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The relation between text reading fluency and reading comprehension for students with autism spectrum disorders

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ABSTRACT

Deficits in reading comprehension have been well documented in individuals with autism. Researchers have begun to identify predictors of reading comprehension; we sought to add to this knowledge base by investigating the role of text reading fluency in the prediction of reading comprehension in a sample of individuals with higher functioning autism (HFASD). A comprehensive reading battery was administered to students with HFASD ($N = 68$) and age- matched typically developing (TD) students ($N = 38$). Significant differences were detected between the HFASD and TD samples on every reading measure, favoring the TD sample. Structural Equation Models with the HFASD indicates that text reading fluency significantly predicts reading comprehension above and beyond the contribution of other reading variables which have been shown to be significant predictors in previous studies. This finding has important implications for the treatment of reading deficits in individuals with HFASD.

1. Introduction

The importance of understanding the course, nature, and treatment of autism spectrum disorders (ASD) during the early preschool years is often emphasized (Mundy & Crowson, 1997; Dawson, 2008). Yet, it is not clear that preschool research alone can lead to a complete understanding of the neurodevelopmental course, or treatment, of this heterogeneous disorder. In part, this is because many children affected by higher functioning ASD (HFASD) are identified after the preschool period (Daniels & Mandell, 2014). Furthermore, a noteworthy phase of neural plasticity and frontal cortical organization occurs between 8 and 16 years of age, which is associated with significant changes in social-cognition, communication, executive mental faculties, and behavior (Best, Miller, & Jones, 2009; Paus, 2005; van den Bos, van Dijk, Westenberg, Rombouts, & Crone, 2011). This marks a post-preschool period of vulnerability for children with neurodevelopmental disorders, including those with ASD (Crone, 2009; Luna, Doll, Hegedus, Minshew, & Sweeney, 2007); this period has potential to be critical for both behavioral and academic development. Extant data suggests that between 35% and 80% of samples of students with ASD display difficulties in one or more components of literacy development, which is lower than expected based on their IQs (Estes, Rivera, Bryan, Cali, & Dawson, 2011; Huemer & Mann, 2010; Jones et al., 2009; Mayes & Calhoun, 2008; Nation, Clarke, Wright, & Williams, 2006). Underachievement in one specific literacy domain, reading comprehension, is one of the most frequent and pernicious domains of academic learning impairment displayed by students with ASD (Huemer & Mann, 2010; Jones et al., 2009; Mayes & Calhoun, 2008; McIntyre et al., 2017; Randi,

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Newman, & Grigorenko, 2010; Ricketts, 2011; Whitby & Mancil, 2009); there is a convergence of evidence that 35% to 58% of students identified with ASD have difficulties with reading comprehension. This current study investigates reading comprehension and its subcomponent skills in a sample of individuals was HFASD in order to better understand its developmental patterns and areas of difficulties in this population.

Reading comprehension is a multifaceted process that requires successful integration of a wide range of capacities and abilities; these processes include a variety of cognitive abilities, including early decoding skills, motivation, and linguistic abilities. One pertinent hypothesis is that the cognitive impairments related to the social communication deficits that characterize ASD overlap with the cognitive demands of reading comprehension. In other words, reading comprehension is a receptive social communication skill that develops in the school age years of childhood and its impairment may be an important part of the cognitive and social communication phenotype for a substantial subgroup of individuals with ASD (Jones et al., 2009; McIntyre et al., 2017; Norbury & Nation, 2011; Randi et al., 2010; Ricketts, 2011). In addition to the social communication deficit hypotheses of reading comprehension for individuals with ASD, there may also be other underlying subcomponent skills important for reading development that impede successful reading comprehension for students with ASD.

2. Reading development in individuals with ASD

Recent attempts to synthesize research investigating impairments in reading comprehension among individuals with ASD have emerged in the literature (Randi et al., 2010; Ricketts, 2011; Whalon, Al Otaiba, & Delano, 2009). This new emphasis on research related to reading impairments in ASD reflects the recognition that the development of adequate reading comprehension, by the end of elementary school, is essential to subsequent academic achievement, cognitive development, and ultimately vocational success (Ricketts, 2011). Hence, research that provides a deeper understanding of the development of the necessary skills with the intent to prevent or reduce reading comprehension impairments is crucial to the comprehensive treatment of ASD.

Simple View of Reading. Recent empirical investigations of the development of reading comprehension in samples of students with ASD have relied upon the Simple View of Reading (Huemer & Mann, 2010; Randi et al., 2010; Ricketts, 2011). The Simple View postulates that reading comprehension is the product of word decoding and linguistic comprehension. Decoding is an individual's ability to accurately read single words; this requires the ability to map speech sounds onto single letters and letter combinations, and to use this knowledge to accurately read words. Linguistic comprehension refers to an individual's ability to understand spoken language. The Simple View has been used in two important ways in the reading literature when investigating reading development in samples of students with typical development. First, the Simple View has been used as a theoretical framework by which researchers have modeled empirical data to understand the development of reading comprehension. Empirical data highlights the importance of word decoding when children are younger; linguistic comprehension becomes the more salient predictor of reading comprehension in middle elementary years and later (e.g., Kendeou, Van den Broek, White, & Lynch, 2009; Storch & Whitehurst, 2002; Vellutino, Tunmer, Jaccard, & Chen, 2007). Second, researchers have used the Simple View to profile struggling readers (Catts, Hogan, & Fey, 2003; Gough & Tunmer, 1986), demonstrating that reading comprehension challenges may be the result of poor linguistic comprehension, poor word decoding, or difficulty with both of these skills.

In the ASD reading literature, The Simple View has also proven to be a useful framework; multiple studies have shown that both word decoding and linguistic comprehension impairments help explain reading comprehension difficulties in ASD samples (Nation et al., 2006; Norbury & Nation, 2011; Ricketts, Jones, Happé, & Charman, 2013). However, evidence suggests that while word decoding and reading comprehension were associated in samples with ASD, the correlation was lower than in typically developing samples, due to a higher incidence of a discrepant profile characterized by adequate word reading alongside poorer comprehension in many children and adolescents with ASD (e.g., Jones et al., 2009; Nation et al., 2006). Some studies have reported adequate single word decoding for individuals with ASD (Brown, Oram-Cardy, & Johnson, 2013; Huemer & Mann, 2010; Jones et al., 2009; Nation et al., 2006), others have demonstrated considerable heterogeneity in word decoding, associated with supporting language and phonological skills, in their samples (Åsberg & Sandberg, 2012; Henderson, Clarke, & Snowling, 2014; Nation et al., 2006; White et al., 2006). Linguistic comprehension skills have been shown to predict word reading and reading comprehension skills in children with ASD (Brown et al., 2013; Lindgren, Folstein, Tomblin, & Tager-Flusberg, 2009; Lucas & Norbury, 2014; Norbury & Nation, 2011).

One critique of the Simple View is that the framework does not take into account additional ability domains that have been shown to be important in the prediction of reading comprehension; one of these is measured in terms of oral reading fluency. Oral reading fluency involves the cognitive and motor functions that enable the oral translation of text with speed and accuracy (Adams, 1990; Fuchs, Fuchs, Hosp, & Jenkins, 2001; Wolf & Katzir-Cohen, 2001), resulting in automatic reading of connected text. Oral reading fluency goes beyond basic word decoding as decoding assessments simply measure accuracy of word reading, not the automaticity of reading words. Furthermore, oral reading fluency measures an individual's ability to read connected text, not single word reading. While theories differ slightly on the relation between word decoding, reading fluency, and comprehension, in general, theories suggest that the significant relation is due to the allocation of attentional stores (Fuchs et al., 2001; LaBerge & Samuels, 1974; Posner & Snyder, 1975). Reading comprehension demands considerable cognitive resources, therefore, it is likely the rate at which words are recognized is an important consideration in successful reading comprehension. Specifically, it is theorized that individuals who are skilled at oral reading fluency free up cognitive capacity for higher-level comprehension of text, perhaps, more specifically, in formulating inferences about text while reading (Thurlow & van den Broek, 1997). The verbal efficiency theory (Perfetti, 1985) suggests that the cognitive system has limited capacity to both decode words and extract meaning at the same time. This would suggest that it is important for word decoding to become automatic, or as it is often referred to, fluent, in order for an individual to fully attend to extracting meaning from written text. If word decoding is accurate, but not automatic or fluent, it is possible that the cognitive resources necessary to attend to meaning will be taxed, and consequently reading comprehension performance will be poor.

Oral reading fluency is considered critical for reading development given its relation with reading comprehension (Fuchs et al., 2001) and its ability to differentiate typically developing readers from at-risk readers (Bourassa, Levy, Dowin, & Casey, 1998); the relation between oral reading fluency and comprehension has been well established in the literature in both cross-sectional investigations and longitudinal studies (Chard, Vaughn, & Tyler, 2002; Fuchs, Fuchs, & Maxwell, 1988; Fuchs et al., 2001; Jenkins, Fuchs, Van Den Broek, Espin, & Deno, 2003). Further evidence of the importance of reading fluency in concurrent and later reading comprehension comes from studies that train reading fluency and detect gains in reading comprehension scores (Meyer & Felton, 1999; National Reading Panel, 2000). In a meta- *meta*-analysis of studies that included both typically developing students and those with reading disabilities, Therrien (2004) found that targeted fluency instruction improved reading fluency and reading comprehension performance in both subgroups. Additionally, this study found significant effect sizes for fluency instruction in both subgroups with familiar and unfamiliar or new text, demonstrating that targeted fluency instruction can generalize to new and unfamiliar text. There is some evidence in the existing literature base that suggests that the Simple View may not fully explain reading comprehension as children get older. For example, Silverman, Speece, Harring, and Ritchey, 2013 found adding fluency to the predictive model eliminated the direct effect between decoding and reading comprehension in 4th grade typically developing students. Tilstra, McMaster, Van den Broek, Kendeou, and Rapp, 2009, in a cross-sectional study with 4th, 7th and 9th grade students, found that fluency added unique variance after the effects of linguistic comprehension and decoding were considered.

To date, very little is known about how individuals with ASD perform on measures of oral reading fluency, as previous reading development studies that include ASD samples have not measured this construct. While studies have shown variability in single word decoding for individuals with ASD (e.g., Brown et al., 2013; Huemer & Mann, 2010; McIntyre et al., 2017; Nation et al., 2006), to date, studies have not tested the relation of reading fluency and reading comprehension. Given the empirical evidence that suggests oral reading fluency plays an important role in reading comprehension in typically developing populations, investigating its role, while also accounting for the influence of decoding and linguistic comprehension in a sample of ASD could help to further explain reading comprehension impairment. Beyond the empirical data that suggest reading fluency plays a critical role in reading comprehension for individuals not diagnosed with ASD, it is possible that deficits in cognitive domains such as processing speed, specific to this population, could impact reading fluency. Processing speed deficits in samples of children with ASD have been shown be related to greater social communication impairment (Oliveras-Rentas, Kenworthy, Martin, & Wallace, 2012), and to significantly predict poorer academic achievement (Mayes & Calhoun, 2007, 2008). The processing speed and automaticity within and across the individual components of the word recognition system, such as eye saccades, working memory, and the connection of orthographic to phonological and linguistic information, can be measured by rapid automatized naming (RAN) tasks (e.g., Denckla & Rudel, 1976; Norton & Wolf, 2012). RAN tasks have been shown to be strong predictors of reading fluency across many written language systems (Georgiou, Parrila, & Liao, 2008; Tan, Laird, Li, & Fox, 2005), and many children with developmental reading disabilities perform poorly on RAN tasks (e.g., Compton, Olson, DeFries, & Pennington, 2002; Wolf & Bowers, 1999). Furthermore, individuals affected by ASD have been shown to exhibit deficits in RAN ability (Losh, Esserman, & Piven, 2010).

In order to be able to adequately treat reading comprehension impairment in individuals with ASD, an investigation of the relation between reading fluency and reading comprehension, while also considering the concurrent impact of linguistic comprehension and word decoding, is necessary. It is possible that by overlooking the relations between reading fluency and reading comprehension, the field has inadequately described the nature of the reading impairments in the ASD population. The development of effective, targeted reading intervention depends upon understanding the variability of performance across all reading comprehension subcomponent skills.

3. Current study and research questions

The goal of this study is to investigate the relation between oral reading fluency and reading comprehension when other components of the Simple View, linguistic comprehension and word recognition, are taken into account. Additionally, we include RAN in our predictive model, to determine the relation between RAN and decoding and oral reading fluency as it is possible that processing speed could be a significant variable in the prediction of reading fluency and indirectly, reading comprehension. The dataset in this study employed a wide range of variables that cover all aspects of the Simple View and reading fluency, so that a deeper understanding of these relations and their prediction of reading comprehension could be obtained in a sample of students with ASD. To this end, this study aims to answer the following research questions: First, how do students identified with ASD perform on several reading comprehension subcomponent skills (fluency, decoding and linguistic comprehension) as compared to their typically developing peers? Based on previous literature, we hypothesize that the ASD sample will perform significantly worse than the TD sample on the fluency and linguistic subcomponent skills, while performing equally as well on measures of decoding. Second, what is the role of the subcomponent reading skills in the prediction of reading comprehension in sample of students identified with ASD? For the second research question, we hypothesize that reading fluency, decoding and linguistic comprehension will all significantly contribute to the prediction to reading comprehension and that processing speed, as measured by RAN, would be significantly related to both word decoding and oral reading fluency.

Table 1
Sample Demographic and Diagnostic Information Disaggregated by HFASD and TD.

	HFASD (N = 68)			TD (N = 38)			
Variable	*M*	*SD*	%	*M*	*SD*	%	*t*
Age	13.80	2.13		14.05	2.31		
Ethnicity							
Latino/a			10.3			0.0	
Asian			2.9			2.6	
Caucasian			67.6			76.3	
Decline to State			2.9			0.0	
Other			2.9			2.6	
Mixed			13.2			18.5	
Mother's Education Level							
Some High School			1.5			0.0	
Completed High School			2.9			0.0	
Some College			25			18.4	
Completed College			30.9			44.7	
Some Graduate School			7.4			2.6	
Completed Graduate School			30.9			28.9	
Decline to State			1.5			2.6	
IQ							
VIQ	95.15	15.44		110.39	14.36		5.00***
PIQ	102.09	17.08		116.55	15.76		4.30***
FIQ	98.22	15.18		114.87	13.70		5.60***
CELF Recalling Sentences	7.76	3.03		12.18	2.22		7.41***
ADOS-2							
Social Affect	8.66	3.38		N/A	N/A		
RRB	2.49	1.26		N/A	N/A		
ADOS-2 Total	11.06	3.66		N/A	N/A		
SCQ Lifetime Total	18.51	5.70		2.47	2.11		−19.15***
ASSQ	18.51	5.70		1.92	2.86		−19.93***
SRS	81.55	10.73		45.26	9.00		−17.57***

Note. VIQ = verbal IQ; PIQ = performance IQ; FIQ = full-scale IQ; ADOS–2 = Autism Diagnostic Observation Scale, Second Edition; RRB = Restricted and Repetetive Behaviors; SCQ = Social Communication Questionnaire, Lifetime Edition, total raw score; ASSQ = Autism Symptom Screening Questionnaire, total raw score; SRS = Social Responsiveness Scale, T-scores. ***$p < .001$

4. Method

4.1. Participants

This research was conducted in compliance with the university Institutional Review Board, and written parental consent and child assent was obtained prior to data collection. Participants were 68 children, aged 10 to 18 who had a diagnosis of ASD, and 38 age matched Typically Developing (TD) students (see Table 1). All enrolled students were recruited from the local community through a research subject tracking system, local school districts, and word of mouth; data collection occurred in a clinical setting. Subjects were included in the HFASD sample ($n = 68$) if they had a community diagnosis of ASD that was confirmed by trained researchers using the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012), and if they had a full-scale IQ (FIQ) estimate ≥ 70 as measured on the Wechsler Abbreviated Scales of Intelligence-II (WASI-2, Wechsler & Hsiao-pin, 2011); therefore, from this point forward, we call our sample higher functioning ASD (HFASD). All children in the sample had adequate expressive language skills to score within this range on the verbal IQ subtests. However, children in the HFASD sample scored significantly lower on the CELF Recalling Sentences task, a measure of structural language, compared to children in the TD sample. Children in the HFASD sample also exceeded parent report criterion scores on a combination of the Autism Symptom Screening Questionnaire (ASSQ; Ehlers, Gillberg, & Wing, 1999), the Social Communication Questionnaire (SCQ; Rutter, Le Couteur, & Lord, 2003), and the Social Responsiveness Scale (SRS; Constantino & Gruber, 2005). Children in the TD sample did not meet criteria for ASD on any parent report measure. Exclusionary criteria for all participants included an identified syndrome other than ASD (e.g., Fragile X), significant sensory or motor impairment (e.g., visual impairments), a neurological disorder (e.g., epilepsy, cerebral palsy), psychotic symptoms (e.g., hallucinations or delusions), or any major medical disorder that could be associated with extended absences from school.

Demographic data indicated that the ratio of boys ($n = 57$) to girls ($n = 11$) in the HFASD sample, approximately 4:1, is similar to national prevalence rates (Christiansen, 2016). Table 1 presents demographic and diagnostic data for both samples. In general, participants' mothers completed at least some college and participants mainly attended public schools. The majority of the HFASD sample had an IEP or 504 Plan and spent much or all of their school day in the general education classroom, many with a full-time aide.

4.2. Measures and procedures

Participants were recruited to participate in a longitudinal study of academic and social development in children with ASD. Members of a trained research group in a university-based child assessment laboratory collected the data reported here during two 2.5-h sessions within a two-week interval. For this study, we report only data that was collected at the third time point; therefore, we present cross-sectional data.

4.2.1. Diagnostic measures

The ADOS-2 (Lord et al., 2012) is a diagnostic, semi-structured observational measure used to assess for ASD that is shown to have strong predictive validity against best estimate clinical diagnoses (Charman & Gotham, 2013). Trained personnel administered the ADOS-2 to confirm ASD diagnosis through evaluation of two core domains: Social Affect and Restricted and Repetitive Behavior. The ADOS has been validated on two independent samples of 1,630 children (Gotham, Risi, Pickles, & Lord, 2007) and 1,282 children (Gotham et al., 2008) yielding sensitivity and specificity estimates of .91 and .84 for the ADOS modules used in this study.

The ASSQ (Ehlers et al., 1999) is a 27-item checklist screener with demonstrated test-retest reliability (Parents .96, Teachers .94). The ASSQ has demonstrated parent report specificity (.90) and sensitivity (.62) for the diagnosis of ASD (Ehlers et al., 1999; Kadesjö, Gillberg, & Hagberg, 1999). The SCQ Lifetime version (Rutter et al., 2003) was developed as a companion screening measure for the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994). It is a 40-item parent questionnaire rating developmental social communication, and stereotyped and repetitive behavior symptoms of ASD in children four years and older. SCQ scores have been reported to strongly correlated with corresponding ADI-R scores, $r = .55$ to $.71$, $p < .005$, $n = 200$ (Rutter et al., 2003). The SRS (Constantino & Gruber, 2007) is a 65-item parent-report index of social behaviors in children with ASD or TD. The total score has excellent short- and longer-term test-retest reliability (.83 to .88, respectively; Constantino et al., 2004).

4.2.2. Cognition

The Wechsler Abbreviated Scale of Intelligence (WASI-2; Wechsler & Hsiao-pin, 2011) provided an estimate of nonverbal and verbal cognitive ability. Two nonverbal subtests, Block Design and Matrix Reasoning, measured spatial perception, visual abstract processing & problem solving with motor and non-motor involvement and formed the performance composite (PIQ). Two verbal subtests, Vocabulary and Similarities, measured expressive vocabulary and abstract semantic reasoning and formed the verbal composite (VIQ). Combined, the four subtests yielded an age-normed standard score ($M = 100$, $SD = 15$) measurement of FIQ. Reported internal consistency for the FIQ index was .96 and test-retest reliability for children ages 6–16, $r = 0.94$, in their norming sample. In this study sample, internal consistency Cronbach's alpha coefficients were .89 for Vocabulary, .88 for Similarities, .87 for Block Design, and .92 for Matrix Reasoning.

4.2.3. Structural language

In order to better describe the sample and differences between the TD and HFASD sample in terms of structural language, we provide descriptive statistics for the CELF Recalling Sentences subtest. The Recalling Sentences subtest from the Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-4; Semel et al., 2003) provided an age-normed scaled score ($M = 10$, $SD = 3$) assessing sentence-level semantic and syntactic expressive language skills.

4.2.4. Rapid automatized naming

The Comprehensive Test of Phonological Processing, Second Version (CTOPP-2; Wagner et al., 2013) was used to measure the speed at which participants were able to connect orthographic and phonological representations. Two RAN tasks, Rapid Letter Naming and Rapid Digit Naming, yielded separate age-normed scaled scores ($M = 10$, $SD = 3$) and combined for an age-normed RAN index, or composite, score ($M = 100$, $SD = 15$). Alternate-form reliability coefficients from our study for Rapid Letter Naming (.89) and Rapid Digit Naming (.87) were consistent with publisher (Wagner et al., 2013) reported alternate-form reliability coefficients (.70–.93) for their norming sample.

4.2.5. Word decoding

The Test of Word Reading Efficiency, Second Edition (TOWRE-2, Torgesen et al., 2012) provided an age-normed standard score ($M = 100$, $SD = 15$) measuring accuracy and fluency of sight word recognition (Sight Word Efficiency: SWE) and phonemic decoding (Phonemic Decoding Efficiency: PDE). Participants were asked to read as many real words (SWE) or decodable nonwords (PDE) as they could in 45 seconds. Internal consistency Cronbach's alpha coefficients from our study for SWE (.97), and PDE (.87) were generally consistent with publisher reported alphas for both subtests (alphas $> .90$; Torgesen et al., 2012).

4.2.6. Linguistic comprehension

The Auditory Reasoning subtest of the Test of Auditory Processing Skills, Third Edition (TAPS-3; Martin, 2005) provided an age-normed scaled score ($M = 10$, $SD = 3$) designed to tap higher-order linguistic processing related to making inferences and understanding implied meanings or idioms. Participants heard short vignettes and then were asked to respond to one question for each vignette. The internal consistency Cronbach's alpha from our study for Auditory Reasoning (.87) was generally consistent with publisher reported alphas (alphas = .91–.96; Martin, 2005). The Story Recall subtest of the Wide Range Assessment of Memory and Learning, Second Edition (WRAML-2, Adams & Sheslow, 2003) yielded an age-normed scaled score ($M = 10$, $SD = 3$) measuring the ability to listen to, and utilize narrative structure to organize and retell gist and verbatim details of, two orally presented narratives.

The internal consistency Cronbach's alpha from our study for Story Recall (.95) was generally consistent with publisher reported alphas (alphas = .91–.92; Adams & Sheslow, 2003).

4.2.7. Reading fluency

The speed of text level reading was measured with two assessments, dependent upon the grade level of the individual assessed. First, the Dynamic Indicators of Basic Early Literacy Skills − Next (DIBELS; Good, Kaminski, & Cummings, 2011) and Florida Oral Reading Fluency, (FORF; Florida Department of Education, 2009). For this study, it was necessary to utilize two different oral reading fluency assessments as the DIBELS assessments only goes from grade 1 to grade 6 and the FORF is used in grade 7 and above. All subjects were administered passages that were consistent with their current grade level.

Second, the Gray Oral Reading Tests − Fifth Edition (GORT-5; Wiederholt & Bryant, 2012) provided a measure of text level reading speed with age-normed scaled Rate scores (M = 10, SD = 3) for individuals aged 6 to 23 years 11 months. The individually administered reading test is comprised of 16 progressively more difficult narrative and expository passages read aloud by the child. Publisher (Wiederholt & Bryant, 2012) reported Cronbach's alpha coefficients for GORT-5 Rate scores ranged between .86 and .95 in the normative sample and .95 in an ASD subgroup.

4.2.8. Reading comprehension

The GORT-5 (Wiederholt & Bryant, 2012) also yielded an age-normed scaled score for reading comprehension. After each passage has been read aloud by the examinee, the passage is removed from view and five open-ended comprehension questions are asked by the tester. Publisher (Wiederholt & Bryant, 2012) reported Cronbach's alpha reliability coefficients for Comprehension scores range between .90 and .96 in the normative sample, and .97 in an ASD subsample.

4.3. Data analysis plan

4.3.1. Comparing HFASD and typically developing subsamples

In order to determine the level of impairment in the HFASD sample, we first ran Analyses of Variance (ANOVAs) on all observed variables to investigate if significant differences existed between the two subsamples. Second, we conducted Analyses of Covariance (ANCOVAs), controlling for FIQ, with Bonferroni correction, to determine whether significant differences remained after controlling for FIQ. To account for multiple comparisons among eight variables, we used an adjusted p-value of .006 to indicate significant differences.

4.3.2. Models predicting reading comprehension

Due to the small sample size of the TD sample, the following analyses were conducted with the only the HFASD sample. First a confirmatory factor analysis (CFA) was conducted to ensure the latent factors were measured well by their respective indicators. Next, we fit a series of structural equation models (SEM) that systematically examined the contributions of decoding, linguistic comprehension, and oral reading fluency to reading comprehension. All models were conducted in M*plus* 7.4 (Muthén & Muthén, 1998 − 2015) using full information maximum likelihood estimation, which allows individuals to be included if they have data on at least one of the observed indicators.

Decoding, linguistic comprehension, and oral reading fluency were represented as latent factors. We used standardized scores for all variables to account for demographic differences among the participants. The decoding factor was measured by SWE and PDE from the TOWRE-2. The linguistic comprehension factor was measured by Auditory Reasoning from the TAPS-3 and Story Recall from the WRAML-2. The oral reading fluency factor was measured by text reading fluency measured by the DIBELS/FORF and the Rate sub score of the GORT-5. Rapid automatized naming (RAN) was an observed variable derived from the Rapid Letter and Rapid Digit subtests of the CTOPP. Finally, reading comprehension was an observed variable from the comprehension subtest of the GORT-5.

The first SEM predicted reading comprehension from the decoding and linguistic comprehension factors, which aligned with the traditional Simple View model. We controlled for RAN skills with respect to decoding as RAN has been empirically identified as a precursor of decoding skills (e.g., Manis, Seidenberg, & Doi, 1999; Wolf & Bowers, 1999). In the second SEM, we added oral reading fluency as a predictor of reading comprehension and, again, controlled for rapid automatized naming. We did not allow the predictors to covary in order to examine the unique contribution of each predictor to reading comprehension. Conceptual diagrams of the models can be seen in Figs. 1 and 2.

All models were assessed using commonly employed fit indexes and following the guidelines suggested by Hu and Bentler (1999). A non-significant chi-square value was considered indicative of good fit. Additionally, we considered the root mean square error of approximation (RMSEA) and standardized root mean square residual (SRMR) where values less than .05 were indicative of good fit. Finally, we utilized the comparative fit index (CFI) and Tucker-Lewis index (TLI) with values between .90 and .95 indicative of adequate fit and values of .95 or greater indicative of good fit. Finally, we compared the SEMs (i.e., with and without fluency) by examining differences in fit statistics.

5. Results

5.1. Descriptive statistics

Descriptive statistics of the normed scores (when available) for both the HFASD and TD samples are in Table 2; correlations

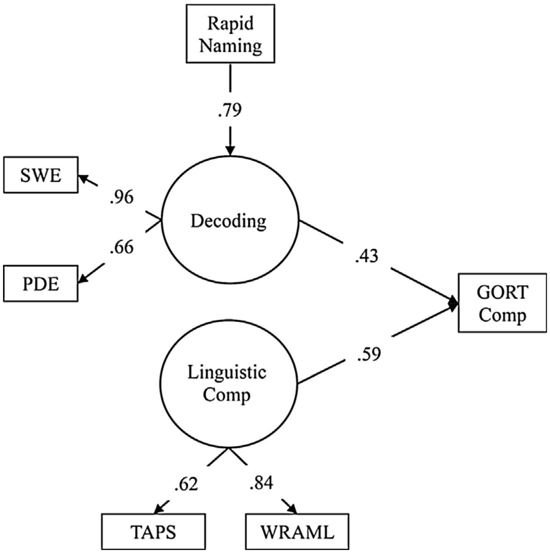

Fig. 1. SEM without oral reading fluency. SWE = TOWRE-2 Sight Word Efficiency; PDE = TOWRE-2 Phonemic Decoding Efficiency; TAPS = Test of Auditory Process Skills, third edition, Auditory Reasoning subtest; WRAML = Wide Range Assessment of Memory and Learning, Second Edition; GORT Comp = GORT-5 reading comprehension. All coefficients significant at $p < .001$.

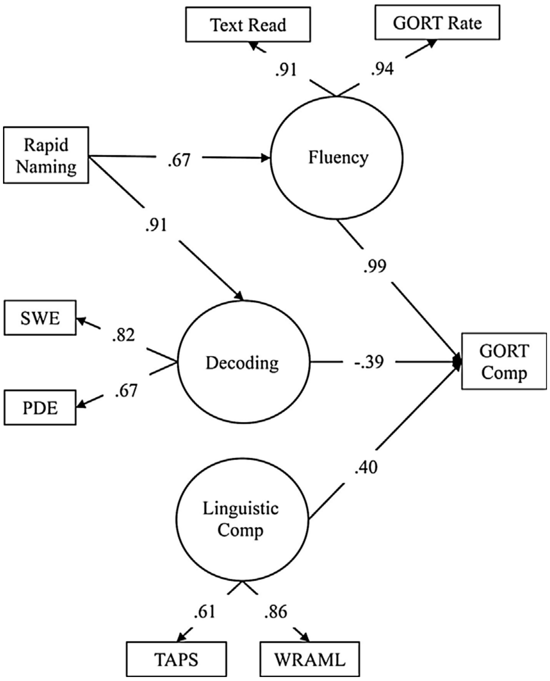

Fig. 2. SEM with oral reading fluency. SWE = TOWRE-2 Sight Word Efficiency; PDE = TOWRE-2 Phonemic Decoding Efficiency; TAPS = Test of Auditory Process Skills, third edition, Auditory Reasoning subtest; WRAML = Wide Range Assessment of Memory and Learning, Second Edition; Text Read = DIBELS and Florida Oral Reading Fluency; GORT Rate = GORT-5 Rate score; GORT Comp = GORT-5 Reading Comprehension score. All coefficients significant at $p < .001$.

between the variables for the HFASD sample are presented in Table 3. As seen in the ANOVA section of Table 2, there were significant differences between the subsamples on all variables when IQ was not controlled. This was true even when using the adjusted *p*-value of .006 (RAN was significant at $p = .005$). However, when controlling for FIQ, the HFASD sample performed significantly lower on TAPS and WRAML, using the adjusted *p*-value of .006. Reading fluency, GORT rate, and GORT comprehension were significant at $p < .05$, but not $p < .006$. Most means for the HFASD sample of the observed variables were within one standard deviation of national norms with two exceptions. The mean of TAPS-3 was nearly two standard deviations below national norms and the mean of GORT comprehension was considered below average. As expected, the variables used to measure linguistic comprehension (TAPS-3 and WRAML-2) were either not significantly correlated or weakly correlated with the decoding and oral reading fluency measures

Table 2
ANOVAs and ANCOVAs of all Observed Variables Comparing HFASD and TD Groups.

	HFA		TD			
Variable	*M*	*SD*	*M*	*SD*	ANOVA *F*	ANCOVA *F*
RAN	90.12	18.85	100.55	15.86	8.34**	0.81
PDE	95.56	12.20	106.34	15.54	15.60***	1.34
SWE	92.87	13.49	106.32	14.90	22.48***	2.96
TAPS	5.25	2.75	8.37	2.88	30.01***	10.77***
WRAML	8.92	3.25	12.55	2.24	37.14***	13.50***
Text Read	125.20	32.35	159.88	28.26	29.17***	5.96*
G Rate	9.44	2.85	12.50	3.08	26.47***	3.96*
G Comp	7.51	3.07	10.87	2.54	32.73***	5.98*

Note. RAN = Rapid Automatized Naming; SWE = TOWRE-2 Sight Word Efficiency; PDE = TOWRE-2 Phonemic Decoding Efficiency; TAPS = Test of Auditory Process Skills, third edition, Auditory Reasoning subtest; WRAML = Wide Range Assessment of Memory and Learning, Second Edition; Text Read = DIBELS and Florida Oral Reading Fluency; G Rate = GORT-5 Rate score; GORT Comp = GORT-5 Reading Comprehension score. $*p < .05$, $**p < .01$, $***p < .001$

Table 3
Correlations of Observed Variables for the HFA Group.

Variable	1	2	3	4	5	6	7	8
1. RAN	–							
2. PDE	0.60	–						
3. SWE	0.76	0.62	–					
4. TAPS	0.13†	0.23†	0.36	–				
5. WRAML	0.23†	0.17†	0.37	0.51	–			
6. Text Read	0.63	0.60	0.73	0.34	0.42	–		
7. G Rate	0.57	0.52	0.75	0.36	0.42	0.85	–	
8. G Comp	0.31	0.37	0.47	0.47	0.60	0.72	0.79	–

Note. RAN = Rapid Automatized Naming; SWE = TOWRE-2 Sight Word Efficiency; PDE = TOWRE-2 Phonemic Decoding Efficiency; TAPS = Test of Auditory Process Skills, third edition, Auditory Reasoning subtest; WRAML = Wide Range Assessment of Memory and Learning, Second Edition; Text Read = DIBELS and Florida Oral Reading Fluency; G Rate = GORT-5 Rate score; GORT Comp = GORT-5 Reading Comprehension score. All correlations significant at $p < .01$ except †*ns*.

(see Table 3 for correlations). This is evidence that linguistic comprehension skills are distinct from those associated with word and text reading, which is consistent with the Simple View of Reading. The variables used to measure decoding and oral reading fluency were moderately to strongly correlated ($r = .52$–$.75$).

5.2. Confirmatory factor analysis

The fit statistics for the CFA can be seen in Table 3 and demonstrated the model fit the data well. Specifically, the chi-square value was non-significant, RMSEA and SRMR were less than .05, and CFI and TLI were both 1.00. Additionally, the indicators loaded strongly on their respective factors with factor loadings ranging between .61–.96 (see Figs. 1 and 2). Oral reading fluency was particularly well-measured by its indicators as both loadings were greater than .90 (Table 4).

5.3. Structural equation models

The first SEM predicted the observed reading comprehension variable from the latent factors of decoding and linguistic comprehension. The fit statistics in Table 3 suggest this model did not fit the data well, according to the traditional cutoff standards (Hu & Bentler, 1999). However, Hancock and Mueller (2011) showed that a strong measurement model (i.e., high factor loadings) leads to over rejection of structural models when using the traditional cutoff standards. That is, strong factor loadings may exaggerate minor misspecifications among the structural parameters and this is reflected in the fit indexes. While Hancock and Mueller (2011)

Table 4
Fit Statistics of the CFA and SEMs.

Model	χ^2	df	RMSEA	CFI	TLI	SRMR
CFA	5.83†	6	0.00	1.00	1.00	0.02
SEM no fluency	26.44***	8	0.18	0.89	0.80	0.15
SEM with fluency	70.04***	17	0.21	0.85	0.76	0.21

Note. χ^2 = chi-square; RMSEA = Roor Mean Square Error of Approximation; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; SRMR = Standardized Root Mean Square Residual. $***p < .001$, †*ns*.

did not provide specific guidelines for this situation, the implication of their study is that more liberal fit index cutoff guidelines should be utilized when assessing SEMs with strong measurement parameters. Given the magnitude of the factor loadings and the well-documented theoretical underpinnings of the Simple View (e.g., Hoover & Gough, 1990; Kendeou et al., 2009), we proceeded to continue with our modeling process.

The standardized structural coefficients for the first SEM can be seen in Fig. 1. Rapid automatized naming significantly predicted decoding ($\beta = .79$, $p < .001$). Both decoding and linguistic comprehension were significant predictors of reading comprehension. Linguistic comprehension was a stronger predictor ($\beta = .59$, $p < .001$) than decoding ($\beta = .43$, $p < .001$). This model accounted for 53.7% of the variance in reading comprehension.

The second SEM included oral reading fluency as a predictor of reading comprehension and allowed this factor to covary with decoding. We also controlled for rapid automatized naming when estimating oral reading fluency. Fit statistics for this model were worse than the first SEM, but this was not surprising given strong measurement of the oral reading fluency factor. That is, any misspecifications in the structural aspects of the model involving oral reading fluency were exaggerated by the high factor loadings for *Text Read* and *GORT Rate* and this was reflected in the fit statistics.

The standardized coefficients can be seen in Fig. 2. Oral reading fluency was the strongest predictor of reading comprehension ($\beta = .99$, $p < .001$). Unexpectedly, adding oral reading fluency caused decoding to become negatively related to reading comprehension ($\beta = -0.39$, $p < .001$). Linguistic comprehension became a weaker predictor of reading comprehension ($\beta = 0.40$, $p < .001$) compared to the first SEM. This model accounted for 83.3% of the variance in reading comprehension.

6. Discussion

The overarching goal of this study was to investigate the role of oral reading fluency in the prediction of reading comprehension when the traditional Simple View constructs, linguistic comprehension and decoding, were controlled. To our knowledge, previous studies of reading comprehension development in samples of students with ASD have not included oral reading fluency as an independent predictor of reading comprehension, but instead have concentrated on the influence of single word decoding and linguistic comprehension. Given the significant relation between oral reading fluency and comprehension in samples of students not affected by ASD, we sought to determine if similar findings could be detected within this sample. We predicted that oral reading fluency would play a significant role in reading comprehension performance, and that processing speed, as measured by RAN, would be significantly related to both word decoding and oral reading fluency.

Descriptive results concur with previous literature that suggests that individuals with ASD, when IQ is controlled, perform similar to their typically developing peers in single word decoding, while performing worse in skills that require higher level processing such as linguistic comprehension and reading comprehension (e.g., Huemer & Mann, 2010; Nation et al., 2006). While single word decoding was not significantly different between groups in this study, our descriptive results also show that when IQ is controlled, the HFASD sample performed significantly worse on reading connected text, or oral reading fluency; previously studies have not reported on this subcomponent skill of reading comprehension. These data indicate that automaticity impairments on complex tasks such as text-level oral reading fluency measures are an important factor, to consider when evaluating reading comprehension difficulties for this population. There are a few potential explanations for the deficits noted in reading fluency in the children. First, it demonstrated in Table 1 that on a measure that has been shown to be a marker for structural language impairment for individuals was ASD (CELF Recalling Sentences; Condouris et al., 2003; Rapin et al., 2009; Riches et al., 2010), that the HFASD group performed significantly worse when compared to the TD sample. It is possible that deficits related to structural language could impede fluent text reading.

The SEM results indicate that reading fluency does play a significant role in the prediction of reading comprehension for children affected by HFASD when both decoding and linguistic comprehension were controlled. We also found, as hypothesized, that RAN is significantly predictive of both decoding and oral reading fluency in this sample. A broad range of ability was exhibited by the HFASD sample on the RAN subtests, with some participants demonstrating significant impairments on this measure of processing speed that requires efficiency and automaticity within and across the individual components of the word recognition system. In the second SEM model, when fluency was added, the relation between decoding and reading comprehension became negative. The negative decoding coefficient suggests that, when controlling for oral reading fluency and linguistic comprehension, the remaining variance in reading comprehension is negatively related to decoding. This suggests a strong relation between oral reading fluency and decoding, such that they share overlapping variance. This is supported by the correlations among these constructs' indicators in Table 2. The strong relation likely results from the word decoding subtests being timed assessments, which necessitates a certain level of fluency. Once oral reading fluency was included in the model, there was little unique variance left to be explained by decoding, which suggests the negative relation between decoding and reading comprehension was likely a statistical artifact. The fact that the subsamples performed similarly on decoding measures, but differently on text reading measures indicates the HFASD subsample experienced a specific difficulty translating word level skills to the text reading level. These findings suggest that word level decoding and text-level oral reading fluency are distinct skills in children with HFASD, and that text-level oral reading fluency deficits may act as a bottleneck, limiting cognitive capacity for higher-level comprehension of text in some children with HFASD, as the verbal efficiency theory would predict (Perfetti, 1985).

Finally, linguistic comprehension was a considerably weaker predictor of reading comprehension when oral reading fluency was added to the model; whereas it was the strongest predictor when decoding was the only other predictor in the model. This also supports the notion that simply measuring word level decoding in this population is not sufficient. The addition of oral reading fluency considerably increased the amount of variance explained in reading comprehension, further highlighting its importance. As theorized in the verbal efficiency theory, text level fluency deficits constrain cognitive resources that would otherwise be available for higher-level linguistic comprehension abilities such as making inferences and retelling narratives. Furthermore, linguistic comprehension deficits were observed in this sample of HFASD readers, as exhibited by the low means on those measures (see Table 2). This is consistent with findings of prior studies reporting difficulties with linguistic comprehension skills such as verbal reasoning and inference generation (Norbury & Bishop, 2002; Norbury & Nation, 2011), answering inferential questions (Tirado & Saldena, 2016), and narrative retelling (Diehl et al., 2006), observed in samples of children affected by ASD that have been shown to relate to reading comprehension impairments (Norbury & Nation, 2011).

6.1. Limitations and future directions

The findings of the current study should be considered within the context of the study's limitations. First, our study recruited individuals with ASD in our local community, resulting in a sample that was not extremely diverse ethnically nor in terms of economic diversity. A second limitation is the related to the nature of our ASD sample; the study design called for the recruitment of individuals with HFASD, therefore, it would be important to investigate the relations noted in this study in other samples of individuals with ASD. Additionally, this study also had a smaller TD control sample, not match by IQ; the sample size did not allow for adequate power to run a concurrent SEM analysis. Therefore, we could not make direct comparisons through SEM modeling between the HFASD and TD samples to show the development of reading comprehension in both groups. Our group comparison analyses only allowed for the ANOVA and ANCOVA analyses. Finally, it is possible that other impairments that are common in individuals with ASD could affect reading fluency performance. For example, it is possible that the co-occurrence of ADHD symptomatology, including attentional difficulties could have influenced reading fluency. It will be important for future research to investigate these relations. Another important future direction will be the implementation of intervention studies that include reading fluency as an instructional target for students with HFASD.

7. Conclusion

In recent years, several studies have investigated reading development in individuals with ASD. As a result of these studies, a picture of the specific reading deficits in this population is beginning to emerge. One consistent finding across all the studies are specific impairments in reading comprehension; in most of the studies at least 50% of the sample showed evidence of reading comprehension difficulty. What is less clear is the nature of reading deficits at the word reading and text reading levels. Previous literature has indicated that individuals with ASD are adequate word readers, which may have lead the field to interpret these findings to conclude that this population is able to adequately decode connected text. However, in previous studies, connected text reading has not been adequately measured. The current study presents a variation on these previous findings. Similar to previous studies, this sample of individuals with HFASD did perform similar to their TD peers on word reading (e.g., Brown et al., 2013), however, significant differences were seen between the groups on tasks that required connected text reading, favoring the TD group. When oral reading fluency, or reading connected text, was added to the predictive model for reading comprehension, it became the most important predictor, and, negated the effect of single word decoding, and accounted for more variance in the overall prediction of reading comprehension. This finding has important implications for the development and implementation of reading intervention for students with HFASD; connected text reading fluency should be considered a specific instructional target in a comprehensive reading intervention program.

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