Social Cognition and Reading Comprehension in Children and Adolescents with Autism Spectrum Disorders or Typical Development

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Abstract

Background: Many individuals with autism spectrum disorders (ASD) exhibit social cognitive impairments in the development of theory of mind (ToM), or the ability to attribute mental states to oneself and others. ToM has been shown to relate to reading comprehension for children and adolescents with typical development (TD) and with ASD. This study examined the relation between reading comprehension, word recognition, oral language, and ToM for higher-functioning children and adolescents with ASD (HFASD) as compared to those with TD.

Method: 70 children with HFASD and 40 children with TD, aged 9-17 years, participated in the study. In order to describe the HFASD as compared to the TD sample, a series of ANOVAs and ANCOVAs were conducted. Multiple regression analyses were conducted with reading comprehension as the outcome variable. Separate regression models (TD & HFASD) were run with IQ, word recognition, oral language, and two ToM measures (Happé's Strange Stories and the Silent Films Task) as predictors.

Results: The TD group performed better than the HFASD group on all standardized and experimental measures. Regression analyses revealed that after controlling for IQ, word recognition, and oral language, both ToM measures predicted unique variance in reading comprehension in the HFASD, but not the TD, sample. Furthermore, the TD and HFASD groups displayed different patterns of significant predictors of reading comprehension.

Conclusions: This study suggests that in addition to oral language and higher-order linguistic comprehension, social cognition is an important factor to consider when designing reading interventions for students with ASD.

Keywords: ASD; social cognition; theory of mind; oral language; reading comprehension

Introduction

Social and communication difficulties are hallmark characteristics of individuals with autism spectrum disorder (ASD; Christensen et al., 2016*)* and have been linked to underlying social cognitive impairments in the development of theory of mind (ToM). ToM is the ability to attribute mental states (e.g., beliefs, desires, intentions) to oneself, and infer others' mental states in order to understand and predict their behavior (Baron-Cohen, Leslie, & Frith, 1985; White, Hill, Happé, & Frith, 2009). Impairments in ToM are evident across developmental stages and functioning levels in individuals with ASD, and these deficits remain evident throughout adolescence and into adulthood, even among individuals without comorbid intellectual disabilities (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Kaland, Callesen, Moller-Nielsen, Mortensen, & Smith, 2008; White et al., 2009).

ToM enables one to understand that oral and written language are about the expression of thoughts, emotions, and desires, as well as the interpretation of intended meaning rather than literal meaning (Tomasello, 2010). Relatedly, performance on ToM tasks is associated with oral language skills (Happé, 1995) and communicative competence (Hale & Tager-Flusberg, 2005). ToM and language have been posited to have a bidirectional relation in development (Miller, 2006; Slade & Ruffman, 2005). For instance, evidence from typically developing (TD) children suggests that ToM is a contributing factor to semantic development (Baldwin & Moses, 2001; Birch & Bloom, 2002). On the other hand, research also suggests that exposure to, and engagement in, conversations about mental states influence children's ToM development (Dunn, Brown, Slomkowski, Tesla, & Youngblade, 1991; Ruffman, Slade, & Crowe, 2002). Furthermore, a large body of evidence has demonstrated that general language skills (e.g., syntax and semantics) contribute to performance on ToM tasks, including false belief tasks (Astington & Jenkins, 1999; Cutting & Dunn, 1999; Happé, 1995; Slade & Ruffman, 2005), and that mastery of mental state words such as "think" and "know" are related to children's ToM development (Bartsch & Wellman, 1995; Shatz, Wellman, & Silber, 1983).

Challenges with ToM have the potential to impact performance in a variety of contexts, including educational settings. While data indicate that many children with ASD have difficulty understanding the mental states or beliefs of others, there is a dearth of information about how this could specifically impact academic achievement for these children. Reading achievement, which is also related to language development, underpins learning in many academic milieus and serves as a conduit to overall academic achievement. This study investigates the relation between ToM and reading achievement. Understanding the influence of language and ToM on reading in school-aged children with ASD may provide insights into syndrome specific academic challenges.

Reading Framework and Reading Achievement in ASD

The Simple View of Reading framework (Gough & Tunmer, 1986) posits that successful reading comprehension is the product of proficient word reading skills and oral language comprehension and that poor reading comprehension may reflect weaknesses in either, or both, domains. Prior research has demonstrated the utility of this framework for understanding reading skill in TD readers or those with reading disorders (e.g., Catts, Adlof, & Weismer, 2006; Joshi & Aaron, 2000; Tunmer & Chapman, 2012), as well as those with ASD (Jones et al., 2009; McIntyre et al., 2017; Norbury & Nation, 2011; Ricketts, 2011). Studies with children with ASD have demonstrated that proficient reading comprehension is a particular challenge that impacts between 33 and 65% of ASD samples (Jones et al., 2009; Lucas & Norbury, 2014; McIntyre et al., 2017; Nation et al., 2006; Ricketts, Jones, Happé, & Charman, 2013). Many children with ASD exhibit impairments in oral language development (Eigsti et al., 2011; Tager-Flusberg, 2006), and while considerable variability in both domains of the Simple View has been demonstrated, a strong relation between structural language components (i.e., phonology, semantics, syntax, morphology) and reading comprehension has been established (Lindgren et al., 2009; McIntyre et al., 2017; Norbury & Nation, 2011; Ricketts, Jones, Happé, & Charman, 2013). In several studies, children with ASD and structural language impairments performed significantly more poorly on measures of word recognition, word decoding, and overall reading comprehension (Lindgren et al., 2009; Lucas & Norbury, 2014; Norbury & Nation, 2011). Data from studies by Ricketts et al. (2013) and Williams et al. (2015) indicated that for children with

ASD and adequate sentence level language skills, reading comprehension impairments may be related to syndrome specific higher order inferential and cognitive processing challenges. Individuals with ASD have demonstrated difficulty with verbal reasoning, inference generation, and answering questions about inferences (Lucas & Norbury, 2015; Norbury & Nation, 2011; Saldana & Frith, 2007; Tirado & Saldana, 2016); this is particularly evident when needing to use ToM to make inferences about social information regarding emotional states, mental states, or intentionality (Bodner, Engelhardt, Minshew, & Williamsl, 2015; Happé, 1994; Kaland et al., 2005; Le Sourn-Bissauoi, Caillies, Gierski, & Motte, 2009).

Relation Between ToM and Reading Achievement

Emerging research highlights the impact of individual differences in ToM on TD children's experiences in school and the pathways that might link ToM to academic success. One pathway Hughes & Devine (2015) reviewed posited links between ToM and metacognitive skills such as understanding that texts have an intended meaning and are representational, like mental states, and, therefore, are open to different, sometimes incorrect, interpretations by different people. Lecce, Zocchi, Pagnin, Palladino, and Taumoepeau (2010) reported that, when controlling for verbal abilities, individual differences in TD children's ToM predicted later meta knowledge about reading including understanding the attitudes and differences of people as readers, the various goals a reader might have for a text, knowledge about different types of texts and their characteristics, and possible strategies that can be applied to different types of texts. Kim (2015) provided evidence that ToM indirectly predicted reading comprehension through its significant relation with listening comprehension in TD kindergarteners, supporting the hypothesis that ToM tasks capture inference making and complex social reasoning skills that are important for understanding story characters' and authors' beliefs and intentions. Reading literary fiction has been shown to promote ToM, empathy, and social development in TD children (Doise et al., 2013; Mar, Tackett, & Moore, 2010) and adults (Kidd & Castano, 2013; Mar, Oatley, & Peterson, 2009), suggesting that exposure to fiction may change how individuals think about themselves and others. Taken together, these data indicate that ToM and reading comprehension are interrelated and, therefore, deficits in one might suggest deficits in the other.

Although within the ASD literature ToM deficits have been heavily studied for more than two decades, research investigating the relation between individual differences in ToM and reading has been limited. However, examining whether individual differences in ToM underlie interactions with, and comprehension of, texts for individuals with ASD is important since understanding the specific factors impacting reading comprehension is a crucial step in ASD academic achievement research. Emerging research suggests that reading comprehension difficulties are part of the social communication phenotype of individuals with ASD without intellectual disabilities, or higher-functioning school-aged children with ASD (HFASD), demonstrating significant negative associations between reading development and ASD symptom intensity or social functioning (Estes, Rivera, Bryan, Cali, & Dawson, 2011; Jones et al., 2009; McIntyre et al., 2017; Ricketts et al., 2013). Narratives in particular may be challenging for children with ASD due to their delays in development of ToM (Randi, Newman, & Grigorenko, 2010; Ricketts, 2011). Ricketts et al. (2013) examined social cognition, operationalized by two advanced ToM tasks, as a predictor of reading comprehension. Their sample of 100 adolescents with ASD ranged in age from 14 – 16 years and had nonverbal IQs ranging from 53-126 (M = 90.37, SD = 18.61). Utilizing two ToM measures, a verbal-based ToM task (Strange Stories; Happé, 1994) and a non-verbal ToM task assessing the ability to interpret intentions of silent animations of two interacting cartoon triangles (Frith-Happé animations; Abell, Happé, & Frith, 2000), Ricketts et al. (2013) found that ToM was a unique predictor of reading comprehension even after controlling for word reading and oral language for adolescents with ASD. This finding provided evidence that the additional factor, ToM, contributes to variance in reading comprehension in ASD that is not accounted for by the Simple View of Reading.

Rationale for Current Study

The current study has two aims: (1) to replicate the finding of Ricketts et al. (2013) that ToM predicts unique variance in reading comprehension beyond that explained by word reading and oral language in a sample of children with HFASD, and (2) to extend their work by examining this relation in an HFASD sample comprised of a broader age range and to determine if differential relations exist when comparing an HFASD with a TD control group. Our hypothesis

was that after controlling for full-scale IQ (FIQ), word reading, and oral language, ToM indices would explain significant unique variance in both the HFASD and TD groups.

Methods

Participants

This longitudinal research was conducted in compliance with the Institutional Review Board and written parental consent and child assent was obtained prior to data collection. The sample consisted of 70 (58 male) children with HFASD and 35 (22 male) TD children, aged 9 to 17 years. Enrolled participants were recruited from a university research subject tracking system, the local community through school districts, and word of mouth. Exclusionary criteria included parent report of a syndrome other than ASD (e.g., Fragile X), a neurological disorder (e.g., epilepsy), psychotic symptoms (e.g., hallucinations), significant sensory or motor impairment, or any major medical disorder that could be associated with extended absences from school. Individuals were included in the HFASD sample if they had a community diagnosis of ASD, confirmed by trained researchers using the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012), and a FIQ estimate between 75-130 on the Wechsler Abbreviated Scales of Intelligence-II (WASI-2, Wechsler, 2011). Participants in the TD group did not have a community diagnosis of, or meet criteria by parent questionnaire for, ASD and had an FIQ estimate between 75-130.

All participants included in the HFASD sample met criteria on the ADOS-2 and scored significantly higher in ASD symptomatology than those in the TD group on the parent report questionnaires as shown in Table 1. Demographic data presented in Table 2 indicate that the ratio of boys to girls in the HFASD sample, approximately 4.8:1, is similar to national prevalence rates (Christensen et al., 2016). Generally, participants' mothers in both groups completed at least some college, with 30% in the HFASD and 23% in the TD sample completing graduate school. The groups were matched on age (see Table 1 for descriptive statistics). However, full scale IQ (FIQ), verbal IQ (VIQ), and nonverbal performance IQ (PIQ) were significantly lower in the ASD group than TD group, with moderate to large associated effect sizes. We took two complementary approaches to tackling this methodological limitation: (a) "controlling" for FIQ in statistical analyses and (b) creating closely matched subsamples prior to statistical analysis.

Procedures and Measures

Participants were recruited to take part in a longitudinal study of social and academic development. Data reported are from assessment sessions that were conducted by members of trained research group in a university-based child assessment laboratory during 2.5-hour sessions. Diagnostic, demographic, and IQ data were collected at the first time point. Reading, oral language, and ToM measures were collected 15 months later at the second time point. All assessments were standardized except the experimental ToM measures; age-normed standard scores are reported on standardized measures.

Diagnostic measures. The ADOS-2 (Lord et al., 2012) is a diagnostic assessment for ASD that has a strong predictive validity against best estimate clinical diagnoses (Charman & Gotham, 2013). Trained research personnel administered Module 3 or 4 to confirm community ASD diagnoses through the evaluation of two core domains: Social Affect and Restricted and Repetitive Behaviors. The cutoff score of seven places a child on the autism spectrum. Parent report questionnaires were administered to provide converging evidence of ASD symptomatology in the HFASD sample and to rule out ASD symptomatology in the TD sample. The SCQ Lifetime version (Rutter, Bailey, & Lord, 2003) is a 40-item parent report rating developmental symptoms of ASD in children four years and older. Scores greater than 15 suggest autism. The SRS (Constantino & Gruber, 2005) is a 65-item parent questionnaire rating dimensions of communication, social behavior, and the repetitive/stereotypic behaviors characteristic of ASD. T-scores between 60-75 indicate deficiencies in reciprocal social behavior in the mild-moderate range, while those above 76 fall in the severe range.

Cognition. The WASI-2 (Wechsler, 2011) provided an estimate of nonverbal and verbal cognitive skills. The verbal composite (VIQ) was comprised of two subtests, Vocabulary and Similarities, which measured expressive vocabulary and abstract semantic reasoning respectively. The Performance composite (PIQ) was comprised of two nonverbal subtests, Block Design and Matrix Reasoning, which measured visual spatial processing and problem solving. The four subtests combine to provide an age-normed standard score (M = 100, SD = 15) measurement of full scale IQ (FIQ).

Reading. The Gray Oral Reading Tests – Fifth Edition (GORT-5; Wiederholt & Bryant,

2012) assessed reading comprehension and yielded an age-normed standard score. The assessment is comprised of 16 progressively more difficult narrative or expository reading passages read aloud by the child, followed by 5 open-ended questions that required an oral response. Some questions rely on recall of details while others require higher order processing such as synthesis of the main idea, explaining causal relations, or making inferences. Word reading was assessed with the Test of Word Reading Efficiency, Second Edition (TOWRE-2, Torgesen, Wagner, & Rashotte, 2012), measuring accuracy and fluency of sight word recognition (Sight Word Efficiency: SWE) and phonemic decoding (Phonemic Decoding Efficiency: PDE). Participants read as many real words (SWE) or decodable nonwords (PDE) as they were able to in 45 seconds. The TOWRE-2 also yielded an Index score which is a standardized composite score comprised of the SWE and PDE subtests.

Oral Language. Receptive vocabulary was measured by the Wechsler Individual Achievement Test, 3rd edition (WIAT-III; Wechsler 2010). The assessment requires one to point to the picture that depicts the meaning of progressively more semantically sophisticated words, and yields an age-normed standard score. Linguistic comprehension skills such as those necessary to listen to and utilize narrative structure to organize and retell gist and verbatim details were measured with the Story Recall subtest of the Wide Range Assessment of Memory and Learning, Second Edition (WRAML-2, Sheslow & Adams, 2003). This assessment yielded an age-normed standard score. The Language Composite used in subsequent analyses was created by averaging participants' receptive vocabulary and story recall standard scores.

Theory of Mind. ToM was measured by two advanced ToM measures that were appropriate for children and adolescents; these tasks were more complex than the false belief tasks used with young children as they required participants to apply their mental state understanding to contextualized social scenarios. The Strange Stories (Happé, 1994; White, Hill, Happé, & Frith, 2009) task was comprised of five short stories; text was presented on a computer screen while a recorded voice read the story aloud. The stories used in this study depicted social scenarios involving deceptions, double bluffs, or misunderstandings. Participants were required to verbally respond to one question per story about a character's beliefs, desires or behavior based on their imputed mental state. The second measure, the Silent Films Task, was created by

Devine and Hughes (2013) to study advanced ToM in middle childhood and adolescence in TD individuals and to be an analogous task to Strange Stories. It was comprised of five short silent film clips presented on a computer screen; the clips were drawn from a silent comedy film by Harold Lloyd called *Safety Last* (Roach et al., 1923). Immediately after each clip, one or two questions about the characters' beliefs and intentions appeared on the screen and were also read aloud by the examiner.

Each task was coded by one of two trained experimenters using the coding scheme developed for Strange Stories (Happé, 1994). For both measures, responses were scored using a 0-1-2 system where 0 represented an incorrect or "don't know" response, 1 represented partial credit for reference to lower order mental states, and 2 represented a complete, correct answer that was based on an explicit inference about characters' beliefs or intentions. Participants could receive a maximum score of 10 on Strange Stories and 12 on Silent Films. Raw scores were averaged together for each participant to form a ToM Composite score. For each ToM task, a trained experimenter coded the full sample and a second trained experimenter coded 15% of the sample. Inter-rater reliability was good for both Strange Stories (Cohen's kappa = 0.97) and Silent Films (Cohen's kappa = 0.85).

Data Analysis

In order to describe the HFASD as compared to the TD sample, a series of Analyses of Variance (ANOVAs) and Analyses of Covariance (ANCOVAs) controlling for FIQ, were conducted in SPSS version 25 to calculate sample means and standard deviations and to examine diagnostic group differences in (a) reading comprehension, (b) word reading and decoding, (c) oral language, and (d) ToM. Alpha levels below .05 were considered statistically significant for all analyses. Effect size for these analyses was calculated as partial eta squared (η^2_p) to measure the strength of association between variables. For this statistic, values between .01 and .05 are considered a small effect size, values between .06 and .14 are considered medium effect size, and above .14 are considered a large effect size. Next, correlations among the reading, FIQ, language and ToM variables were examined for strength of associations between reading comprehension and predictor variables in both diagnostic groups. Hierarchical multiple regression analyses were conducted separately for each diagnostic group with reading comprehension as

the outcome variable. A series of regressions were run in the HFASD full sample (n = 70) and TD sample (n = 35) controlling for FIQ at step 1. Next, the Word Reading Index was entered as step 2, followed by the Language Composite as step 3 in each model. Finally, since all three ToM variables were significantly correlated with reading comprehension in the HFASD sample, Strange Stories, Silent Films, or ToM Composite was entered as step 4 in Model 1, 2 and 3 respectively. None of the ToM variables were significantly correlated with reading comprehension in the TD sample, however, to allow between-group comparisons, the ToM Composite score was entered as step 4 in the TD sample.

Due to the difficulty of recruiting a sample of typically developing children matched on FIQ to a large sample of higher functioning school-aged children with ASD, covariance analyses controlled for FIQ. However, Miller and Chapman (2001) raised concerns about the limitations of covariance analyses, thus we addressed this in supplemental analyses in which we utilized a more rigorously controlled FIQ-matched subsample of individuals with HFASD (*n* = 37) to explore the consistency of the main findings. All analyses as described above were run for the matched samples.

Results

Full Sample

Descriptive statistics and diagnostic group differences on the standardized and experimental measures are presented in Table 3. HFASD means on the standardized word recognition, decoding, and oral language measures were in the average range as compared to the tests' norming samples, but the group mean on the reading comprehension measure was approximately one standard deviation below average. The TD sample means were within the average to above average range on all standardized reading and language variables. Raw scores were computed for the ToM tasks and measures of normality of the distributions in each sample were examined. The Strange Stories task was designed for ASD populations, and was normally distributed in the HFASD sample, with skewness of -0.59 (*SE* = 0.29) and kurtosis of -0.54 (*SE* = 0.57). Fifty-four percent of the TD sample in this study scored 90% or higher on this measure, although skewness of -0.91 (*SE* = 0.40) and kurtosis of -0.27 (*SE* = 0.78) was within normal limits. Overall, this task was not an area of deficit for this TD sample. The Silent Films

task was normally distributed in both samples: TD skewness of 0.05 (*SE* = 0.40) and kurtosis of -0.72 (*SE* = 0.57), and in ASD skewness of -0.49 (*SE* = 0.29) and kurtosis of -0.94 (*SE* = 0.78). The ToM composite variable was normally distributed in both samples [ASD skewness of -0.70 (*SE* = 0.29) and kurtosis of -0.54 (*SE* = 0.57; TD skewness of -0.41 (*SE* = 0.40) and kurtosis of -0.50 (*SE* = 0.78)] and is a more robust measure of ToM. The TD group performed significantly better than the HFASD group on all standardized and experimental measures when FIQ was not controlled. With FIQ controlled, significant differences remained in Reading Comprehension, Sight Word Recognition, Word Reading Index, Receptive Vocabulary, Story Recall, Language Composite, and the ToM composite score.

Correlations between observed variables are presented in Table 4. In the HFASD group, reading comprehension was moderately to strongly correlated with FIQ, standardized measures of word recognition, decoding, word reading index, vocabulary, story recall, and oral language composite. Furthermore, all ToM variables were moderately to strongly positively correlated with reading comprehension in the HFASD sample. In the TD sample, reading comprehension was also moderately to strongly correlated with FIQ and all standardized measures of reading and language. However, none of the ToM variables were significantly correlated with reading comprehension in the TD sample.

This study examined social cognition and reading skill in TD and HFASD samples spanning middle childhood through adolescence, and one would expect these skills to develop over this timeframe. Correlations between age and measures of reading comprehension, the word reading index, and the language composite, were nonsignificant as would be expected of age-normed standard scores (r = 0.07, 0.02, -0.09 respectively in HFASD; r = 0.25, 0.19, 0.16 respectively in TD). However, the ToM measures yielded raw scores. We would expect ToM to be at least moderately correlated with age through this developmental span, and in fact this was the case in the TD sample for Strange Stories (r = 0.43, p = .01), Silent Films (r = 0.44, p = .01), and ToM Composite (r = 0.54, p = .001). In the HFASD sample a different pattern was displayed wherein Strange Stories was not significantly correlated with age (r = .19, p = .14), but Silent Films (r = 0.44, p < .001) and ToM Composite (r = .36, p = .003) were significantly correlated with age.

The results for the regression models predicting reading comprehension in the HFASD group are presented in Table 5. In all models, FIQ explained 44% significant variance in reading comprehension at step 1, the Word Reading Index explained 2% at step 2, and the Language Composite accounted for 16% significant variance at step 3. In Model 1, Strange Stories accounted for 6% significant additional variance at step 4. In Model 2, Silent Films explained 3% significant additional variance at step 4, and in Model 3, the ToM Composite accounted for 6% significant additional variance in reading comprehension at step 4. When all variables were included, inspection of the standardized β weights for each model indicated that not all variables explained significant unique variance in reading comprehension. In Model 1, Language Composite (β = .39) and Strange Stories (β = .32) explained significant unique variance in Reading Comprehension, but FIQ (β = .20) and Word Reading Index (β = .08) did not. In Model 2, FIQ (β = .28), Language Composite (β = .44), and Silent Films (β = .20) were significant predictors of reading comprehension but Word Reading Index was not (β = .09). In Model 3, FIQ (β = .23), Language Composite (β = .22), and the ToM composite score (β = .30) were significant unique predictors of reading comprehension but Word Reading Index (β = .09) was not.

The results for the regression model predicting reading comprehension in the TD group are presented in Table 6. FIQ accounted for 23% significant variance in reading comprehension at step 1, the Word Reading Index explained 17% at step 2, and the Language Composite accounted for 14% significant variance at step 3. The ToM Composite accounted for 3% additional variance in reading comprehension at step 4, but this was not statistically significant. When all variables were included, inspection of the standardized β weights for Model 1 indicated that not all variables explained significant unique variance in reading comprehension; Word Reading Index (β = .63) and Language Composite (β = .42) were significant unique predictors of reading comprehension, but FIQ (β = -.11) and ToM Composite (β = -.20) were not.

Matched Samples

A subsample of participants with HFASD (n = 37) was matched to the TD control participants (n = 35). As shown on Table 7, the samples were not significantly different on VIQ, PIQ, FIQ, or age. The HFASD means on the standardized reading comprehension, word recognition, decoding, and oral language measures were in the average range as compared to

the tests' norming samples. The TD group performed significantly better than the HFASD group on all standardized measures, except pseudoword decoding (PDE). This pattern of significant group differences is identical to that of the ANCOVAs controlling for FIQ, except that in the matched sample analyses the between group effect sizes are larger and in the medium to large range. The TD group also performed significantly better than the matched HFASD group on the Strange Stories, Silent Films, and the ToM Composite measures, with medium effect sizes.

Correlations between observed variables are presented in Table 8. Patterns of associations between reading comprehension and FIQ, word reading, oral language and ToM variables within matched diagnostic groups were similar to those in the full sample, with the exception that SWE was not significantly correlated with reading comprehension in the HFASD sample.

The results for the regression models predicting reading comprehension in the matched HFASD group display a similar pattern to those in the full sample analyses and are presented in Table 9. However, while all ToM measures continued to explain 3-4% unique variance in reading comprehension beyond that explained by FIQ, word reading and oral language, increases in the coefficient standard errors reflect the loss of power to detect significant effects due to reduced sample size. In all three models, FIQ explained 40% significant variance in reading comprehension at step 1, the Word Reading Index explained 0% variance in reading comprehension at step 2 and the Language Composite accounted for 19% significant variance at step 3. In Model 1, Strange Stories accounted for 4% additional variance at step 4. In Model 2, Silent Films explained 3% additional variance at step 4, and in Model 3, the ToM Composite accounted for 4% additional variance in reading comprehension at step 4. When all variables were included, inspection of the standardized β weights for each model indicated that not all variables explained significant unique variance in reading comprehension. In Model 1, FIQ (β = .34) and Language Composite (β = .41) explained significant unique variance in Reading Comprehension, Strange Stories (β = .25) explained marginally significant variance and Word Reading Index (β = -.07) did not. In Model 2, Language Composite (β = .47) was a significant predictor of Reading Comprehension, FIQ (β = .31) was marginally significant, but Silent Films (β = .19) and Word Reading Index (β = -.004) were not. In Model 3, Language Composite (β = .42)

was a significant unique predictor of Reading Comprehension, FIQ (β = .28) and the ToM composite score (β = .27) were marginally significant, but Word Reading Index (β = -.02) was not.

Discussion

These data support previously established research that advanced ToM explained unique variance in reading comprehension in a sample of students with ASD after accounting for variance explained by word recognition and oral language (Ricketts et al., 2013). While Ricketts et al. (2013) examined this in a large sample of adolescents, we found similar results in a sample comprised of a broader age range from middle childhood through adolescence. This pattern held for both the more verbal-based (Strange Stories) and less verbal (Silent Films) tasks as well as the ToM composite score in our full HFASD sample. The regression analyses revealed a different pattern of significant predictors in the HFASD and TD samples. We controlled for potential differences due to IQ both statistically, and by creating an FIQ-matched HFASD subsample. FIQ was a significant predictor in the HFASD group but not the TD group, suggesting that it is an important factor to consider in understanding reading comprehension in ASD samples. In both sets of analyses when all the variables were included, the oral language composite but not the Word Reading Index, predicted significant unique variance in reading comprehension in the HFASD group. As previous studies have indicated, there is an important association between word reading abilities and oral language skills for children with ASD (Lindgren et al., Norbury & Nation, 2011), thus when considered together, differences in word reading did not make a unique contribution to reading comprehension in the HFASD sample. In the full HFASD sample, all three ToM variables explained significant unique variance (3-6%) in reading comprehension, which was similar to significant variance explained in Ricketts et al. (2013) that ranged from 2-4% beyond that accounted for by word recognition and oral language. In the much smaller FIQ-matched HFASD sample, the pattern of effect sizes remained with ToM explaining 3-4% unique variance in reading comprehension beyond other predictors, but the reduced sample size and associated increased standard error led to loss of power to detect statistical significance. Therefore, the primary observations in this study provide a compelling replication of evidence of the contribution of differences in social cognition to differences in the development of reading comprehension in students with ASD, but the results from smaller IQ matched subsamples raise the possibility of an

interpretive caution and suggest the utility of additional larger matched sample research and replication. In the TD sample, the pattern was different. Word reading and oral language were both significant predictors of reading comprehension, a finding that converges with those in existing literature on the Simple View of Reading (e.g., Hoover & Gough, 1990; Tunmer & Chapman, 2012). The ToM measures did not predict significant variance in reading comprehension for the TD sample, giving rise to the notion that individual differences in ToM may have a less powerful effect on performance on the reading comprehension measure in the TD sample than in the HFASD sample. These data provide support for the hypothesis that there are factors specific to children and adolescents with HFASD that are not included in the Simple View of Reading, but that are important to consider when examining targets for intervention to improve reading comprehension in this population of students (e.g., McIntyre et al., 2017).

Participants in the full HFASD sample performed more poorly than controls on all three ToM variables and demonstrated significant group differences in the more robust ToM Composite even after controlling for FIQ. Notably, in the matched sample analyses, the diagnostic groups differed significantly on all three ToM variables with medium effect sizes. This finding is consistent with previous literature. Strange Stories has been used in prior studies of children and adults with HFASD and TD; when samples were matched on age and verbal ability, those with HFASD performed significantly more poorly than those in a TD control group (Happé, 1994; White et al., 2009). Also consistent with extant data (e.g., Cutting & Dunn, 1999; Happé, 1995), performance on the ToM measures was associated with oral language skills in both the HFASD and TD groups, with the HFASD sample displaying stronger correlations than the TD sample.

It is important to consider the possibility that there were overlapping language demands on the reading comprehension and ToM measures. An oral response was required on all the measures; however, in an effort to compare the language comprehension demands of the ToM measures, this study utilized both a text-based ToM measure (Strange Stories) as well as one designed with nonverbal film clips appropriate for use with children of varying language abilities (Silent Films). Both the Strange Stories and Silent Films tasks explained unique variance in reading comprehension, beyond that explained by oral language in the HFASD sample; this

suggests that the entire relation between ToM and reading comprehension is unlikely to be due to shared variance across measures.

ToM deficits limited reading comprehension in individuals with HFASD in this study. While this study was not designed to determine why this was the case, previous research suggests that this may be due to difficulties in mentalizing which in turn impair the ability to make inferences about characters' thoughts, feelings, and actions (Kim, 2015; Ricketts et al., 2013). White et al. (2009) found that difficulty comprehending passages requiring inferences about live agents (i.e., people and animals) as opposed to natural events was a specific problem in individuals with ASD. Difficulty understanding an author's intent (Hughes & Devine, 2015) or lack of meta knowledge about reading (Lecce et al., 2010) may also contribute to the relation between ToM and reading comprehension in ASD samples.

Beyond ToM, the findings in this study raise the possibility that a) the pattern of cognitive processes that are most tightly associated with reading comprehension are different for the two diagnostic groups, and b) that variance in comprehension development in the HFASD sample aligns with a set of syndrome specific cognitive and social-cognitive vulnerabilities. If future studies concur, ToM would be an important instructional target to include in reading comprehension curricula designed to meet the needs of children and adolescents with ASD.

Limitations and Future Directions

The ToM task Strange Stories was easier for the majority of the TD sample; despite this potential limitation in the TD sample, evidence from the HFASD sample suggests that theory of mind deficits persist throughout the school-age years and relate to reading comprehension difficulties for these children. In addition to targeting oral language and higher-order linguistic comprehension, comprehensive reading comprehension intervention research for students with ASD should explicitly and systematically investigate teaching social cognitive skills.

The relation between age and ToM was weaker in the HFASD group, suggesting that ToM was related to factors specific to the social communication characteristics of ASD. Correlations between age and the ToM variables suggest that ToM is continuing to develop in middle childhood and adolescence in individuals with ASD and TD, however, this evidence is cross-sectional and limits our understanding of ToM development in this study. ToM can present

differently and be measured differently across ages; thus we might expect different measures to be more sensitive to developmental changes in ToM in younger versus older children and adolescents. Future research should explore this hypothesis using additional measures of ToM across narrower age brackets to further investigate the dynamic construct of ToM in relation to reading comprehension across ages,

In the current study, due to the difficulty of recruiting a sample of typically developing children matched on FIQ to a large sample of higher functioning school-aged children with ASD, covariance analyses controlled for FIQ. We addressed this in part by examining relations between the study variables in a small FIQ-matched HFASD sample and demonstrated similar patterns of association to those in the analyses controlling for FIQ. However, decreasing the sample size from 70 to 37 participants with HFASD resulted in a loss of power and limited the interpretation of the matched samples regressions. Future studies should recruit TD controls matched closely to the ASD participants to address this confound. It is possible that with larger sample sizes in both groups, the unique contribution of social cognition to reading comprehension would be more evident.

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Conflict of Interest

All authors declare they have no conflict of interest.

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Table 1
Descriptive Statistics and Significant Group Differences in Full Sample

	HFASD	TD			
N	70	35	ANOVA	*p*	η^2_p
Measures	*M* (*SD*)	*M* (*SD*)	*F*		
Age	12.50 (2.13)	12.84 (2.30)	0.55	.46	.01
IQ					
VIQ	95.64 (15.19)	107.29 (12.31)	15.47	<.001	.13
PIQ	103.36 (14.82)	113.54 (11.74)	12.56	< .01	.11
FIQ	99.16 (13.65)	111.66 (10.34)	22.76	<.001	.18
ASD Diagnostic Measures					
ADOS-2					
Social Affect	8.43 (3.43)	-	-	-	-
RRB	2.53 (1.21)	-	-	-	-
ADOS-2 Total Score	10.87 (3.71)	-	-	-	-
SCQ Lifetime Total	21.13 (7.02)	2.37 (2.28)	236.04	<.001	.70
SRS	82.00(10.49)	45.00 (9.03)	314.84	<.001	.76

Note. HFASD = high-functioning autism spectrum disorders; TD = typically developing; *M* = mean; *SD* = standard deviation; VIQ = verbal IQ; PIQ = performance IQ; FIQ = full-scale IQ; ADOS-2 =Autism Diagnostic Observation Scale, Second Edition; RRB = Restricted and Repetitive Behaviors; SCQ = Social Communication Questionnaire, Lifetime Edition, total raw score; SRS = Social Responsiveness Scale, T-scores.

Table 2
Demographics across Subgroups

	HFASD	TD
N	70	35
	%	%
Gender		
Male	83	63
Female	17	37
Ethnicity		
African American	0	0
Asian	4	0
Caucasian	67	74
Caucasian Plus One Other Ethnicity	13	11
Hispanic/Latino/a	9	6
Native American	0	0
Native Hawaiian/Pacific Islander	0	3

Other	4	0
Decline to State	3	6
Mother's Highest Level of Education		
Some High School	1	0
Completed High School	3	0
Some College	24	26
Completed College	33	43
Some Graduate School	7	3
Completed Graduate School	30	23
Decline to State/Unavailable	2	5

Table 3
Descriptive Statistics and Diagnostic Group Differences on Standardized and Experimental Variables for Full HFASD (n = 70) and TD (n = 35) Samples.

Variable	HFASD *M (SD)*	TD *M (SD)*	ANOVA *F*	η^2_p	ANCOVA *F*	η^2_p
Read Comp	7.44 (2.86)	10.51 (2.29)	30.47***	.23	8.69**	.08
PDE	94.01 (15.67)	104.63 (13.57)	11.67**	.10	1.47	.01
SWE	89.50 (14.51)	102.83 (14.10)	20.05***	.16	4.97*	.05
Word Read Index	91.24 (14.39)	103.97 (13.67)	18.87***	.16	3.95*	.04
Vocab	105.38 (16.86)	120.38 (11.17)	21.72***	.19	4.59*	.05
Story Recall	91.98 (18.11)	110.00 (9.84)	28.94***	.23	12.17**	.12
Lang Composite	98.68 (13.87)	115.19 (8.44)	40.03***	.30	15.08***	.14
Strange Stories	5.70 (2.68)	7.83 (2.05)	17.12***	.14	2.98	.03
Silent Films	6.29 (2.91)	8.14 (1.83)	11.81**	.10	3.08	.03
ToM Composite	5.99 (2.50)	7.99 (1.54)	18.56***	.15	4.18*	.04

Note. ANCOVAs control for FIQ. Read Comp = GORT-5 Reading Comprehension; PDE = TOWRE-2 Phonemic Decoding Efficiency; SWE = TOWRE-2 Sight Word Efficiency; Word Read Index = Composite of TOWRE-2 Phonemic Decoding Efficiency (PDE) and Sight Word Efficiency (SWE); Vocab = WIAT-III Receptive Vocabulary; Story Recall = WRAML-2 Story Recall; Lang Composite = Composite of WIAT-III Receptive Vocabulary and WRAML-2 Story Recall; Strange Stories = Happé's Strange Stories task; Silent Films = Silent Films task; ToM Comp = Theory of Mind composite. *p<.05, **p<.01, ***p<.001

Table 4
Correlations of Observed Variables for Full HFASD and TD Samples. HFASD Below Diagonal

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Read Comp	-	.48**	.47**	.62***	.58***	.45**	.36*	.44**	.19	.33	.32
2. FIQ	.66***	-	.40*	.46**	.46**	.43*	.33	.48**	.35*	.37*	.45**
3. PDE	.42***	.49***	-	.74***	.93***	-.02	.02	-.06	-.15	.07	-.05
4. SWE	.46***	.50***	.67***	-	.94***	.09	.05	.06	.00	.12	.07
5. Word Read Index	.48***	.54***	.92***	.91***	-	.04	.03	-.01	-.08	.11	.01
6. Vocab	.62***	.58***	.20	.31*	.27*	-	.29	.83***	.30	.33	.40*
7. Story Recall	.53***	.41**	.32**	.43***	.42**	.26*	-	.77***	.09	.31	.24
8. Lang Composite	.74***		.38**	.49***	.48***		.83***	-	.24		

		.60***				.78***				.38*	.38*
9. Strange Stories	.69***	.59***	.26*	.36**	.34**	.60***	.34**	.59***	-	.26	.82***
10. Silent Films	.50**	.33**	.10	.18	.15	.42***	.26*	.43***	.61**	-	.77***
11.ToM Composite	.66***	.51***	.20	.30*	.27*	.57***	.33**	.56***	.89***	.91***	-

Note. Read Comp = GORT-5 Reading Comprehension; PDE = TOWRE-2 Phonemic Decoding Efficiency; SWE = TOWRE-2 Sight Word Efficiency; Word Read Index = Composite of TOWRE-2 Phonemic Decoding Efficiency (PDE) and Sight Word Efficiency (SWE); Word Read Index = Composite of TOWRE-2 Phonemic Decoding Efficiency (PDE) and Sight Word Efficiency (SWE);Vocab = WIAT-III Receptive Vocabulary; Story Recall = WRAML-2 Story Recall; Lang Composite = Composite of WIAT-III Receptive Vocabulary and WRAML-2 Story Recall; Strange Stories = Happé's Strange Stories task; Silent Films = Silent Films task; ToM Comp = Theory of Mind composite. *p<.05, **p<.01, ***p<.001

Table 5
Regression Analyses Predicting Reading Comprehension in Full HFASD Group

Model	Step	Variable	R^2 change	*F* change	*p*	*β*	*p*
1	1	FIQ	.44	51.72	<.001	.20	.06
	2	Word Read Index	.02	2.62	0.11	.08	.37
	3	Lang Composite	.16	27.63	<.001	.39	<.001
	4	Strange Stories	.06	11.31	0.01	.32	.01
		Total R^2	.68				
2	1	FIQ	.44	51.72	<.001	.28	.01
	2	Word Read Index	.02	2.62	.11	.09	.35
	3	Lang Composite	.16	27.63	<.001	.44	<.001
	4	Silent Films	.03	5.74	.02	.20	.02
		Total R^2	.65				
3	1	FIQ	.44	51.72	<.001	.23	.03
	2	Word Read Index	.02	2.62	.11	.09	.30
	3	Lang Composite	.16	27.63	<.001	.39	<.001
	4	ToM Composite	.06	11.02	.01	.30	.01
		Total R^2	.68				

Note. FIQ =WASI-2 Full Scale IQ; Word Read Index = Composite of TOWRE-2 Phonemic Decoding Efficiency (PDE) and Sight Word Efficiency (SWE); Lang Composite = Composite of WIAT-III Receptive Vocabulary and WRAML-2 Story Recall; Strange Stories = Happé's Strange Stories task; Silent Films = Silent Films task; ToM Comp = Theory of Mind composite.

Table 6
Regression Analyses Predicting Reading Comprehension in TD Group

Model	Step	Variable	R^2 change	*F* change	*p*	*β*	*p*
1	1	FIQ	.23	9.64	.01	-.11	.52
	2	Word Read Index	.17	8.78	.01	.63	<.001
	3	Lang Composite	.14	9.53	.01	.42	.01
	4	ToM Comp	.03	2.11	.16	.20	.16

Total R^2	.57

Note. FIQ =WASI-2 Full Scale IQ; Word Read Index = Composite of TOWRE-2 Phonemic Decoding Efficiency (PDE) and Sight Word Efficiency (SWE); Lang Composite = Composite of WIAT-III Receptive Vocabulary and WRAML-2 Story Recall; ToM Comp = Theory of Mind composite.

Table 7
Diagnostic Group Differences on Demographic, Standardized and Experimental Variables for Matched HFASD (n = 37) and TD (n = 35) Samples.

Measure	HFASD *M (SD)*	TD *M (SD)*	ANOVA *F*	*p*	η^2_p
VIQ	104.11 (12.10)	107.29 (12.31)	1.22	.27	.02
PIQ	112.05 (13.30)	113.54 (11.74)	0.25	.62	.01
FIQ	108.78 (9.74)	111.66 (10.34)	1.47	.23	.02
Age	12.68 (2.00)	12.84 (2.30)	0.10	.75	.01
Read Comp	8.51 (2.74)	10.51 (2.29)	11.25	<.01	.14
PDE	98.62 (15.94)	104.63 (13.57)	2.95	.09	.04
SWE	93.73 (15.64)	102.83 (14.10)	6.70	.01	.09
Word Read Index	95.84 (15.10)	103.97 (13.67)	5.72	.02	.08
Vocab	108.90 (14.63)	120.38 (11.17)	12.62	<.01	.17
Story Recall	95.74 (17.41)	110.00 (9.84)	17.29	<.001	.21
Lang Composite	104.31 (12.46)	115 (8.84)	19.80	<.001	.22
Strange Stories	6.65 (2.26)	7.83 (2.05)	5.35	.02	.07
Silent Films	6.84 (2.47)	8.14 (1.83)	6.43	.01	.08
ToM Composite	6.74 (2.08)	7.99 (1.54)	8.20	<.01	.11

Note. VIQ = WASI-2 verbal IQ; PIQ = WASI-2 performance IQ; FIQ = WASI-2 full-scale IQ; Read Comp = GORT-5 Reading Comprehension; PDE = TOWRE-2 Phonemic Decoding Efficiency; SWE = TOWRE-2 Sight Word Efficiency; Vocab = WIAT-III Receptive Vocabulary; Story Recall = WRAML-2 Story Recall; Lang Composite = Composite of WIAT-III Receptive Vocabulary and WRAML-2 Story Recall; Strange Stories = Happé's Strange Stories task; Silent Films = Silent Films task; ToM Comp = Theory of Mind composite.

Table 8
Correlations of Observed Variables for Matched HFASD and TD Samples. HFASD Below Diagonal

Variable	1	2	3	4	5	6	7	8	9	10	11
1.Read Comp	-	.48**	.47**	.62***	.58***	.45**	.36*	.44**	.19	.33	.32
2.FIQ	.64***	-	.40*	.46**	.46**	.43*	.33	.48**	.35*	.37*	.45**
3. PDE	.33*	.48**	-	.74***	.93***	-.02	.02	-.06	-.15	.07	-.05
4. SWE	.29	.51**	.69***	-	.94***	.09	.05	.06	.00	.12	.07
5.Word Read Index	.34*	.53**	.92***	.92***	-	.04	.03	-.01	-.08	.11	.01
6. Vocab	.65***	.57***	.10	.26	.19	-	.29	.83***	.30	.33	.40*
7. Story Recall	.37*	.21	.18	.33	.29	.14	-	.77***	.09	.31	.24
8. Lang Composite	.70***	.50**	.24	.42*	.36*	.72***	.80***	-	.24	.38*	.38*
9. Strange Stories	.63***	.51**	.22	.39*	.33*	.72***	.16	.56***	-	.26	.82***
10. Silent Films	.52**	.48**	.01	.09	.05	.49**	.13	.37*	.55**	-	.77***
11. ToM Composite	.65***	.56***	.12	.26	.20	.68***	.16	.52**	.87***	.89***	-

Note. Read Comp = GORT-5 Reading Comprehension; PDE = TOWRE-2 Phonemic Decoding Efficiency; SWE = TOWRE-2 Sight Word Efficiency; Word Read Index = Composite of TOWRE-2 Phonemic Decoding Efficiency (PDE) and Sight Word Efficiency (SWE); Vocab = WIAT-III Receptive Vocabulary; Story Recall = WRAML-2 Story Recall; Lang Composite = Composite of WIAT-III Receptive Vocabulary and WRAML-2 Story Recall; Strange Stories = Happé's Strange Stories task; Silent Films = Silent Films task; ToM Comp = Theory of Mind composite. *p<.05, **p<.01, ***p<.001

Table 9
Regression Analyses Predicting Reading Comprehension in Matched HFASD Group

Model	Step	Variable	R^2 change	*F* change	*p*	*β*	*p*
1	1	FIQ	.40	23.77	<.001	.34	.02
	2	Word Read Index	.00	0.00	.99	-.07	.58
	3	Lang Composite	.19	15.93	<.001	.41	<.01
	4	Strange Stories	.04	3.34	.08	.25	.08
		Total R^2	.64				
2	1	FIQ	.40	23.77	<.001	.31	.06
	2	Word Read Index	.00	0.00	.99	-.004	.62
	3	Lang Composite	.19	15.93	<.001	.47	<.01
	4	Silent Films	.03	2.13	.16	.19	.16
		Total R^2	.62				
3	1	FIQ	.40	23.77	<.001	.28	.07
	2	Word Read Index	.00	0.00	.99	-.02	.89
	3	Lang Composite	.19	15.93	<.001	.42	<.01
	4	ToM Composite	.04	3.91	.06	.27	.06
		Total R^2	.64				

Note. Word Read Index = Composite of TOWRE-2 Phonemic Decoding Efficiency (PDE) and Sight Word Efficiency (SWE); Lang Composite = Composite of WIAT-III Receptive Vocabulary and WRAML-2 Story Recall; Strange Stories = Happé's Strange Stories task; Silent Films = Silent Films task; ToM Comp = Theory of Mind composite.