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Prosodic awareness is related to reading ability in children with autism spectrum disorders

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Prosodic awareness has been linked with reading accuracy in typically developing children. Although children with autism spectrum disorders (ASD) often have difficulty processing prosody and often have trouble learning to read, no previous study has looked at the link between explicit prosodic awareness and reading in ASD. In the current study, 29 early readers with ASD (5–11 years) completed word and nonword reading accuracy tasks and two measures of prosodic awareness. Tasks relating to phonological awareness, oral language, vocabulary, letter knowledge and nonverbal intelligence were also administered. A key finding was that there was a relationship between prosodic awareness and both word and nonword reading accuracy.

Communication across a variety of modalities can be disrupted in autism spectrum disorders (ASD). Although children with ASD vary greatly in the nature and degree of this disruption, it is not uncommon for them to present with language impairments. Because of the link between language and reading acquisition in typically developing children and a variety of other populations, it is expected that many children with ASD will experience difficulty in learning to read. This is a major concern because difficulties in learning to read limit access to educational material and lead to risk of poorer vocational and social endeavours over the lifespan. In this study, we sought to determine the subskills associated with reading accuracy in children with ASD. Advancing our understanding of the subskills associated with reading can, in the longer term, inform literacy instruction and remediation programmes. Here, we were particularly interested to know whether awareness of word-level and phrase-level prosody might be associated with word and/or nonword reading accuracy. Awareness of prosody, in the form of explicit awareness of metrical stress and of lexical stress, has been linked with reading accuracy in typically developing children. However, as far as we are aware, ours is the first study to examine this link in children with ASD.

Reading ability in children with autism spectrum disorder

Reading is a complex task that involves two basic components: decoding of words and comprehending the intended meaning of the text (in line with the simple view of reading; e.g., Gough & Tunmer, 1986). For some children with ASD, these skills develop together.

However, for others, reading comprehension is lower than expected for their level of decoding ability (e.g., Huemer & Mann, 2010). This reading profile is consistent with the term 'hyperlexia', and although typically developing children may demonstrate hyperlexia, it is a term more commonly associated with children with ASD (Newman et al., 2007).

In a seminal study of reading and autism, Nation, Clarke, Wright and Williams (2006) investigated the reading skills of 41 children with ASD. Inclusion criteria were broad in that participants were 6–15 years of age and had 'measurable language skills, however minimal' (p. 913). Participants were assessed on word and nonword reading accuracy, text-level reading accuracy and reading comprehension. A total of 22% of this sample were unable to read. For the 32 children with measurable reading ability, results showed that the mean standard scores for all three measures of reading accuracy (i.e., word, nonword and text-level reading accuracy) were within 1*SD* of population norms. In contrast, most participants scored below population norms on reading comprehension. Sixty-five per cent of participants scored at least 1*SD* below population norms on reading comprehension, and 38% scored more than 2*SD* below population norms. Results reported by Arciuli, Stevens, Trembath and Simpson (2013) were generally in line with those of Nation et al. (2006) in suggesting that reading comprehension and reading accuracy can develop unevenly in some individuals with ASD.

Another interesting finding from the study by Nation and colleagues was that despite performing within the average range for word reading accuracy, participants demonstrated difficulties in decoding nonwords: 42% scored at least 1*SD* below population norms, and 22% scored at least 2*SD* below population norms. Some children with ASD are thought to rely on memorisation of letter–sound patterns and visual association strategies rather than phonological processing when reading, which may contribute to their higher scores on tests of real word reading compared with nonword reading (e.g., Cardoso-Martins & Ribeiro da Silva, 2010).

In contrast with the findings of Nation et al. (2006), an earlier study by Frith and Snowling (1983) found that children with ASD did not exhibit better decoding of real words compared with nonwords. Minshew, Goldstein, Taylor and Siegel (1994) showed that individuals with ASD performed slightly better when decoding nonwords in comparison with real words. However, these studies only included children with age-appropriate or advanced reading skills, making it difficult to generalise results given the significant variability of reading competence across the population of children with ASD.

In summary, there is conflicting evidence concerning word and nonword reading in children with ASD. It is necessary to further explore both word and nonword reading accuracy in children with ASD and determine the subskills underlying reading achievement in this population.

Subskills associated with reading words and nonwords

Phonological awareness. Reading involves decoding written strings by learning the connections between graphemes and phonemes (i.e., between letters and sounds). In order to develop these connections, children must have an explicit knowledge of the phonemes within their oral language system. This knowledge is known as phonological awareness. Phonological awareness is defined as the ability to compare, segment and blend various parts of spoken words such as syllables, onsets and rimes and phonemes. An early study by Bradley and Bryant (1983) found that phonological awareness skills prior to reading instruction predicted later reading performance. Numerous studies have since reported a link between reading and phonological awareness in typically developing children (e.g., Anthony & Francis, 2005; Blaiklock, 2004; Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg & Poe, 2003). In contrast with the sizeable body of research indicating that phonological awareness is an important predictor of reading success in typically developing children, only a handful of studies have investigated phonological awareness and its role in literacy development in children with ASD (e.g., Cardoso-Martins & Ribeiro da Silva, 2010; Newman et al., 2007; Smith-Gabig, 2010).

Newman et al. (2007) assessed participants on the phonological awareness skills of rhyming, sound deletion, sound substitution and sound reversal within words. They found that children with ASD performed poorly on measures of phonological awareness in comparison with a typically developing control group.

In a recent study, Cardoso-Martins and Ribeiro da Silva (2010) examined the correlations between a range of cognitive and linguistic skills and reading accuracy, in a total of 14 children with ASD and 27 typical peers. Results showed that children with ASD performed more poorly than typically developing children on the phonological awareness task of initial phoneme identification. This task required participants to select, from a choice of three words, the one that started with the sound spoken by the examiner. Children with ASD who exhibited hyperlexia obtained lower scores on the phonological awareness task than children with ASD who did not exhibit hyperlexia.

In another recent study, Smith-Gabig (2010) investigated the reading accuracy and phonological awareness skills of 14 children with ASD and 10 typically developing peers. Results revealed that children with ASD scored below average on measures of phonological awareness in comparison with typically developing peers: a total of 43% scored below average on both elision (i.e., omitting the initial or final phoneme of a word) and sound blending (i.e., combining individual syllables or phonemes to produce a word), and 26% scored below average on the elision task but within the average range for sound blending. This indicates that although some children with ASD may be capable of blending phonemes together to create words, isolating and manipulating phonemes within words remain a difficult task for some. Interestingly, there was no relationship between measures of phonological awareness and measures of word reading accuracy in children with ASD. However, a significant positive relationship was found between the elision task and decoding of nonwords for the typically developing group.

The results from these studies indicate that children with ASD tend to perform at a level below typically developing children on a variety of phonological awareness tasks. As far as we are aware, Smith-Gabig (2010) and Cardoso-Martins and Ribeiro da Silva (2010) were the first to explore the link between phonological awareness and reading accuracy in children with ASD and are the only ones to do so. This highlights the need to further explore the phonological awareness skills of children with ASD and its relationship with reading ability. Of particular interest is a construct that has only relatively recently emerged in the literature on reading ability known as awareness of prosody.

Prosodic awareness. Prosodic awareness refers to the ability to perceive cues that relate to duration, intensity, pitch and pausing. These cues assist the listener to process the speech stream as phrases, words and syllables and help the listener attend to salient information to facilitate understanding (Whalley & Hansen, 2006). For example, lexical stress refers to the contrastivity between syllables in polysyllabic words such as 'INcense' (where the first syllable is more strongly emphasised relative to the second) versus 'inCENSE' (where the second syllable is more strongly emphasised relative to the first). Although prosodic awareness could be thought of as a form of suprasegmental phonological awareness, decades of research on reading development that has explored phonological awareness have generally neglected consideration of prosodic awareness.

In more recent research on reading development, prosodic awareness has been assessed in a number of ways including awareness of lexical stress, which, as demonstrated in the example earlier, refers to a rhythmic pattern that occurs within a word and can be lexically distinctive. By comparison, awareness of metrical stress refers to the rhythmic pattern that occurs across a phrase or several syllables (e.g., it can be used to differentiate between a compound noun and a noun phrase, such as 'lighthouse' versus 'light house'; Goodman, Libenson & Wade-Woolley, 2010).

The ability of typically developing early readers to cope with changes in lexical stress was examined by Wood (2006) by assessing their ability to identify mispronounced disyllabic words. In their Mispronunciation Task, the following features of the words were changed: reversal of primary lexical stress (e.g., 'CARpet' became 'carPET'), reduction of a previously full vowel sound to a schwa and production of a full vowel sound that was previously a schwa. Wood explored the link between performance on the Mispronunciation Task and phonological awareness, alphabet knowledge, word reading and spelling ability. Awareness of lexical stress accounted for significant variance in word and nonword reading accuracy and spelling. Using a larger sample and an adapted version of the Mispronunciation Task, Holliman, Wood and Sheehy (2010) also found that lexical stress awareness explained variance in reading accuracy performance even after age, vocabulary, phonological awareness and short term memory had been taken into consideration. In fact, research on reading in a number of different languages has highlighted the importance of awareness of lexical stress for reading accuracy in early reading development (Goetry, Wade-Woolley, Kolinsky & Mousty, 2006; Gutierrez-Palma, Raya-Garcia & Palma-Reyes, 2009; Williams & Wood, 2012).

In another study, Goodman et al. (2010) investigated the relationship between awareness of linguistic stress and phonological awareness and between linguistic stress and reading achievement in typically developing preschool children. Awareness of lexical stress was measured using the Mispronunciation Task (adapted from Wood, 2006), and awareness of metrical stress was measured using the Compound Noun Task (Whalley & Hansen, 2006), which required participants to determine whether a spoken phrase represented two or three items depending on its stress assignment (e.g., 'chocolate-cake and honey' or 'chocolate, cake and honey'). Results showed that lexical stress awareness explained variance in reading accuracy. It may be that awareness of lexical stress helps to focus children's attention on stressed syllables, making it easier to build specific phonological representations of words, which is necessary for subsequent phoneme-to-grapheme mapping during reading acquisition.

Although it has been reported that children with ASD often have difficulty perceiving and producing prosody, no previous study has looked at the link between explicit prosodic awareness and literacy development in children with ASD. It is thought that around 50% of individuals with ASD that have functional verbal communication skills have problems processing prosody (Paul, Shriberg, et al., 2005). The nature and degree of these problems is highly variable across individuals and appears to be unrelated to the severity of ASD symptoms, as prosodic difficulties have been reported at all levels of ability, including high-functioning autism (Peppe, McCann, Gibbon, O'Hare & Rutherford, 2007).

Paul, Augustyn, Klin and Volkmar (2005) investigated perception and production of three prosodic functions in 27 individuals with ASD and 13 typical peers: stress, intonation and phrasing. Researchers examined participants' ability to perceive and produce stress within words that signal the grammatical shift from noun to verb (e.g., 'PREsent' versus 'preSENT'). The perception and production of intonation patterns that signal grammatical function in statements versus questions was measured, as was the perception and production of pauses used to group words into phrases within sentences. Significant group differences were found for perception and production of lexical stress, but not for intonation or phrasing. This is in line with previous findings (for a recent review of prosody in ASD, see Arciuli, 2014).

Given the relationship between prosodic awareness and reading ability in studies of typically developing children, it is reasonable to hypothesise that prosodic deficits commonly seen in children with ASD may contribute to their difficulties with reading.

Other subskills related to reading ability. In addition to phonological awareness and prosodic awareness, a range of other skills are associated with reading achievement. In particular, various aspects of oral language have been found to be important for reading acquisition. Betourne and Friel-Patti (2003) found that oral language ability (including measures of semantic, morphological and syntactic skills) accounted for significant variance on measures of word reading accuracy for typically developing fourth-grade children. Similarly, in a longitudinal investigation of 208 children, Catts, Fey, Tomblin and Zhang (2002) found that oral language (including measures of vocabulary, grammar, narration and expressive and receptive language) as assessed in kindergarten accounted for unique variance in word reading accuracy in Grades 2 and 4. In that same study, phonological awareness, letter identification and rapid automatic naming also emerged as predictors of later reading ability. Interestingly, nonverbal intelligence also played a role in predicting word and nonword reading accuracy – the nonverbal cognitive skills of visual–spatial and analytic reasoning may contribute to early reading development. In addition, nonverbal abilities may correlate to higher-level language skills, which in turn influence reading (Catts et al., 2002).

Subskills of particular interest when examining reading accuracy are vocabulary and letter knowledge. Verhoeven, van Leeuwe and Vermeer (2011) examined the relationship between vocabulary growth and reading development across Grades 1–6 in a longitudinal investigation of 2,790 typically developing Dutch children. Vocabulary knowledge at the beginning of reading instruction was found to predict later word decoding skills. It is thought that continued vocabulary growth leads to increased specificity of phonological representations of words, which in turn supports phonemic awareness and subsequent phoneme-to-grapheme mapping during reading acquisition (Elbro, Borstrom & Petersen, 1998; Scarborough, 2001). Letter knowledge is also thought to contribute to reading performance. Numerous studies have found a significant correlation between letter name and letter sound knowledge and early reading ability, in typically developing children (e.g., Gallagher, Frith & Snowling, 2000; Muter & Diethelm, 2001).

Although it has been found that oral language and vocabulary contribute to reading development in typically developing children, research regarding their role in literacy development in children with ASD is lacking. However, evidence that oral language and vocabulary predicts unique variance in reading comprehension for children and adolescents with ASD is emerging. A recent study by Ricketts and colleagues of 100 adolescents with ASD examined the role of oral language and social functioning for reading comprehension. Regression analyses showed that oral language comprehension, as measured by a receptive grammar test and a receptive language composite score, was a unique predictor of reading comprehension (Ricketts, Jones, Happe & Charman, 2013). These findings are consistent with those of Asberg, Kopp, Berg-Kelly and Gillberg (2010) who found a relationship between expressive vocabulary and reading comprehension in their study of children and adolescents with ASD. Nation et al. (2006) compared children with ASD who performed within or above the normal range on a measure of passage-level reading comprehension with those who performed below the normal range. They found that skilled reading comprehenders had significantly higher oral language ability as measured by a receptive vocabulary test. Similarly, Norbury and Nation (2011) reported the importance of oral language competence for reading comprehension in their study of 27 adolescents with ASD.

The current study

The current study was designed to provide a comprehensive examination of word and nonword reading accuracy of children with ASD. We were especially interested in examining whether prosodic awareness is related to word and/or nonword reading in ASD, although a range of possible subskills were investigated including phonological awareness, oral language, vocabulary, letter knowledge and nonverbal intelligence.

It was difficult to predict the results of this study because of the limited amount of research conducted on reading accuracy in children with ASD. However, it was hypothesised that there would be a relationship between reading accuracy and each of the following: phonological awareness, prosodic awareness, oral language, vocabulary, letter knowledge and perhaps nonverbal intelligence.

Method

Participants

Participants were 29 children with ASD aged 5–11 years (mean = 8.08 years) – 24 male and five female children, all of whom spoke English as their only language. Parent report revealed no history of hearing impairment or visual problems for any of the participants. Parent and/or teacher report indicated that all children could read at the single word level.

All participants had a current clinical diagnosis of ASD according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV; American Psychiatric Association, 1994): 25 with autistic disorder (autism), two with Asperger's disorder and two with atypical autism or pervasive developmental disorder not otherwise specified. The educational setting varied: 14 attended mainstream schools, nine attended satellite classes (support classes for ASD conducted within mainstream schools) and six attended schools dedicated to the needs of children with ASD. Five children had a concomitant diagnosis of intellectual disability, as reported by a parent or teacher.

The study was approved by the University of Sydney Human Research Ethics Committee and Autism Spectrum Australia's Ethics and Research Committee.

Materials

Phonological awareness. Phonological awareness was assessed using the Comprehensive Test of Phonological Processing (CTOPP: Wagner, Torgesen & Rashotte, 1999). A composite score was derived from particular subtests, as per the recommendations of the test creators. For children aged 5–6, three subtests were used: Elision, Blending Words and Sound Matching. For children aged 7–12, two subtests were used: Elision and Blending Words. The Elision subtest had six practice and 20 test items. For the first three practice items and first two test items, participants repeated a compound word and then said the word that remained after dropping one of the words (e.g., 'brush' is the word that remains after you drop 'tooth' from 'toothbrush'). For the remaining items, participants repeated a word and then said the word minus a specific sound (e.g., 'time' without the sound 'm' is 'tie'). Feedback (correct/incorrect) was given for all practice items and the first five test items. Participants received a score of 1 for each correct response (testing was discontinued after three consecutive incorrect responses). The Blending Words subtest had six practice and 20 test items. Participants combined syllables or sounds to form words (e.g., 's-un' makes 'sun'). Feedback (correct/incorrect) was given for practice items and the first three test items. Participants received a score of 1 for each correct response (testing was discontinued after three consecutive incorrect responses). The Sound Matching subtest required participants to match initial and final sounds in words. For the first three practice items and 10 test items, participants selected a visual item (from a choice of three) corresponding to the word that started with the same first sound as the stimulus word spoken by the examiner (e.g., 'Which word starts with the same sound as pan? Pig, hat or cone?'). For the remaining three practice items and 10 test items, participants selected a visual item (from a choice of three) that corresponded to the word that ended with the same last sound as the stimulus word spoken by the examiner (e.g., 'Which word ends with the same sound as cap? Car, lip or fan?'). Feedback (correct/incorrect) was given for the practice items and the first three test items for both initial and final sound matching. Participants received a score of 1 for each correct response (testing was discontinued when four out of seven responses were incorrect).

Prosodic awareness. To assess prosodic awareness, participants completed two tasks. Lexical stress was measured using stimuli from the Mispronunciation Task (Holliman et al., 2010), which required participants to recognise disyllabic words when they were presented with inverted syllabic stress (e.g., 'PAper' becomes 'paPER'). Participants were shown a drawing of a scene (a house and garden belonging to a toy bear) and had to find 16 items located on the drawing. Each item carried primary lexical stress on its first syllable and a reduced vowel in its second syllable. They heard a recording of an adult female producing each of the 16 items with reversed lexical stress (the first was a practice item). Participants received a score of 1 for each test item correctly identified.

Metrical stress was measured using the Compound Noun Task (Whalley & Hansen, 2006), which required participants to determine whether phrases represented two items or three items depending on pausing and stress assignment (e.g. 'breadstick and eggs' or 'bread, stick and eggs'). A recording of an adult female saying 23 phrases was used (the first three were practice items). For each phrase, participants were presented with two line drawings, one which contained two items and the other containing three items. They pointed to the line drawing that best depicted the phrase that was presented. Participants received a score of 1 for each correct response.

Oral language. Oral language was assessed using the Formulated Sentences subtest of the Clinical Evaluation of Language Fundamentals – Fourth Edition (Semel, Wiig & Secord, 2003). Participants were asked to create a sentence when given a picture and single-word or short-phrase stimuli. Participants were given a demonstration item and two trial items (no score for trial items). A score of 2 was given for a semantically and syntactically correct sentence. A score of 1 was given for a complete sentence that had one to two deviations in syntax or semantics. A score of 0 was given for an incomplete sentence, for a complete sentence with more than two errors in syntax or semantics, for a complete sentence that was not logical or meaningful or if the sentence did not contain the stimulus word/phrase or was not related to the stimulus picture. Participants aged 5–8 years completed test items 1–24, and participants aged 9–12 were given credit for items 1–7 and completed test items 8–28 (if a score of 0 was given for items 8 or 9, participants completed items 1–7). Testing was discontinued after five consecutive scores of 0.

Vocabulary. Receptive vocabulary was assessed using the Peabody Picture Vocabulary Test – Fourth Edition (Dunn & Dunn, 2007). Participants were required to select a picture (from a choice of four) that best illustrated the meaning of a word spoken by the examiner (with a score of 1 for each correct response). The test consists of four practice items and 228 test items grouped into sets of 12. A recommended starting point is given for each age. If more than one error was made in the first set, earlier sets were administered until a basal rule of 1 or 0 errors was met or until Set 1 was completed. Testing continued until the participant made eight or more errors in a set or until all items were administered.

Letter knowledge. To assess letter knowledge, participants were required to produce the letter name for each letter in the alphabet. Alphabet cards were lain out on the floor, and participants were provided with a small ball to throw. Participants were required to pick up the card the ball landed on and produce the name of the letter printed on it.

Nonverbal intelligence. Nonverbal intelligence was assessed using the Test of Nonverbal Intelligence – Third Edition (Brown, Sherbenou & Johnsen, 1997). Participants were shown abstract figures and were asked to select the missing figure from four or six options. The test consists of five practice items and 45 test items. For the practice items, the examiner pointed to the empty square and then went through each response choice whilst looking questioningly at the participant. The examiner gave a head nod or a head shake in response to each choice and encouraged the participant to point to the correct choice. For the test items, the examiner pointed to the empty square and ran her finger along the response choices whilst looking questioningly at the participant. A score of 1 was given for each correct response. Testing continued until three incorrect responses for five consecutive items were given.

Reading ability. Reading accuracy was assessed using the Word Identification and Word Attack subtests of the Woodcock Reading Mastery Tests-Revised (Woodcock, 1998). The Word Identification subtest required participants to read aloud real words of increasing difficulty. Participants received a score of 1 for each correct response (with a maximum score of 106). A recommended starting point was given for each age level. A basal was established when the first six items administered were answered correctly (if not, participants were required to complete all items on the previous easel page). Testing was discontinued when participants failed on six consecutive items. The Word Attack subtest required participants to read aloud nonsense words of increasing difficulty. Participants received a score of 1 for each correct response (with a maximum score of 45). Participants were given two demonstration items for familiarisation purposes. Testing continued until participants failed on six consecutive items.

Procedures

Children were assessed individually over two sessions (1-hour duration each session). Some assessments were not administered because of participant fatigue, limited attention and/or behavioural issues.

Results

Descriptive statistics are presented in Table 1. Raw scores are displayed, with the exception of the CTOPP, which is displayed as a percentage because of the differing number of subtests comprising the composite score for 5- to 6-year-olds and 7- to 12-year-olds, and the Formulated Sentences subtest of the Clinical Evaluation of Language Fundamentals – Fourth Edition, which is displayed as a percentage because of the differing number of test items for 5- to 8-year-olds and 9- to 12-year-olds. Note the high degree of variability across all assessment tasks. The number of participants who completed each test varied as some tests were too cognitively demanding for some children, especially for participants with concomitant intellectual disability.

Table 1. Descriptive statistics for chronological age and performance on phonological awareness, prosodic awareness, oral language, vocabulary, letter knowledge, nonverbal intelligence and reading assessments

Variable	*N*[a]	Mean	*SD*	Range	Maximum possible
Chronological age (years)	29	8.07	2.25	5.42–11.75	
Phonological awareness	24	30.45	21.37	1.67–70	100 (%)
Prosodic awareness – Mispronunciation Task	28	4.79	3.76	0–11	15
Prosodic awareness – Compound Noun Task	26	12.85	6.40	0–20	20
Oral language	18	45.73	31.10	0–91.07	100 (%)
Vocabulary	29	94.21	47.98	19–190	228
Letter knowledge	29	23.07	6.23	1–26	26
Nonverbal intelligence	25	12.20	7.25	1–24	45
Word reading accuracy	27	38.37	27.10	0–93	106
Nonword reading accuracy	27	12.30	14.30	0–37	45

Note: [a]Number of participants' scores included. All scores are raw scores with the exception of oral language and phonological awareness.

Comparison of word and nonword reading

A significant positive correlation was found between word and nonword reading accuracy when using raw scores (Pearson's $r = .877$; $p < .001$; Spearman's rho $= .869$, $p < .001$) and when using raw scores partialling out age ($r = .870$, $p < .001$). Additionally, there was no statistically significant difference between age-based percentile ranks obtained on word and nonword measures (means of 50.38 and 46.35, respectively; $t[26] = 0.953$, $p = .349$). However, a greater number of participants scored $>1SD$ above population norms on the measure of word reading ($n = 10$) compared with the measure of nonword reading ($n = 5$). A comparable number of participants scored more than 1*SD* below population norms on the measure of word reading ($n = 10$) compared with the measure of nonword reading ($n = 9$).

Relationships between variables of interest and reading ability

Word reading accuracy. Table 2 shows bivariate parametric correlations using Pearson's r to examine the relationships between the variables of interest and word reading accuracy. A significant positive correlation was found between word reading accuracy and each of four variables: phonological awareness, oral language, vocabulary and letter knowledge. One of the measures of prosodic awareness, the measure of lexical stress (Mispronunciation Task), was significantly correlated with word reading accuracy. Neither the measure of metrical stress (Compound Noun Task) nor the measure of nonverbal intelligence showed a significant correlation with word reading accuracy. Oral language had the strongest correlation with word reading accuracy ($r = .809$, $p < .001$).

In view of the sample size, we conducted nonparametric analyses – Spearman's rho indicated the same results. As participants varied in age, we also used partial correlations to control for age and found the same results. Both the nonparametric correlations and the partial correlations revealed that the same five variables were significantly correlated with word reading accuracy and that the relationship between oral language and word reading accuracy was the strongest. We reran all correlations, excluding the five participants with intellectual disability. The pattern of results was the same in every case except for the relationship between word reading accuracy and letter knowledge, which changed from $p = .033$ to $p = .070$.

Table 2. Bivariate parametric correlations using Pearson's r

	1	2	3	4	5	6	7	8	9
1. Phonological awareness									
2. Prosodic awareness – Mispronunciation Task	.672**								
3. Prosodic awareness – Compound Noun Task	.292	.278							
4. Oral language	.735***	.839***	.183						
5. Vocabulary	.633**	.774***	.331	.835***					
6. Letter knowledge	.420	.383	.058	.520*	.294				
7. Nonverbal intelligence	.131	.600*	.523*	.428	.527**	.358			
8. Word reading accuracy	.744***	.755***	.164	.809***	.790***	.639**	.393		
9. Nonword reading accuracy	.893***	.711***	.105	.759***	.709***	.463	.149	.887***	

***$p < .001$ or $p = .001$; **$p < .01$ or $p = .01$; *$p < .05$.

Nonword reading accuracy. Bivariate parametric correlations using Pearson's *r* to examine the association between nonword reading accuracy and the other variables are shown in Table 2. Results were similar to those reported earlier for word reading accuracy. A significant positive correlation was found between nonword reading accuracy and each of the following: phonological awareness, oral language and vocabulary. A significant positive correlation was also found between nonword reading accuracy and one of the measures of prosodic awareness, the measure of lexical stress (Mispronunciation Task). As with the results for word reading, neither nonverbal intelligence nor performance on the measure of metrical stress (Compound Noun Task) showed a significant relationship with nonword reading. Unlike the results for word reading, letter knowledge did not show a significant correlation with nonword reading ($p = .061$). Phonological awareness showed the strongest relationship with nonword reading accuracy ($r = .893$, $p < .001$).

Nonparametric analyses using Spearman's rho indicated very similar results. The same four variables were significantly correlated with nonword reading accuracy, and the relationship between phonological awareness and nonword reading accuracy was the strongest. The only difference in the results of the nonparametric versus parametric analyses was that Spearman's rho indicated a significant relationship between letter knowledge and nonword reading accuracy ($p = .038$). We also used partial correlations to control for age and found very similar results – the only difference was that the relationship between letter knowledge and nonword reading accuracy was not significant ($p = .177$). We reran all of these correlations, excluding the five participants with intellectual disability. The pattern of results was the same.

Performance for poor versus average and above-average readers

Scores on the Word Identification subtest were used to separate participants into two groups: (1) poor word readers (i.e., scored at least 1*SD* below population norms) and (2) average and above-average word readers (i.e., scored within 1*SD* or >1*SD* above population norms). There were 10 children in the poor word reader group (mean age = 8.81 years) and 19 in the average and above-average group (mean age = 7.68 years). We report independent *t*-test results for equal variance assumed or equal variance not assumed, as appropriate. There were significant group differences on both measures of prosodic awareness (the Mispronunciation Task and the Compound Noun Task), vocabulary and nonverbal intelligence ($t[23.72] = 2.43$, $p = .023$; $t[24] = 2.62$, $p = .015$; $t[27] = 2.88$, $p = .008$; and $t[23] = 2.13$, $p = .044$, respectively). Poor word readers had significantly lower prosodic awareness, vocabulary, letter knowledge and nonverbal intelligence than the average and above-average group.

Similarly, scores on the Word Attack subtest were used to separate participants into two groups (i.e., poor nonword readers versus average and above-average nonword readers). There were nine children in the poor nonword reader group (mean age = 9.19 years) and 20 in the average and above-average group (mean age = 7.57 years). We report the results of independent *t* tests for equal variance assumed or equal variance not assumed, as appropriate. There were significant group differences in vocabulary and on the Mispronunciation Task ($t[23.56] = 3.63$, $p = .001$; and $t[27] = 2.98$, $p = .006$). Poor nonword readers had significantly lower Mispronunciation Task scores and lower vocabulary than the average and above-average group.

Discussion

This study was designed to increase the knowledge base concerning the literacy skills of children with ASD and to determine the subskills linked to word and nonword reading in a sample from this population. On the basis of previous research, it was expected that reading accuracy would be variable across participants. Indeed, our results indicated a high degree of variability for both word and nonword reading. There is conflicting evidence concerning the comparison of word and nonword reading in children with ASD in previous research. Some investigators reported no advantage for the decoding of words over nonwords (Frith & Snowling, 1983; Minshew et al., 1994). However, Nation et al. (2006) and Arciuli et al. (2013) suggested that many children with ASD struggle with nonword reading. Our results provide some support for the idea that word reading may be easier than nonword reading in at least some children with ASD (in that we found twice as many children to be above average in terms of word reading compared with nonword reading).

A significant positive relationship was found between one measure of prosodic awareness, awareness of lexical stress (Mispronunciation Task), and both measures of reading accuracy (word and nonword reading). Interestingly, our measure of metrical stress awareness (Compound Noun Task) was not significantly correlated with either word or nonword reading. We hypothesise that perhaps awareness of the stress patterns within words, as measured by lexical stress tasks, is most important for single word and nonword reading accuracy, whereas awareness of pausing and stress patterns across a phrase, as measured by metrical stress tasks, may be more important for passage-level reading accuracy and perhaps passage-level comprehension. Future research could explore this by incorporating tests of passage-level reading accuracy and comprehension.

Despite knowing that (1) many children with ASD experience difficulties processing prosody, (2) many children with ASD experience problems learning to read and (3) prosodic awareness is linked to reading development in typically developing children, the current study is the first to investigate the link between prosodic awareness and reading accuracy in children with ASD. Our results revealed that awareness of lexical stress was significantly related to word and also nonword reading in children with ASD. This supports previous research in typically developing children that highlights the importance of prosodic awareness for reading acquisition (Goodman et al., 2010; Holliman et al., 2010; Wood, 2006).

Taken together, our results for word and also nonword reading suggest that higher levels of phonological awareness, awareness of lexical stress, oral language and vocabulary tend to be associated with higher reading accuracy. We did not find a significant relationship between reading accuracy and nonverbal intelligence. Letter knowledge showed a significant correlation with word reading, but not nonword reading.

Phonological awareness is widely known to be a significant predictor of reading performance in the typically developing population (Anthony & Francis, 2005; Blaiklock, 2004). Our findings showed a significant relationship between phonological awareness and reading accuracy, which indicates that children with ASD, too, require strong phonological awareness skills for reading. This result is in contrast to that of Smith-Gabig (2010) who did not find a significant link between phonological awareness and reading ability in her study of children with ASD. Although Smith-Gabig (2010) used the same measure of phonological awareness (i.e., CTOPP composite score), only 14 children with ASD participated in that study, as opposed to the 24/29 participants in the current study. Oral language skills, including semantic and syntactic skills, are also important for competent readers (Davidson & Ellis Weismer, in press). Children must apply their knowledge of structure, grammar and meaning of oral language when reading. Syntactic skills are thought to be especially important for word identification (Betourne & Friel-Patti, 2003). Vocabulary growth is thought to contribute to reading by increasing the specificity of phonological representations of words (Elbro et al., 1998; Scarborough, 2001).

A note on subtypes of autism spectrum disorders

We acknowledge that there has been interest in subtypes of autism in many areas of research, but this interest in subtypes is not as prevalent in research on reading in ASD. Moreover, there is a move away from subtypes, more generally. For example, Asperger's and autistic disorder are now under one heading in DSM-5 (American Psychiatric Association, 2013). The current study recruited participants with diagnoses across the autism spectrum as we were following a precedent of broad recruitment from the ASD population. This precedent was set by Nation et al. (2006). Since then, studies by Newman et al. (2007), Huemer and Mann (2010) and Arciuli et al. (2013) have followed this precedent by recruiting individuals that have been diagnosed with varying subtypes of autism under DSM-IV.

Limitations

Recruitment for this type of research is challenging, however; a larger sample size would allow for additional statistical analyses to be conducted. For example, a larger sample would allow for multiple regression analyses to determine the relative contribution of each of the variables of interest in predicting reading outcomes. However, it is important to note that the number of participants in our study ($n = 29$) compares favourably with other recent studies on literacy in children with ASD. For example, both Smith-Gabig (2010) and Cardoso-Martins and Ribeiro da Silva (2010) included only 14 participants with ASD in their investigations.

Broad recruitment resulted in some low-functioning children participating in the study, including five with intellectual disability. Some of the children in our study had trouble completing the hour-long assessment sessions and were unable to complete some tasks as they were too cognitively demanding. This is a challenging issue to address. On the one hand, recruitment of higher-functioning children capable of completing all tasks may provide a clearer understanding of the subskills associated with reading in children with ASD. On the other hand, recruitment of higher-functioning children may not represent the wider ASD population.

Future research

The results from this study cannot speak to causality. However, the significant relationship between awareness of lexical stress (a measure of prosodic awareness) and reading accuracy found in the current study may, in the longer term, have implications for the design of literacy programmes for children with ASD. Ideally, future research ought to establish that prosodic awareness is causally linked to reading, through longitudinal studies and then smaller pilot intervention studies. The results reported in this study are a crucial first step in investigating the role of prosodic awareness in reading development in this population.

Previous studies suggest that many, but not all, children with ASD have difficulty processing prosody (Paul, Augustyn, et al., 2005). It may be worthwhile recruiting children with ASD known to have problems with prosody and children with ASD that do not have problems with prosody. One could then compare reading accuracy *across* the groups and also examine whether the patterns of relationships between underlying subskills and reading ability are the same *within* each of these groups.

Conclusion

The present study provides important insights for researchers, clinicians and educators working on reading development in children with ASD. First, the study confirms that children with ASD present with highly variable language and reading skills. Many children with ASD experience difficulties with reading, and some may find nonword reading more challenging than word reading. Second, as is the case with typically developing children, a range of subskills are associated with reading accuracy in children with ASD, most notably, phonological awareness, oral language and vocabulary. A novel finding is that prosodic awareness is significantly related to word and also nonword reading in children with ASD. Children with ASD who have higher prosodic awareness, with regard to awareness of lexical stress, tend to be more accurate readers.

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References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Anthony, J.L. & Francis, D.J. (2005). Development of phonological awareness. *Current Directions in Psychological Science*, 14, 255–259. doi: 10.1111/j.0963-7214.2005.00376.x.

Arciuli, J. (2014). Prosody and autism. In J. Arciuli & J. Brock (Eds.), *Communication in autism* (pp. 103–122). Amsterdam: John Benjamins Publishing Company.

Arciuli, J., Stevens, K., Trembath, D. & Simpson, I. (2013). The relationship between parent report of adaptive behaviours and direct assessment of reading ability in children with autism spectrum disorders. *Journal of Speech, Language, and Hearing Research*, 56, 1837–1844. doi: 10.1044/1092-4388(2013/12-0034).

Asberg, J., Kopp, S., Berg-Kelly, K. & Gillberg, C. (2010). Reading comprehension, word decoding and spelling in girls with autism spectrum disorders (ASD) or attention deficit/hyperactivity disorder (AD/HD): Performance and predictors. *International Journal of Language and Communication Disorders*, 45, 61–71. doi: 10.3109/13682820902745438.

Betourne, L.S. & Friel-Patti, S. (2003). Phonological processing and oral language abilities in fourth-grade poor readers. *Journal of Communication Disorders*, 36, 507–527. doi: 10.1016/S0021-9924(03)00035-2.

Blaiklock, K.E. (2004). The importance of letter knowledge in the relationship between phonological awareness and reading. *Journal of Research in Reading*, 27, 36–57. doi: 10.1111/j.1467-9817.2004.00213.x.

Bradley, L. & Bryant, P.E. (1983). Categorizing sound and learning to read: A causal connection. *Nature*, 301, 419–421. doi: 10.1038/301419a0.

Brown, L., Sherbenou, R.J. & Johnsen, S.K. (1997). *Test of nonverbal intelligence* (3rd edition, TONI-3). Austin, TX: PRO-ED.

Cardoso-Martins, C. & Ribeiro da Silva, J. (2010). Cognitive and language correlates of hyperlexia: Evidence from children with autism spectrum disorders. *Reading and Writing*, 23, 129–145. doi: 10.1007/s11145-008-9154-6.

Catts, H.W., Fey, M.E., Tomblin, J.B. & Zhang, X. (2002). A longitudinal investigation of reading outcomes in children with language impairments. *Journal of Speech, Language, and Hearing Research*, 45, 1142–1157. doi: 10.1044/1092-4388/02/4506-1142.

Davidson, N.M., & Ellis Weismer, S. (in press). Characterization and prediction of early reading abilities in children on the autism spectrum. *Journal of Autism and Developmental Disorders*. doi: 10.1007/s10803-013-1936-2.

Dickinson, D.K., McCabe, A., Anastasopoulos, L., Peisner-Feinberg, E.S. & Poe, M.D. (2003). The comprehensive language approach to early literacy: The interrelationships among vocabulary, phonological sensitivity, and print knowledge among preschool-aged children. *Journal of Educational Psychology*, 95, 465–481. doi: 10.1037/0022-0663.95.3.465.

Dunn, L.M. & Dunn, D.M. (2007). *The peabody picture vocabulary test (4th edition, PPVT-4)*. MN: NCS Pearson Inc.

Elbro, C., Borstrom, I. & Petersen, D.K. (1998). Predicting dyslexia from kindergarten: The importance of distinctness of phonological representations of lexical items. *Reading Research Quarterly*, 33, 36–60. doi: 10.1598/RRQ.33.1.3.

Frith, U. & Snowling, M. (1983). Reading for meaning and reading for sound in autistic and dyslexic children. *British Journal of Developmental Psychology*, 1, 329–342. doi: 10.1111/j.2044-835X.1983.tb00906.x.

Gallagher, A., Frith, U. & Snowling, M.J. (2000). Precursors of literacy delay among children at genetic risk of dyslexia. *Journal of Child Psychology and Psychiatry*, 41, 203–213. doi: 10.1111/1469-7610.00601.

Goetry, V., Wade-Woolley, L., Kolinsky, R. & Mousty, P. (2006). The role of stress processing abilities in the development of bilingual reading. *Journal of Research in Reading*, 29, 349–362. doi: 10.1111/j.1467-9817.2006.00313.x.

Goodman, I., Libenson, A. & Wade-Woolley, L. (2010). Sensitivity to linguistic stress, phonological awareness and early reading ability in preschoolers. *Journal of Research in Reading*, 33, 113–127. doi: 10.1111/j.1467-9817.2009.01423.x.

Gough, P.B. & Tunmer, W E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education (RASE)*, 7, 6–10. doi: 10.1177/074193258600700104.

Gutierrez-Palma, N., Raya-Garcia, M. & Palma-Reyes, A. (2009). Detecting stress patterns is related to children's performance on reading tasks. *Applied Psycholinguistics*, 30, 1–21. doi: 10.1017/S0142716408090012.

Holliman, A.J., Wood, C. & Sheehy, K. (2010). The contribution of sensitivity to speech rhythm and non-speech rhythm to early reading development. *Educational Psychology*, 30, 247–267. doi: 10.1080/01443410903560922.

Huemer, S.V. & Mann, V. (2010). A comprehensive profile of decoding and comprehension in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 40, 485–493. doi: 10.1007/s10803-009-0892-3.

Minshew, N., Goldstein, G., Taylor, H. & Siegel, D. (1994). Academic achievement in high functioning autistic individuals. *Journal of Clinical and Experimental Neuropsychology*, 16, 261–270. doi: 10.1080/01688639408402637.

Muter, V. & Diethelm, K. (2001). The contribution of phonological skills and letter knowledge to early reading development in a multilingual population. *Language Learning*, 51, 187–219. doi: 10.1111/1467-9922.00153.

Nation, K., Clarke, P., Wright, B. & Williams, C. (2006). Patterns of reading ability in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 36, 911–919. doi: 10.1007/s10803-006-0130-1.

Newman, T.M., Macomber, D., Naples, A.J., Babitz, T., Volkmar, F. & Grigorenko, E.L. (2007). Hyperlexia in children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 37, 760–774. doi: 10.1007/s10803-006-0206-y.

Norbury, C. & Nation, K. (2011). Understanding variability in reading comprehension in adolescents with autism spectrum disorders: Interactions with language status and decoding skill. *Scientific Studies of Reading*, 15, 191–210. doi: 10.1080/10888431003623553.

Paul, R., Augustyn, A., Klin, A. & Volkmar, F.R. (2005). Perception and production of prosody by speakers with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 35, 205–220. doi: 10.1007/s10803-004-1999-1.

Paul, R., Shriberg, L.D., McSweeny, J., Cicchetti, D., Klin, A. & Volkmar, F. (2005). Brief report: Relations between prosodic performance and communication and socialization ratings in high functioning speakers with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 35, 861–869. doi: 10.1007/s10803-005-0031-8.

Peppe, S., McCann, J., Gibbon, F., O'Hare, A. & Rutherford, M. (2007). Receptive and expressive prosodic ability in children with high-functioning autism. *Journal of Speech, Language, and Hearing Research*, 50, 1015–1028. doi: 10.1044/1092-4388(2007/071).

Ricketts, J., Jones, C.R.G., Happe, F. & Charman, T. (2013). Reading comprehension in autism spectrum disorders: The role of oral language and social functioning. *Journal of Autism and Developmental Disorders*, 43, 807–816. doi: 10.1007/s10803-012-1619-4.

Scarborough, H. (2001). Connecting early language and literacy to later reading (dis)abilities: Evidence, theory and practice. In S.B. Neuman & D.K. Dickinson (Eds.), *Handbook of early literacy research* (pp. 97–110). New York: Guildford Press.

Semel, E., Wiig, E.H. & Secord, W.A. (2003). *Clinical evaluation of language fundamentals* (4th edition, CELF-4). Sydney: Harcourt Assessment.

Smith-Gabig, C. (2010). Phonological awareness and word recognition in reading by children with autism. *Communication Disorders Quarterly*, 31, 67–85. doi: 10.1177/1525740108328410.

Verhoeven, L., van Leeuwe, J. & Vermeer, A. (2011). Vocabulary growth and reading development across the elementary school years. *Scientific Studies of Reading*, 15, 8–25. doi: 10.1080/10888438.2011.536125.

Wagner, R.K., Torgesen, J.K. & Rashotte, C.A. (1999). *Comprehensive test of phonological processing (CTOPP).* Austin, TX: PRO-ED.

Whalley, K. & Hansen, J. (2006). The role of prosodic sensitivity in children's reading development. *Journal of Research in Reading*, 29, 288–303. doi: 10.1111/j.1467-9817.2006.00309.x.

Williams, G.J. & Wood, C. (2012). Sensitivity to the acoustic correlates of lexical stress and their relationship to reading in skilled readers. *Advances in Cognitive Psychology*, 8, 267–280. doi: 10.2478/v10053-008-0122-0.

Wood, C. (2006). Metrical stress sensitivity in young children and its relationship to phonological awareness and reading. *Journal of Research in Reading*, 29, 270–287. doi: 10.1111/j.1467-9817.2006.00308.x.

Woodcock, R.W. (1998). *Woodcock reading mastery tests – Revised (WRMT-R).* Bloomington, MN: Pearson Assessment.

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