkmar, & Grigorenko, 2007). In spite of this good decoding, children with ASD often are poor at comprehending the text that they have decoded (Frith & Snowling, 1983; Holman, 2004; Minshew, Goldstein, Taylor, Siegel, 1994; Nation et al., 2006; Shankweiler, Lundquist, Katz, Stuebing, Fletcher, Brady, Fowler, Dreyer, Marchione, Shaywitz, & Shaywitz, 1999).

The primary purpose of the present study was to investigate some possible sources of the reading comprehension difficulty experienced by children with ASD, as the evidence to date indicated that poor decoding is likely not the primary cause. To address this, real word and non-word decoding were assessed in order to corroborate previous findings on their decoding ability. The present study also assessed vocabulary, spelling, non-verbal intelligence, and listening comprehension to see if any of these factors were associated with reading comprehension. There is evidence that the knowledge and use of vocabulary have been related to the ability to decode and comprehend words accurately (Snowling & Frith, 1986) so vocabulary was tested. Spelling is also an important aspect of reading skill (Fisher, Shankweiler, & Liberman, 1985; Kroese, Hynd, Knight, Himenz, & Hall, 2000). Spelling was tested here to determine how it might relate to non-word decoding and comprehension. Non-verbal intelligence was examined to assess how children in this sample compared to norms and also whether non-verbal intelligence was associated with decoding ability and comprehension. Listening comprehension is a measure of the understanding of language presented orally and was tested in order to make a comparison with reading comprehension.

Although studies have shown that children with ASD can decode words as well as typically developing children, it is not known whether they acquire decoding skills in the same way as do typically developing children. It is possible that children with ASD learn to decode using less efficient or incorrect strategies that may influence their comprehension of text. For example, many children with ASD develop a preoccupation with letters and words (Aaron, Frantz, & Manges, 1990). This intense interest may increase their success at decoding, but does not help with comprehension. Therefore, a second goal of this study is to examine how children with ASD learn to decode words by studying their phonological awareness. Phonological awareness is the development of the knowledge of the sound structure of words (e.g., syllables, onsets, rimes, and phonemes) when they are presented auditorally. Decoding is the ability to apply letter-sound associations to correctly read a word that has been presented visually. To examine these processes the present study included testing procedures based on a study by Breen (2007). Breen isolated the sequence of phonological understanding during the partial alphabetic phase of reading development in typically developing children. Following Breen's procedure might help identify whether children with ASD show differences in this knowledge compared to typically developing children. Collectively, these measures might provide better understanding of how children with ASD decode and comprehend text during reading.

Reading Development in Typical Children

Reading development is the process that children go through to achieve fluent decoding and comprehension of text. Reading development has been described in terms of a sequence of phases or stages (Ehri 1994; 2005; Spear-Swerling & Sternberg, 1994). For example, Ehri (1994, 2005) described four sequential phases: pre-alphabetic, partial alphabetic, full alphabetic, and consolidated alphabetic. Only after progressing through these phases can children become proficient and strategic readers and comprehend efficiently. The first stage involves paired-associate learning in which children remember salient visual cues and link the visual stimulus directly with the pronunciation and meaning of the word. For example, children recognize the word McDonalds from the figure "M" formation which allows them to link the symbol to the pronunciation.

Children in this first phase do not yet use knowledge of the alphabet to read words. The second stage of reading is the partial alphabetic phase or phonetic-cue reading (Spear-Swerling & Sternberg, 1994). In this stage readers begin to gain alphabetic insight, develop phonological awareness, and form connections between letters and sounds in the words (Ehri, 2005). For example the letter B signifies the sound "buh".

Following the partial-alphabetic stage readers proceed to the full alphabetic phase as knowledge of the correspondence between letters and their pronunciation increases and print-to-sound connections are complete. In this phase readers can now decode unknown words by transforming unfamiliar spellings of words into recognizable pronunciations (Ehri, 1994; Fisher, Shankweiler, & Liberman, 1985; Kroese, Hynd, Knight, Himenz, & Hall, 2000; Masonheimer, Drum, & Ehri, 1984; Treiman, Sotak, & Bowman, 2001). Finally, in the consolidated alphabetic phase readers read increasingly more sight words (Ehri, 2005). Children learn to recognize letter strings as consolidated units and can easily retrieve the sound represented by the string from memory (Ehri, 1994). These consolidated units represent morphemes, syllables, onsets and rimes, or short words. Once in the consolidated phase the ability to retrieve information about decoding from memory occurs more quickly.

Decoding is an important process that improves and develops through all the phases of reading and it becomes increasingly sophisticated. With development and increasing experience, decoding becomes less effortful and more automatic, leaving more mental resources available for proper comprehension of material. Good reading comprehension is a complex process that requires automatic decoding skills. In addition, reading comprehension requires the search of long-term memory to integrate background information with the decoded information (Ehri, 1994, 2005; Spear-Swerling & Sternberg, 1994). If decoding is effortful, resources are allocated to decoding the words and not to extracting the information from sentences and integrating information from successive sentences. Automatic decoding requires minimal cognitive resources freeing mental resources which can be devoted to comprehension and retention (LaBerge & Samuels, 1974; Stanovich, 1982).

After achieving the consolidated alphabetic stage, in which readers have automatic decoding that is effortless, they can develop into strategic and proficient readers who can employ various comprehension strategies. The process of reading comprehension begins with the orthographic representations of words from which the reader must retrieve the pronunciation and meaning of the word. The reader must then extract the syntax of each sentence and integrate the syntax with the word meanings required to construct the meaning of each sentence. Readers must then integrate the new information in the most recent sentence with background information stored in memory to formulate a mental representation of the presented information (Snow & Sweet, 2003). For highly proficient reading, strategies making higher-order connections among different sources are critical. For example, the reader must interpret the meaning of both sentence and background information and use fix up strategies, such as monitoring, re-reading, reading ahead or looking up definitions of unknown words. Moreover, they must integrate information from the sentences before with the current sentence to get the bigger picture (Spear-Swerling & Sternberg, 1994).

As reading development progresses, readers become better and more efficient at decoding words, until finally they achieve the ability to decode automatically. Atypical reading development occurs when there is a failure to attain all the skills that are necessary for proficient reading (Spear-Swirling & Sternberg, 1994). For example, dyslexia may occur in otherwise normally developing children who experience phonological deficits and cannot proceed through the normal sequence of reading development (Spear-Swirling & Sternberg, 1994). Individuals with dyslexia show phonemic deficits such as poor phonological awareness and slow retrieval of words that cause difficulty in learning letter-sound associations (Aaron, Frantz, & Manges, 1990; Golinkoff & Rosinski, 1976). This poor ability to form letter-sound associations as well as slow word retrieval interferes with the development of automatic decoding. Therefore, children with dyslexia do not attain automatic decoding and, as a result, have difficulty making use of reading comprehension strategies, such as making inferences, predicting from context, and glancing back.

Reading in Children with Autism Spectrum Disorder

Good decoding skills have been shown to be an important pre-requisite for good reading comprehension in typically developing children. Poor decoding in children with dyslexia limits their comprehension and consequently their reading performance (Martino & Hoffman, 2002; Sabatini, 2002; Stanovich, Cunningham, & Freeman, 1984). Interestingly, children with ASD have good decoding skills but poor reading comprehension. The phases of reading development just described show how typically developing children learn to read and the steps involved with each phase. Several research groups have examined the pattern of decoding and comprehension skills in children with ASD.

In an early study, Frith and Snowling (1983) compared children with ASD to typically developing children and children with dyslexia. Children were aged 9 to 17 and groups were matched for reading age. The children completed tests for decoding non-words, concrete words, and abstract words. The authors found that typically developing children and children with autism were both able to decode accurately and showed average performance on all decoding tasks. The typically developing children and the children with autism had significantly better non-word decoding than the dyslexic children, however the children with autism demonstrated poorer reading comprehension than both typical and dyslexic children. Frith and Snowling (1983) concluded that because children with ASD perform similar to typically developing children and better than dyslexic children, children with autism were able to use phonological and lexical strategies for decoding printed words.

In addition, Frith and Snowling (1983) also explored the aspects of reading that might underlie poor comprehension in children with autism. The authors compared children with autism, typically developing children, and children with dyslexia on homographs, gap tests, and a restricted-choice task. These tests measured the use of syntax and semantics, both of which are important for good comprehension. Syntax refers to the rules and principles in sentence structure and the proper arrangement of words in a sentence. Semantics refers to the meaning of the words and the form of the sentence. For the homographs test children had to read a story with homographs placed throughout (e.g. I tied a *bow*, I had to *bow* to the queen) and correct pronunciation was measured. The children with autism performed worse than both typically developing children and children with dyslexia, indicating that children with ASD do not always use syntax effectively. To further examine this, the gap test was used which measured children's ability to read sentences with a blank and to fill in the word. All children performed similarly in this task in that they were able to make correct syntactic choices. Finally, for the restricted-choice test the children had to remember and use the information read in a short story to pick the correct option for a missing blank in a sentence. There was a choice of three words that would fit the meaning of the text, where only one word of the three words was semantically and grammatically appropriate. Only the children with autism had difficulty with this task as both typically developing children and children with dyslexia performed at ceiling. The children with autism had difficulty selecting the correct word to complete the sentences, where selecting the incorrect word would lead to further difficulty in understanding the rest of the written text. These comprehension tests showed that children with ASD had the most significant problem using semantics when reading, in spite of the fact that they were able to use some syntactic strategies and also phonological, and lexical strategies. The authors concluded that the children's problems lay beyond word reading and were related to "access of meaning of sentences" (p. 338). If these children could not understand individual sentences, it would be unlikely that they could combine the information from these sentences to understand a paragraph. If children with autism were unable to extract meaning from sentences, it would greatly interfere with their comprehension of text.

In a subsequent study, Minshew, Goldstein, Taylor, and Seigel (1994) examined whether there were consistent differences or similarities across the academic profiles of children with ASD and typically developing children in reading, problem solving, visuo-spatial, and mathematical abilities. Children with ASD were compared to an age- and

IQ-matched control group, determined by using the WISC-R. They were examined using the Detroit Tests of Learning Aptitude – 2, Woodcock Reading Mastery Test, and the Kaufman Test of Educational Achievement. Children with autism scored higher on individual word reading, real-word decoding, and spelling tests than did the typically developing individuals. Children with autism also showed average scores on tests of non-word reading and non-word decoding, but scored lower on reading comprehension. The children with autism performed the same level as typically developing children on the mathematical and visuospatial tests. Minsher et al. concluded that children with ASD showed a "psychoeducational profile that is different in configuration from that seen in normal individuals" (p. 266).

The pattern of reading ability in children with ASD was further examined by Nation et al. (2006) who tested the reading skills of children with autism ranging in age from 6 to 15 years. Nation et al. (2006) assessed word recognition, non-word decoding, reading comprehension, and reading accuracy. Nation et al. (2006) described reading accuracy as the combination of reading processes that provide contextually appropriate word meanings, combine information in word strings, and integrate inferential information with sentence information. Reading accuracy is necessary for good reading comprehension to be achieved. In addition, they also examined non-verbal ability, receptive vocabulary, and listening comprehension. Even though participants' real-word decoding performance was within the normal range, many of the children (64%) were one standard deviation or more below average for non-word decoding. This finding indicated that the children could decode familiar words but had difficulty with decoding unfamiliar words even if they follow typical word patterns. Sixty-five percent of the sample was significantly below average for reading comprehension. In addition, of the children who could read, 34.2 % displayed reading comprehension that was significantly lower than their reading accuracy. Although a few children who showed normal decoding also showed normal levels of reading comprehension, most displayed normal decoding but relatively impaired reading comprehension.

Nation et al's findings were further supported by Smith-Gabig (2010) who examined single word reading and phonological awareness to determine if the latter played a role in the pattern of reading skills and deficits shown by children with ASD. Previous research has shown that children with ASD have lower reading comprehension than decoding but phonological awareness had not been examined directly. Phonological awareness is the detection and ability to manipulate the sound structures of words including onset, coda, rime, and syllables. Smith-Gabig (2010) compared children with autism, ages 5-7, with age-matched, typically developing children on vocabulary using the Peabody Picture Vocabulary Test (PPVT – III), on articulation using the Language Development - Primary, on phonological awareness using the Comprehensive Test of Phonological Processing (CTOPP), and on word recognition using the Woodcock Reading Mastery Test – Revised, with the subtests for Word Identification and Word Attack. The results showed that children with autism had significantly lower scores for vocabulary and word articulation than did typically developing children. To assess decoding, Word Identification and Word Attack were used. The results showed that children with autism performed similar to typically developing children on decoding. On measures of phonological awareness children with autism scored significantly lower than typically developing children, which suggests that children with ASD "are delayed in their acquisition of phonological awareness relative to TD children" (p. 76). Interestingly, the Word Attack scores, which are a measure of non-word decoding, were correlated with the phonological awareness scores for typically developing children but not for children with ASD. This lack of correlation between non-word decoding and phonological awareness suggests that the children with ASD may not acquire decoding skills in the same way that typically developing children do.

To further confirm previous findings, Huemer and Mann (2010) compared a very large sample of 171 10-year-old children with ASD to 100 11-year-old children with dyslexia on measures of oral and written comprehension and on decoding. Huemer and Mann tested children using the WRMT – R and the Grey Oral Reading Test – Revised (GORT) that measures rate, accuracy, and comprehension. Consistent with other research, children with ASD had better decoding skill but poorer comprehension than children with dyslexia. Huemer and Mann further examined children with different levels of ASD. Instead of grouping all children under the umbrella category of ASD, they compared children by Asperger syndrome, autism, and PDD. Interestingly they found that children with PDD and autism had the lowest comprehension scores while children with Asperger syndrome scored slightly above the other groups with comprehension scores closer to that of the dyslexic group.

Collectively, the findings from the above studies suggest that decoding does not appear to be the major factor that limits reading comprehension in children with ASD. As Nation et al. (2006) suggested "in children with ASD [who could read], component reading skills have a tendency to develop out of step with each other" (p. 915). Such an asynchrony could occur in the decoding process itself or in the processes involved in comprehension. In any event, there appear to be other factors that diminish reading comprehension in children with ASD. These need to be identified and confirmed in further research.

What Are the Possible Factors That Might Limit Reading Comprehension?

Children with ASD have been found to have problems with a wide range of language functions and any one of these might impede their comprehension of text as well as spoken language. Children with ASD tend to use less speech and acquire fewer words than do typically developing children (Wilkinson, 1998). They have difficulty understanding semantics, forming sentences, using pronouns, and experience delayed language development (Wilkinson, 1998). Even children with high functioning autism experience language problems, a finding that supports that delayed language development is characteristic of the disorder. Their delay in listening comprehension suggests that language processing may influence reading comprehension especially as delays in language and delays in reading coincide (Beisler, Tsai, & Vonk 1987; Jones, 2007; Richman & Wood, 2002).

Production and Comprehension of Language

Examination of the language profiles of 120 children with autism ages between 5 years 6 months and 19 years, 7 months (mean age 11 years, 7 months) was completed by Jarrold, Boucher, and Russell (1997). All children in the study had some expressive language and receptive language capabilities. Children were tested on a variety of language tests covering comprehension of grammar, production of sentences, and identification and production of nouns. The British Picture Vocabulary scale was used to assess vocabulary comprehension. Children had to select a picture that corresponded to a spoken utterance. The Test of Receptive Grammar evaluated morphology and syntax. Children had to indicate a picture that best described a work or construct spoken by the tester. The Action Picture Test required children to answer questions about pictures and assessed their language production. The Word Finding Test assessed children's production of nouns. Jarrold et al. (1997) compared the results of the tests to each other and found that all the children with ASD showed uniform language ability across the tests, and that it was well below that of typically developing children. More specifically, all children with ASD experienced difficulty with grammar, production of language, and production of nouns. Their ability to comprehend vocabulary was compared to their ability to comprehend grammar. Although children did show slightly better vocabulary comprehension than grammar, the results were statistically not significant. As well, children showed the same level of difficulty with grammar across tests but they were not impaired in morphology and syntax. This general and widespread difficulty in production and comprehension of vocabulary and grammar is likely an influential factor in poor the reading comprehension that characterizes children with ASD. One thing that the authors never took into consideration was that the vocabulary and noun tests were only single words while the grammar test required comprehension of sentences. Therefore the problem may not be grammar as they concluded, but of the amount of information to be processed.

Listening Comprehension

Similar results have been demonstrated in children with ASD with respect to listening comprehension. Griswold, Barnhill, Myles, Hagiwara, and Simpson (2002) tested reading and listening comprehension in children with Asperger syndrome using the

Wechsler Individual Achievement Test (WIAT). Basic word identification and word comprehension (as measures of vocabulary) scores were above average while listening comprehension scores were significantly below average and were significantly lower than reading comprehension scores. This finding indicates that listening comprehension may relate to vocabulary and vocabulary might affect reading comprehension. This is consistent with the findings of Nation et al. (2006) who found that listening comprehension was correlated positively with both vocabulary and reading comprehension. It appears that children with ASD tend to have poor listening comprehension compared to reading comprehension. Moreover the listening comprehension may be a contributing factor to their low reading comprehension.

Diagnosed Language Delay

Language delay and communication difficulties are associated with the disorder of autism. This delay in language could be similar to that experienced by children with developmental language disorders. Beisler et al. (1987) compared children with ASD to children with a diagnosed language delay. Groups were matched by chronological age, sex, and mental age. Children were compared on the WISC, PPVT, Test of Language Development-Primary, Sequenced Inventory of Communication Disorders, and the Test for Auditory Communication of Language (TALC). The group with autism performed similarly to the group of children with language delay on the TALC and also on tests of vocabulary, morphology, and syntax. These findings provide evidence that children with ASD have a similar pattern of language difficulties as children with language delay.

To further understand language delays experienced by children with ASD, Jones (2007) compared children with high functioning autism to children with developmental language disorder (DLD). This condition is characterised by communication impairment and is defined in the DSM-IV separately from PDD and ASD. Children with DLD have a delay in oral language and auditory comprehension. Jones found that children with ASD performed significantly better than children with DLD on tests of written language and decoding, but showed significantly poorer listening and reading comprehension. However, children with ASD and children with DLD had comparable levels of oral language abilities (listening and speaking). These findings suggested that children with ASD were similar to children with DLD in that they both had delayed development in oral language; however, children with ASD demonstrated a relative strength in written language and decoding.

Research has shown that children with ASD experience difficulties with vocabulary, grammar, verbal ability, and listening comprehension, and display some similarities in language development to children diagnosed with developmental language disorder (Beisler et al., 1987; Griswold et al., 2002; Jarrold et al., 1997; Jones, 2007; Nation et al., 2006; Snowling & Frith, 1986). These aspects of language may be contributing factors to poor reading comprehension ability. As delays in language and delays in reading coincide (Jones, 2007; Richman & Wood, 2002), it is possible that these language problems also contribute to difficulties with reading comprehension.

Hyperlexia

Many children with ASD show a precocious pattern of reading ability that appears comparable to a reading condition known as "hyperlexia". Hyperlexia is a reading anomaly that is defined as a "phenomenon of specific word recognition skill" (p. 41, Silberberg & Silberberg, 1967) where children show advanced word recognition, but poor comprehension ability. The diagnosis and definition of hyperlexia has not always been consistent but it appears to occur more often (though not exclusively) in children with a comorbid developmental delay such as ASD. For example, Healey (1982) examined children with the primary characteristics of hyperlexia and found that all exhibited some evidence of Pervasive Developmental Disorder (PDD). In addition, Grigorenko et al. (2002) found that among 80 children with developmental disabilities, 12 exhibited hyperlexia. The authors observed that all of the children diagnosed with hyperlexia also had a diagnosis of either autism or PDD.

Despite their advanced decoding skills, children with hyperlexia show poor reading comprehension (Cardoso-Martins & da Silva, 2010; Healey, 1982; Sparks, 1995; Welsh, Pennington, & Rogers, 1987). Healey (1982) found that children with hyperlexia scored above mental ability and age for decoding single words and non-words. However, they displayed poor performance on both listening and reading comprehension tests. In addition, Welsh, Pennington, and Rogers (1987) tested children with ASD on a variety of intelligence and reading tests and found that all children with a comorbid diagnosis of hyperlexia displayed higher than average word-recognition scores and average reading comprehension scores. Myles, Hilgenfeld, Barnhill, and Simpson (2002) provided further evidence that children with ASD have better word recognition than reading comprehension. Using the Classroom Reading Inventory (CRI) they analysed reading skill in children aged 6 to 16 years with Asperger syndrome. The authors found that although word recognition was slightly below average, children with Asperger syndrome had superior word recognition ability as compared to their reading comprehension. This reading profile may be typical of all children with Asperger syndrome rather than a separate disorder of hyperlexia, although not all children achieve the precocious decoding skill. Furthermore, Grigorenko et al. (2002) noted no significant difference in intelligence between those with hyperlexia and those without, but there was a significant difference in performance in decoding.

Reading comprehension deficits that occur in children with comorbid diagnosis of ASD and hyperlexia and children with ASD and no hyperlexia have been compared. Holman (2004) compared typically developing children, children with both ASD and hyperlexia, and children with ASD without hyperlexia on several tests including the Woodcock-Johnson Psycho-Educational Battery (WJB), the Woodcock Reading Mastery Test (WRMT), and the Classroom Assessment of Reading Processes (CARP). Holman (2004) found a consistent pattern of performance in which the typically developing children had the highest scores on the reading tests from the WRMT and CARP, followed by the children with ASD and hyperlexia. Children with ASD without hyperlexia demonstrated the lowest scores on each of the reading sub-tests from the WRMT and CARP. It appears that children with ASD and hyperlexia have better decoding skills and listening comprehension than children with ASD without hyperlexia. These findings are further supported by Newman, Macomber, Naples, Babitz, Volkmar, and Grigorenko (2007), who also compared children with ASD plus hyperlexia to children with ASD without hyperlexia. They found that on most reading tests of the Woodcock Johnson Tests of Achievement children with ASD plus hyperlexia performed as well as typically developing children. Only on the test of reading comprehension did the children with ASD plus hyperlexia perform at the lower level similarly as children with ASD.

Since the prevalence among children with high functioning ASD and Asperger syndrome is so high, some researchers suggest that hyperlexia is not a separate disorder but simply a precocious reading ability that may occur in children with ASD (Grigorenko et al., 2002; Myles et al., 2002). Although hyperlexia is occasionally diagnosed in children without ASD, it is most commonly found among those with ASD. This supports the notion that it is the obsessive interest in words and reading that has been noted in children with ASD that might underlie this apparently precocious decoding skill that is known as hyperlexia.

Summary

Typical children develop language along the same general developmental timeline. Ehri (1994) described how typically developing children learn to read by following a standard sequence of phases labelled: pre-alphabetic, partial alphabetic, full alphabetic, and consolidated alphabetic. Although this may be the typical sequence for reading development, not all children follow the phases exactly. When a different sequence is followed, these children will still learn to read but the errors that they make can lead to problems with decoding and reading comprehension. Such a divergence from the typical path of reading development may be what has happened to children with ASD, who do learn to read, but may make errors. Children with ASD show a different pattern in reading than typically developing children in that they display good decoding ability, where they can read a word as quickly as typically developing children, but have difficulty comprehending the meaning of the word (Frith & Snowling, 1983; Nation et al., 2006). The factors that might cause children with ASD to have poor comprehension include errors in syntax, semantics, vocabulary, and auditory comprehension (Griswold et al., 2002; Minshew et al., 1994; Nation et al., 2006). Another factor that might contribute to the poor reading comprehension that has been observed in children with ASD is that they have a language and communication delay associated with the condition. In fact, children with diagnosed language delay (but without ASD) and children with ASD also share a listening comprehension deficit (Griswold et al., 2002; Minshew et al., 1994; Nation et al., 2006) as well as certain phonological and comprehension deficits (Jones, 2007; Richman & Wood, 2002). Finally, the discrepancy between word identification and comprehension that characterizes children with ASD also defines the condition of hyperlexia. The presence of hyperlexia may indicate that these children learn to decode through a different route than typically developing children, perhaps related to phonological development. The possible different method of decoding and any phonological errors experienced during reading may cause a problem in underlying reading skill that contributes to poor reading comprehension for children with ASD.

The Present Study

The problems with language experienced by children with ASD likely translate into problems with reading, as shown by the common errors in pragmatics, semantics, and phonological awareness that these children show (Frith & Snowling, 1983; Smith-Gabig, 2010; Snowling & Frith, 1986). As well, the findings that both listening comprehension and reading comprehension are found to be poor when compared to word recognition and decoding further indicate that that there might be a connection between language and reading comprehension (Griswold et al., 2002; Minshew et al., 1994; Nation et al., 2006).

Problems in reading comprehension in children with dyslexia are usually due to decoding errors, but this relationship is not observed in children with ASD. However, it is important to try to identify the sources of poor reading comprehension for children with ASD.

The study had two objectives. The first objective was to explore the possible sources of reading comprehension problems in children with ASD that have been indicated in the literature. Several tests were completed to determine whether vocabulary, spelling, and reading as measured through the Woodcock Reading Mastery Test were related to reading comprehension. Vocabulary was tested using the Peabody Picture Vocabulary Test – IV revised (PPVT-IV-R) and Spelling was tested using the Test of Written Spelling (TWS). Non-verbal reasoning was tested using the Raven's Progressive Matrices (RPM) to establish whether intelligence is related to reading comprehension. Both real-word and non-word decoding were tested with the WRMT in order to replicate previous findings and as a comparison to other measures. Different levels of comprehension were measured through the WRMT, using the Word Comprehension and Passage Comprehension subtests. To assess whether the comprehension deficit could be a language based or reading based problem, listening comprehension was measured using the subtest from the Woodcock Johnson Psycho-Educational Battery (WJB). From the findings of previous studies we expected to find that lower vocabulary, spelling, and non-verbal reasoning scores would be associated with lower reading comprehension. As well, reading comprehension and listening comprehension were expected to be lower than word reading and decoding.

The second objective was to establish that children with ASD have acquired all of the various aspects of phonological awareness and word decoding that typically developing children acquire during the early phases of reading development. Children with ASD tend to be good decoders but it is possible that they are successful at decoding by using ineffective or incorrect strategies or by obsessive attention to, and practice with, letters and words. Previous studies have shown that poor decoding is also related to deficits in phonological awareness (Ehri, 1994; Share, Jorm, Maclean, & Matthews, 1984; Smith-Gabig, 2010; Tunmer & Hoover, 1993).

Breen (2007) studied typically developing children to determine the development of phonological awareness and reading skills through preschool, kindergarten, and first-grade. Breen (2007) had identified a sequence of development in typical children during which phonological skills emerge during the partial alphabetic phase of reading development. To understand and identify phonemes, individuals develop the knowledge that words can be divided into syllables that can be further divided into onsets and rimes, and that codas are contained within rimes. An onset is the first consonant(s) in a syllable before the vowel. For example, in the word "dog", "d" is the onset, and "og" is the rime. The coda consists of the consonant(s) in a syllable that follows the final vowel, for example where the "g" in the word "dog" is the coda. The parts of a word (i.e. onset, vowel, and coda) are the units of sounds representing phonemes. Breen (2007) used phonetic tests to measure the acquisition of onsets, and codas.

The tests used by Breen (2007) isolated the different phonological units in the words (onset and coda) to determine at what rate and order these units develop. Breen used Onset and Coda Identities tests to measure children's ability to recognize a phoneme in context. For example to test phoneme identity the experimenter said a short sentence and a specific phoneme (e.g. *d*) which the child repeated, then the experimenter said two words from the sentence and asked the child which word had the sound (e.g. is the *d* in *dog* or *hog*). Also, she used the Onset and Coda Phonetic-cue Reading (OPCR and CPCR) test to measure children's knowledge of grapheme-phoneme associations for the onset and coda in a word. On each trial the children were shown a card containing three words differing in only one letter (e.g *dog, hog, pog*). The experimenter said one of the three words and asked the child to point to the printed word that matched. Children were also given word identification and spelling tests, which assessed the number of words that a child could read or spell. Onset and coda deletion tests were completed by asking a child to say a word without a specific sound, for example "say dog without the "*d*" sound". Last, the children were asked to complete the Phoneme Counting (PC) test in which they were asked to identify the number of phonemes they heard in a word spoken by the experimenter.

Breen (2007) found that knowledge of letter names was the first step in learning to read, followed by onset identity and onset phonetic-cue reading. The next phonological skills to develop were coda identity and coda phonetic-cue reading. In Breen's study, phonetic-cue reading for onsets and codas were mastered before onset and coda deletion. In summary, Breen found that children learned to identify and manipulate phonemes during the partial alphabetic phase of reading development and that most children learned skills in the same sequence. Children knew how letters represented simple onsets and codas before they could read words, but word identification and spelling developed together with onset deletion, coda deletion, and phoneme counting. These skills were typically mastered before moving on to the full alphabetic phase. It is possible that children with ASD may not learn to decode in this same sequence as typically developing children and this might contribute to their comprehension problems.

In the present research project a group of children with ASD were tested on a variety of early reading skills to determine if they had achieved them as did typically developing children or if there was a disruption in the acquisition of these skills. To determine whether phonological development was different in children with ASD, tests of onset, coda and vowel identification and phonetic-cue reading were completed. For the identities tests children heard a sentence and had to differentiate between two words that differed by only one sound. The phonetic-cue reading tests require the child to identify the correct word spoken by the researcher from a selection of three printed words differing by only the onset, coda or vowel. The sequence identified by Breen (2007) showed that children learned to identify onsets, codas, and vowels before they were able to read them. The tests were used here to determine whether the same sequence was found for children with ASD. Phoneme counting was also tested to determine whether children with ASD were able to analyze words into their component parts. Breen (2007) found that phoneme counting came after word reading. These tests may help determine how children with ASD completed decoding.

Method

Participants

Participants were 10 children ages 4 to 9 years old ($M = 7.17$; $SD = 1.70$) from St. John's, NL, with a diagnosis of Autism Spectrum Disorder (ASD). All participants were Caucasian, and there were nine boys and one girl. Participants were recruited through personal contacts with parents and professionals who work with children with ASD. The Autism Society of Newfoundland and Labrador distributed information sheets to parents which contained information about the project and how parents could become involved. The research project was reviewed and approved by the Interdisciplinary Committee on Ethics in Human Research (ICEHR).

All of the children with ASD had been diagnosed previously by a certified paediatrician as meeting the DSM-IV-R criteria and using the Autism Diagnostic Observation Schedule (ADOS) and The Autism Diagnostic Interview Revised (ADI-R). The ADOS (Lord, Rutter, DiLavore, & Risi, 2000) consists of a set of structured and unstructured tasks designed to test the social interaction of children. As part of the ADOS, both the examiner and the child participate in completing the tasks while the examiner rates the child and assigns the behaviours to predetermined observational categories. The ADI-R (Le Couteur, Lord, & Rutter, 1994) is the companion test to the ADOS and consists of a structured interview by a trained professional with the parent or guardian.

All children were receiving or had received early intervention in the form of Applied Behaviour Analysis (ABA) home therapy. Families have the option of entering into therapy once the child is diagnosed and the program ends when the child begins grade one. All children in the sample were in elementary school except for one child who was pre-kindergarten. Parents reported that all children in the sample had an early interest in letters, words, and reading.

Testing Procedures

Testing was completed from January to April of 2009. The experimenter visited the children's homes where they were tested individually. Before testing began, several minutes was spent before each session conversing to make the children feel comfortable. Each session took approximately 30 to 45 minutes to complete, but breaks were given as needed. For some participants testing was completed in as few as three visits, but one extra visit was required for three of the children.

During the first and second sessions, participants completed tests of letter naming, onset, coda and vowel identity tests, onset, coda and vowel phonetic-cue reading tests as in Breen (2007). They also completed the test of Written Spelling (TWS; Larsen, Hammill, & Moats, 1999), and phoneme counting in the order listed. These were followed by the Woodcock Reading Mastery Test (WRMT; Woodcock, 1987) and the Listening Comprehension (LC) subtest of the Woodcock Johnson Psycho-Educational Battery (WJB; Woodcock & Johnson, 1989) in that order. The first session usually ended after the phoneme-counting test, but earlier if the child was tired or distracted. Therefore, the second session may have started with different tests depending on where the first session ended, but the second session always ended with the LC subtest. In the third session, the Peabody Picture Vocabulary Test Fourth Edition (PPVT – IV; Dunn & Dunn, 2007) and the Raven's Standard Progressive Matrices (RPM; Raven, Court, & Raven, 1986) were administered to measure vocabulary and nonverbal intelligence respectively. Half of the participants completed the PPVT-IV first and the other half completed the RPM first.

Tests Administered

Peabody Picture Vocabulary Fourth edition. The PPVT-IV is a receptive vocabulary test used for individuals between the ages of 2.5 to 40 years. It takes 10 to 20 minutes to complete. The experimenter followed the standard procedure outlined in Dunn and Dunn (2007) for administering the PPVT-R. The experimenter showed the child four pictures of common objects and said a word. The child had to indicate the picture that best represented the meaning of the word.

Raven's Standard Progressive Matrices. The Raven's Standard Progressive Matrices (RPM) (Raven, Court, & Raven, 1986) is a test of general non-verbal reasoning designed for individuals between the ages of 6 and 89 years and takes approximately 20 minutes to complete. The RPM consists of an array of visual patterns with a part missing. The child must select from six different patterns to find the one that completes the pattern accurately (Raven, et al. 1986). The child must then write the number associated with the smaller pattern on the answer sheet. The book contains five series of patterns with 12 patterns in each series. Two children in the sample were under 6 years of age and were excluded from analysis with this test.

Rapid Letter Naming test (RLN). Rapid letter naming test measures children ability to quickly recognize and name letters. Participants received two different lists of letters, one list of 26 upper-case letters and one of 26 lower-case letters in random order. Participants were instructed to name the letters as quickly as possible, but were told that it was more important to get the letters right than to go fast. The experimenter demonstrated the direction the children should read the letters on a blank piece of paper to ensure that the children understood the task. The experimenter recorded errors and time (to the nearest second) for the child to read the 26 letters.

Onset, Coda, and Vowel Identities Test. The Onset (OID) and Coda (CID) identities tests were modeled after those used by Breen (2007). An analogous Vowel Identity (VID) test was developed for this project. The OID, CID, and VID tests measured children's ability to recognize a phoneme in context. The experimenter said a short sentence and a specific sound (phoneme), that the child repeated. The experimenter said two words from the sentence and asked the child which word had the sound. For example on the OID test the experimenter asked the child to repeat a phrase such as "*He flew the kite at night*", and then said the target sound /k □/ (kuh). The child was asked to repeat the sound, and then indicate which of the two words, *kite* or *night*, contained the sound. If the child did not respond, the experimenter repeated the word pairs. There were three Identity tests with 10 sentences each, one test for onsets, one for codas, and one for vowels. Each test had one practice trial. All test words had consonant vowel consonant (CVC) phonological structure. The consonant target sounds that were tested were represented by the letters b, d, g, k, l, m, n, p, r, s, t, z. Vowel Identity (VID) followed the same procedure but the target sounds were vowels. The OID was presented first followed by the CID then VID.

Onset, Coda, and Vowel Phonetic-cue Reading Test. The Onset (OPCR) and Coda Phonetic-cue Reading (CPCR) tests were modeled after those used by Breen (2007). An analogous vowel (VPCR) test was also developed. The OPCR, CPCR, and VPCR tests measure children's knowledge of grapheme-phoneme associations for specific locations in a word. On each trial the children were shown a card containing three words differing in only one letter. The experimenter said one of the three words and asked the child to point to the written word that matched. For example, for the OPCR test the experimenter showed the child a card with the three words differing by only the first letter (*dig, rig,* and *pig*) and asked the child to point to the word that says "*dig*". The experimenter allowed 10 seconds for the child's response and then moved on to the next item. Second choices were also recorded. The children were given one practice trial and 13 experimental trials. For the OPCR the target letter sounds were represented by the letters b, d, f, h, m, n, p, r, s, t, v, z, "hard" c, and "hard" g. For the CPCR test the three words differed in only the final letter (e.g. *hat, ham* and *had*). For the CPCR the target letter sounds were represented by the letters b, d, f, k, m, n, p, r, s, t, v, z, and "hard" g. VPCR followed the same procedure but the target sounds were vowels (e.g. *rod, red* and *rid*).

Woodcock Reading Mastery test. The Woodcock Reading Mastery (WRMT, Woodcock, 1987) is a standardized test composed of six subtests, four of which were used: Word Identification (real-word decoding), Word Attack (non-word decoding), Word Comprehension, and Passage Comprehension. For the Word Identification subtest the child read isolated words aloud. On the Word Attack subtest the child had to read pronounceable nonsense words (e.g. tat). In the first two sections of the Word Comprehension subtest, the children read words and had to produce antonyms or synonyms. In a third section, children read three words and produced a fourth word that completed the analogy given. For Passage Comprehension the child read a short passage with a word missing and had to provide the missing word.

Listening Comprehension Subtest. The Listening Comprehension (LC) subtest of the Woodcock Johnson Psycho-Educational Battery (WJB, Woodcock & Johnson, 1989) is similar to the Passage Comprehension subtest of the WRMT except the child listened to the passage from an audio tape rather than reading it, and provided the missing word.

Test of Written Spelling (TWS). The Test of Written Spelling (TWS, Larsen, Hammill, & Moats, 1999) is a standardized measure of spelling in two parts, predictable and unpredictable words. Predictable words have more frequent or more regular spelling patterns (e.g. stop), while unpredictable words are less frequent and have more irregular spelling (e.g. knife). The experimenter dictated a word in sentence context and the participant wrote the word on paper. The TWS provides norms for spelling ability for ages 6 to 18 and takes approximately 15 minutes to complete. The test continued until the participant incorrectly answered five consecutive items. Two participants were under 6 years of age and were excluded from analysis of this test.

Phoneme Counting (PC). The Phoneme Counting (PC) which is a test of phonemic awareness was adapted from Breen (2007) and began with three training trials. Each training trial consisted of three words with increasing phoneme complexity, for example "*owe, go*, and *goat*". Puzzle pieces were used to demonstrate how the training words could be segmented into phonemes. The experimenter showed the child the training word, then demonstrated how the word was segmented by separating the puzzle pieces showing that each puzzle piece has one phoneme. For example "*go*" was represented by two puzzle pieces with "*g*" on one and "*o*" on the other, but "*owe*" stayed in one piece because even though it is three letters it is one phoneme. The experimenter manipulated the pieces while teaching the child to "tap out" the phonemes on the table with their hand in a movement similar to that used by Liberman, Shankweiler, Fischer, and Carter (1974). Children were taught to identify the number of phonemes in words by tapping on the table with their hand while speaking the words slowly, phoneme by phoneme. Three training trials were completed with three words in each trial with increasing number of phonemes so children could first learn the concept of phoneme counting in words.

Following Breen's (2007) procedure, children were then pre-tested on nine new words to ensure that they understood the task. Children had to get six out of nine correct on the pretest to continue to the test. The children were then tested on 22 novel words, which determined children's phoneme-counting score. Words ranged in number of phonemes from two (e.g. *at*) to four (e.g. *clap*). The experimenter said a word aloud and the children were asked to indicate sounds they heard in each word either by saying a number or by tapping on the table. The experimenter recorded the children's responses.

Results

Table 1 provides a descriptive summary of the results of all the tests that were completed. Throughout the results section, Table 1 will be referred to clarify the variables discussed. The present study had two goals. The first was to determine which factors may be associated with reading comprehension, and the second was to determine whether children with ASD showed phonological awareness similar to that of typically developing children. As was shown in previous studies, results were highly variable within the sample. Means and standard deviations (SD) for all tests are shown in Table 1.

Table 1: Descriptive Statistics for Reading and Phonological Tests

Measures	*Mean*	*SD*	*Min*	*Max*
Age (months)	86.0	20.3	53	112
WRMT standard scores				
Word ID	108.1	21.9	76	145
Word Attack	98.5	20.3	75	145
Word Comprehension	106.8	21.0	71	140
Passage Comprehension	87.9	22.3	40	114
WJB standard scores				
Listening Comp	85.6*	17.0	54	110
TWS – total (stan.)	81.6*	21.3	62	121
PPVT (stan.)	91.2	13.1	73	111
RPM (stan.)	87.0	14.1	64	108
RLN – time	30.2	15.3	16.4	59.4
– errors	.5	0.53	.00	1.5
Onset ID	10.3	2.36	6	12
Coda ID	10.3	1.25	8	12
Vowel ID	7.6	2.17	4	10
OPCR	13.8	0.42	13	14
CPCR	12.5	1.51	10	14
VPCR	12.1	2.96	4	14
Phoneme counting				
Pre-test	3.2	2.09	0	6
Test	3.6	5.82	0	13

Notes: The table above uses abbreviations for several tests, Woodcock Reading Mastery Tests (WRMT), Woodcock Johnson Psycho-educational Battery (WJB), Test of Written Spelling (TWS), Peabody Picture Vocabulary Test (PPVT), Ravens Progressive Matrices (RPM), Rapid Letter Naming (RLN), Onset Phonetic-Cue Reading (OPCR), Coda Phonetic-Cue Reading (CPCR), and Vowel Phonetic-Cue Reading (VPCR).
* Means that were significantly different from population average with $p < .05$ level

Factors that Might Contribute to Reading Comprehension Problems

To identify the possible sources of reading comprehension problems two things were done, first tests were compared to the standardized population mean of 100, and then tests were compared to each other to determine the consistency between pairs of scores. One sample *t*-tests were used to compare the children in the current sample to population averages for the Woodcock Reading Mastery Test (WRMT), Test of Written Spelling (TWS), and Listening Comprehension subtest of the Woodcock Johnson Psycho-educational Battery (WJB). The children were not significantly different from the population average on Word Identification, Word Attack, and Word Comprehension (all $p > .05$). Although the Passage Comprehension mean was almost one standard deviation below the population mean, the difference was not statistically significant, $t(9) = -1.71$, $p = .12$, but notably in this small sample it approached significance. However, the children did score significantly below the population average for Listening Comprehension, $t(9) = -2.67$, $p = .03$, and the TWS, $t(7) = -2.42$, $p < .05$. See Figure 1 for a comparison between ASD children with the population mean.

In addition to the *t*-tests that compared the sample to population norms, paired sample *t*-tests were completed to compare the scores of each test to each other. Scores on the subtests of the WRMT were compared to each other and to vocabulary and spelling using paired-samples *t*-tests. Correlations were also completed to see how the individual measures were related (see Table 2). Preliminary examination of individual scatterplots indicated few outliers. Children scored highest on Word Identification ($M = 108.1$, $SD = 21.9$) and Word Comprehension ($M = 106.8$ $SD = 21.0$), and these tests were not significantly different from each other, $t(18) = .44$, $p = .67$. Passage Comprehension did not differ significantly from the population mean, however, a paired-sample *t*-test revealed that Passage Comprehension was significantly lower than Word Identification, $t(18) = 4.21$, $p < .01$. As can be seen in Table 2, the two were significantly correlated ($r = .765$, $p < .01$). This finding implies that Passage Comprehension was not limited by poor decoding for children with ASD and is consistent with previous studies which found that children with ASD have higher decoding ability than reading comprehension (Frith & Snowling, 1983; Minshew et al., 1994; Nation et al., 2006).

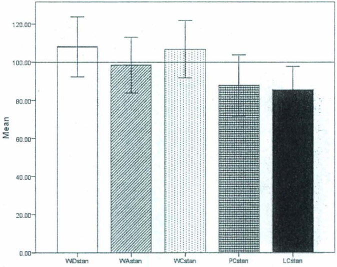

Figure 1: Mean scores for reading and comprehension tests with a line representing population average showing that Word ID and Word Comprehension are both above population means while Passage Comprehension and Listening Comprehension are below. Bars represent standard error.

Word Comprehension was compared to Passage Comprehension to determine whether the children showed differences in comprehension for individual words than for sentences. Word Comprehension scores were significantly higher than Passage Comprehension, $t(18) = 4.08, p < .01$, and the two were significantly correlated (see Table 2). The superior performance on Word Comprehension compared to Passage Comprehension suggests that children with ASD have no problem comprehending individual words, but may have problems comprehending sentences in which they have to interpret and integrate extra information.

Table 2: Inter-correlations for tests of Reading, Listening Comprehension, and Spelling.

	Word Attack	*Word Comprehension*	*Passage Comprehension*	*Listening Comprehension*	*Spelling*
Word ID	.793**	.908**	.765**	.272	.848**
Word Attack		.720*	.482	.392	.894**
Word Comprehension			.774**	.364	.883**
Passage Comprehension				.389	.748*
Listening Comprehension					.484

*. Correlation is significant, p < .05 level
**. Correlation is significant, p < .01 level

The Listening Comprehension subtest of the Woodcock Johnson Psycho-Educational Battery was included to compare auditory comprehension and reading comprehension. Passage Comprehension and Listening Comprehension were not significantly correlated ($r = .39, p = .27$). This is surprising, because in typically developing children Passage Comprehension and Listening Comprehension are usually significantly correlated. Listening Comprehension did not correlate with any other reading tests (see Table 2) suggesting that Listening Comprehension develops differently than Passage Comprehension and other reading skills. Interestingly, children had the lowest standard scores for Passage Comprehension ($M = 87.1$, $SD = 22.3$) and Listening Comprehension ($M = 85.6$, $SD = 17.0$), both test comprehension of sentences. Paired-sample *t*-tests showed that there was no significant difference between Passage Comprehension and Listening Comprehension, $t(18) = -.33, p = .75$. This finding suggests that the children with ASD had trouble understanding information from sentences both when they read and also when they heard the sentences. Given that children did well on the single word reading subtests of Word ID and Word Comprehension, their low performance on the Passage Comprehension and the Listening Comprehension subtest suggests that they might have a general comprehension deficit that is separate from reading.

Interestingly, although spelling was significantly lower than population average it significantly correlated with Word ID, Word Attack, Word Comprehension, and even Passage Comprehension (Table 2). Given these correlations, paired sample t-tests were completed to compare spelling to the reading tests. Spelling was found to be significantly different from Word ID ($t(7) = -5.08, p < .01$), Word Attack ($t(7) = -4.16, p < .01$), and Word Comprehension ($t(7) = -5.95, p < .01$). This finding is surprising as spelling should be similar to decoding scores.

To determine whether vocabulary is related to reading comprehension, the scores from the PPVT were compared to Word Comprehension. Standard scores on the PPVT were slightly below average, $t(9) = -2.13, p = .06$, but Word Comprehension from the WRMT was slightly but not significantly higher than average, $t(9) = 1.02, p = .33$. The PPVT and Word Comprehension both measure vocabulary knowledge, therefore scores should be similar. The two were significantly correlated, $r = .63, p = .05$, which suggests that Word Comprehension and the PPVT are similar, but the Word Comprehension scores were found to be significantly higher than PPVT scores, $t(18) = -3.03, p = .01$. This finding is interesting considering that Word Comprehension and PPVT are both measures of vocabulary, yet they have different relationships to Passage Comprehension (see Table 2). Thus, poor vocabulary knowledge would not appear to be a limiting factor in reading comprehension in this population.

Non-verbal intelligence was tested via the Raven's Progressive Matrices (RPM) to determine whether there was an association with comprehension. Scores on the RPM were significantly below average, $t(7) = -2.61, p = .04$. A correlation was calculated between the RPM and comprehension measures to determine if poor reading comprehension was related to intelligence. Passage Comprehension did not correlate with the RPM ($r = -.13, p = .18$). These results suggest that nonverbal intelligence was likely not a factor associated with comprehension for children with high functioning ASD.

Like the participants of Nation et al. (2006), those in the present study showed a broad range in ability. Even though the current sample size was much smaller than the Nation et al. sample, the percentages of scores within certain ranges are similar. From the Nation et al. study, 32 children had "measurable" reading skill and 10.3% had a reading comprehension score 2 SD below mean reading accuracy scores. In the present study, 20% of participants had reading comprehension scores 2 SD below mean Word Identification scores. A z-test was used to compare the proportion of reading comprehension scores that were 2 SD below the mean of Word Identification scores between the sample in the present study and the Nation et al. sample. The proportion of low reading comprehension scores in the two samples was not found to differ, $p > .05$. A z-test was then used to compare the proportion of participants whose reading of non-words was 1 SD below population norms between the present sample and the Nation et al.

(2006) sample. Of the 32 children in the Nation et al. sample who could read, 42% were 1 SD below population norms. In the present sample, 30% (i.e. three of the ten children) were 1 SD below population norms. There was no significant difference between the proportions of participants whose reading of non-words was 1 SD below population average between the two samples, $p > .05$.

A comparison of the current findings for the WRMT and spelling to those of Minshew et al. (1994) is provided in Table 3. Both samples had comparable WRMT Passage Comprehension mean scores, 87.7 and 87.9, which were almost 1 SD below population average. However, a significant difference in spelling scores was observed between the two samples, $t(7) = -2.79$, $p < .05$. The present sample had below average spelling scores whereas Minshew et al's (1994) sample had slightly above average spelling scores. This is another surprising finding when considering that the decoding scores are so high. If children are able to decode real-words and non-words they should be able to spell as well.

Table 3: Comparison of Means and Standard Deviations of Minshew, Goldstein, Taylor, and Seigel (1994) to the findings presented here.

	Current Sample		*Minshew et al (1994)*	
	M	*SD*	*M*	*SD*
WRMT-R Standard scores				
Word ID	108.1	21.9	100.7	21.9
Word Attack	98.5	20.4	104.6	20.1
Word Comprehension	106.8	21.0	97.6	20.6
Passage Comprehension	87.9	22.4	87.7	20.3
Spelling*	81.7	21.3	102.8	21.2

Notes: In the table above Abbreviations were used for Woodcock Reading Mastery Test – Revised (WRMT-R).
*Significantly different from population p < .05

Overall, the findings reported here suggests that average word reading skill but poor reading comprehension in the ASD sample are comparable to the findings from Nation et al. (2006) and Minshew et al. (1994). These consistent findings across the three studies provide strong evidence that average word reading skill and poor reading comprehension may be a pattern typical of children with high functioning ASD.

Early Phonological Awareness

The second objective of this study was to examine phoneme awareness and decoding skills in children with ASD. Breen (2007) found that knowledge of letter names was the first step in phoneme development, followed by onset identity and onset phonetic-cue reading, and then coda identity and coda phonetic-cue reading. After these steps came word ID, spelling, and phoneme counting. To determine whether phonological awareness was delayed in children with ASD, tests of onset, coda and vowel identification and phonetic-cue reading were compared. In addition, the present study included a test of Vowel Identification (VID) and Vowel Phonetic-Cue Reading (VPCR), which Breen did not include. Means and standard deviations for the sample of children with ASD are shown in Figure 2. Breen did not test VID because her sample was too young, but it is hypothesized to develop after OID and CID as the results here show.

A repeated-measures ANOVA showed a significant difference in the means of the three ID tests, $F\ (1, 9) = 40.8$, $p < .01$, indicating that the children with ASD scored higher on Onset Identification tests and Coda Identification, and lower on Vowel Identification tests (Table 1). OID and VID correlated significantly, $r = .83$, $p < .01$, but CID did not correlate with either, $r = .27$, $p = .45$, and $r = .29$, $p = .41$. This finding suggests that children with ASD may follow the sequence described by Breen (2007) for phoneme identity. Children learn to identify onsets, followed by codas, and finally vowels. However, a future study in which age is included as a variable would be necessary to confirm this sequence in children with ASD.

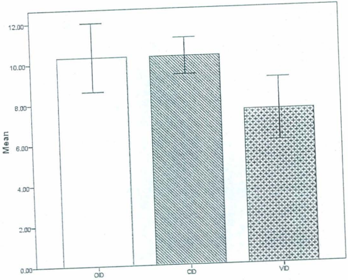

Figure 2: Means and Standard Deviations for Identity tests showing that Vowel ID is lower than both Onset ID and Coda ID.

Notes: In the above figure abbreviations were used to label variables, Onset Identification (OID), Coda Identification (CID), and Vowel Identification (VID) each test had a max score of 12.

There was no significant difference between the Phonetic-Cue Reading (PCR) variables when compared to each other. The children with ASD in this sample were older than the children in Breen's sample and had reached near ceiling levels of performance for the PCR tests. For example, the lowest score on the OPCR test was 13, the highest possible is 14. Some children had lower scores on the CPCR and VPCR than OPCR, which was expected, but there were no significant differences between VPCR and the other PCR tests.

Do Children with ASD have a Phonological Deficit?

As was expected, children with ASD displayed average decoding and word comprehension scores. However they displayed very low spelling and Phoneme Counting scores. The children in the current sample showed a degree of phonological knowledge as did Breen's sample. To determine if children with ASD have a phonological deficit, phonological ability was further explored *post hoc*. Spelling and Word Attack scores were compared to assess the existence of a phonological deficit because they are both measures of phonological awareness. Total standard scores for the Test of Written Spelling (TWS) were found to be significantly lower than population average, $t(7) = -2.42, p < .05$. Word Attack scores were found to be average (Table 1). Spelling was significantly lower than Word Attack, $t(16) = -4.16, p < .01$, but significantly correlated with Word Attack, $r = .89$, $p < .01$. The difference in Word Attack and Spelling scores is inconsistent and surprising considering Word Attack is non-word decoding. If children can name letters and decode, then they should be able to spell at the same level.

Another test of phonological awareness was Phoneme Counting, which was positively correlated with spelling, $r = .81, p = .05$. Children were very poor at Phoneme Counting as only four children passed the pre-test and only three were able to complete the phoneme counting test. Children scored lowest on Spelling and Phoneme Counting in comparison to the other tests (Table 1), which is consistent with Breen's (2007) findings that Spelling and Phoneme Counting develop together. But this finding is difficult to explain, as children with ASD have average scores for Word Attack. If the children truly had a phonological deficit then they would not be able to do well on the test of Word Attack. These findings suggested that although children with ASD can decode well, some aspects of their phonemic awareness are inconsistent with that of typically developing children. It may be that they do not acquire decoding skills in the same way as do typically developing children.

Hyperlexia and ASD

All of the children in the sample showed better decoding and individual word comprehension than passage comprehension (Figure 3). Four participants' Passage Comprehension scores were 1 *SD* below their Word Identification scores and two participants' Passage Comprehension scores were 2 *SD*s or more below their Word Identification scores. As a result, 6 of the 10 participants had reading comprehension scores 1 *SD* or more below their word reading scores. Despite the high group scores for decoding and word comprehension, one child's decoding and word comprehension abilities were particularly high. This child, who will be referred to as Sam, was diagnosed with autism at the age of two years and since then has been receiving intensive Applied Behaviour Analysis (ABA) therapy. When tested for the present study, Sam was 6 years and 3 months. His standard score on the PPVT was 106 (percentile rank of 66). He had the highest score in the sample on the decoding tests of Word ID and Word Attack, with Standard scores of 145 in both with the 99.9^{th} percentile rank (PR). His standard scores of 111 for Passage Comprehension (PR = 77) and 108 for Listening Comprehension (PR = 71) were above average, but markedly low when compared to his decoding scores. To investigate his reading abilities further, the Grey Oral Reading Test

(GORT) was administered. His scores on the GORT were as high as they were for the WRMT with a Standard score of 1 (PR = 50) for Rate, and a Standard score of 14 (PR = 91) for Accuracy. His standard scores indicate that his reading was average for speed and above average for accuracy. His GORT score for comprehension was lower than his passage score (standard score = 11, PR = 63). His spelling scores on the TWS were also the highest in the sample with a standard score of 121 and PR of 92. Although the entire sample showed higher word reading than comprehension, Sam's scores indicate that he may have hyperlexia as well.

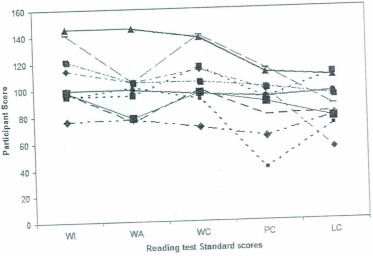

Figure 3: Scores for each of the individual participants across standardized reading tests for Word ID, Word Attack, Word Comprehension, Passage Comprehension, and Listening Comprehension.

Notes: Each line represents a different participant.

Discussion

The present study had two main goals. The first was to investigate the factors that might interfere with reading comprehension among children with ASD. The second was to determine whether these children showed the same level of phonological awareness and decoding ability as seen in typically developing children. The findings from examining the first goal were consistent with previous studies: decoding ability for children with ASD did not differ from the population average, sentence comprehension was significantly below decoding (Frith & Snowling 1983; Minshew et al., 1994; Nation et al., 2006), and listening comprehension was below sentence comprehension (Griswold et al., 2002; Nation et al., 2006). Children showed average vocabulary scores, but below average scores in spelling and non-verbal reasoning. These findings replicate previous results in showing that children with ASD had reading comprehension that was not consistent with their good decoding skills (Minshew et al, 1994; Nation et al., 2006; Smith-Gabig, 2009). Despite this replication, the inconsistent scores phonological awareness tests suggest that children with ASD do not decode words the same as typically developing children.

In the present study several measures of decoding were compared to measures of comprehension in order to eliminate decoding as the primary factor that limited reading comprehension. Specifically, the subtests of the WRMT were used as tests of decoding and comprehension. The Word ID subtest measured real-word decoding and the Word Attack subtest measured non-word decoding. In the present sample, scores for Word ID and Word Attack were within the average range. These decoding measures were higher than scores on the Passage Comprehension subtest. Interestingly, Passage

Comprehension was significantly lower than individual Word Comprehension. As both Passage and Listening Comprehension were significantly lower than decoding skills on these tests, it may be the case that the comprehension and integration of more information (i.e., as in sentences and longer passages) is the limiting factor for reading comprehension rather than decoding.

This possibility is consistent with other research that has consistently shown that decoding does not limit reading comprehension in children with ASD (Minshew et al., 1994; Nation et al., 2006; Smith-Gabig, 2010). To determine which other aspects of reading might interfere with reading comprehension, the WRMT, PPVT, TWS, and RPM were used in this study. Picture vocabulary was tested by using the PPVT to determine whether vocabulary was related to poor reading comprehension. PPVT standard scores were slightly below average while Word Comprehension was slightly above average (although not significantly). Picture vocabulary was better than word vocabulary making it difficult to evaluate the relationship between vocabulary and comprehension.

The results of the present study also indicated that children with ASD had poor spelling scores. This was surprising considering that decoding scores were within the normal range. The ability to spell is an important component in the development of linguistic knowledge and reading (Fisher et al., 1985; Kroese et al., 2000). Spelling is the mapping of orthographic representation of words onto linguistic representation and the ability to use this information in writing words (Fischer et al., 1985). Therefore, spelling should be at the same level as Word Attack and Word Comprehension. As well, the results of the present study were compared with those of Minshew et al. (1994) and although the pattern of results was similar across the two studies, one notable difference was in the spelling scores. The findings suggest that spelling may not generally interfere with reading comprehension, but it did suggest a possible decoding anomaly in the present sample.

Another factor that could influence reading comprehension is intelligence. The role of non-verbal reasoning was tested using the Raven's Progressive Matrices. Although the scores of the children with ASD were slightly below average, there were no significant correlations between the RPM and tests of reading comprehension, suggesting that intelligence and reading comprehension were not related in this sample.

Word Comprehension, which is a measure of individual word reading and comprehension, was also within the average range. Passage Comprehension, which is a measure of sentence comprehension, was significantly lower than Word Comprehension. This suggested that poor comprehension may be affected by the poor integration of meanings of different words and the processing and integration of sentences. For example, children may be able to read each word individually but may not be able to recall the meanings of the words from memory or understand them in the context of the sentence. Perhaps also, children with ASD have difficulty with comprehension because they have to process the extra information involved in sentences such as semantics and retrieval of information from memory. This would reduce the cognitive resources available for understanding the information (Martino & Hoffman, 2002; Shankweiler et al., 1999; Spear-Swerling & Sternberg, 1994). They also may not be able to hold the information in working memory from the beginning of the sentence in memory until they finish the sentence to then integrate the information.

It appears likely that, as the amount of information to be processed increases, the children's ability to comprehend decreases. The Passage Comprehension subtest required the processing of sentences. The present findings suggested that it is not likely phonological factors that disrupt reading comprehension, but possibly the amount of information to be processed. What this means is that the problem with comprehension may not lay within the realm of decoding, but of retrieving and processing information. To comprehend effectively, one must have the ability to integrate different types of information in order to understand the words (Snow & Sweet, 2003). Several studies provided support for this interpretation of the comprehension deficit in children with ASD. For example, Snowling and Frith (1986) examined how children with autism use background knowledge during comprehension. To determine how much children's comprehension is influenced by general world knowledge, the children were asked questions that tested memory for information specific to a story, as well as questions which assessed the child's ability to answer using general knowledge. They found that children with ASD with higher verbal ability were able to use general knowledge to answer the questions, but children with ASD with lower verbal ability were impaired in performance. This is an indication that language and general knowledge are both factors that work together in the processing of information.

Similarly, Wahlberg and Magliano (2004) examined how children with ASD use background knowledge when reading and comprehending passages. They provided background information about a topic to one group of children with ASD and no background knowledge to another group, and then had the children read ambiguous text. The ambiguous text was a short passage that could apply to different scenarios and could not be understood without knowledge of the topic or background information. Wahlberg and Magliano (2004) found that when children with ASD had to recall details of the ambiguous text, they were not influenced by background information and did not use the information to interpret the passages, whereas typically developing children were greatly influenced by background information and could understand and recall the ambiguous text. This is evidence that children with ASD have difficulty integrating information even when it has been explicitly provided. Thus, Wahlberg and Magliano (2004) and Snowling and Frith (1986) have provided evidence that children with ASD have difficulty utilizing background information to interpret what they have read, leading to poor comprehension.

The inability to integrate previous knowledge with current information may be an indication that children with ASD have difficulty combining information from different sources, which may be an indication of retrieval failure. Wahlberg and Magliano's (2004) explanation of integrating background knowledge to comprehend passages may account for why children in the current sample had difficulty comprehending sentences presented orally and in print. Working memory may also play a role here in holding the current information long enough to integrate previous knowledge.

It is also possible that limitations in language and communication experienced by children with ASD might affect their reading and listening comprehension. The Listening Comprehension subtest of the WJB was used to assess language comprehension in the present study. It is also a measure of the auditory comprehension of sentences. Previous studies have found that listening comprehension is poor for children with ASD (Minshew et al., 1994; Nation et al., 2006). The Listening Comprehension subtest of the WJB required that the children listen to short sentences from a cassette tape. In the present study, both listening comprehension and reading comprehension were significantly lower than word reading, which corroborates the previous findings of Minshew et al. (1994) and Nation et al. (2006) that poor listening comprehension may be an indication that poor language abilities may be related to poor comprehension.

Consistent with this, a recent examination of literature by Hulme and Snowling (2011) indicated that reading-comprehension deficits are surprisingly common among typically developing children in the general population. The authors defined a reading comprehension impairment as a deficit in reading comprehension that is markedly discrepant with their reading accuracy (i.e., decoding). They noted that many of these children have not even been identified as having a problem with reading. Interestingly, this pattern of reading difficulty is consistent with the pattern that has been observed in this and other studies with children with ASD. Hulme and Snowling reported that many of these typically developing children with a reading-comprehension deficit also showed very poor performance on various measures of language, particularly vocabulary, grammatical understanding, and listening comprehension. The fact that these deficits are also typical of children with ASD supports the suggestion that language deficits may be an important factor underlying their reading comprehension deficits (Wilkinson, 1998).

The second objective of the present study was to examine phoneme awareness and decoding skill in children with ASD. Although research shows that these children do well on decoding and phonemic awareness tasks, the suggestion has been made that there might be something anomalous about the manner or perhaps the order in which they acquire the skills that may differ from that of typically developing children (Jones, 2007;

Nation et al., 2006; Minshew et al., 1994). As Breen (2007) had identified a sequence in which phonological and decoding skills were acquired in typically developing children, her tests and procedures were used to examine whether children with ASD show similar profile of phonological awareness and decoding skill as those of typically developing children.

The results showed that although the children with ASD displayed similarities to Breen's (2007) sample, there were certain anomalies that indicated that they might acquire, process, or use this information differently. For example, spelling and Phoneme Counting were very poor. The children in this sample scored significantly lower on spelling than Minshew's (1994) sample. This fact becomes more interesting considering that Word ID and Work Attack are average, and these are measures of decoding which should be similar to spelling, as it also requires auditory decoding. In addition, Phoneme Counting in the current sample was lower than it was in Breen's sample, yet the children in this sample did better on the other decoding and phonological tasks. As well, spelling and Phoneme Counting were correlated indicating that they are related factors and all the children in the sample did poorly on both. This provides evidence that although decoding in the children with ASD is at population average overall, there may be errors or anomalies in development as indicated by poor spelling and Phoneme Counting. They may have acquired these seemingly good decoding skills through an entirely different route, such as extensive practice and the preoccupation with letters and words that sometimes characterizes children with ASD (e.g., Aaron et al., 1990). It is also possible that children had learned to compensate for deficits in decoding by using alternative strategies. This suggests that it might be useful to look for these when phonological inconsistencies are observed. These children may appear to be proficient decoders but if they were, they should do better on tests of spelling. Future research should examine the relationship between decoding and phonological awareness in children with ASD, perhaps using a larger sample of children.

That children with ASD often develop preoccupations with letters and numbers could explain some children's advanced decoding ability as seen in hyperlexia, i.e., the reading pattern in which decoding is advanced but comprehension is relatively weak. For example, one participant in the present study referred to as Sam, showed extreme interest in letters and the alphabet at two-years of age, was reading words at three, and was reading sentences at four. Sam's decoding ability was greater than 99.9 percent of typical children his age. Even though he still showed higher than average comprehension ability in both reading and listening, his comprehension abilities were weak in comparison to his decoding abilities. He also displayed better individual word reading than both sentence and listening comprehension but his comprehension was still better than average. Although his scores were especially high compared to the other children in the sample, most children did very well on the Word ID and Word Comprehension subtests, with some children scoring higher than population norms, yet also had poor scores on Passage and Listening Comprehension. The important point to note is that although children with ASD appear to be able to decode words effectively, they may have acquired this skill in an atypical manner, one that did not facilitate comprehension of those words. The processes that underlie these atypical patterns are not well understood at this point but should be the subject of future research.

Limitations and Considerations for Future Research

Autism exists on a spectrum and as such shows high variability in the symptoms and a broad range in the severity of the disorder. Children with milder symptoms are significantly different in cognitive ability, behaviour, and social ability from those with more severe symptoms. The severity of symptoms was not measured in the current study, but these factors should be taken into account in future research. In particular it is important to know the baseline profile of these children to determine how the symptoms might influence reading and comprehension.

An additional confounding factor in the present study was the amount of training in word reading and decoding the children may have received. All of the children in this sample were either receiving, or had received ABA therapy, in which they were explicitly taught pre-reading or early reading skills. It is possible that the children received direct training in word identification and word reading, but not in phoneme counting or spelling, which may explain the lower scores in these latter areas. This factor may explain the way some children in the sample had very high skills on some tests (e.g. Word Attack) but not others (e.g. spelling). However, it is unlikely that children received training in non-word reading, which was found to be above average. Therefore, the high variability found in the results could be a result of the variation within the symptoms of ASD, or possibly the training the children have received. Whatever the case it can be assumed that children with various skill sets could benefit from being taught spelling, phonological skills, and comprehension techniques (see Hulme & Snowling, 2011).

Previous ABA training may also have contributed to the self-selection bias that existed in the participants in this study. Information to recruit participants about the study was sent to all available families in the St. John's and Avalon Peninsula areas who had a child diagnosed with ASD and were in contact with the health care system and were in an intervention program with that organization or with the Autism Society. Participation in the study was voluntary, but children in this sample may have been from families who were better educated about programs for children with ASD and who felt the child would enjoy the task or who would do well. This might result in a sample comprised of children with a higher aptitude or motivation as compared to the general ASD population.

Related to the self-selection bias was sample size. Out of approximately 150 possible participants in the greater St. John's area only 11 families volunteered and 10 agreed to participate in the study. The small sample size may explain some of the inconsistencies in the findings. However, recruiting children with clinical conditions is often difficult, so having 10 children able to participate and complete a study is an excellent start. Despite the small sample size there were several interesting findings identified and the study was able to replicate and confirm previous findings from larger studies, such as Nation et al. (2006).

Given the limitations of the present study, future research will be necessary to determine why both Passage Comprehension and Listening Comprehension were low in comparison to decoding, and to investigate whether the problem with comprehension is connected with language or to the ability to retrieve and process information. As well, a group of age-matched typically developing children would provide a better comparison group for reading ability to further understand the sequence of reading development and would provide further information on how children with ASD process and comprehend information.

Conclusions

The findings presented above corroborate previous research that showed that children with ASD often have good decoding ability but poor reading comprehension. The findings that decoding ability for children with ASD is at the population average but that Passage Comprehension and Listening Comprehension are below decoding were replicated here. This supports the conclusion that the difficulty with comprehension observed in children with ASD does not appear to be related to a decoding problem as is often the case with typically developing children. Picture vocabulary scores were slightly below average but higher than reading and listening comprehension therefore, inadequate vocabulary is not the problem either. Because the PPVT and Word Comprehension were almost average, this suggests that these also do not interfere with comprehension. The difference between individual Word Comprehension and Passage Comprehension suggest that the amount of information to be processed and recall of background knowledge that are required to comprehend sentences and text may be an important factor. These findings indicate that children with ASD can understand the meaning of words in isolation but have problems when understanding the meaning of sentences. There is also evidence that the common listening comprehension deficit described in children with ASD indicates a language deficit may also contribute poor reading comprehension (Griswold et al., 2002; Minshew et al., 1994; Nation et al., 2006).

The present findings also suggested that there may be limitations in the way that children with ASD acquire phonological and decoding skills that ultimately limit their reading comprehension, although these have not yet been identified. This disputes Frith and Snowling's (1983) conclusion that phoneme awareness does not interfere with comprehension. Children from those studies were able to use the same reading strategies as typically developing children, which suggested phonological ability was not related to reading (Frith & Snowling, 1983). Children in the present study showed inconsistencies in their scores on the phonological tests scoring almost at ceiling for some and at base or others. This suggests that there may be a phonological deficit or some different way that children have learned to decode and read words. The findings here suggest that even though children with ASD may show some similarities in reading development to typically developing children there may be other factors that lead them to decode words differently from the sequence acquired by typically developing children.

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Appendix A
Sample Rapid Letter Naming Test

Identification #: ____________

Test Date: __________________________

Indicate any errors or substitutions. Cross off each letter read correctly.
Record the time to read each list (seconds).

Upper Case Letters: First

	List 1	List 2	List 3	List 4	List 5
	C	I	P	E	V
	S	D	W	R	Z
	X	G	N	T	F
	H	Y	Q	U	M
	B	L	A	J	K
					O
Errors	________	________	________	________	________

Total Time: ____________

Lower Case Letters: Second

	List 1	List 2	List 3	List 4	List 5
	e	q	y	m	h
	k	s	b	g	r
	w	c	x	p	j
	l	f	i	v	t
	o	n	z	d	u
					a
Errors	________	________	________	________	________

Total Time: ____________

Appendix B
Sample Onset Identity Test

Onset Identity test (12 items total)

Identification #:____________ Test date:______________

Directions: Experimenter: We're going to play a repeating game. First, I'll say a sentence, and then you say it back. Then I'll say a sound, and you say it back. Then I want you to listen for the sound in a word. Ready? Set? Let's go (say in a fun voice).

1. /n/: Say: Those girls have the *same name*. Now say /n/. Do you hear /n/ in *same* or *name*?

2. /p/: Say: I have a *pair* of *rare* socks. Now say /p// Do you hear the /p/ in *pair* or *rare*?

3. /k/: Say; He flew the *kite* at *night*. Now say /k/. Do you hear /k/ in *night* or *kite*?

4. /b/: Say: She likes to *boil* her *soil* in a pot. Now say /b/. Do you hear /b/ in *boil* or *soil*?

5. /g/: Say: We like to play the *fame game*. Now say /g/. Do you hear /g/ in *fame* or *game*?

6. /t/: Say: The fish had a *fin* made of *tin*. Now say /t/. Do you hear /t/ in *fin* or *tin*?

7. /z/: Say: *Zed led* the marching band. Now say /z/. Do you hear /z/ in *Zed* or *led*?

8. /s/: Say: We'll see the *moon soon*. Now say /s/. Do you hear /s/ in *moon* or *soon*?

9. /m/: Say: We can *make* a *lake* with water. Now say /m/. Do you hear /m/ in *make* or *lake*?

10. /d/: Say: Her *jeep* slipped *deep* into the mud. Now say /d/. Do you hear /d/ in *jeep* or *deep*?

11. /r/: Say: The *rake* went in the *lake*. Now say /r/. Do you hear /r/ in *rake* or *lake*?

12. /l/: Say: He saw a *white light*. Now say /l/. Do you hear /l/ in *white* or *light*?

Raw Score:__________

Take a stretch for half a minute before continuing.

Appendix C
Sample Coda Identity Test

Coda Identity test (12 items total)

Identification #:_____________ Test date:_______________

Directions: Experimenter: We're going to play a repeating game. First, I'll say a sentence, and then you say it back. Then I'll say a sound, and you say it back. Then I want you to listen for the sound in a word. Ready? Set? Let's go (say in a fun voice).

1. /n/: Say: She likes to give her *son some* candy. Now say /n/. Do you hear /n/ in *son* or *some*?
2. /p/: Say: Have you seen a *cat* wearing a *cap*? Now say /p/. Do you hear /p/ in *cat* or *cap*?
3. /k/: Say: The *rat* fell off the *rack*. Now say /k/. Do you hear /k/ in *rat* or *rack*?
4. /b/: Say: *Rob* and *Rod* have a turtle named Frank. Now say /b/. Do you hear /b/ in *Rob* or *Rod*?
5. /g/: Say: Aladdin sat on a *rug* to *rub* his lamp. Now say /g/. Do you hear /g/ in *rug* or *rub*?
6. /t/: Say: The ball *hit* my *hip*. Now say /t/. Do you hear /t/ in *hit* or *hip*?
7. /z/: Say: Her *bug* can *buzz* a happy song. Now say /z/. Do you hear /z/ in *bug* or *buzz*?
8. /s/: Say: Can a *moose move* a train? Now say /s/. Do you hear /s/ in *moose* or *move*?
9. /m/: Say: I *hope* to get *home* early. Now say /m/. Do you hear /m/ in *hope* or *home*?
10. /d/: Say: The *mat* got *mad* at the shoe. Now say /d/. Do you hear /d/ in *mat* or *mad*?
11. /l/: Say: The *fin* can *fill* with water. Now say /l/. Do you hear /l/ in *fin* or *fill*?
12. /r/: Say: The *cow* jumped over the *car*. Now say /r/. Do you hear /r/ in *cow* or *car*?

Raw score:___________

Appendix D
Sample Vowel Identity Test

Vowel Identity test (12 items total)

Identification #:____________ Test date:______________

Directions: Experimenter: We're going to play a repeating game. First, I'll say a sentence, and then you say it back. Then I'll say a sound, and you say it back. Then I want you to listen for the sound in a word. Ready? Set? Let's go (say in a fun voice).

1. /I/: Say: The dog started running to be *fit* not *fat*. Now say /I/. Do you hear /I/ in *fit* or *fat*?
2. /ɛ/: Say: He *bet* the *bat* could fly. Now say / ɛ/. Do you hear / ɛ/ in *bet* or *bat*?
3. /e/: Say: The captain *met* the *mate* at the boat. Now say /e/. Do you hear /e/ in *met* or *mate*?
4. /æ/: Say: She named her *cat Kate*. Now say /æ /. Do you hear /æ/ in *cat* or *Kate*?
5. /aI/: Say: The *boy* likes to *buy* presents. Now say /aI/. Do you hear /aI/ in *boy* or *buy*?
6. /aʊ /: Say: He *saw* that he must *sow* the pants. Now say /aʊ /. Do you hear /aʊ/ in *saw* or *sow*?
7. /OI/: Say: *Lloyd lied* to his teacher. Now say /OI/. Do you hear /OI/ in *Lloyd* or *lied*?
8. /ɑ/: Say: She *caught* the *cat* when he jumped. Now say /ɑ/. Do you hear /ɑ/ in *caught* or *cat*?
9. /ʌ/: Say: He had *seen* the *sun* in the sky. Now say /ʌ/. Do you hear /ʌ/ in *seen* or *sun*?
10. /o/: Say: The ducks had a *loan* of the *lawn*. Now say /o/. Do you hear /o/ in *loan* or *lawn*?
11. / ʊ/: Say: She *shook* him awake and he got a *shock*. Now say ʊ/. Do you hear /ʊ/ in *shook* or *shock*?
12. /u/: Say: He *wrote* about the *root* on the tree. Now say /u/. Do you hear /u/ in *wrote* or *root*?

Score:________

Appendix E
Sample Onset Phonetic-Cue Reading Test

Matching initial Consonants

Identification #:____________ Test date:______________ Age:____________

Date of Birth:______________ Grade Level:____________ Sex:____________

Directions: Show the child the card with the appropriate set of words. Ask the child to point to the word you say. For example, in set 1 you would ask the child "can you point to the word that says MOB?" Put "1" beside the first word the child points to and "2' beside his or her second choice. Do not allow a third choice. If there is no response within 10 seconds, go on to the next item.

Set 1. MOB	MOB _____	SOB _____	JOB _____
Set 2. PIT	FIT _____	PIT _____	HIT _____
Set 3. SUN	FUN _____	BUN _____	SUN _____
Set 4. NUT	NUT _____	HUT _____	GUT _____
Set 5. FOG	LOG _____	BOG _____	FOG _____
Set 6. HOW	POW _____	WOW _____	HOW _____
Set 7. ROD	NOD _____	ROD _____	COD _____
Set 8. COT	NOT _____	DOT _____	COT _____
Set 9. TAP	TAP _____	SAP _____	CAP _____
Set 10. DIG	DIG _____	RIG _____	PIG _____
Set 11. BEG	LEG _____	BEG _____	PEG _____
Set 12. ZED	LED _____	ZED _____	BED _____
Set 13. VAN	CAN _____	TAN _____	VAN _____
Set 14. GILL	GILL _____	PILL _____	FILL _____

Total score:____________

Comments:

Appendix F
Sample Coda Phonetic-Cue Reading Test

Matching Final Consonants

Identification #:____________ Test date:______________

Directions: Show the child the card with the appropriate set of words. Ask the child to point to the word you say. For example, in set 1 you would ask the child "can you point to the word that says HAM?" Put "1" beside the first word the child points to and "2' beside his or her second choice. Do not allow a third choice. If there is no response within 10 seconds, ask the question again. If there is no response within 10 seconds mark NR next to the answer and go on to the next item.

Set 1. HAM	HAT ____	HAM ____	HAD ____
Set 2. COP	COB ____	COT ____	COP ____
Set 3. GUS	GUM ____	GUT ____	GUS ____
Set 4. SUN	SUN ____	SUM ____	SUB ____
Set 5. LEAF	LEAD ____	LEAP ____	LEAF ____
Set 6. BED	BEG ____	BED ____	BET ____
Set 7. TAR	TAP ____	TAR ____	TAB ____
Set 8. MAKE	MAKE____	MANE____	MADE____
Set 9. PET	PET ____	PEN ____	PEG ____
Set 10. LAP	LAB ____	LAG ____	LAP ____
Set 11. RIB	RIM ____	RIP ____	RIB ____
Set 12. GAVE	GAME____	GAVE ____	GATE ____
Set 13. PIG	PIG ____	PIT ____	PIN ____
Set 14. ROZ	RON ____	ROZ ____	ROD ____

Total Score:________

Comments:

Appendix G
Vowel Phonetic-Cue Reading Test

Matching Vowels

Identification #:____________ Test date:______________

Directions: Show the child the card with the appropriate set of words. Ask the child to point to the word you say. For example, in set 1 you would ask the child "can you point to the word that says FULL?" Put "1" beside the first word the child points to and "2' beside his or her second choice. Do not allow a third choice. If there is no response within 10 seconds, ask the question again. If there is no response within 10 seconds mark NR next to the answer and go on to the next item.

Set 1. FULL	FULL ____	FEEL ____	FILL ____
Set 2. SHOP	SHEEP____	SHOP ____	SHIP ____
Set 3. LAD	LEAD ____	LID ____	LAD ____
Set 4. RED	ROD ____	RED ____	RID ____
Set 5. WIN	WIN ____	WHEN____	WON ____
Set 6. NET	NOT ____	NUT ____	NET ____
Set 7. MAD	MAD ____	MUD ____	MID ____
Set 8. BOOK	BEAK ____	BACK ____	BOOK ____
Set 9. GET	GOT ____	GET ____	GUT ____
Set 10. RAM	RUM ____	RAM ____	RIM ____
Set 11. SOD	SOD ____	SAD ____	SIDE ____
Set 12. TEEN	TOWN____	TEEN ____	TONE ____
Set 13. LOON	LOAN ____	LAWN____	LOON ____
Set 14. BIT	BIT ____	BET ____	BAT ____

Score: ____

Comments:

Appendix H
Sample Phoneme Counting Pre-test

ID#: ________________ Date: ______________

Training Items:

Set 1)	I	hi	kite
Set 2)	A	may	cake
Set 3)	owe	go	goat

Pretest Items:

Site ______

Low ______

Rain ______

Tie ______

Ape ______

Boat ______

Toe ______

Bye ______

Ray ______

Score: ______

Appendix I
Sample Phoneme Counting Test
Experimental Test

Identification #:____________ Test date:______________

List 1	# of tokens		List 2	# of tokens	
at	(2)	____	we	(2)	____
shin	(3)	____	now	(2)	____
off	(2)	____	clap	(4)	____
blood	(4)	____	of	(2)	____
egg	(2)	____	fan	(3)	____
tin	(3)	____	sigh	(2)	____
it	(2)	____	drum	(4)	____
them	(3)	____	she	(2)	____
my	(2)	____	trip	(4)	____
train	(4)	____	ice	(2)	____
sun	(3)	____	clear	(4)	____

Score: ________

Comments: