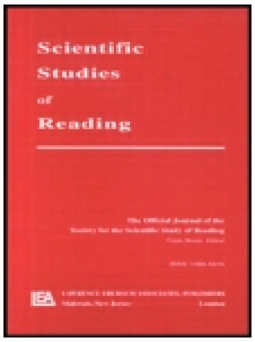

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Understanding Variability in Reading Comprehension in Adolescents With Autism Spectrum Disorders: Interactions With Language Status and Decoding Skill

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Although it is well recognized that reading skills vary in people with autism spectrum disorders (ASD), reasons for this variability are not well understood. We used the simple view of reading model to investigate both word decoding and text comprehension processes in two well-established subtypes within the autism spectrum, those with age-appropriate structural language skills and those structural language impairments. Generally, participants with language impairments performed less well than those with age-appropriate language skills. Word-level reading was a relative strength for both groups, although it showed declines with age. Comprehension weaknesses were especially marked among those with poor structural language skills. Reading outcomes in ASD are related to variations both in decoding and comprehension and in the oral language skills that support the development of these processes.

Reading is a complex skill that draws on a number of interacting processes and can therefore fail for a variety of reasons (Cain & Oakhill, 2007; Nation, 2005). The simple view of reading (cf. Hoover & Gough, 1990; Perfetti, Landi, & Oakhill, 2005) posits that skilled literacy depends on two intimately related

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events: the decoding and/or identification of individual words and the engagement of language processes that assemble individual words into meaningful text. Both events are necessary to ensure comprehension: without adequate word-level reading skills, comprehension will fail. At the same time, skilled word-level reading in isolation does not guarantee understanding at text level. In turn, decoding and comprehension are thought to depend on underlying language skills. Bishop and Snowling (2004) presented a model in which decoding ability is supported by phonological language skills, whereas comprehension is supported by nonphonological language skills. These may include structural language skills such as semantics (word knowledge) and grammar as well as higher-level comprehension processes such as inferencing. In general, decoding and comprehension skills develop in concert, but in developmental disorders of reading, they may become dissociated (Nation & Norbury, 2005).

Children with autism spectrum disorders (ASD) are frequently reported to have precocious word-reading abilities (Grigorenko, Klin, & Volkmar, 2003). However, these early developments may be tempered by longer term deficits in word reading and reading comprehension (Nation, 1999). In a study examining the reading profiles in ASD, Nation, Clarke, Wright, and Williams (2006) found that many children with an ASD had difficulties with both decoding and comprehension. Approximately 65% of their cohort demonstrated poor reading comprehension, but for many children poor comprehension was seen in the context of poor word-level reading. Arguably however, the most striking finding of Nation et al.'s (2006) study was the amount of variation observed with floor-to-ceiling levels of performance being seen on most of the reading and reading-related measures.

One potential source of variation in reading development within ASD is individual differences in oral language competence. In particular, structural language skills (phonology, semantics, syntax) are extremely variable: Approximately 20% of children with ASD fail to acquire verbal language, whereas others produce verbally fluent and grammatically accurate speech (see Tager-Flusberg, Paul, & Lord, 2005, for a review). Of interest to the current study, a high proportion of children with ASD and normal nonverbal intelligence experience impairments in structural language abilities that are similar to those that characterize specific language impairment (SLI; Loucas et al., 2008; Tager-Flusberg, 2004; Kjelgaard & Tager-Flusberg, 2001). Nonautistic children with language impairments are at increased risk of reading comprehension deficits (Botting, Simkin, & Conti-Ramsden, 2006), and many children with reading comprehension difficulties have structural language deficits that are reminiscent of SLI (Nation, Clarke, Marshall, & Durand, 2004). Thus, difficulties with word-level reading and text comprehension may align with oral language competence. Indeed, early work by Snowling and Frith (1986) indicated that text comprehension was influenced more by verbal ability than by diagnostic status. However, in this study children were selected on the basis of word recognition scores, which may limit the range of outcomes for children with ASD and language impairment. Furthermore, verbal ability was defined by cutoff scores on a receptive vocabulary test rather than by identifying children with a language impairment phenotype, as is current practice (cf. Tager-Flusberg, 2006). In a more recent study, Lindgren, Folstein, Tomblin, and Tager-Flusberg (2009) compared groups of cognitively able children with ASD and no language impairment (autism language normal [ALN]) to children with ASD and additional language impairment (autism language impaired [ALI]) and children with SLI on standardized measures of language and reading. On all measures, children with ALN outperformed their ALI peers. In addition, the ALI and SLI groups were for the most part indistinguishable; however, on a measure of nonword reading, the ALI group achieved significantly higher scores than their SLI counterparts, demonstrating potentially superior decoding skills. Despite these similarities, it is notable that variation within the ALI group was substantial and standard deviations across measures were frequently larger in this group relative to either the ALN or SLI groups. This suggests that structural language impairments alone cannot explain variance in decoding and comprehension skill. One limitation of measuring literacy skill using only standardized assessments is that it is unlikely to reveal *why* reading comprehension goes wrong.

An additional source of variation in literacy outcome concerns cognitive deficits that are characteristic of individuals with ASD and may present particular challenges to skilled reading comprehension. For instance, a core cognitive deficit in social understanding could interfere with the ASD reader's ability to understand characters' intentions and therefore the motivations behind story events. Weak central coherence (Frith, 1989/2003) could lead to particular difficulties with integrating information in context, whereas executive dysfunction may affect memory for connected text and the strategies children adopt to facilitate comprehension. O'Connor and Klein (2004) argued that these cognitive differences may lead to difficulties with comprehension monitoring and text cohesion, for instance, the ability to integrate prior general knowledge with text information to make relevant inferences.

Snowling and Frith (1986) tested comprehension monitoring and integrative processes in children with ASD. In a comprehension monitoring task, anomalous words were inserted into a text and the children were simply asked to cross out any words that did not make sense to the story as they read it. Two types of error were inserted: a *sentence-appropriate* word that fit the local sentence context but was not appropriate to the global story context, and an *implausible* word, which was inappropriate to either the story or sentence contexts. Children of low verbal ability were unable to complete this task, making a large number of false alarms (crossing out perfectly acceptable words). Children of high verbal ability were indistinguishable from typical readers in readily identifying implausible word errors, though sentence-appropriate errors were more challenging for all participants.

Integrative skills were assessed using a modified cloze procedure in which children were asked to complete sentences interspersed throughout the text by selecting the most appropriate word from a choice of three. As before, the choices included implausible and sentence-appropriate words in addition to a *story-appropriate* target. In addition, children answered questions about the story they had just read; performance on literal questions that could only be answered correctly by direct reference to the text was compared with performance on questions that evoked text-relevant general knowledge. Again, results indicated that performance varied according to the verbal ability, rather than the diagnostic status. Children with poor verbal ability were equally likely to make sentence-appropriate choices as story-appropriate choices in the cloze procedure task, though implausible choices were rare. The higher verbal ability children did not differ from typical readers in successfully choosing more story-appropriate choices on this task. With regard to general knowledge, both typical readers and readers with ASD and high verbal ability scores showed a distinct advantage for general knowledge questions relative to literal, text specific information. In contrast, participants with lower levels of verbal ability found both types of question equally challenging, suggesting that they were less able to draw on their general knowledge as they processed text.

These findings suggest that children with ASD may have difficulty making text appropriate inferences, particularly if they have oral language deficits (cf. Jolliffe & Baron-Cohen, 2000; Norbury & Bishop, 2002). The ability to make inferences is crucial to successful reading comprehension. Even the most straightforward text requires the reader to go beyond what is explicitly stated in print to form connections between different parts of the text and between the text and background knowledge. Bowyer-Crane and Snowling (2005) conducted an items analysis on two commonly used standardized tests of children's reading comprehension and found they required a variety of different inferences to be made. Children who are poor at making inferences show text comprehension deficits, even when care is taken to make sure they are familiar with all of the knowledge needed to make the inferences (Cain, Oakhill, Barnes, & Bryant, 2001).

Saldana and Frith (2007) investigated the extent to which adolescents with ASD made automatic inferences when reading. Like Snowling and Frith (1986), they found readers with ASD did not differ from a comparison group matched for verbal ability in their ability to make an inference; both groups were faster to answer comprehension questions that had been primed by information arising from an earlier inference. However, text reading comprehension was significantly poorer in the ASD group, though extremely variable, with standard scores ranging between 57 and 104. Likewize, the range of verbal skills was also considerable, with standard scores varying from 53 to 147. It is possible therefore that group data masked individual differences in inference generation and text comprehension. Thus, further data are needed to assess how well readers with ASD make inferences and to address whether inference skills when reading are associated with differences in language skill.

A final observation is that no previous research has explored reading skills in an ASD population over time. Over time, there is a shift in the demands of reading, from "learning to read" to "reading to learn" (Catts, Hogan, & Adlof, 2005). On this view, comprehension deficits could adversely affect word recognition abilities over time, as connected text is a means of learning new vocabulary (Cain, Oakhill, & Elbro, 2003). Therefore, over time, word reading scores for children with ASD should show regression toward the mean (Nation, 1999).

In summary, individuals with ASD are at risk of reading difficulties with reading comprehension skills being particularly vulnerable. In this study, we explored the possibility that variation in reading comprehension may be due to the variation in language skills that inevitably characterize unselected samples of individuals with ASDs. Like Lindgren et al. (2009) we compared two well-established behavioural and cognitive phenotypes of ASD—those with age-appropriate structural language skills (ALN) and those structural language impairments (ALI). Working within the framework proposed by Bishop and Snowling (2004), we addressed two key questions:

1. What is the role of structural language ability in reading profiles within ASD? We predicted that decoding and reading comprehension impairments would be particularly marked in those with ALI, given the close association between poor oral language skills and reading comprehension deficits seen in the non-ASD population. We also predicted that word-level reading abilities would change over time as limitations in reading comprehension impacted on word recognition and decoding.
2. What are the relationships between word-level reading skills, oral language comprehension, and autistic status? Given the wide range in word reading and decoding abilities identified within ASD (Nation et al., 2006), we wanted to explore the role of oral language in comprehension processes uncontaminated by word-level reading skills. Regression analyses were used to pinpoint the unique contributions of oral language to reading comprehension and to identify any remaining influences associated with ASD status.

METHOD

Participants

Twenty-seven adolescents (26 male) with ASD were recruited from special schools in England: Participants and their parents provided informed consent for entry into the study. All of these adolescents had participated in earlier studies by the first author (Norbury, 2005); the sample reported here represents approximately one third of the original cohort. These adolescents were selected because they were still in full-time specialist education and could therefore be assessed in their school environment.

Clinical diagnoses of ASD were made by multidisciplinary teams according to *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; American Psychiatric Association, 1994) criteria prior to school entry; these diagnoses were validated for the present study using the Social Communication Questionnaire (Rutter, Bailey, & Lord, 2003) and the Autism Diagnostic Observation Schedule (Lord et al., 2000). Language status was assigned on the basis of a history of language delay, diagnosis of language impairment from a speech-language therapist, and current scores of at least -1.25 *SD* on the Recalling Sentences subtest (RS) of the Clinical Evaluation of Language Fundamentals (Semel, Wiig, & Secord, 2006), an excellent clinical marker of language impairment in both non-ASD and ASD populations (Conti-Ramsden, Botting, & Faragher, 2001; Riches, Loucas, Baird, Charman, & Simonoff, 2010). Thirteen participants met these criteria (ALI). Remaining participants served as the ALN group ($n = 14$).[1] Measures of receptive vocabulary (British Picture Vocabulary Scales [BPVS]; Dunn, Dunn, Whetton, & Burley 1997) and nonword repetition were taken at both time points and measures of receptive grammar (Test for Reception of Grammar [TROG]; Bishop, 2003) and general comprehension (Wechsler Intelligence Scale for Children [WISC] Comprehension; Wechsler, 1991) were available at Time 2. All scores are reported in Table 1.

A comparison group of 19 typically developing (TD) teenaged boys were recruited for this study and matched to participants with ASD for age and nonverbal ability. None had a history of language impairment, psychiatric illness, or special educational provision. Longitudinal data were not available for these participants; however, relevant test scores available at Time 2 are reported in Table 1.

ASD group w/o LI
ASD group w/ LI
TD group

Materials and Procedure

Standardized measures of reading. The Phonemic Decoding Efficiency and Sight Word Efficiency subtests of the Test of Word Reading Efficiency (Torgeson, Wagner, & Rashotte, 1999) provided estimates of nonword and word reading respectively and were available for ASD participants at Time 1 and Time 2. Each subtest requires individuals to read as many items as possible from a list in 45 sec.

[1]These participants overlap with Norbury et al. (2009). However, one participant with ALI did not participate in this study due to school absence on the day reading measures were administered.

TABLE 1
Age, Autistic Symptomatology, and Performance on Measures of Verbal and Nonverbal Ability at Time 1 and Time 2 for the ALI and ALN Groups

	ALI *N = 13*		*ALN* *N = 14*		*TD* *N = 19*		
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*
Time 1							
Age	10.99	1.46	11.29	1.24	—	—	< 1.0
Nonverbal ability	99.00	12.79	103.93	12.24	—	—	1.05
BPVS	79.62	6.92	100.50	12.08	—	—	29.75**
Recalling Sentences	4.62	1.89	7.43	2.31	—	—	11.85**
Nonword Repetition	31.09	5.05	33.79	4.25	—	—	2.10
SCQ	20.92	5.77	25.00	6.05	—	—	2.97
Time 2							
Age	14.78	1.38	14.99	1.92	14.39	0.81	1.24
Nonverbal ability	98.15	15.86	99.14	11.77	106.32	9.97	2.15
BPVS	79.46_a	11.89	107.07_b	14.73	108.58_b	13.35	21.10**
Recalling Sentences	5.38_a	2.29	7.93_b	2.53	9.79_b	2.42	12.82**
Nonword Repetition	34.31_a	6.41	38.79_b	4.02	41.00_b	3.13	8.30**
WISC Comprehension	76.15_a	15.15	93.93_b	10.95	102.37_b	9.78	18.91**
TROG	94.38_a	10.15	103.71_b	3.52	104.11_b	5.11	9.82**
ADOS–Module 4	11.31	3.73	9.36	3.54	—	—	1.94

Note. Missing data: nonword repetition, two participants in autism language impairment (ALI) group at Time 1; Social Communication Questionnaire (SCQ), two participants, one in ALI and one in autism language normal (ALN) group. Means with the same subscript do not differ from each other, Sheffé test. TD = typically developing; BPVS = British Picture Vocabulary Scales; WISC = Wechsler Intelligence Scale for Children; TROG = Test for Reception of Grammar; ADOS = Autism Diagnostic Observation Schedule.
$^{**}p < .05$.

Text reading accuracy and reading comprehension were assessed at Time 2 only using a truncated version of the Neale Analysis of Reading Ability–II (NARA; Neale, 1997). Individuals are asked to read stories of graded difficulty aloud and then answer questions about the story. These questions include both factual and inferential recall. Stories 2, 3, and 4 were administered in order to estimate comprehension when text reading demands were not overly taxing.

Experimental measures. We adapted materials developed by Snowling and Frith (1986). Two nature stories were included; these were selected because they did not contain social references or emotional content that adolescents with ASD may find perplexing. Instead, these were simple stories suitable for individuals with a reading age of 7 or 8 that enabled us to gage integrative and inferential processes as well as comprehension monitoring skills.

The first text (Hedgehog story) contained 549 words. In this story, words were periodically replaced with one of three kinds of errors: an *orthographic* error, a *grammatical* error, or a *context* error. Orthographic errors were designed to test phoneme-grapheme correspondences. Grammatical errors were designed to mimic the types of errors that are characteristic of individuals with SLI. These included omission of past-tense -ed and third-person singular -s. Finally, context errors were words that did not fit either the sentence or story context. There were 15 instances of each error type. Children were asked to read through the story and circle the mistakes they found. Scores were calculated as the number of errors overlooked by the child. Thus, higher scores reflect poorer performance on this task. We also counted the number of *false alarms*, or appropriate words circled by our participants.

CLOZE TASK

The second text (Beaver story) contained 789 words. At periodic intervals throughout the text, children had to select one of three alternative words to complete a sentence. The choices included *globally coherent* target words, *locally coherent* words (appropriate to the immediate sentence context, but not the story as a whole), and implausible words. There was a maximum score of 24 on this index. In addition, children were asked to answer a number of questions about the story. To alleviate memory demands, these questions occurred at three different points in the story. Two types of question were included: questions that required literal recall of story details and questions that required the child to make an inference that integrated story information with general knowledge. There were seven literal and seven inferential questions.

Participants were tested individually in a quiet room at their school or in the university lab. Standardized tests of reading were undertaken before the experimental measures to ensure a basic level of decoding that would enable reading of connected text. The order of presentation of the experimental measures was counterbalanced. Participants read the stories silently to themselves but were allowed to ask for assistance in decoding unfamiliar words.

RESULTS

Our approach to statistical analysis includes both comparison of group means and regression to tease apart the contributions of oral language abilities, word-level reading skill, and diagnostic status to reading outcome. Unless otherwise indicated, we compared the means of the three groups (ALI, ALN, and TD) using a one-way analysis of variance (ANOVA) and followed up significant findings with Scheffé tests. Our a priori prediction was that the ALI group would achieve significantly lower scores than both the ALN and TD groups on all reading measures. Due to the small sample size and the number of statistical comparisons, we report effect size (Cohen's *d*) to give a clearer indication of the magnitude of significant group differences.

Language and Reading as Measured by Standard Assessments at Time 1 and Time 2

Table 1 shows the performance of the two ASD groups on measures of verbal and nonverbal ability at each time point. Confirming the criteria used to define ALI and ALN, the two groups differed in terms of language skills at Time 1 with significant differences in sentence recall (Cohen's $d = 1.33$) and receptive vocabulary ($d = 2.17$). Note that differences in nonword repetition were not statistically significant, though there was a trend for participants in the ALN group to achieve higher scores, with a moderate effect size ($d = .58$). Difference in performance on nonword repetition was significant at Time 2 ($d = .85$). At Time 2, the ALI group continued to experience severe language deficits, scoring significantly below the ALN group on all language measures (BPVS, $d = 2.07$; RS, $d = 1.06$; WISC, $d = 1.37$; TROG, $d = 1.39$). The ALN group did not differ from typically developing peers on any measure, confirming that their language skills were appropriate for their age.

Table 2 summarizes the performance of the two groups on the standardized measures of reading ability. At Time 1, individuals with ALN read more words and nonwords than those with ALI; on average scores of the ALN group were 1 *SD* higher than scores of the ALI group (word, $d = 1.21$; nonword, $d = .74$). Within groups, scores were very similar for both words and nonwords. At Time 2, the ALN group obtained higher mean scores than the ALI group, though these differences were not statistically significant and the effect sizes were moderate (word, $d = .69$; nonword, $d = .60$). In addition, there was a decline in standard scores for word reading of 10 points in the ALN group. These observations were tested statistically in a 2 (group: ALI vs. ALN) × 2 (lexicality: word vs. nonword) × 2 (time: T1 vs. T2) repeated measures ANOVA. There were significant main effects of group, confirming the superior performance of the ALN group, $F(1, 23) = 4.97$, $p = .036$. The main effect of lexicality was significant showing that nonwords were read more successfully than words, $F(1, 23) = 4.39$, $p = .047$. There was also a main effect of time, with higher scores at Time 1 relative to Time 2, $F(1, 23) = 8.42$, $p = .008$. This was modified by a significant Group × Time interaction, showing that declines in reading over time were more marked for the ALN group, $F(1, 23) = 6.39$, $p = .019$. None of the other interaction terms was significant.

Data from typically developing adolescents were also available at Time 2. For nonwords, the adolescents with ALN did not differ significantly from TD peers, whereas the ALI group had significantly lower scores. For words, a slightly different pattern emerged with the ALI performing less well than the ALN participants who in turn performed less well than TD peers. Two further observations are noteworthy. First, there is considerable within group variation in both ASD groups; thus, whereas oral language status is clearly associated with decoding and word reading, the relationship is far from perfect. Second, for ALN participants, group means are within the expected range for age; evidence of precocious word reading abilities is lacking. Only three individuals within the ALN group obtained scores on either the word or nonword tests greater than 1 *SD* above the normative range; all three obtained performance IQ scores and/or receptive vocabulary scores of 114 or greater, indicating that word reading abilities were entirely in keeping with cognitive abilities.

Performance of the ALI and ALN groups on the modified version of the NARA–II is summarized in the lower portion of Table 2, alongside data from TD peers. Group differences for text reading accuracy were not large, with the ALI participants making marginally more errors ($p = .08$). In terms of reading comprehension, adolescents with ALI answered fewer questions correctly than TD peers. Adolescents in the ALN group did not differ from either group in terms of reading comprehension.

Comprehension Monitoring

Performance on the monitoring task (the Hedgehog story) was analysed using a 3 (group: ALI vs. ALN vs. TD) $\times$ 3 (error type: grammatical vs. phonological vs. context) ANOVA. Grammatical anomalies were harder to spot than either the phonological or contextual anomalies, leading to a main effect of anomaly type, $F(2, 40) = 8.47$, $p < .01$. This did not interact with group, although the main effect

TABLE 2
Standard Tests of Reading at Time 1 and Time 2

	ALI *N = 13*		*ALN* *N = 14*		*TD* *N = 19*		
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*
Time 1							
Word Reading	83.31	14.84	98.36	10.22	—	—	9.54**
Nonword Reading	85.92	20.08	99.69	17.43	—	—	3.37*
Time 2							
Word Reading	81.23_a	11.16	88.29_a	9.37	101.00_b	9.42	16.41**
Nonword Reading	85.62_a	13.82	$94.64_{a,b}$	16.39	103.63_b	10.32	7.07**
Text Comprehension	13.08_a	6.06	$17.15_{a,b}$	4.39	18.74_b	4.34	5.29**
Text Accuracy	7.92	12.09	4.54	3.80	2.21	1.87	2.66*

Note. Means with the same subscript do not differ from each other, Sheffé test. Nonword reading scores unavailable for one additional language impairment (ALI) and one autism language normal (ALN) participant at Time 1; Neale Analysis of Reading Ability data unavailable for one ALN participant due to testing time constraints.
$*p = .08$. $**p < .05$.

of group was significant, $F(2, 40) = 8.29$, $p < .01$. Across all three conditions, adolescents with ALI performed less well than adolescents with ALN who did not differ significantly from their typically developing peers. Differences between the two ASD groups were of large effect ($d = 1.59$–3.42). Note that the three groups made a similar number of false alarms, indicating they were all able to perform the task (ALI $M = 4.50$; ALN $M = 2.08$; TD $M = 3.29$), $F(2, 40) = 2.40$, *ns*.

Contextual Processing and Inferencing Ability

Figure 1 illustrates the number of literal and inference questions answered correctly on the Beaver story. A 3 (group: ALI vs. ALN vs. TD) $\times$ 2 (question type: inference vs. literal) with repeated measures on the second factor revealed no main effect of question type ($F = 2.69$, *ns*), but a main effect of group, $F(2, 39) = 7.20$, $p < .01$. This was qualified by a significant interaction between question type and group, $F(2, 39) = 4.96$, $p < .01$. Simple main effects confirmed that the three groups differed only in the literal condition ($F < 1.0$) but did in the inference condition ($F = 13.42$, $p < .01$) with the ALI group performing significantly less well than both ALN and TD groups (*p*s $< .01$, *d*s $= 1.23$, 2.15 respectively). In addition, the ALN group was marginally less accurate in the inference condition than the TD group ($p = .08$, $d = .61$).

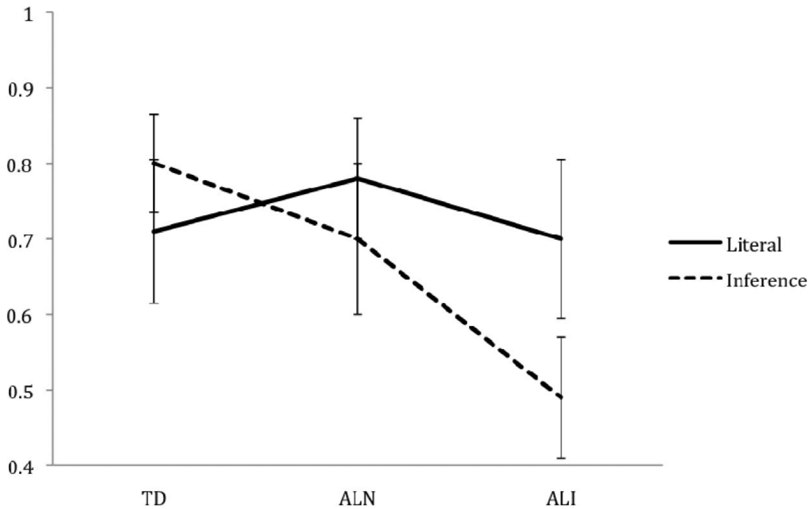

FIGURE 1 Mean literal and inferential comprehension of typically developing (TD), autism language normal (ALN), and autism language impairment (ALI) adolescents as measured by the Beaver story. Error bars show standard deviation.

Cloze results

With regard to story choices, individuals in the ALI group made significantly fewer globally coherent story choices than either the ALN or the TD groups, who did not differ from one another, $F(2, 39) = 10.68$, $p < .001$. Implausible story choices were extremely rare; instead, locally coherent choices were the most prevalent error types across all three groups.

Reading Comprehension and the Interaction of Language Status With Decoding Skill

Taken together, the analyses presented so far show that although adolescents with ALI are generally poorer at comprehending connected text, there is considerable variation in word-level reading and reading comprehension scores in both ASD groups. We therefore sought to identify more specifically the role of oral language in reading comprehension, taking word-level reading abilities into account. We conducted regression analyses on three of the comprehension tasks: NARA comprehension, the inferencing task (the Beaver story), and the number of contextual errors spotted in the comprehension monitoring task (the Hedgehog story). We also asked whether oral language ability was *specifically* involved in text-level processing by looking at the role of oral language skill on the ability to detect orthographic errors (the Hedgehog story). Because this task tapped orthographic knowledge specifically, we predicted that word-level reading skills would account for more variance in performance than oral language abilities.

For each analysis we computed two composite scores for measures taken at Time 2, a word-level reading composite comprised of the average standard scores on the two subtests of the Test of Word Reading Efficiency (Sight Word Efficiency and Phonemic Decoding Efficiency) and an oral language composite composed of the average standard scores achieved on receptive vocabulary (BPVS) and world knowledge (WISC comprehension). As standard scores are age adjusted, we did not include age in our regression models. Word-level skills were entered at the first step, whereas the oral language composite was entered at the second step. Finally, we entered a group term to determine whether an ASD diagnosis predicted unique variance in reading outcome, not accounted for by word reading or oral language comprehension.

The results of the regression analyses are presented in Table 3. All final models were significant, accounting for approximately 40% of the variance in reading outcome.[2] In addition, it is clear that for all three measures of reading

[2]We also tested the four models with nonverbal ability included at the first step, before word-level reading was entered. This did not significantly improve the fit of the model, and nonverbal ability did not predict unique variance in any of the models. Therefore, for the sake of brevity and in keeping with the aims of the article, we have reported only those models with word-level reading and oral language skill as predictor variables.

TABLE 3
Regression Models for Three Measures of Reading Comprehension and One Measure of Phonological (Orthographic) Text Monitoring

	NARA Comprehension		*Inferencing (Beaver)*		*Context (Hedgehog)*		*Phonological (Hedgehog)*	
	% R^2 Change	*F R^2 Change*	*% R^2 Change*	*F R^2 Change*	*% R^2 Change*	*F R^2 Change*	*% R^2 Change*	*F R^2 Change*
Step 1 Word-level reading	16.4	8.46**	6.6	2.81	27.7	15.72**	37.0	24.10**
Step 2 Oral language	27.3	9.96**	31.7	9.74**	15.4	5.29**	3.7	1.21
Step 3 Autism group	< 1.0	< 1.0	10.70	7.74**	< 1.0	< 1.0	< 1.0	< 1.0

Note. Word-level reading is average standard scores of TOWRE sight word efficiency and phonological decoding efficiency measured at Time 2. Oral language is average standard scores of British Picture Vocabulary Scales and Wechsler Intelligence Scale for Children comprehension, also measured at Time 2.
**$p < .01$.

comprehension, oral language ability plays a highly significant and unique role. In both the NARA and the inferencing task, the oral language composite uniquely predicts 27 to 31% of variance, much greater than the variance predicted by word-level reading alone. The contribution of oral language to the comprehension monitoring task is substantial, but to a lesser degree, accounting for 15% of the variance. This is likely a reflection of the very different task demands in this task, where participants were asked to identify text anomalies in contrast to NARA and inferencing, which required more substantial integration of information from within the text and with broader world knowledge. Note also that the relationship between oral language and reading outcome was selective; when the task was limited to identifying orthographic errors, oral language did not predict unique variance in task performance. Instead, word-level reading predicted 37% of variance in comprehension monitoring. For the most part, diagnostic status did not improve model fit. The exception was in inferencing ability, where group status predicted an additional 10% of the variance in comprehension score.

DISCUSSION

The current study investigated reading skill in different language phenotypes within ASD. We framed our questions with reference to the simple view of reading (Hoover & Gough, 1990) that highlights interactions between decoding and comprehension in developing literacy skills, and the dimensional model of reading put forward by Bishop and Snowling (2004), which highlights the phonological and nonphonological language skills that support decoding and comprehension. To our knowledge, this is the first attempt to apply these models directly to reading performance within ASD. The prevailing message from the current study is that no one reading profile is characteristic of individuals with ASD; even in a high-ability sample, the range of reading abilities was large and the profiles were varied. A critical question for researchers and clinicians is, What accounts for individual differences in reading attainment? To address this, we return to the specific questions we put forward in the introduction.

What Is the Role of Structural Language Ability in Reading Profiles Within ASD?

As noted previously and consistent with previous findings (e.g., Nation et al., 2006), we see a wide range of ability in decoding and word-level reading skill (decoding and word recognition), even though we selected participants with age-appropriate nonverbal abilities. Word-level reading abilities aligned with oral language status in that as a group, individuals with ALN achieved significantly higher scores on both word and nonword reading measures, relative to participants with ALI. However, the association between oral language and word-level reading was not perfect, as many individuals with significant language impairment could nevertheless read single words at an age-appropriate level.

Word-level reading skills in this cohort were available at two time points: at Time 1, when participants were 10 to 11 years of age, and again 4 to 5 years later as adolescents. Word-reading skills diminished over time, particularly for individuals with ALN. In this group, word-level reading skills at Time 1 were equivalent to the normative mean; however, by Time 2, scores had dropped by an average of 10 standard score points. Decoding (nonword reading) skills were consistent at both time points, suggesting that words that do not obey consistent phoneme-grapheme correspondences may pose the greatest challenge for these individuals. In typical development, children may rely on well-developed semantic skills to support word recognition when phonological decoding is not an option; likewise, children with poor semantic skills frequently have difficulties reading such irregular words (Nation & Snowling, 1998; Ricketts, Nation, & Bishop, 2007). In this case, however, receptive vocabulary scores for the ALN group are above average, suggesting that semantics is not necessarily a barrier to performance in this group. Instead, we propose that poor comprehension of connected text, and particularly limitations in inferencing skill, ultimately limit word recognition in ASD. Numerous studies of non-ASD populations have documented the important contribution contextual processing makes to word recognition and word learning: Context supports decoding attempts and good inferencing skills enable readers to infer meanings of unfamiliar words from surrounding context (Cain et al., 2003). Previous investigations have also highlighted deficits within ASD populations in inferencing (Jolliffe & Baron-Cohen 2000; Norbury & Bishop, 2002) and using written context to modify word reading (Lopez & Leekam, 2003). Given that even our most verbally able participants experienced some difficulty with inferencing, it is possible that this has a negative effect on word reading over time.

What Are the Relationships Between Word-Level Reading Skills, Oral Language Comprehension, and Autistic Status?

According to our reading models, deficits in oral language are intimately related to reading comprehension deficits, a prediction well founded in studies of nonautistic individuals with language and reading impairments (Catts, Adlof, & Ellis-Weismer, 2006; Nation et al., 2004). This was indeed the case for our participants as well, as the ALI group achieved lower scores on all measures of reading comprehension and was particularly poor at inferencing. However, the word-level reading skills of the ALI group also varied substantially, raising the possibility that comprehension deficits were attributable to word-level reading deficits. We tested this possibility using regression and found that oral language contributed uniquely and selectively to reading comprehension. These findings confirm that models of typical reading development can be applied to reading processes in development disorders (cf. Nation & Norbury, 2005).

What Additional Factors Account for Reading Comprehension Performance in ASD?

Although word-level reading and oral language comprehension are strong predictors of reading comprehension, it is clear that aspects of autistic cognition may also influence reading development within the ASD population; diagnostic status predicted a further 10% of the variance in scores on the inferencing measure, even after accounting for the effects of word-level reading and oral language ability. This finding may appear to contradict Saldana and Frith (2007), who reported adequate inferencing skills in their participants with ASD. However, there was considerable variation in performance in their sample, and we suggest that this may be attributable to variations in underlying oral language abilities. Differences in the measurement of inferencing skill may also contribute to differences between the two studies. We employed a standard technique that assessed inferencing by asking questions after the participant had read a piece of text, though we asked questions at regular intervals to minimize memory demands. Saldana and Frith used an online measure of inferencing skill and suggested that individuals with ASD are able to make appropriate inferences as text unfolds. However, the texts they used comprised only two sentence vignettes; thus difficulties in inferencing could emerge over longer stretches of connected text. Indeed, ALI participants made more locally coherent story choices in the Beaver story than any other group, but these same participants were less likely to make globally coherent choices and experienced marked deficits making inferences in the same story.

There was a clear trend for the ALN group to achieve lower scores on the inferencing measure despite their relatively strong oral language abilities. The regression analysis suggested that factors aligning with ASD diagnosis may also be important in inferencing skill. Much has been written about weak central coherence theory (Frith, 1989/2003) as a core cognitive difference in ASD, in which individuals focus on detail at the expense of global meaning. In practice, weak central coherence has been linked to difficulties integrating information from different sources and a preference for local coherence over global coherence (Happe, 1999; Jolliffe & Baron-Cohen, 2000). Such differences would clearly affect inferencing skill, and our findings could be construed as evidence of weak central coherence. However, previous research (Brock, Norbury, Einav, & Nation, 2008; Norbury, 2004, 2005), and data from the current study suggests that these skills are highly dependent on structural language abilities.

Another possibility is that readers with ASD do strive for coherence but have difficulty suppressing irrelevant information (Norbury & Bishop, 2002). For instance, encountering the word *animal* in the text may prompt some readers to activate information concerning their favourite animals (or animals that are part of their obsessive interests), which is then difficult to inhibit, preventing links with the story context to be made. A related issue may be the goals that individuals have when they approach a written text. Skilled comprehenders have understanding as their ultimate goal and adopt strategies to facilitate comprehension (Perfetti et al., 2005). An important component of this process is to monitor comprehension and revisit passages that don't make sense. In our study, we measured monitoring skill by asking participants to identify anomalous words embedded in connected text. Once again, individuals with oral language impairments were particularly poor at this task, even failing to notice contextual anomalies which were very salient to other readers. This suggests a fairly superficial engagement with written text. This can be damaging to comprehension, as it does not afford the reader an opportunity to revise and update his or her representation of what has been read.

Limitations and Future Directions

We took an opportunistic look at reading in a diverse set of participants within an established framework of reading development and disorder. We were fortunate to have word and nonword reading measures at two time points; however, it would have been desirable to have reading comprehension data at both time points as well. Similarly, the children were in middle childhood when first seen—a better understanding of the processes contributing to reading outcome in adolescents with ASD requires a fuller picture of reading behaviour prior to school entry. We suggest that future longitudinal research obtains detailed measures not just of language, phonological ability, and reading skill but indices of autistic symptomatology and autistic cognition. Finally, division of our sample according to language phenotype resulted in relatively small group sizes. Despite this small sample size, we found a number of striking differences between the two language phenotypes, and most of these differences were of large effect. Nevertheless, our results must be treated with caution, and replication of these findings is a necessary next step.

CONCLUSION

Overall, we have demonstrated that as in the typical population, reading comprehension in ASD is built on a foundation of oral language competence: individuals with ALI experienced deficits on all measures of comprehension and in component skills such as comprehension monitoring, whereas individuals with ALN were frequently indistinguishable from TD peers. However, we are cautious in concluding that ALN individuals have age-appropriate reading comprehension. Our goal in this work was to explore comprehension processes when decoding demands were low and social content was minimal. Thus, the texts that we utilized surely did not tax our readers to the extent that a high-school curriculum would. Remember, the reading age of our stories was pitched at about 7 to 8 years, whereas our participants were teenagers. Recommended English texts for 14- to 16-year-olds in the United Kingdom include *Wuthering Heights, Of Mice and Men, The Great Gatsby,* and *Brave New World.* Such texts require readers to maintain a narrative thread over hundreds of pages, integrate text information with learned knowledge about social values and the individual's own experiences, and make quite complex inferences about social relationships that will be alien to many teenagers with ASD. It is encouraging that many basic skills are in place for a significant proportion of adolescents with ASD who have well-developed oral language skills but highly likely that even the most linguistically able participants with ASD will need support to develop reading comprehension skills to this level.

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