RUNNING HEAD: READING COMPREHENSION IN AUTISM SPECTRUM DISORDERS

Reading comprehension in autism spectrum disorders: The role of oral language and social functioning

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Abstract

Reading comprehension is an area of difficulty for many individuals with autism spectrum disorders (ASD). According to the Simple View of Reading, word recognition and oral language are both important determinants of reading comprehension ability. We provide a novel test of this model in 100 adolescents with ASD of varying intellectual ability. Further, we explore whether reading comprehension is additionally influenced by individual differences in social behaviour and social cognition in ASD. Adolescents with ASD aged 14-16 years completed assessments indexing word recognition, oral language, reading comprehension, social behaviour and social cognition. Regression analyses show that both word recognition and oral language explain unique variance in reading comprehension. Further, measures of social behaviour and social cognition predict reading comprehension after controlling for the variance explained by word recognition and oral language. This indicates that word recognition, oral language and social impairments can constrain reading comprehension in ASD.

Key words: autism spectrum disorders, reading comprehension, mentalising, oral language

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Reading comprehension in autism spectrum disorders: The role of language and mental state understanding

Autism spectrum disorders (ASD) refers to a group of neurodevelopmental disorders characterised by impairments in social interaction, communication and repetitive and restricted behaviours and interests. Prevalence estimates vary according to the diagnostic criteria employed, but a recent UK population study indicates that approximately 1% of children meet criteria for ASD (Baird et al., 2006; for a slightly lower global estimate, see Elsabbagh et al., 2012).

In the early stages of learning to read, children must develop the word recognition skills that will enable them to read words and connected texts accurately and fluently. However, skilled reading also involves understanding the meaning conveyed by texts and it is well accepted that oral language skills underpin successful reading comprehension (Clarke, Snowling, Truelove, & Hulme, 2010; Muter, Hulme, Snowling, & Stevenson, 2004; Nation, Cocksey, Taylor, & Bishop, 2010). Research on reading in ASD has focused on investigating precocious word recognition in hyperlexia – a profile of advanced word recognition relative to weaknesses in other cognitive domains that is observed in a small subgroup of individuals with ASD (for reviews and recent findings, see Grigorenko, Klin, & Volkmar, 2003; Nation, 1999; Newman et al., 2007; Saldaña, Carreiras, & Frith, 2009).

Few studies have systematically investigated reading in more heterogeneous (and representative) ASD samples (Ricketts, 2011). In a large and varied sample, we found that adolescents with ASD show a discrepancy between reading comprehension and word recognition abilities such that reading comprehension is poorer than word recognition (Jones et al., 2009). This discrepancy is consistent with other available data (Frith & Snowling, 1983; Huemer & Mann, 2010; Lindgren, Folstein, Tomblin, & Tager-Flusberg, 2009; Nation,

Clarke, Wright, & Williams, 2006; Newman et al., 2007). Inspecting group means across studies also indicates that reading comprehension is typically impaired in individuals with ASD relative to test norms, while word recognition skills are close to, or within the average range (e.g., Huemer & Mann, 2010; Nation et al., 2006; Jones et al., 2009). Individuals with ASD show deficits in word recognition and reading comprehension although reading comprehension difficulties are more common (Nation et al., 2006). Therefore, reading comprehension appears to be an area of greater difficulty in ASD than word recognition. However, reading skills in ASD vary greatly, with many studies reporting unusually large standard deviations (e.g., Lindgren et al., 2009; Nation et al., 2006, Newman et al., 2007; Jones et al., 2009). Given that oral language provides a foundation for reading development, large variation in reading skills is consistent with the well-established finding that oral language skills in ASD also show considerable heterogeneity (Kjelgaard & Tager-Flusberg, 2001; Williams, Botting & Boucher, 2008).

Group means can mask heterogeneity in ASD (Boucher, 2012) and this has prompted a number of researchers to urge future research to move beyond studies that compare group means so as to actively consider what explains individual differences *within* ASD (Brock, 2011; Lord & Jones, 2012). In what follows, we will describe the Simple View of Reading and consider the evidence that this framework is consistent with existing data on reading in ASD. We will then explore the proposal that the social communicative impairments in ASD may also constrain reading comprehension in these individuals.

The Simple View of Reading (Gough & Tunmer, 1986; Hoover & Gough, 1990) posits that both word recognition and oral language comprehension (e.g., receptive vocabulary, receptive grammar) make independent contributions to skilled reading (reading comprehension). On this view, skill in both word recognition and oral language comprehension are necessary for skilled reading and poor reading comprehension may be the

consequence of weak word recognition, oral language comprehension, or both. There is substantial evidence that the Simple View holds in typically developing readers and children with reading disorders (e.g., Catts, Adlof, & Weismer, 2006; Chen & Vellutino, 1997; Cutting & Scarborough, 2006; Harlaar et al., 2010; Keenan, Betjemann, & Olson, 2008; Muter, et al., 2004). However, existing research on reading comprehension in ASD is largely descriptive and few studies have probed factors that explain individual differences in reading comprehension in this group. Notwithstanding, there is evidence that reading comprehension correlates with performance on word recognition and oral language tasks in children and adolescents with ASD (Nation, et al., 2006) and at an individual level both oral language comprehension and word recognition impairments have been reported in ASD (Åsberg & Dahlgren Sandberg, 2012; Kjelgaard & Tager-Flusberg, 2001; Nation et al., 2006; White et al., 2006). Therefore, impoverished word recognition and oral language comprehension may present barriers to successful reading comprehension in ASD.

In an empirical test of the application of the Simple View to ASD, Norbury and Nation (2011) used hierarchical regressions to show that after controlling for word recognition, oral language comprehension was a significant predictor of reading comprehension in a heterogeneous group of adolescents (N = 46) both with and without an ASD diagnosis (for similar findings, see Åsberg, Kopp, Berg-Kelly & Gillberg, 2010). Norbury and Nation interpreted this as indicating that the Simple View of Reading can be applied to ASD. However, because non-ASD controls were included in their analysis (and that of Åsberg et al., 2010) it is not clear that both word recognition and oral language are important determinants of reading comprehension success in ASD specifically. Our first aim was to explore whether word recognition and oral language make independent contributions to reading comprehension in a sample that includes only individuals with an ASD diagnosis, thus providing a more stringent test of the Simple View of Reading's application to ASD.

In order to fully understand texts, a reader usually needs to go beyond what is explicitly stated to make a range of inferences and in some cases this involves integrating what is conveyed in the text with general knowledge. Skilled readers also monitor their comprehension and engage in repair strategies (e.g., re-reading) where necessary. A number of researchers have highlighted the importance of inferential processes, background knowledge and comprehension monitoring for reading comprehension, in addition to word recognition and oral language, so that readers can construct a meaning-based representation of a text (e.g., Cain, 2010; Perfetti, Landi & Oakhill, 2005). Perfetti, Landi and Oakhill (2005) hypothesised that a reader's 'standard for coherence' will determine the extent to which he or she reads for understanding, makes inferences and monitors comprehension. Weak central coherence is proposed to be a core feature of ASD cognition (Happé & Frith, 2006), and this processing style could limit the integration of information in context for global comprehension (Norbury & Nation, 2011). Another hypothesis is that a core social cognitive deficit in understanding the mental states of others (Baron-Cohen, 2000) could constrain reading comprehension. For example, deficits in 'mentalising' may impact on the ability to make inferences regarding the writer's communicative intentions or the intentions and desires of protagonists in a text. Consistent with the proposal that the social and communication impairments seen in individuals with ASD contribute to their reading comprehension difficulties, we have recently found that greater reading comprehension difficulties (relative to IQ) were associated with more pronounced social and communication impairments in adolescents with ASD (Jones, et al., 2009).

It is worth noting an alternative explanation for the correlation between reading comprehension and socio-communicative skills observed in our previous study (Jones, et al., 2009). Given that limited oral language skills are often observed in individuals with ASD (e.g., Kjelgaard & Tager-Flusberg, 2001; Lindgren, et al., 2009; Nation, et al., 2006), and oral

language is closely related to both social communication and reading comprehension, oral language comprehension impairments may underpin both social communication and reading comprehension deficits. This raises the empirical question of whether the social and communication impairments associated with ASD play a role in their reading comprehension difficulties, and whether this relationship is separable from the relationship between oral language and reading comprehension. Norbury and Nation (2011) found that diagnosis (ASD vs. no ASD) was not a significant predictor of reading comprehension once oral language comprehension and word recognition had been controlled in regression analyses. However, Åsberg et al. (2010) showed that a continuous measure of autism symptomatology was associated with reading comprehension after controlling for word recognition and oral language (vocabulary) in a group of 110 Swedish-speaking girls aged 3-18 years that comprised 20 girls with ASD, 36 girls with attention-deficit/hyperactivity disorder (ADHD) and 54 typically developing girls. As with Norbury and Nation, regression analyses were conducted across the whole sample obscuring the specificity of the results for ASD. In addition, the participants with ASD were all female while most individuals with ASD are male (approximately 3:1, Baird et al., 2006). Our second aim was to extend these two studies by exploring whether three continuous measures of social behaviour and social cognition would predict significant unique variance in reading comprehension after controlling for word recognition and oral language comprehension in a large group of adolescents, all of whom had a diagnosis of ASD.

The present study was motivated by the reading comprehension difficulties that are observed frequently in ASD. Given that reading and understanding texts (and oral language) provides important opportunities for learning and accessing information, difficulties comprehending text will have wide ranging implications throughout the lifespan (National Institute of Child Health and Human Development, 2000). We collected data on performance

IQ, oral language, word recognition, reading comprehension, social behaviour and social cognition from 100 adolescents with ASD using standardised and experimental tasks. Analysis of this unusually large data set allowed us to explore individual differences in reading comprehension within ASD in a way that has not been previously undertaken. A number of researchers have recently argued that in order to advance our understanding of ASD, we need to move beyond studies that simply compare groups (ASD vs. controls), and actively investigate variation in behaviour within groups of individuals with ASD (Brock, 2011; Lord & Jones, 2012). Based on the Simple View and previous research (Åsberg et al., 2010; Norbury & Nation, 2011), we anticipated that both word recognition and oral language comprehension would explain unique variance in reading comprehension in ASD. Second, we hypothesised that indices of social skills and social cognition would also predict individual differences in reading comprehension (cf. Åsberg et al., 2010). We sought to extend previous research by testing these two hypotheses in a sample that exclusively comprised individuals with ASD.

Method

Participants

Participants were 100 adolescents with a consensus clinical ICD-10 diagnosis of ASD, all of whom were taking part in the Special Needs and Autism Project (SNAP) cognitive phenotype study (see Charman, Jones, Pickles, Simonoff, & Happé, 2011; and see Baird et al., 2006 for a description of the original cohort, including approach to diagnosis). The mean age of the participants was 15 years 6 months (*SD* = 6 months; range 14 years 8 months – 16 years 9 months) and 91 were male. The study was approved by the South East Research Ethics Committee (05/MRE01/67), and informed consent was obtained from all participants.

Materials and procedure

The measures administered are outlined below. Standardised measures of performance IQ, reading and language were administered according to manual instructions. Unless otherwise stated, data were collected during two testing days (interspersed with other tasks from the SNAP cognitive phenotype study), with an average lag between testing sessions of 34 days (*SD* = 38 days, range 1 – 259 days). For a small number of participants, data were not available for selected tasks, this was due to their age surpassing the boundary for standard score calculation, the participant being unable to access the task, or for practical reasons related to time constraints.

Performance IQ: The Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) provided a measure of performance IQ. Participants completed both nonverbal measures; the Block Design subtest in which they were required to construct visual patterns using blocks and the Matrix Reasoning subtest, which is a visual pattern completion task. The WASI provides norms for individuals aged 6 years to adult.

Reading: The Basic Reading subtest from the Wechsler Objective Reading Dimensions (WORD; Rust, Golombok, & Trickey, 1993) provided a measure of word recognition. In this task, participants are required to read parts of words (items 1-4) or whole words (items 5-55) of increasing difficulty. Performance is not timed; therefore this is a measure of word recognition accuracy not fluency. Reading comprehension was measured using the Reading Comprehension subtest from the WORD. This task includes items that range from single sentence statements to expository paragraphs. Participants are able to read the texts silently or aloud and are not given feedback on their reading accuracy. After reading each text, comprehension is assessed with one question. Correct responses require a mixture of literal understanding and inferential processing. The WORD provides norms for children and adolescents aged 6 to 16 years.

Language: The computerised version of the Test for Reception of Grammar (TROG-E; Bishop, 2005) was used to obtain standard scores for receptive grammar. In the TROG-E participants select pictures that correspond to sentences of increasing grammatical complexity. The TROG-E provides norms for individuals aged 4 years to adult. Receptive, expressive and total language composite scores from the Clinical Evaluation of Language Fundamentals – Third Edition UK (CELF-UK-3; Semel, Wiig, & Secord, 2000) were used as broader indices of language function. The total language composite score comprises performance on a mixture of receptive and expressive language measures. The CELF-UK-3 provides norms for children and adolescents aged 5 to 16 years. This measure was administered during the first phase of the SNAP study (see Baird, et al., 2006; *M* age = 11 years 10 months; *SD* = 13 months; range 9 years 11 months – 14 years 8 months) and is available for a subgroup of participants only (see Table 1).

Social and communication behaviour: The composite social and communication score from the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000) was used as an index of social and communication behaviour. The ADOS-G was administered to participants during the first phase of the SNAP study (see Baird, et al., 2006; *M* age = 11 years 10 months; *SD* = 13 months; range 9 years 11 months – 14 years 8 months).

Social cognition: Two cognitive tasks that measure mental state attribution were included. First, the Strange Stories (Happé, 1994) required understanding of concepts such as double bluff, misunderstanding, lies and persuasion. Participants were read a series of narrative texts and each story was followed by a question assessing the ability to infer the intention behind a nonliteral utterance. Stories and questions were presented in written form for the participant to follow, if wished, while the experimenter read the text aloud. Data were analysed from four Strange Stories that had a mentalising component. Following Happé et al.

(1998), a 0-1-2 scoring system was implemented, with 0 representing an incorrect or "don't know" response and 2 representing a full and explicitly correct answer. An average score was calculated across the four items.

The second task, the Frith-Happé animations (Abell, Happé, & Frith, 2000; Castelli, Happé, Frith, & Frith, 2000) required the attribution of mental states to two interacting cartoon triangles. Four short (c. 45 seconds) silent animations showed the triangles moving together in ways that suggested one triangle manipulating or anticipating the mental state of the other (coaxing, mocking, seducing, surprising). The participants' verbal descriptions of the triangles' action and interaction were recorded for later transcription and scoring. An intentionality score was given for each description, reflecting the degree of mental state attribution, ranging from 0 = no mental state language to 5 = sophisticated attribution of mental states. An average score was calculated for performance across the four animations.

Each task was scored by one of three trained experimenters. Reliability of the scoring was assessed by double marking 16 of the Strange Stories and 53 of the Frith-Happé animations. Intraclass correlations were high for both tasks (.93 and .95, respectively), indicating good reliability. Any discrepancies in the scoring between the double marked items were resolved by consensus agreement. Both the series of stories and the series of animations were counterbalanced for order.

Results

Descriptive information on the standardised and experimental tasks is shown in Table 1. Scores on standardised measures showed great variation and means were either in the lower average range (performance IQ, word recognition) or below the average range (reading comprehension, oral language).

Table 1 about here

Table 2 presents the percentage of individuals obtaining scores on reading and language that were more than one or two standard deviations below the test mean. Comparing these values with the percentages for less than one and two standard deviations that would be expected based on the normal distribution (approximately 16% and 2% respectively) indicates widespread impairment at an individual level. Nonetheless, a substantial proportion of the sample obtained standardised scores on reading and oral language measures that were in the average range or above.

Table 2 about here

A series of regressions were conducted with reading comprehension standard score as the outcome variable (see Table 3). Our first hypothesis was that word recognition and oral language comprehension would make unique contributions to reading comprehension. We further hypothesised that after controlling for word recognition and oral language comprehension, indices of social behaviour and social cognition would explain significant additional variance. To test these hypotheses, hierarchical regression models were used to predict reading comprehension, with word recognition and oral language comprehension standard scores entered first, at steps 1 and 2 respectively, followed by scores on ADOS social communication (model 1) *or* strange stories (model 2) *or* Frith-Happé animations (model 3) at step 3. Two participants did not complete the reading comprehension task. A further three participants completed the task but did not have measurable reading

comprehension skills; these participants were excluded from the regression analyses.[1] Two indices of oral language were used, yielding two versions of each model (a, b). The TROG-E was used as our primary measure of language comprehension as scores were available for 94 of our 95 participants with measurable reading comprehension (models 1a, 2a and 3a) and this measure was administered concurrently with reading comprehension. The TROG-E measures receptive grammar. Although receptive grammar is posited to play an important role in reading comprehension, other aspects of oral language comprehension are also important (Clarke et al., 2010; Muter et al., 2004; Nation et al., 2010). Therefore, we included a second measure of language in our analyses, which was a more global measure, the CELF-UK-3 receptive language score (models 1b, 2b and 3b). However, the CELF-UK-3 receptive language score was only available for 87 participants with measurable reading comprehension and this assessment was administered approximately four years before the reading comprehension (and other) measures.[2]

Table 3 about here

As shown in Table 3, word recognition and oral language comprehension (as indexed by both TROG-E and CELF-UK-3 receptive language) accounted for significant variance in reading comprehension at steps 1 and 2 of all regression models. At step 3, scores on ADOS social communication and strange stories explained significant additional variance. The variance explained by performance on the Frith-Happé animations was significant in combination with word recognition and CELF-UK-3 receptive language (model 3b) but only marginally significant (p = .05) in combination with word recognition and TROG-E (model 3a). Inspection of standardised β weights for each model with all variables included,

indicated that all variables explained significant unique variance in reading comprehension, with two exceptions. This effect was marginal (p = .05) for the Frith-Happé animations in combination with word recognition and TROG-E (model 3a) and non-significant for the CELF-UK-3 receptive language in combination with word recognition and performance on the strange stories task (model 2b).

Discussion

A group of 100 adolescents with ASD completed assessments of performance IQ, word recognition, reading comprehension, oral language, social behaviour and social cognition. Our large sample size allowed us to conduct novel regression analyses that probe explanations for heterogeneity in reading comprehension within a group of adolescents with ASD. To our knowledge, this is the first study to explore word recognition, oral language comprehension and social factors as predictors of individuals differences in a sample exclusively made up of individuals with ASD. Consistent with the Simple View of Reading, we found that both word recognition and oral language comprehension were unique predictors of reading comprehension. In addition, we demonstrated that the social impairments in ASD, whether measured behaviourally using an index of social and communication impairment or cognitively using two measures of mental state understanding, were significant predictors of reading comprehension, after accounting for the variance explained by word recognition and oral language. This suggests that there are factors that contribute to reading comprehension in ASD that are not conceptualised within the Simple View of Reading. In what follows, we first consider performance of the group and individuals on standardised measures of reading and language tasks relative to test norms. We then move on to interpret the regression analyses.

As a group, the adolescents with ASD showed mean reading and language scores that were in the lower average range (word recognition) or below the average range (reading comprehension, oral language). There was also considerable heterogeneity within the group, particularly on standardised measures of reading. As reported elsewhere (Jones et al., 2009), relative to test norms, the mean reading comprehension score was substantially lower than the mean word recognition score (for similar findings see Lindgren et al., 2009; Nation et al., 2006). When participants were considered individually, a substantial minority were impaired on word recognition and a greater number were impaired on reading comprehension (for similar findings, see Nation et al., 2006). Thus, reading comprehension may present more of a challenge for adolescents with ASD than word recognition. Nevertheless, word recognition is also an area of weakness for many. In line with the Simple View of Reading, it is therefore likely that successful reading comprehension was constrained by word recognition in some cases. This is consistent with our finding that across regression analyses word recognition was a unique predictor of reading comprehension. A substantial proportion of our group exhibited oral language impairments, indicating that reading comprehension difficulties occur in the context of broader comprehension difficulties across oral and written domains. Indeed, when considered together, many participants showed both oral language and reading comprehension impairments when cut-offs of one and two standard deviations were employed (47% and 22% respectively). Again, regression analyses indicated a role for oral language comprehension in reading comprehension success. This effect was consistent across analyses where oral language comprehension was indexed by the TROG-E and two of the three analyses that included CELF-UK-3 receptive language.

The results of our regression analyses are consistent with Norbury and Nation (2011) and Åsberg et al. (2010) who found that, in mixed groups of participants with and without an ASD diagnosis, both word recognition and oral language comprehension predicted unique

variance in reading comprehension. Norbury and Nation also observed that after controlling for word recognition and oral language, group status (ASD vs. no ASD diagnosis) was a significant predictor of performance on an experimental measure of inferencing ability, which taps comprehension processes. However, group status did not predict reading comprehension on a standardised test. In contrast, our findings show that beyond the factors encapsulated by the Simple View of Reading, a dimensional diagnostic measure of the severity of social and communication symptoms in ASD (ADOS social and communication score) predicted performance on a standardised reading comprehension test (for a similar finding with Swedish-speaking girls with ASD, see Åsberg et al., 2010).

Our findings may appear inconsistent with those of Norbury and Nation; however, it is worth noting a number of differences between the two studies. Although the adolescents in the two studies completed reading comprehension tasks at a similar age (on average our participants were approximately six months older), our sample was less able and more varied in terms of performance IQ, oral language and word recognition. Our sample exhibited low and varied reading comprehension scores in relation to test norms but Norbury and Nation did not report standardised reading comprehension scores for their sample. Therefore, the extent to which their group had reading comprehension difficulties is unclear. Further, the measures of reading comprehension used in the two studies are substantially different (Bowyer-Crane & Snowling, 2005) and there is evidence that the relative contributions of variables in predicting reading comprehension can be moderated by the task used (Cutting & Scarborough, 2006; Keenan, et al., 2008). Finally, our continuous measure of ASD severity might have been more sensitive to individual differences than Norbury and Nation's dichotomous group variable.

In this study, we draw on behavioural and cognitive measures of social and communication abilities. The ADOS measure of social communication was a consistent predictor of reading comprehension. Our study also considered mental state understanding – impairments in this domain are a core feature of ASD (Baron-Cohen, 2000) – and this variable was associated with reading comprehension above and beyond word recognition and oral language. Importantly, this finding was replicated across two quite different indices of mental state understanding. The strange stories task developed by Happé (1994) involves listening to/reading and comprehending stories. Therefore, the association between this and reading comprehension could be explained by task-related overlap. Inferences about mental states must be made for full credit on each strange story and the majority of questions on the WORD reading comprehension task require inferential processing of some kind (Bowyer-Crane & Snowling, 2005). It is likely that task demands on the strange stories task also overlap to some extent with the measures of oral language that we employed, this may explain why CELF-UK-3 scores were not associated with reading comprehension in a model that also included strange stories scores (model 2b). The Frith-Happé animations (Abell, et al., 2000; Castelli, et al., 2000) involve nonverbal stimuli and do not involve reading or listening comprehension, and thus provide more convincing evidence for a link between mental state understanding and reading comprehension. It is worth noting though that the relationship between performance on this task and reading comprehension was less robust.

Our findings indicate that for adolescents with ASD, impairments in social interaction and communication and difficulties with mental state understanding limit reading comprehension above and beyond the influence of word recognition and oral language deficits. Construction of an adequate ‘situation model’, a meaning-based representation of text that is integrated with prior knowledge and experience, is considered to be essential for successful text comprehension (e.g., Kintsch, 1988; Perfetti, Landi & Oakhill, 2005). While

word recognition and oral language comprehension contribute to the development of a situation model, discourse skills such as inferential processing, comprehension monitoring and knowledge of text structure are also important (Cain, 2010; Perfetti, Landi & Oakhill, 2005). This raises a number of potential mechanistic accounts for the relationship between reading comprehension and social skills and social cognition. One possibility is that failing to understand social and communicative norms and difficulties with mentalising may hamper a reader's ability to make inferences and therefore constrain their situation model of the text. Developmentally, mentalising may also act as a 'gate-keeper', facilitating acquisition of skills (e.g., inferencing) and knowledge through socially-mediated learning (Scheuffgen, Happé, Anderson, & Frith, 2000).

Although we propose that the social behaviour and social cognitive profile found in ASD constrains reading comprehension, there are other possible explanations for our findings. First, the associations that we observed may reflect the opposite, that reading comprehension somehow determines the impairments in social interaction, communication and mental state understanding observed in ASD. This seems unlikely, not least because ASD can be detected well before the onset of reading. However, more plausible is the possibility raised earlier; the association could be mediated by an additional factor such as oral language. We addressed this concern by controlling for language in our analyses. However, other potential factors affecting both social ability and reading comprehension, such as attentional difficulties, have yet to be explored.

It is worth noting a limitation of our study. The ADOS-G and CELF-UK-3 were administered approximately four years prior to the other measures and this might impact on the strength of the relationships that we observed in regression analyses. Importantly, it might explain why, in one regression model, scores on the CELF-UK-3 were not associated with

reading comprehension (this may also be related to overlapping task demands with the strange stories measure as suggested above). Nonetheless, our finding that oral language predicts reading comprehension after controlling for word recognition was replicated across five of the six regression models including all models where the TROG-E, a concurrent measure, was included to index oral language.

To our knowledge this study is the first of its kind and therefore requires replication. This line of research in ASD is in its infancy, with very few studies investigating predictors of reading comprehension in this group. It is likely that the dearth of studies exploring individual differences in reading comprehension in ASD is partly due to difficulties associated with recruiting and assessing the large numbers of individuals with ASD that are necessary to systematically explore heterogeneity. As suggested by Norbury and Nation (2011) children with ASD may also find reading comprehension difficult because weak central coherence impacts on contextual processing and integration while reading (cf. López & Leekam, 2003). Perfetti, Landi and Oakhill (2005) have hypothesised that a poor 'standard for coherence' may inhibit inferential processing and therefore comprehension more generally across readers. Individuals with ASD may also be disadvantaged when engaging with narratives (Norbury & Bishop, 2003) and texts that involve animate objects (White et al., 2009). Further, given that reading comprehension places demands on executive processes such as working memory (Oakhill, Cain & Bryant, 2003), poor reading comprehension in ASD may be associated with the executive weaknesses that can be observed in this group (Henderson, Clarke & Snowling, 2011; Ricketts, 2011). Future studies should aim to investigate more fully the factors that contribute to variability in reading comprehension in ASD and extend this research to children and adults as well as adolescents. To our knowledge no longitudinal data on reading comprehension in ASD have been published (but see Norbury & Nation, 2011 for longitudinal data on word recognition). Future studies that employ

longitudinal and experimental designs will enable us to discriminate between alternative explanations for the associations between characteristics of ASD and reading comprehension.

In sum, it appears that the Simple View of Reading is applicable to ASD to the extent that it posits a role for both word recognition and oral language in reading comprehension (cf. Norbury & Nation, 2011). However, our data suggest that this framework needs to be extended to include variables other than word recognition and oral language. Specifically, we found that social behaviour and mental state understanding were also associated with reading comprehension in ASD. Analysis of this unusually large data set allowed us to extend studies of reading comprehension in ASD that have compared individuals with ASD to controls by exploring individual differences *within* ASD (cf. Brock, 2011; Lord & Jones, 2012). Understanding the factors that influence reading comprehension may be especially important for pupils with ASD, for whom written language may have a number of advantages over face-to-face aural language (cf. Randi, Newman & Grigorenko, 2010; Ricketts, 2011).

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Author notes

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Footnotes

[1]We thank an anonymous reviewer for noting that sentence and paragraph comprehension require somewhat different processes. In the WORD, a reading comprehension score is based on sentence and paragraph comprehension and there were four participants who obtained a comprehension score that reflected comprehension at the sentence but not paragraph level. With these participants removed, the results of regression analyses were identical except that the small/marginal effects of the Frith-Happé animations in models 3a (p for $\beta = .05$) and 3b (p for $\beta < .05$) became trends ($p = .07$ and .08 respectively).

[2]Performance IQ was not included in analyses as this variable was not central to our aims and hypotheses. However, given variability in our sample on this measure, and the potential role for nonverbal ability in predicting reading comprehension (Ricketts, 2011), additional analyses were conducted with performance IQ included as a control variable at the first step of each regression model. Performance IQ did not predict significant unique variance in reading comprehension in any model.

Table 1. *Descriptive information on standardised and experimental measures*

Measure	N	Mean	SD	Range
Performance IQ[1]	100	90.37	18.61	53 – 126
Word recognition[1]	99	85.24	20.07	40 – 118
Reading Comprehension[1]	98	76.29	19.07	40 – 114
TROG-E[1]	98	82.89	17.20	55 – 109
CELF-UK-3 Total[1]	88	78.53	14.62	63 – 120
CELF-UK-3 Receptive[1]	88	78.43	14.89	64 – 124
CELF-UK-3 Expressive[1]	88	81.36	15.44	64 – 117
ADOS Soc Comm[2]	100	9.53	5.12	0 – 22
Strange stories[3] (max=2)	88	.85	.53	0 – 2
Frith-Happé animations[3] (max=5)	87	2.87	.94	0 – 4.75

Notes. [1]Standard score, *M* = 100, *SD* = 15; [2]Raw score; [3]Average score; TROG-E = Test of Reception for Grammar – Electronic; CELF-UK-3 = Clinical Evaluation of Language Fundamentals (3rd UK Ed.); Total = Total Language Score; Receptive = Receptive Language Score; Expressive = Expressive Language Score; ADOS Soc Comm = Autism Diagnostic Observation Schedule Social and Communication Composite Score

Table 2. *Percentage of adolescents with ASD impaired on reading and oral language measures*

Measure	% <1 *SD*	% < 2 *SD*
Word recognition	45	23
Reading Comprehension	60	32
TROG-E	41	28
CELF-UK-3 Total	61	38
CELF-UK-3 Receptive	72	40
CELF-UK-3 Expressive	58	30

Notes. TROG-E = Test of Reception for Grammar – Electronic; CELF-UK-3 = Clinical Evaluation of Language Fundamentals (3rd UK Ed.); Total = Total Language Score; Receptive = Receptive Language Score; Expressive = Expressive Language Score

Table 3. *Regression analyses predicting reading comprehension*

Model	Step	Variable	R^2 change	*F* change	*p*	β	*p*
1a	1	Word recognition	.64	164.60	<.001	.55	<.001
	2	TROG-E	.03	8.71	<.01	.28	<.01
	3	ADOS Soc Comm	.03	7.70	<.01	-.17	<.01
1b	1	Word recognition	.64	151.94	<.001	.62	<.001
	2	CELF-UK-3 Receptive	.03	7.84	<.01	.23	<.01
	3	ADOS Soc Comm	.03	8.37	<.01	-.18	<.01
2a	1	Word recognition	.64	150.13	<.001	.54	<.001
	2	TROG-E	.03	7.93	<.01	.21	<.05
	3	Strange stories	.05	13.55	<.001	.24	<.001
2b	1	Word recognition	.64	142.89	<.001	.63	<.001
	2	CELF-UK-3 Receptive	.03	7.37	<.01	.12	ns
	3	Strange stories	.04	10.27	<.01	.23	<.01
3a	1	Word recognition	.64	148.32	<.001	.58	<.001
	2	TROG-E	.03	7.83	<.01	.23	<.05
	3	Frith-Happé animations	.02	3.96	.05	.14	.05
3b	1	Word recognition	.64	139.28	<.001	.63	<.001
	2	CELF-UK-3 Receptive	.03	7.18	<.01	.20	<.05
	3	Frith-Happé animations	.02	5.19	<.05	.16	<.05

Note. β corresponds to standardised β in a model with all variables included; TROG-E = Test of Reception for Grammar – Electronic; CELF-UK-3 Receptive = Clinical Evaluation of Language Fundamentals (3rd UK Ed.) Receptive Language Score; ADOS Soc Comm = Autism Diagnostic Observation Schedule Social and Communication Composite Score.