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ORIGINAL PAPER

The Scope and Nature of Reading Comprehension Impairments in School-Aged Children with Higher-Functioning Autism Spectrum Disorder

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Abstract This study of 8-16-year-olds was designed to test the hypothesis that reading comprehension impairments are part of the social communication phenotype for many higher-functioning students with autism spectrum disorder (HFASD). Students with HFASD ($n=81$) were compared to those with high attention-deficit/hyperactivity disorder symptomatology (ADHD; $n=39$), or typical development (TD; $n=44$), on a comprehensive battery of oral language, word recognition, and reading comprehension measures. Results indicated that students with HFASD performed significantly lower on the majority of the reading and language tasks as compared to TD and ADHD groups. Structural equation models suggested that greater ASD symptomatology was related to poorer reading comprehension outcomes; further analyses suggested that this relation was mediated by oral language skills.

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Introduction

Much of the current understanding of the social communication development of children with autism spectrum disorder (ASD) comes from research conducted during the early childhood years (e.g., Mundy 2016). Social cognition, interaction, and communication have been shown to be associated with learning during this time period in all children (Mundy and Jarrold 2010; Tomasello 2010). However, human social communication follows a vibrant and dynamic path of development after early childhood, well into the school-age years and beyond (e.g., Hayiou-Thomas et al. 2012; Homer and Tamis-LeMonda 2005). Yet we currently know relatively little about the social communication phenotype, or characteristic behaviors, of school-aged children with ASD and how the associated impairments in social cognition, social interaction, and communication may impact their learning and achievement in educational settings (Machalicek et al. 2008; McDonald and Machalicek 2013; Parsons et al. 2011). This dearth of information hinders the design of educational interventions that target the specific needs of school-aged children with ASD (Estes et al. 2011). This gap in knowledge is unfortunate, since the elementary and secondary school years constitute the longest and most consistent and widely available venue for intervention for many children with ASD.

Recent estimates indicate that by second grade a majority of children with ASD in schools (68%) are not affected by intellectual disabilities (Christensen et al. 2016). These are often referred to as higher-functioning children with

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ASD (HFASD), and their level of verbal and intellectual development recommends that they receive much of their education in general education settings (Wagner et al. 2006; White et al. 2007). Efforts to develop school-based interventions for this large subgroup tend to focus on improving behavioral and social skills outcomes (McDonald and Machalicek 2013; Parsons et al. 2011). While essential, it is not clear that a behavioral focus meets all the needs of these students or of schools, teachers, and parents (Hess et al. 2008; McDonald and Machalicek 2013), and research concentrating on improving academic achievement for students with HFASD is needed (Fleury et al. 2014). In particular, teachers and parents recognize that the academic achievement of school-aged children with HFASD is often not commensurate with their intellectual status (Ashburner et al. 2010; Estes et al. 2011; Jones et al. 2009; Whitby and Mancil 2009), indicating a need to identify and analyze factors underlying this inconsistency. This study was designed to address this need.

Theoretical Framework

Prior research has demonstrated the utility of Gough and Tunmer's (1986) simple view of reading (Chen and Vellutino 1997; Cutting and Scarborough 2006; Hoover and Gough 1990; Joshi and Aaron 2000; Tunmer and Chapman 2012), and this model has guided many of the extant investigations of reading comprehension in children and adolescents with ASD (e.g., Ricketts 2011). According to this model, word recognition skills and oral language comprehension both make independent, and necessary, contributions to proficient reading comprehension. Word recognition skills, decoding in particular, are underpinned by phonological awareness, phonological memory, and rapid automatized naming skills. Seidenberg and McClelland (1989) proposed the "triangle model" of word reading that detailed three ways in which information is encoded: orthography (spelling), phonology (pronunciation and sound), and semantics (meaning). According to this model, words can be read by orthography-to-phonology or orthography-to-semantics mapping. Poor readers who struggle with accurate word recognition, often referred to as dyslexic readers, typically demonstrate deficits in phonological processing and rapid sound-symbol connections (e.g., Swanson et al. 2003). Oral language comprehension is reliant upon structural language abilities and higher order linguistic comprehension skills. Structural language refers to the processes required to accurately comprehend and express phonology (pattern of speech sounds), morphology (smallest grammatical units of meaning within words), syntax (structure of sentences), and semantics (vocabulary) (Norbury and Nation 2011; Whitehouse et al. 2009; Williams et al. 2008). These skills have been shown to predict reading comprehension in typically developing (TD) children (Nation and Snowling 2004; Preston et al. 2010; Solari and Gerber 2008). Higher order language and cognitive abilities include those associated with integrating background knowledge during reading to generate inferences, verbal reasoning, and focusing on the global meaning of texts (Hannon and Daneman 2001; Long and Lea 2005; McNamara 2001). If skills in one of these broad domains are weak, reading comprehension will be compromised.

Reading Comprehension Impairments in School-Aged Children Affected by Autism

Extant data suggest that difficulty in the development of age-appropriate reading comprehension is one problem that affects students with HFASD, impacting between 33 and 65% of the samples of HFASD in several recent studies (Jones et al. 2009; Lucas and Norbury 2014; McIntyre et al. 2017; Nation et al. 2006; Ricketts et al. 2013). This learning difficulty complicates the academic and cognitive development of school-aged children with HFASD (Randi et al. 2010; Whitby and Mancil 2009) and may be specific to the social communication phenotype of these children (Estes et al. 2011; Norbury and Nation 2011; Ricketts et al. 2013).

The wide range of estimates of the prevalence of comorbid reading comprehension difficulty among children with HFASD noted above may be a method artifact of small sample sizes in existing studies, age and developmental differences across study samples, and the infrequent use of comprehensive reading batteries. Comprehensive reading batteries employ assessments to measure both broad domains of the simple view of reading: basic word recognition assessments as well as measures of structural language and higher-level linguistic skills such as verbal reasoning and comprehension. Comprehensive measurement is particularly important in studies with students with HFASD because word level reading may be commensurate with age and IQ through second and third grade for many children affected by HFASD (Whitby and Mancil 2009). Beyond that, however, difficulties with advances in critical thinking, verbal reasoning, complex processing, and attention may begin to impede progress in reading comprehension development (Norbury and Nation 2011; Randi et al. 2010; Whitby and Mancil 2009). Thus, studies with comprehensive measures and adequately large samples that span a broad age range are required to develop a sufficiently precise picture of HFASD reading development to inform interventions for these students.

Reading for meaning is a singularly important skill for school-aged development because it underpins academic learning across disciplines and content areas, especially in secondary school (Bulgren et al. 2013). Moreover, learning to read has been shown to be integral to continued development in sharing experiences and social cognition (Doise et al. 2013), as well as to the promotion of intellectual development in 7- to 16-year-old children (Ritchie et al. 2015). This literature raises the novel hypothesis that systematic reading comprehension instruction may be one viable approach to the development of school-based interventions that continue to advance the social communication, academic, and cognitive development of 5- to 18-year-old children affected by HFASD (Mundy et al. 2012; Randi et al. 2010).

Components of Reading Comprehension and ASD-Specific Characteristics

Processes associated with word recognition and oral language have been observed to account for unique variance in reading comprehension development among children with HFASD (Jones et al. 2009; Lindgren et al. 2009; Nation et al. 2006; Norbury and Nation 2011). No single profile of word recognition ability is displayed by children with ASD. While many children with ASD demonstrate adequate word recognition abilities (Brown et al. 2013; Huemer and Mann 2010), other studies have noted significant variability within ASD samples on word recognition and decoding measures (McIntyre et al. 2017; Nation et al. 2006; Norbury and Nation 2011); subgroups of poor readers with ASD who demonstrate significant concomitant phonological, rapid naming, and/or decoding deficits have been identified (Asberg and Sandberg 2012; Gabig 2010; White et al. 2006).

Oral language often develops atypically in children with ASD; many individuals have been shown to have impairments in some, or all, components of structural language (Eigsti et al. 2011; Tager-Flusberg 2006). Extant data have demonstrated a strong relation between structural language and reading comprehension in children with ASD (Brown et al. 2013; Lindgren et al. 2009; Nation et al. 2006; Norbury and Nation 2011; Ricketts et al. 2013), and those affected by language impairments have performed significantly worse on measures of reading comprehension, word recognition, and word decoding (Lindgren et al. 2009; Lucas and Norbury 2014; Norbury and Nation 2011).

Research has also suggested that higher order language and cognitive abilities overlap with the specific social communication and cognitive characteristics of ASD (Randi et al. 2010), and that many individuals with ASD may find verbal reasoning, inference generation, and answering questions about inferences challenging (Lucas and Norbury 2015; Norbury and Nation 2011; Saldaña and Frith 2007; Tirado and Saldaña 2016). The cognitive characteristics of many children with ASD include the tendency to focus on details rather than global meaning (Booth and Happé 2010). This can lead to particular problems generating global coherence or processing at the gist level across a text (Pellicano 2010; Williams et al. 2006), which in turn leads to difficulty recalling, retelling, and comprehending stories (Diehl et al. 2006). Hence, higher order inferential, referential, semantic, and especially social-semantic language problems have been hypothesized to play a critical role in reading comprehension impairments among individuals with HFASD (Norbury and Nation 2011; Ricketts et al. 2013; Saldaña and Frith 2007; Williams et al. 2015). Furthermore, Norbury and Nation (2011) observed that language impairment in adolescents with ASD was associated with poorer performance on a passage-level inference measure than for those with ASD who did not have language impairments. They suggested that difficulties integrating information from different sources for global coherence and inference might be highly dependent on variance in the structural language skills of students with ASD.

Reading Comprehension and the Social Communication Phenotype of ASD

Several studies have reported significant associations between individual differences in reading development and differences in autistic symptom severity in samples of school-aged children with ASD (Estes et al. 2011; Jones et al. 2009; McIntyre et al. 2017; Norbury and Nation 2011; Ricketts et al. 2013). This evidence is consistent with the hypothesis that risk for reading comprehension impairment is a specific characteristic of the social-communication phenotype of many HFASD children (Randi et al. 2010; Ricketts et al. 2013). Moreover, Ricketts has suggested that difficulties with oral language skills may mediate the association of ASD symptomatology with reading comprehension disturbance. Therefore, the relation to ASD symptoms could reflect the previously established association between reading and oral language observed in all children (Nation and Snowling 2004; Preston et al. 2010; Roth et al. 2002; Solari and Gerber 2008). Alternatively, data provided by Ricketts et al. (2013) and Williams et al. (2015) have raised the hypothesis that, among individuals with ASD with adequate sentence level expressive and receptive language skills, reading comprehension may be closely related to syndrome specific higher order inferential, semantic, and conceptual language development problems, above and beyond general phonological, morphological, and syntactic aspects of language development.

The Heterogeneity and Specificity of Reading Problems in ASD

While the current literature suggests that reading development may be impaired in many children with ASD, the issue of the specificity of these reading problems to ASD has rarely been examined. To address this issue it is desirable to include comparison groups with reading problems, as well as those with typical development, in studies of reading in children with ASD. However, this has rarely been done in past research. In research on reading in ASD, one important comparison group is children with attention-deficit/hyperactivity disorder (ADHD). Previous research suggests 50–70% of students with ASD exhibit clinical levels of comorbid ADHD symptoms (Corbett and Constantine 2006; Sinzig et al. 2008; van der Meer et al. 2012). The presence of higher ADHD symptoms has a negative impact on academic, behavioral and student–teacher relations in students with ASD (Ashburner et al. 2010; Fleury et al. 2014).

It is also the case that students with ADHD frequently exhibit chronic reading difficulties in the area of accurate and fluent word recognition skills (Boada et al. 2012; Cain and Bignell 2014; Miller et al. 2013; Miranda et al. 2013), and sometimes with listening and reading comprehension skills (Bignell and Cain 2007; Brock and Knapp 1996; McInnes et al. 2003) that may be related to reduced attentional resources (Cain and Bignell 2014; Miller et al. 2013). More generally, impairments in attention, vigilance, and inhibition are also negatively associated with reading development and academic achievement (Ashburner et al. 2010; Mayes and Calhoun 2008). These observations of ADHD comorbidity in children with ASD, and reading impairments in children with ADHD, raise the issue of specificity, or whether the pattern of reading comprehension disability in ASD children is comparable to that of children with ADHD and, therefore, whether this pattern stems from similar types of impairments in children with these distinct clinical conditions.

Current Study

The current study was designed to advance the understanding of reading comprehension and related processes in school-aged children with HFASD. To this end, the study employed a comprehensive battery of measures that assessed ASD and ADHD symptomatology, reading comprehension, word and text level reading skills, phonological processing, and structural and higher order language abilities. This extensive battery facilitated examination of the scope of the reading comprehension disturbance in a large sample of school-aged children with HFASD as compared to those with ADHD or TD, and to probe the specificity of a reading comprehension disturbance particular to students with HFASD. Furthermore, to better inform possible intervention research for children with HFASD, this study probed the heterogeneity in reading comprehension by examining direct and indirect effects of autism-specific social communication and cognitive characteristics on oral language, word recognition skills, and reading comprehension within the HFASD sample.

This research study examined the scope and nature of reading comprehension abilities by asking the following questions:

1. Did school-aged children with HFASD display comparable proficiency and patterns of reading comprehension development to those with TD and those with ADHD?
2. Did school-aged children with HFASD display comparable proficiency and patterns of abilities on measures of word recognition and oral language to those with TD and those with ADHD?
3. Which variables predicted individual differences in reading comprehension in the HFASD sample?
4. Did differences in ASD symptomatology display a significant and unique path of association with differences in reading comprehension performance in the HFASD sample?

Based on the literature reviewed above, we predicted that school-aged children with HFASD would display evidence of significant problems in, and differing patterns across, reading comprehension proficiency as compared to children with TD, but would be comparable to those with ADHD. Furthermore, it was anticipated that school-aged children with HFASD would display evidence of significant difficulties in, and differing patterns across, word recognition and oral language abilities as compared to children with TD, but would be similar those with ADHD. Next, we predicted that both components of the simple view of reading, word recognition and oral language skills, would predict reading comprehension within the HFASD sample. Finally, we predicted that greater ASD symptomatology would be directly associated with increased reading comprehension disturbance in the HFASD sample when controlling for word recognition and oral language skills.

Method

Participants

This research was conducted in compliance with the Institutional Review Board and written parental consent and child assent were obtained prior to data collection. Participants were 164 children, aged 8- to 16-years old, who had a community diagnosis of ASD or ADHD, or had TD. All enrolled subjects 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* = 81) 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 ≥75 as measured on the Wechsler Abbreviated Scales of Intelligence-II (WASI-2, Wechsler 2011). Children included in the HFASD sample also exceeded parent report criterion scores on a combination of the Autism Symptom Screening Questionnaire (ASSQ; Ehlers et al. 1999), the Social Communication Questionnaire (SCQ; Rutter et al. 2003), and the Social Responsiveness Scale (SRS; Constantino and Gruber 2005). Children were included the ADHD sample (*n* = 39) if they had a community diagnosis of ADHD and clinical elevations on parental report of current ADHD symptomatology on the Conners-3 (Conners 2008), as well as an FIQ estimate ≥75. These children with high ADHD symptomatology, but no diagnosis of ASD, will hereafter be referred to as the ADHD group. Participants in the TD group (*n* = 44) did not have a community diagnosis of, or meet criteria for, ASD or ADHD, and had an FIQ estimate ≥75. Exclusionary criteria for all participants included an identified syndrome other than ASD or ADHD (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.

The descriptive statistics for the three diagnostic groups are provided in Table 1. The mean FIQ for HFASD and ADHD diagnostic groups were average and comparable, but the mean FIQ for TD group was significantly higher than both the HFASD ($p < .001$) and ADHD ($p < .001$) groups. Therefore, between diagnostic group analyses control for FIQ unless specifically noted. As expected, the

Table 1 Descriptive statistics and significant group differences for three diagnostic groups

Measure	HFASD *n* = 81 *M* (*SD*)	ADHD *n* = 39 *M* (*SD*)	TD *n* = 44 *M* (*SD*)
Demographics			
Age	11.24 (2.19)	11.68 (2.39)	11.59 (2.25)
Grade	5.27 (2.19)	5.56 (2.35)	5.36 (2.16)
IQ			
VIQ[a, b]	95.91 (15.01)	99.95 (13.85)	109.68 (15.11)
PIQ[a, b]	104.68 (16.02)	102.08 (16.42)	115.82 (15.47)
FIQ[a, b]	100.01 (14.31)	101.00 (15.03)	114.11 (14.24)
ASD Diagnostic Measures			
ADOS-2			
Social affect[c]	8.48 (3.45)	2.92 (3.49)	–
RRB[c]	2.54 (1.52)	0.58 (0.76)	–
ADOS-2 total score[c]	10.94 (3.65)	3.50 (3.62)	–
SCQ lifetime total[c, d, e]	21.05 (7.05)	6.49 (5.97)	2.49 (2.22)
ASSQ[c, d, e]	18.66 (5.5)	8.65 (6.99)	2.12 (3.20)
SRS[c, d, e]	81.87 (11.06)	60.11 (14.74)	45.58 (9.49)
ADHD diagnostic measure			
Conners-3			
Hyperactive/impulsive[d, e]	72.01 (15.14)	73.05 (16.82)	48.70 (8.83)
Inattentive[d, e]	74.77 (11.68)	77.08 (11.16)	48.72 (10.46)

Post hoc Tukey test results, $p < .05$

HFASD high-functioning autism spectrum disorders; *ADHD* attention deficit hyperactivity disorder; *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; *ASSQ* Autism Symptom Screening Questionnaire, total raw score; *SRS* Social Responsiveness Scale; *T-scores*, Conner-3 ADHD Parent Questionnaire, DSM-TR T-scores

[a]TD > HFASD, [b]TD > ADHD, [c]HFASD > ADHD, [d]HFASD > TD, [e]ADHD > TD

HFASD group scored significantly higher than the ADHD and TD groups on all ASD diagnostic measures, and the ADHD group scored higher the TD group on the Conners-3 parent report measure of ADHD symptoms. The HFASD group did not significantly differ from the ADHD group in parent report of ADHD symptom levels; 67% of the HFASD sample scored in the clinical concern range, or at least two standard deviations above the mean, on the Conners-3.

Demographic data presented in Table 2 indicate that the ratio of boys to girls in the HFASD sample, approximately 4:1, is similar to national prevalence rates (Christensen 2016). In general, participants' mothers across all diagnostic groups 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. About half the children in the ADHD sample had an IEP or 504 Plan and most spent much or all of their day in the general education classroom, a few with a full-time aide. Almost all children in the TD sample spent their entire school day in the general education classroom, none with full-time aides.

Table 2 Demographics across subgroups

Variable	HFASD (%)	ADHD (%)	TD (%)
Gender			
Male	81	82	64
Female	19	18	36
Ethnicity			
African American	1	3	0
Asian	5	0	3
Caucasian	65	74	76
Caucasian plus one other ethnicity	10	14	10
Hispanic/Latino/a	10	3	5
Native American	0	0	0
Native Hawaiian/Pacific Islander	1	3	2
Other	5	3	4
Decline to state	3	0	0
Mother's highest level of education			
Some high school	1	0	2
Completed high school	3	8	0
Some college	25	39	21
Completed college	36	26	39
Some graduate school	7	5	2
Completed graduate school	27	18	27
Decline to state/unavailable	1	4	9
School type			
Private	12	8	21
Public	84	85	62
Homeschool	4	5	16
School placement			
General education, no aide	47	72	93
General education with aide	21	13	0
Resource	10	10	0
Special day	11	0	0
Other	10	0	5
Decline to state/unavailable	1	5	2
Percent time per day in general education (%)			
81–100	65	80	86
41–80	12	10	7
1–40	10	3	2
0	10	5	0
Decline to state/unavailable	3	2	5
Has IEP or 504 plan			
Yes	91	54	7

Procedures and Measures

Each child was recruited to participate in a longitudinal study of academic and social development. Data reported here are from assessment sessions that were conducted by members of a trained research group in a university-based child assessment laboratory during two sessions lasting 2 h 30 min each, held within a 2-week interval. For this study, we report only data that was collected at the first time point; therefore, we present cross sectional data.

Sample-specific reliability coefficients reported for many measures in this study are reported for the three diagnostic groups in our sample in the following order, unless otherwise noted: HFASD, ADHD, and TD.

Diagnostic Measures

The ADOS-2 (Lord et al. 2012) is a semi-structured diagnostic assessment for ASD, shown to have strong predictive validity against best estimate clinical diagnoses (Charman and Gotham 2013). Trained personnel administered Module 3 or 4 to confirm ASD diagnosis through evaluation of two core domains: social affect (SA) and restricted and repetitive behavior (RRB). The Module 3 algorithm yielded a raw subscore for SA and for RRB that combined to create the total score. Publisher (Lord et al. 2012) reported intraclass correlations (ICCs) for interrater reliability for Module 3 were .92 for SA, .91 for RRB and .94 for overall total raw score (Lord et al. 2012). ICCs for interrater reliability for Module 4 were reported to be .93 for social interaction, .84 for communication, .92 for communication + social interaction, and .82 for stereotyped behaviors and restricted interests (Lord et al. 2012). The ADOS-2 has been validated on two independent samples of 1630 children (Gotham et al. 2007) and 1282 children (Gotham et al.

2008) yielding sensitivity and specificity estimates of .91 and .84 for the ADOS modules used in this study.

Parent report questionnaires were administered to provide additional evidence of ASD symptomatology in the HFASD sample, and to rule out ASD symptomatology in the ADHD and TD samples. The SCQ Lifetime version (Rutter et al. 2003) was developed as a companion screening measure for the Autism Diagnostic Interview-Revised (ADI-R; Lord et al. 1994) and is a 40-item parent report rating developmental social communication and stereotyped and repetitive behavior symptoms of ASD in children 4 years and older. SCQ scores are strongly correlated with the corresponding ADI-R scores, $r = .55$ to .71, $p < .005$, $n = 200$ (Rutter et al. 2003). The ASSQ (Ehlers et al. 1999) is a 27-item checklist screener and one of few measures with demonstrated test–retest reliability (Parents .96, Teachers .94) and diagnostic validity for discriminating children with HFASD from other groups. The ASSQ has also demonstrated parent report specificity (.90) and sensitivity (.62) for the diagnosis of ASD (Ehlers et al. 1999; Kadesjo et al. 1999). The SRS (Constantino and Gruber 2005) 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 and Gruber 2005).

The Conners-3 (Conners 2008) parent report provided a measure of behaviors characteristic of ADHD. The Conners-3 DSM-IV-TR Symptom Scales for Inattentive Type and Hyperactive-Impulsive Type represent the main clinical constructs of the DSM-IV by asking parents to rate their child on items that are close approximations of each of the DSM-IV-TR symptoms for these subtypes. Age- and gender-normed T-scores ($M = 50$, $SD = 10$) allow comparison of an individual's level of symptoms with that of same age and gender peers. Publisher (Conners 2008) reported 4-week test–retest reliability ranged from .71 to .98 (all correlations significant, $p < .001$). Internal consistency reliability alphas ranged from .85 to .93 for all scales.

Cognition

The WASI-2 (Wechsler 2011) provided an estimate of verbal and nonverbal cognitive ability. Two verbal subtests, vocabulary and similarities, measured expressive vocabulary and abstract semantic reasoning and formed the verbal composite (VIQ). Two nonverbal subtests, block design and matrix reasoning, measured spatial perception, visual abstract processing, and problem solving and formed the performance composite (PIQ). Combined, the four subtests yielded an age-normed standard score ($M = 100$, $SD = 15$) measurement of FIQ. The FIQ index has established internal consistency (.96) and test–retest reliability for children ages 6–16, $r = .94$. Wechsler (2011) reported inter-rater reliability coefficients of .98–.99 for the nonverbal subtests and .94–.95 for the verbal subtests. In this study, internal consistency Cronbach's alpha coefficients were .89, .90, and .91 for vocabulary; .88, .86, and .91 for similarities; .87, .87, and .88 for block design; and .92, .88, and .89 for matrix reasoning.

Reading Comprehension

Prior research has indicated that reading comprehension is difficult to assess accurately and consistently with one measure (Cutting and Scarborough 2006; Keenan et al. 2008), therefore, two complementary measures were administered. While the structure and administration of each test is quite different, it was posited that the combination of the two tests would be a more reliable and valid appraisal of a child's reading comprehension ability.

The Gray Oral Reading Tests—Fifth Edition (GORT-5; Wiederholt and Bryant 2012) provided a standardized measurement of reading comprehension that yielded age-normed scaled scores ($M = 10$, $SD = 3$) for individuals aged 6 years to 23 years 11 months. The individually administered test is comprised of 16 progressively more difficult reading passages read aloud by the child, each followed by five open-ended comprehension questions given orally by the tester with the passage removed from view. Publisher (Wiederholt and Bryant 2012) reported Cronbach's alpha reliability coefficients for GORT-5 Comprehension scores range between .90 and .96 in the normative sample, .97 in an ASD subsample, and .97 in an ADHD subsample.

The Qualitative Reading Inventory-5 (QRI-5; Leslie and Caldwell 2011), an individually administered criterion-referenced reading inventory, provided a second assessment of reading comprehension. Participants silently read one narrative passage matched to their word reading accuracy level and then answered an average of eight questions per passage. Two key features further differentiated this assessment from the GORT-5. First, "look-backs" (LB) allowed the examiner to assess reading comprehension under two conditions: with the passage removed from view (total% correct score) versus with the passage returned to view for referencing by the student (LBtotal% correct score). Second, the comprehension questions are clearly delineated as text-explicit (explicit% correct score) or text-implicit (implicit% correct score), allowing direct comparison between questions requiring literal recall versus higher-order inferential abilities respectively. Publisher (Leslie and Caldwell 2011) reported data indicated that students could answer more questions when allowed to look back at the text. Additionally, they reported significant correlations between explicit and implicit comprehension on narrative passages from second grade through sixth grade. Reported alternate-form reliability (alphas >.80) was assessed based on how likely the total comprehension score was to estimate instructional level across passages of the same type. In this study, Cronbach's alpha reliability coefficients for QRI comprehension total raw scores were .50 on second through sixth grade passages and .37 on middle school and high school passages across diagnostic groups. Reliability coefficients for QRI comprehension LBtotal raw scores were .50 on second through sixth grade passages, and .55 on middle school and high school passages across diagnostic groups. Low alpha coefficients were expected because the measure has a low overall number of items. Nevertheless, this measure has been used in previous reading comprehension research (Adlof et al. 2010; Betjemann et al. 2011; Paris and Paris 2003), and has been shown to load onto one comprehension factor along with three standardized reading comprehension tests (Keenan et al. 2008). Because of this evidence of the significant convergent validity of the QRI, it was retained as a measure for inclusion in the structural equation models.

Reading Accuracy

Word recognition was assessed using the Test of Word Reading Efficiency, Second Edition (TOWRE-2, Torgesen et al. 2012), which provided an age-normed standard score ($M = 100$, $SD = 15$) measuring accuracy and fluency of sight word recognition (sight word efficiency) and phonemic decoding (phonemic decoding efficiency). Participants read as many real words (sight word efficiency) or decodable nonwords (phonemic decoding efficiency) as they could in 45 s per subtest. Internal consistency Cronbach's alpha coefficients from our study for sight word efficiency (alphas = .97, .97, and .98), and for phonemic decoding efficiency (alphas = .87, .92, and .91) were consistent with publisher reported alphas for both subtests (alphas >.90; Torgesen et al. 2012).

Text-level reading accuracy was represented by age-normed scaled scores ($M = 10$, $SD = 3$) from the GORT-5 (Wiederholt and Bryant 2012). As the participants read each passage aloud, all deviations from print were marked and totaled to obtain a text reading accuracy score. Publisher (Wiederholt and Bryant 2012) reported Cronbach's alpha coefficients for GORT-5 Accuracy scores ranged between .85 and .94 in the normative sample, .93 in an ASD subgroup, and .95 in an ADHD subgroup.

Phonological Processing and Rapid Automatized Naming

Subskills that support word recognition, phonological awareness and expressive phonology/phonological memory, were measured with the elision and nonword repetition subtests from the Comprehensive Test of Phonological Processing (CTOPP; Wagner et al. 1999), which yielded age-normed scaled scores ($M = 10$, $SD = 3$). The elision subtest measured the extent to which an individual could say a word and then say what is remaining after omitting a designated sound. Internal consistency Cronbach's alpha coefficients from our study for elision (alphas = .93, .91, and .88) were consistent with publisher reported alphas (alphas = .81–.91; Wagner et al. 1999). The nonword repetition subtest measured an individual's ability to repeat nonwords that range in length from 3 to 15 sounds. Internal consistency Cronbach's alpha coefficients from our study for nonword repetition (alphas = .78, .69, and .70) were generally consistent with publisher reported alphas (alphas = .73–.80). The speed at which participants were able to connect orthographic and phonological representations was measured using two rapid automatized naming (RAN) tasks from the CTOPP; rapid letter naming and rapid digit naming subtests yielded separate age-normed scaled scores ($M = 10$, $SD = 3$) and combined for an age-normed RAN index score ($M = 100$, $SD = 15$). Alternate-form reliability coefficients from our study for rapid letter naming (.89, .86, and .90) and rapid digit naming (.87, .86, and .90) were consistent with publisher reported alternate-form reliability coefficients (.70–.93).

Oral Language

Structural language skills were assessed with three subtests. Morphological processing was assessed with an experimental measure, the test of morphological structure–derivation (Carlisle 2000), and yielded a raw total score between 0 and 28. This experimental measure was designed to assess individuals' awareness of the relations of base to derived word forms and required the production of a derived word in order to finish a sentence (e.g., base word = help. "My sister is always _____."). This measure has been used in previous reading research studies that have shown that morphological awareness contributed to word reading and decoding as well as comprehension across grade levels one through eight (Berninger et al. 2010; Tong et al. 2011). Berninger et al. (2010) reported that test–retest reliability over a 1-year period was .61. In our study, Cronbach's alpha reliability coefficients were .93, .91, and .91. 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. In order to be successful one must utilize language structure and meaning to accurately recall increasingly long and complex sentences. It has been shown to be a sensitive marker of language impairment in ASD (Condouris et al. 2003; Rapin et al. 2009; Riches et al. 2010) and specific language impairment (Conti-Ramsden et al.

2001; Cutting and Scarborough 2006). Publisher (Semel et al. 2003) reported Cronbach's alpha reliability coefficients ranged from .86 to .93 in the normative sample and .97 in an ASD subsample. Expressive vocabulary was measured with the vocabulary subtest from the WASI-II (Wechsler 2011), which yielded an age-normed T-score ($M = 50$, $SD = 10$). This subtest was designed to measure semantic knowledge and verbal concept formation.

Higher order language and cognitive processing was operationalized by three tasks. The auditory reasoning subtest of the Test of Auditory Processing Skills, Third Edition (TAPS-3; Martin and Brownwell 2005) provided an age-normed scaled score ($M = 10$, $SD = 3$) assessing higher-order linguistic processing related to understanding of implied meanings, idioms, and abstractions, and to making inferences. Participants were read short vignettes (approximately two sentences each) and asked to respond to one question for each item. Internal consistency Cronbach's alpha coefficients from our study for auditory reasoning (alphas = .87, .92, and .91) were generally consistent with publisher reported alphas (alphas = .91–.96; Martin and Brownwell 2005). The story recall subtest of the Wide Range Assessment of Memory and Learning, Second Edition (WRAML2; Sheslow and Adams 2003) tapped the ability to listen to and utilize narrative structure to organize and retell gist and verbatim details of two orally presented narratives and yielded an age-normed scaled score ($M = 10$, $SD = 3$). Internal consistency Cronbach's alpha coefficients from our study for story recall (alphas = .95, .93, and .89) were generally consistent with publisher reported alphas (alphas = .91–.92; Sheslow and Adams 2003). The sentence completion task, created by Happé et al. (2001), was administered to assess local versus global processing bias at the sentence level. It comprises 14 sentence stems, ten of which are designed to prompt a local completion in individuals with weak central coherence that may not process the sentence for global meaning, and yields a total raw score between 0 and 20. Booth and Happé (2010) reported that this measure was sensitive to individual differences independent of IQ among a TD sample and capable of tapping weak central coherence in the verbal semantic domain in ASD groups versus ability-matched TD and ADHD comparison groups. The sentence completion task, as expected, yielded low alpha estimates in our sample: .52, .43, and .28. This was expected because the measure has only ten items, and each item is scored on a three-level ordinal scale. Nevertheless, this measure was designed for research with children with ASD and has well-established validity (Booth and Happé 2010; Happé et al. 2001; Losh et al. 2009). Therefore, it was retained as valid measure for inclusion in the structural equation models for this group.

Data Analysis

For all analyses, the full sample was included; no subject was excluded due to missing data.

Diagnostic Group Comparisons

Planned Analyses of Covariance (ANCOVA) and Multivariate Analyses of Covariance (MANCOVA), controlling for FIQ, with Bonferroni correction for pairwise follow-up analyses were used to examine diagnostic group differences in: (a) reading comprehension, (b) (word and text) reading accuracy, (c) phonological processing and rapid automatized naming, and (d) oral language. Alpha levels of .05 and below 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.

Predicting Reading Comprehension in HFASD

An adaptation of the simple view of reading was investigated in the HFASD sample in this study. As shown in Fig. 1, latent variables of reading accuracy and oral language were hypothesized to predict reading comprehension. Since prior research provided evidence that language impairment was associated with accurate word recognition in children with ASD (Lindgren et al. 2009; Lucas and Norbury 2014; Norbury and Nation 2011), the relation between these two domains was also examined. Finally, the direct and indirect paths of association between ASD-specific characteristics and reading comprehension were probed.

Structural equation modeling (SEM) analyses provided a detailed examination of the conceptual diagram presented in Fig. 1. SEM was conducted in Mplus version 7 (Muthén and Muthén 1998–2012). The full information maximum likelihood (FIML) procedure was the default estimator. A two-step modeling approach was utilized for these analyses (Kline 2011). First, confirmatory factor analysis (CFA) was used to examine how well the measurement model from this study fit the sample data. Next, structural regression models were used to test hypotheses about the structural associations among variables in the HFASD sample.

Following Kline (2011), the model Chi-squares were used to test the prediction that there were no discrepancies between the population covariance matrix and that predicted by the model. Indices of fit were interpreted in accordance with guidelines described by Hu and Bentler (1999). The Stieger-Lind root mean square error of approximation (RMSEA) is a parsimony-corrected index with a

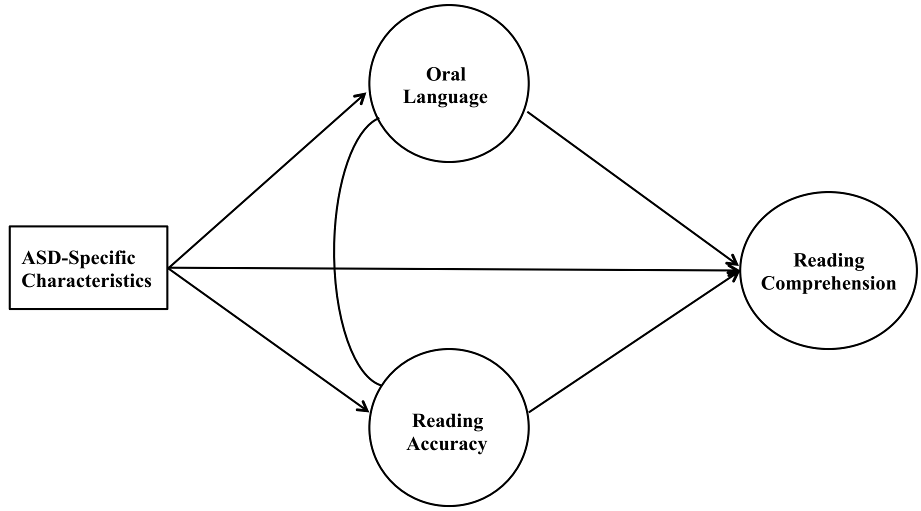


Fig. 1 Conceptual diagram of the relation between ASD-specific characteristics, oral language, reading accuracy, and reading comprehension

90% confidence interval: 0 = best fit, $p \leq .06$ indicates good fit. The Bentler comparative fit index (CFI) is an incremental fit index that measures the relative improvement of fit in the specified model over that of a baseline model, with values ranging from 0 to 1, with 1 indicating best fit. The standardized root mean square residual (SRMR) is a test statistic related to the correlation residuals, or the differences between observed and predicted covariances. CFI values ≥.95 and SRMR values <.08 have been demonstrated to be acceptable thresholds to indicate tenable model fit. Analyses run with smaller samples may need to be interpreted more conservatively and indices of fit may not be as robust.

Results

Diagnostic Group Comparisons of Reading Comprehension Abilities

Standardized Reading Comprehension Scores

We utilized the GORT-5 age-normed reading comprehension scaled scores (GORT-Comp) to investigate differences between the three diagnostic groups. As shown in Table 3, an ANCOVA for GORT-Comp indicated a significant main effect of diagnostic groups while controlling for the significant effects of the IQ covariate. Post hoc analyses showed that students in the HFASD group scored significantly lower on GORT-Comp than those categorized as ADHD or TD, who did not score significantly different from one another. Descriptive statistics indicated that approximately 51% of students in the HFASD group, 33% of students in the ADHD group, and 11% of students in the TD group scored at least 1 *SD* below average on GORT-Comp.

Criterion-Referenced Reading Comprehension Measure

Two QRI-5 scores were examined in a MANCOVA: QRI-total% (total percentage of comprehension questions answered correctly with the passage removed from view) and QRI-LBtotal% (total percentage of comprehension questions answered correctly when looking back at the passage). Analyses revealed that the main effect of diagnostic groups was significant while controlling for the effects of the IQ covariate, $\lambda = .89$, $F(4, 298) = 4.30$, $p = .002$. Univariate analyses indicated that the groups differed on both the QRI-total% and QRI-LBtotal% (see Table 3). Post hoc analyses showed that students categorized as HFASD scored significantly lower on both QRI comprehension variables than the TD sample. On the QRI-LBtotal% variable, students categorized as HFASD also scored significantly lower than those in the ADHD group. Students categorized as ADHD and TD did not score significantly differently from one another on either QRI variable.

MANOVA results indicated all diagnostic group means increased significantly from the initial to the look back condition: HFASD, $\lambda = .10$, $F(2, 75) = 340.93$, $p < .001$; ADHD, $\lambda = .03$, $F(2, 35) = 560.37$, $p < .001$; TD, $\lambda = .04$, $F(2, 41) = 510.78$, $p < .001$. A repeated measures ANCOVA revealed no evidence of a significant difference between the diagnostic groups on the change in performance across the QRI-total% and QRI-LBtotal% measures, $F(2, 153) = .30$, $p = .74$, $\eta^2_p = .004$.

Specific Deficits in Implicit Question Types The QRI also breaks down both total% and LBtotal% condition scores into two types of comprehension questions: explicit (explicit% and LB-explicit%) and implicit (implicit% and LB-implicit%) questions. A MANCOVA for the four dependent variables of explicit%, LB-explicit%, implicit%, and LB-implicit% revealed that the main effect of diagnos-

Table 3 Diagnostic group differences in reading comprehension, reading accuracy, phonological processing, and oral language measures

Measure	HFASD *M (SD)*	ADHD *M (SD)*	TD *M (SD)*	ANCOVA *F*	p	Effect size η^2_p
Reading comprehension						
GORT-Comp[a,b]	7.37 (2.61)	8.82 (2.21)	10.07 (2.60)	7.95	.001	.09
QRI-total%[a]	36.77 (21.08)	44.44 (23.68)	53.08 (18.40)	6.00	<.01	.07
Explicit%	43.25 (27.46)	44.46 (30.55)	51.05 (24.24)	.96	.39	.01
Implicit%[a, b]	29.87 (25.82)	44.19 (28.95)	54.30 (23.92)	8.60	<.001	.10
QRI-LBtotal%[a,b]	64.97 (21.97)	75.37 (14.44)	84.44 (17.12)	8.86	<.001	.10
LB-explicit% [b]	78.77 (24.92)	90.68 (16.12)	91.86 (17.53)	5.03	<.01	.06
LB-implicit%[a]	50.52 (30.47)	59.86 (22.53)	76.28 (22.39)	6.66	<.01	.08
Reading accuracy						
SWE	93.29 (14.75)	94.03 (17.44)	101.20 (16.19)	.01	.99	.00
PDE	94.89 (14.81)	94.44 (17.82)	102.70 (15.20)	.13	.88	.00
TextAcc[a]	8.03 (2.69)	8.58 (2.66)	10.82 (3.49)	3.56	.03	.04
Phono processing						
Elision	9.94 (3.08)	9.72 (2.82)	11.43 (2.61)	1.03	.36	.01
NWR[a]	7.50 (2.15)	7.82 (1.67)	8.95 (2.24)	3.59	.03	.04
RAN index[a]	85.68 (21.92)	88.87 (13.52)	98.70 (12.15)	4.13	.02	.05
Structural language						
Morph[a, b]	15.97 (7.02)	19.62 (6.18)	21.09 (6.92)	7.63	.001	.09
CELFrs[a, b]	7.36 (3.15)	9.03 (3.09)	11.02 (3.20)	13.84	<.001	.15
EVocab[a, c]	46.96 (9.89)	49.44 (10.30)	58.44 (10.16)	11.35	<.001	.13
Higher order language						
AudReas[a]	6.04 (2.77)	7.23 (3.08)	8.64 (2.80)	4.92	.01	.06
StryRec[a, b]	7.94 (3.31)	10.03 (3.23)	11.47 (2.24)	11.78	<.001	.13
SentCmpl	16.21 (2.76)	16.77 (2.29)	18.14 (1.76)	2.16	.12	.03

ANCOVA analyses controlled for full-scale IQ. Post hoc pairwise comparisons using Bonferroni correction

HFASD high-functioning autism spectrum disorder; *ADHD* attention-deficit/hyperactivity disorder; *TD* typically developing; *GORT-Comp* text comprehension, Gray Oral Reading Test-5; *QRI-total%* total percent correct without passage in view, Qualitative Reading Inventory-5; *QRI-LBtotal%* total percent correct with look-back at passage, QRI-5; *Explicit%* percent explicit questions correct without passage in view, QRI; *LB-explicit%* percent explicit questions correct with look-back at passage, QRI-5; *Implicit%* percent implicit questions correct without passage in view, QRI-5; *LB-implicit%* percent implicit questions correct with look-back at passage, QRI-5; *SWE* sight word efficiency, TOWRE-2; *PDE* phonemic decoding efficiency, TOWRE-2; *TextAcc* text reading accuracy, GORT-5; *Elision* CTOPP; *NWR* nonword repetition, CTOPP; *RAN Index* rapid automatized naming index, CTOPP; *Morph* derivational morphology; *CELFrs* recalling sentences, CELF-4; *EVocab* expressive vocabulary, WASI-II; *AudReas* auditory reasoning, TAPS-3; *StryRec* story recall, WRAML-2; *SentCmpl* sentence completion task

[a]TD > HFA, [b]ADHD > HFA, [c]TD > ADHD

tic groups was significant while controlling for the effects of the IQ covariate, λ = .85, $F(8, 300) = 3.24$, p = .002. As shown in Table 3, univariate analyses for explicit% showed no diagnostic group differences in performance. In the look-back condition, LB-explicit%, a significant effect for diagnostic group was observed and post hoc analyses indicated that students categorized as HFASD scored significantly lower than those in the ADHD group, $p = .02$, and marginally lower than those in the TD group, p = .06. The ADHD and TD groups were not different from one another, p = 1.0. MANOVA results indicated all diagnostic group means increased significantly from the initial to the look back condition for explicit question types: HFASD, λ = .09, $F(2, 75) = 379.64$, p < .001; ADHD, λ = .03, $F(2, 35) = 572.34$, p < .001; TD, λ = .03, $F(2, 41) = 586.73$, p < .001.

Univariate analyses for implicit% revealed a significant diagnostic group difference and post hoc analyses indicated that the HFASD sample scored significantly lower than those in the ADHD group, p = .02, and TD group, p = .001. The ADHD and TD groups were not different from one another, p = .91. Univariate analyses for LB-implicit% also revealed a significant diagnostic group difference. Post hoc pairwise comparisons showed that students categorized as HFASD scored significantly lower than those in the TD group, p = .001, but not the ADHD group, p = .26. The ADHD and TD groups were not different from one another, p = .29. MANOVA results also indicated all diagnostic groups increased significantly from the initial to look back condition for implicit question types: HFA, λ = .26, $F(2, 75) = 105.00$, $p < .001$; ADHD, λ = .12, $F(2, 35) = 134.04$, $p < .001$; TD, λ = .08, $F(2, 41) = 244.51$, $p < .001$ (see Table 3).

Diagnostic Group Comparisons of Components of Reading Comprehension

The analyses of reading comprehension measures provided consistent evidence of significant impairments in the HFASD sample versus the ADHD and TD samples. In contrast, the analyses of the components skills of reading comprehension (reading accuracy, phonological processing and rapid automatized naming, and oral language) revealed some, but not consistent, evidence of ASD-specific impairments.

Reading Accuracy Skills

A MANCOVA for the three dependent variables measuring reading accuracy (sight word efficiency, phonemic decoding efficiency, and text reading accuracy) revealed that after taking the significant effects of the IQ covariate into account, the main effect of diagnostic groups was not significant, λ = .94, $F(6, 314) = 1.65$, p = .13. As shown in Table 3, univariate analyses revealed that there were no significant diagnostic group differences on the sight word efficiency and phonemic decoding efficiency subtests. It is interesting to note, however, that while reading and decoding isolated words was not different between groups, post hoc pairwise comparisons indicated that accurately reading connected text on the GORT-5 posed significantly greater difficulty for students affected by HFASD as compared to those in the TD group, p = .02, but not the ADHD group, p = 1.00.

Furthermore, although the analysis of covariance for phonemic decoding efficiency did not reveal significant between-group differences, using the 10th percentile as a cut-off point (Mazzocco and Grimm 2013), 21% of the HFASD sample, 23% of the ADHD sample, and 4% of the TD sample exhibited impaired performance in single word phonemic decoding. As shown in Table 4, on average poor word decoders in all three diagnostic groups exhibited poor performance on phonological awareness (elision), expressive phonology/phonological memory (nonword repetition), and rapid automatized naming (RAN Index) concomitant with average to low-average IQ.

Finally, the subsample of each diagnostic group that scored at or below the 16th percentile on GORT-5 reading comprehension was examined for word decoding proficiency. Twenty-one percent of the HFASD sample, 10% of the ADHD sample, and 7% of the TD sample scored at or above the 37th percentile on phonemic decoding efficiency, exhibiting a profile of poor comprehension alongside average or above word decoding skills.

Table 4 Descriptive statistics for poor word decoders in three diagnostic groups

Measure	HFASD (*n* = 17) *M (SD)*	ADHD (*n* = 9) *M (SD)*	TD (*n* = 2) *M (SD)*
FIQ	89.88 (11.03)	93.11 (12.35)	83.50 (6.36)
Elision	6.76 (2.59)	7.78 (1.92)	7.50 (2.12)
NWR	6.06 (2.33)	7.44 (1.01)	7.50 (0.71)
RAN index	74.35 (21.09)	85.67 (10.25)	80.50 (2.12)

HFASD high-functioning autism spectrum disorders; *ADHD* attention deficit hyperactivity disorder; *TD* typically developing; *M* mean; *SD* standard deviation; *FIQ* full-scale IQ; *Elision* CTOPP; *NWR* nonword repetition, CTOPP; *RAN Index* rapid automatized naming, CTOPP

Phonological Processing and Rapid Automatized Naming

A MANCOVA for the three dependent variables measuring phonological awareness (elision), expressive phonology and phonological memory (nonword repetition), and rapid automatized naming (RAN Index), revealed that the main effect of diagnostic groups was significant, while controlling for the effects of the IQ covariate, λ = .91, $F(6, 312) = 2.67$, p = .02. As shown in Table 3, univariate analyses revealed students in the HFASD sample performed similarly to those in the ADHD and TD samples on phonological awareness as measured by elision. However, on the other measure of phonological processing, nonword repetition, post hoc pairwise comparisons indicated students affected by HFASD scored significantly lower than those in the TD group, p = .03, but students affected by ADHD did not score significantly differently from either the HFASD group, p = .39, or TD group, p = .46. Results indicated students categorized as HFASD displayed significant difficulty with RAN tasks as compared to those in the TD group, p = .01, but not the ADHD group, p = 1.00.

Structural Language

A MANCOVA for the three dependent variables measuring structural language [morphological processing (derivational morphology), syntactic skills (recalling sentences), and vocabulary (expressive vocabulary)], revealed that the main effect of diagnostic groups was significant while controlling for the effects of the IQ covariate, λ = .78, $F(6, 304) = 6.72$, $p < .001$. As shown in Table 3, students affected by HFASD scored significantly lower than students categorized as TD, p = .02, and ADHD, $p < .01$ on derivational morphology, as well as on recalling sentences, p's < .001 and .01 respectively. Furthermore, students affected by HFASD performed significantly lower than the TD group, $p < .001$, on expressive vocabulary. The ADHD group also performed significantly worse than the TD group, $p = .03$, on expressive vocabulary.

Higher Order Language

A MANCOVA for the three dependent variables measuring higher order language (auditory reasoning, story recall, and the sentence completion task), revealed that the main effect of diagnostic groups was significant after controlling for the effects of the IQ covariate, $\lambda = .86$, $F(6, 308) = 4.17$, $p < .001$. Univariate analyses and post hoc pairwise comparisons indicated students affected by HFASD scored significantly lower than those in the TD group, $p = .02$, on auditory reasoning. Furthermore, students in the HFASD group performed significantly lower than those in both the TD, $p < .001$, and ADHD groups, $p = .001$, on story recall. While students in the HFASD and ADHD group performed more poorly than those in the TD group on the sentence completion task, when controlling for IQ, this difference did not reach statistical significance.

Predicting Reading Comprehension in HFASD: SEM Analyses

To determine the nature of the reading comprehension disturbance in children in the HFASD sample, a final set of analyses was conducted to investigate the relation between ASD-specific characteristics and oral language, reading accuracy, and reading comprehension using latent variable modeling methods (see Fig. 1). ADHD symptoms were not included in SEM modeling because analyses indicated that Conners-3 ADHD symptomatology was not significantly correlated with the combined GORT-5 and QRI-5 reading comprehension scores in the HFASD, ADHD, or TD samples; *r*'s = .20, .11, −.23, respectively.

Measurement Model

Three and four factor measurement models were tested using CFA. A latent construct of reading accuracy was hypothesized to be comprised of the following skills: single word phonemic decoding efficiency, sight word reading efficiency, and text level reading accuracy. Therefore, the continuous variables from the TOWRE-2 assessment, phonemic decoding, sight word reading, and text reading accuracy from the GORT-5 were used to infer the reading accuracy construct.

A latent construct of Oral Language was hypothesized to be comprised of structural language skills; the continuous indicators were derivational morphology, CELF-4 recalling sentences, and the WASI II expressive vocabulary. Higher order language skills were also included in the oral language latent variable; the indicators were TAPS auditory reasoning, WRAML story recall, and global processing, using the sentence completion task. These indicators were used to infer the oral language construct.

A latent construct of reading comprehension was hypothesized to be best represented by more than one measure. Since the QRI-5 is not a standardized measure, the percent-correct scores were converted to z-scores (QRI-zlb). GORT-5 comprehension scaled scores were also converted to z-scores (GORTzcomp). These measures were then used to infer the reading comprehension construct.

This three-factor CFA (reading accuracy, oral language and reading comprehension) was fit to the HFASD sample and was found to be an adequate representation of the data, χ^2 (42, $N = 81$) = 57.84, $p = .05$; RMSEA = .07, 90% CI (.000, .11); CFI = .96; SRMR = .07 (see Table 5 for CFA results). All standardized factor loadings in the three-factor CFA were significant ($p < .001$). Correlations between reading accuracy and both oral language and reading comprehension were moderate and significant ($p < .001$), and the correlation between oral language and reading comprehension was high and significant ($p < .001$).

To test the hypothesis that oral language could be conceptualized as two distinct, correlated factors (i.e., structural language and higher order language), a four-factor measurement model was tested in the HFASD sample. The four-factor model fit to the data was good: χ^2 (39, $N = 81$) = 45.03, $p = .23$; RMSEA = .04, 90% CI (.000, .092); CFI = .98; SRMR = .06 (see Table 6 for CFA results). All standardized factor loadings in the four-factor CFA were significant ($p < .001$). The correlation between reading accuracy and structural language was significant and higher than that between reading accuracy and higher order language. Both structural language and higher order language were significantly and highly correlated with one another and with reading comprehension.

To determine if the four-factor model was a better representation of HFASD data a Chi square difference test was conducted. Results indicated that the four-factor model fit the data significantly better than the three-factor model, $\chi^2_D = 12.81$, $df_D = 3$, $p < .01$. Therefore, the four-factor measurement model was used in subsequent structural analyses.

Structural Analysis: ASD-Specific Characteristics, Oral Language, and Reading

Prior studies of reading have reported that both reading accuracy skills and oral language abilities are hypothesized to relate to one another, and together, to predict

Table 5 Maximum likelihood estimates of factor loadings and residuals for three-factor measurement model of reading accuracy, oral language and reading comprehension in HFASD Sample (n = 81)

Indicator	Factor loadings			Measurement errors		
	Unstd.	*SE*	Std.	Unstd.	*SE*	Std.
PDE	11.22	1.58	0.76***	90.50	22.39	0.42
SWE	10.75	1.59	0.73***	99.07	22.51	0.46
TextAcc	2.00	0.29	0.75***	3.10	0.74	0.44
Oral language						
Morph	4.80	0.75	0.68***	26.90	4.80	0.54
CELFrs	2.40	0.31	0.77***	3.98	0.76	0.41
EVocab	6.47	1.01	0.66***	53.75	9.43	0.56
AudReas	1.67	0.29	0.61***	4.76	0.81	0.63
StryRec	2.05	0.35	0.62***	6.60	1.13	0.61
SentCmpl	1.80	0.28	0.66***	4.26	0.74	0.57
Reading Comp						
GORTzcomp	0.76	0.08	0.90***	0.14	0.06	0.20
QRIzlb	0.76	0.08	0.67***	0.69	0.12	0.55
ReadAcc w/OralLang	0.65	0.10	0.65***			
ReadAcc w/ReadComp	0.54	0.11	0.54***			
OralLang w/ReadComp	0.95	0.05	0.95***			

ReadAcc reading accuracy; *OralLang* oral language; *HighLang* higher order language; *ReadComp* reading comprehension; *PDE* phonemic decoding efficiency, TOWRE-2; *SWE* sight word efficiency, TOWRE-2; *TextAcc* text reading accuracy, GORT-5; *Morphology* derivational morphology; *CELFrs* recalling sentences, CELF-4; *EVocab* expressive vocabulary, WASI-II; *AudReas* auditory reasoning, TAPS-3; *StryRec* story recall, WRAML-2; *SentCmpl* sentence completion task; *GORTzcomp* reading comprehension z score, GORT-5; *QRIzlb* total LB% reading comprehension z score, QRI-5

***p < .001

reading comprehension (Cain and Oakhill 2007; Gough and Tunmer 1986; Scarborough 2009). We fit two separate structural models: first, because previous studies have indicated a significant relation between structural language skills and reading in children with ASD (Lindgren et al. 2009; Lucas and Norbury 2014; Norbury and Nation 2011), we fit a model to investigate the associations between structural language, reading accuracy, and reading comprehension when controlling for ASD-specific characteristics as measured by the ADOS-2 total score, which can be seen in Fig. 2. Second, we added higher order language as a predictor of reading comprehension to examine whether it contributed over and above the other predictors, again while controlling for ASD specific characteristics (see Fig. 3).

Model fit for the first model was adequate: $\chi^2 = 38.03$ (24, N = 79), p = .04; RMSEA = .09, 90% CI (.02–.14); CFI = .95; SRMR = .06. In the first model, ADOS-2 total score was negatively and significantly related to each of the three latent variables. That is, as ASD symptoms increased in severity, structural language, reading accuracy, and reading comprehension competencies all decreased. Structural language was a significant and positive predictor of reading comprehension, but reading accuracy did not significantly predict reading comprehension. Structural language and reading accuracy were significantly correlated suggesting children with HFASD who have difficulties with structural language also experience difficulties with reading accuracy.

The second model added higher order language as a latent predictor of reading comprehension. The model fit the data well: $\chi^2 = 48.37$ (47, N = 79), p = .42; RMSEA = .019, 90% CI (.000–.077); CFI = 1.00; SRMR = .06. In this final model, ADOS total score was still significantly related to the latent predictors, but was no longer significantly related to reading comprehension. Higher order language was the only significant predictor of reading comprehension in this model. That is, once higher order language was controlled, structural language and reading accuracy did not contribute to reading comprehension over and above higher order language. All three correlations among the three latent predictors were positive and significant. However, the relation between reading accuracy and higher order language was considerably smaller in magnitude than the other correlations (see Fig. 3 for diagram of results).

Discussion

Previous research has raised the hypothesis that reading comprehension impairment may be part of the social communication phenotype of school-aged children with HFASD (Dawson et al. 2002; Jones et al. 2009; Le Couteur

Table 6 Maximum likelihood estimates of factor loadings and residuals for four-factor measurement model of reading accuracy, oral language and reading comprehension in HFASD sample (n = 81)

Indicator	Factor loadings			Measurement errors		
	Unstd.	*SE*	Std.	Unstd.	*SE*	Std.
Reading accuracy						
PDE	11.40	1.56	0.78***	86.47	21.79	0.40
SWE	10.45	1.57	0.71***	105.52	21.98	0.49
TextAcc	2.03	0.28	0.76***	3.00	0.71	0.42
Structural language						
Morph	4.85	0.76	0.68***	26.79	4.82	0.53
CELFrs	2.43	0.31	0.78***	3.84	0.76	0.39
EVocab	6.49	1.02	0.67***	53.50	9.63	0.56
Higher order lang						
AudReas	1.80	0.30	0.65***	4.36	0.82	0.58
StryRec	2.07	0.35	0.63***	6.53	1.15	0.60
SentCmpl	1.94	0.28	0.70***	3.74	0.75	0.50
Reading Comp						
GORTzcomp	0.76	0.08	0.90***	0.14	0.06	0.20
QRIzlb	0.76	0.08	0.67***	0.69	0.12	0.55
ReadAcc w/StrcLang	0.76	0.09	0.76***			
ReadAcc w/HighLang	0.42	0.13	0.42**			
ReadAcc w/ReadComp	0.54	0.11	0.54***			
StrcLang w/HighLang	0.91	0.08	0.91***			
StrcLang w/ReadComp	0.92	0.06	0.92***			
HighLang w/ReadComp	0.95	0.07	0.95***			

ReadAcc reading accuracy; *StrcLang* structural language; *HighLang* higher order language; *ReadComp* reading comprehension; *PDE* phonemic decoding efficiency, TOWRE-2; *SWE* sight word efficiency, TOWRE-2; *TextAcc* text reading accuracy, GORT-5; *Morphology* derivational morphology; *CELFrs* recalling sentences, CELF-4; *EVocab* expressive vocabulary, WASI-II; *AudReas* auditory reasoning, TAPS-3; *StryRec* story recall, WRAML-2; *SentCmpl* sentence completion task; *GORTzcomp* reading comprehension z score, GORT-5; *QRIzlb* total LB% reading comprehension z score, QRI-5

**p < .01

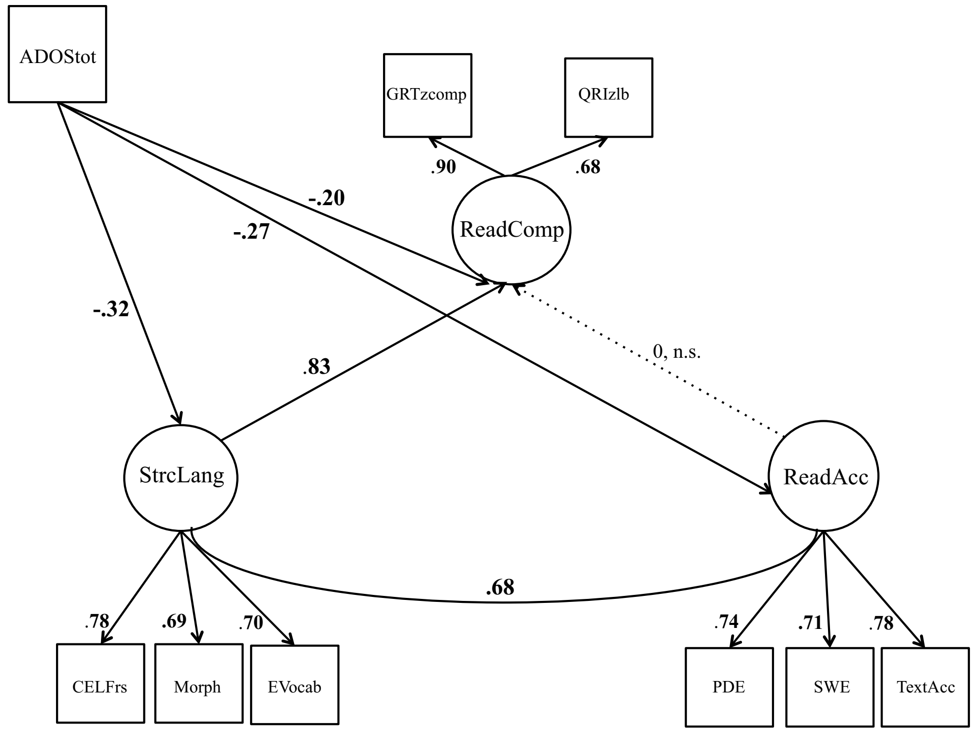
***p < .001

et al. 1996; Norbury and Nation 2011; Ricketts et al. 2013). The large sample size, clinical control sample, and analytic methods allowed this study to provide a more definitive test of this hypothesis. The results provide evidence that students with HFASD display problems in reading comprehension development that appear to be specific to ASD versus a sample of children with high ADHD symptomatology or a TD control sample. The results also indicate that the same factors that place children with HFASD at risk for structural and higher order language problems also may place them at risk for reading comprehension difficulties, if not disability. This finding is consistent with evidence that problems with cognitive processes—e.g., verbal reasoning, inference, and narrative processing—and the apprehension of central meaning (i.e., coherence), contribute to some of the language problems associated with the ASD phenotype, and also contribute to risk for problems in reading comprehension development among students with ASD (Happé et al. 2001; Randi et al. 2010). The details of these observations and assertions are discussed below, as are their implications for understanding the nature and treatment of autism in school-aged children.

The Specificity of Diagnostic Group Differences in Reading Comprehension

Reading comprehension was particularly challenging for the HFASD sample, even after considering the possible mediating effects of differences in FIQ. Moreover, the depth of this challenge appeared to be greater for students with HFASD compared to a clinical sample of students with high ADHD symptomatology. These are among the first data to speak to the issue of the diagnostic specificity of the reading comprehension disturbance in students with HFASD relative to another prominent group of children in schools with a neurodevelopmental disorder who are also at risk for reading disability: those with ADHD. Reading comprehension impairments in this study were more prevalent in children in the HFASD group than those in the ADHD or TD groups: 51% of students with HFASD,

Fig. 2 HFASD sample ($n=79$) structural model of ASD-specific characteristics, structural language, reading accuracy, and reading comprehension. Estimates are reported as standardized. Estimates in **bold** are significant at $p<.05$. *ADOStot* ADOS-2 total raw score; *ReadComp* reading comprehension latent variable; *GORTzcomp* GORT-5 comprehension z score; *QRIzlb* QRI-5 total LB% comprehension z score; *StrcLang* structural language latent variable; *CELFrs* recalling sentences (CELF); *Morphology* Carlisle derivational morphology test, raw score; *EVocab* expressive vocabulary (WASI); *PDE* pseudoword decoding efficiency, TOWRE; *SWE* sight word efficiency, TOWRE; *TextAcc* text reading accuracy, GORT-5



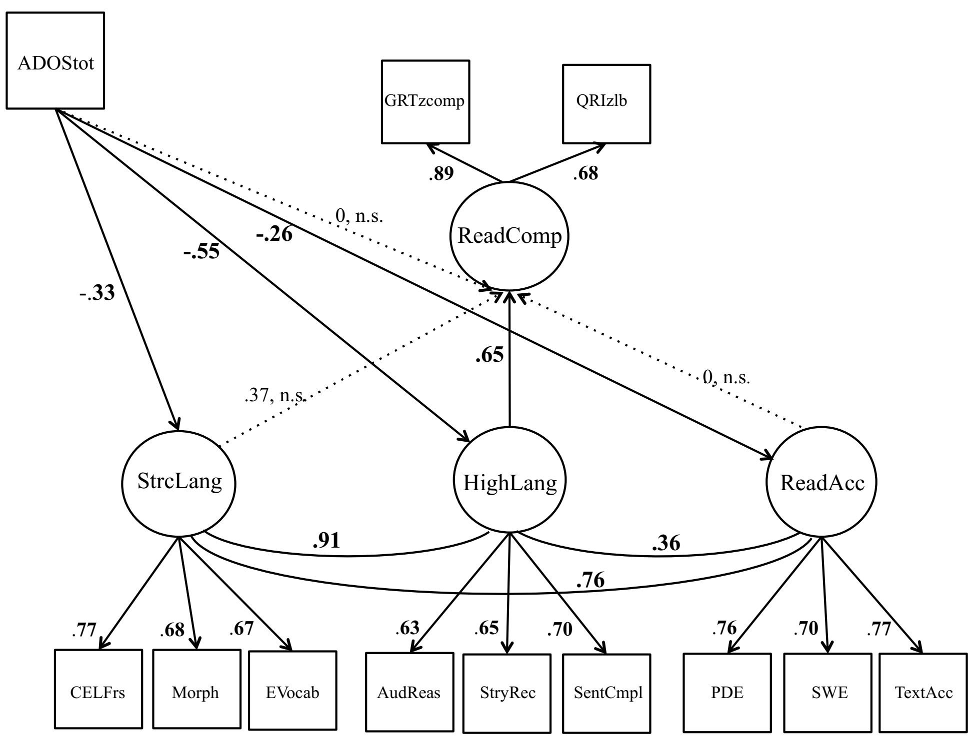


Fig. 3 HFASD sample ($n=79$) structural model of ASD-specific characteristics, structural language, higher order language, reading accuracy, and reading comprehension. Estimates are reported as standardized. Estimates in **bold** are significant at $p<.05$. *ADOStot* ADOS-2 total raw score; *ReadComp* reading comprehension latent variable; *GORTzcomp* GORT-5 comprehension z score; *QRIzlb* QRI-5 total LB% comprehension z score; *StrcLang* structural language latent variable; *CELFrs* recalling sentences (CELF); *Morphology* Carlisle derivational morphology test, raw score; *EVocab* expressive vocabulary (WASI); *AudReas* auditory reasoning, TAPS; *StryRec* story recall, WRAML; *SentCmpl* sentence completion; *PDE* pseudoword decoding efficiency, TOWRE; *SWE* sight word efficiency, TOWRE; *TextAcc* text reading accuracy, GORT-5

33% of students with ADHD, and 11% of students with TD scored at least 1 *SD* below average on the standardized measure of reading comprehension. These prevalence rates generally align with those reported by previous studies. For example, Nation et al. (2006) found that 65% of their heterogeneous ASD sample showed reading comprehension deficits of at least 1 *SD* below population norms, with 38% scoring more than 2 *SDs* below population norms on a British standardized reading comprehension measure.

The differences in reading across the clinical samples were unlikely to be due to gross differences in language development since these two groups did not differ in terms of VIQ: 95.91 (15.01) versus 99.95 (13.85). This included no evidence of a group difference on expressive vocabulary or an independent measure of sentence completion (see Table 3). Nevertheless, significant differences in reading comprehension development were observed between these groups. Alternatively, the ASD and ADHD groups did differ on measures of derivational morphology, recalling sentences, story recall, and auditory reasoning, raising the hypothesis that some aspects of structural and higher order language and/or related memory and inferential processes may have mediated the differences in reading comprehension across these clinical groups.

The true prevalence of this problem can only be estimated from large population-based studies. Nevertheless, the existence of the problem is clear and our data suggest this problem for children with HFASD was significantly different in scope than the reading problems that affected children with high ADHD symptomatology in this study. Children with ASD constitute 8% (520,000) of the children served in schools under the Individuals with Disabilities Education Act (IDEA) and ADHD children constitute a large portion of the 13% (845,000) of children served under the Other Health Impairment Category of this act (Kena et al. 2016). These data contribute to the empirical foundation required to recognize and better serve the specific academic needs of children with HFASD, as well as those affected by ADHD.

The nature of the reading difficulties of the HFASD and ADHD groups shared some similarities, but also exhibited some differences. When examining the diagnostic group comparisons across component processes supporting reading comprehension, we found that group means for the reading accuracy and phonological processing measures were not significantly different; 21% of the HFASD and 23% of the ADHD samples scored at or below the 10th percentile on phonemic decoding, which was associated with poor performance on phonological awareness, expressive phonology/phonological memory, and rapid automatized naming measures, that was concomitant with average to low-average IQ. This finding supports the prediction by Nation et al. (2006) that poor phonological processing would be associated with difficulty with phonemic decoding for children with ASD as it is in non-ASD samples. While reading accuracy deficits likely constrained reading comprehension for some children in both clinical groups, the HFASD sample demonstrated substantially more extensive challenges with morphology, semantics, syntax, and story recall than the ADHD sample, which would further limit their reading comprehension abilities.

Reading Comprehension, Inferences, and Malleability

This study utilized two methods to measure reading comprehension to provide the recommended control for the possible effects of method variance in research on reading comprehension in students with ASD (Cutting and Scarborough 2006; Keenan et al. 2008). The use of multiple measures also provided more details on the nature and malleability of reading comprehension difficulty in students with ASD. Recall that the GORT-5 provides a normative reading comprehension estimate based on students' responses to questions about passages they read, but cannot access during questions. By contrast the QRI-5 provides curriculum-based reading estimates based on how well students respond to explicit or implicit (inferential) passage information, as well as students response to questions with and without access to the passage text. Thus, the QRI-5 provided additional information in this study about reading comprehension in students with HFASD that was not available from the GORT-5.

First, although differing in method, the QRI-5 provided data consistent with those from the GORT-5. The students affected by HFASD displayed lower reading comprehension performance on the QRI-5 than the ADHD or TD samples. Second, the data from the QRI-5 indicated that the problems in reading comprehension for students in the HFASD sample were most pronounced on group comparisons of responses to implicit rather than explicit questions. Problems in understanding implicit meaning have long been recognized as part of the cognitive phenotype of ASD (Klin 2000; Klinger et al. 2007; Surian et al. 1996). Thus, the observation of the difficulty that HFASD students had with implicit or inferential reading aligns with the hypothesis that features of the cognitive phenotype of ASD may specifically interfere with the academic development of reading comprehension in many students with ASD (e.g., Randi et al. 2010). The lack of group differences on explicit reading comprehension questions may also be important because this feature of their reading competency, while an important strength to build upon, may obstruct teacher and school awareness of fundamental reading development problems among many students with HFASD.

A third contribution of the data from the QRI-5 was evidence that reading comprehension problems of students with HFASD may be malleable and, therefore, amenable to treatment. When students with HFASD could look back at passage text to answer comprehension questions they were able to improve their identification of correct information with respect to both explicit and implicit questions. Moreover, the slope of their improvement in the "look back" condition was comparable to the improvements displayed by their TD and ADHD peers. To be sure, the students affected by HFASD remained at a disadvantage relative to their peers in the "look back" condition. Nonetheless, the evidence of their ability to use strategies to scaffold recall and comprehension supports the hypothesis that research on reading comprehension intervention may be an important path for research on school-based interventions for students with HFASD (Chiang and Lin 2007; O'Connor and Klein 2004; Randi et al. 2010; Whalon et al. 2009).

The Factors that Impact Reading Development in Students with ASD

The QRI-5 provided some information about the factors that influence reading comprehension development in students with HFASD. However, a more precise picture of these factors requires an examination of the confluence of multivariate effects. To that end, SEM was employed to use a simple view of reading model (Gough and Tunmer 1986) for the examination of the influence of latent variables from the model of reading comprehension in students with HFASD (see Fig. 1). The results of the most comprehensive SEM model indicated that oral language development was singularly important with respect to variation in reading comprehension development in students with HFASD. Moreover, at least two more detailed conclusions could be drawn from these analyses.

Patterns of performance associated with dyslexia (word decoding impairments), as well as the simple view of reading (Gough and Tunmer 1986), would suggest that differences in word decoding should contribute to differences in reading outcomes (e.g., Perfetti et al. 2005; Scarborough 2009). Indeed, a subset of the students with HFASD in this study demonstrated word decoding impairments, as has been the case in previous studies (Gabig 2010; Nation et al. 2006; Newman et al. 2007; White et al. 2006). However, when considered in the context of other aspects of language development, word recognition abilities do not account for a significant proportion of unique variance in reading comprehension in the HFASD students in the study. Furthermore, the correlation between word recognition abilities and structural language is significant, reflecting the important association between structural language skills and word reading and decoding abilities for children with ASD noted in previous research (Lindgren et al. 2009; Norbury and Nation 2011). McIntyre et al. (2017) reported four subgroups of readers in the HFASD sample: approximately 32% of the sample formed a group of average readers, 20% formed a group that demonstrated oral language and reading comprehension impairments alongside adequate reading accuracy skills, and the remaining two subgroups had difficulties with all oral language, reading accuracy, and comprehension measures, but one (14.1%) was more severe than the other (33%). This pattern of data is consistent with the longstanding notion that word recognition and reading comprehension may display greater developmental dissociation in students with HFASD than in other groups of students (Jones et al. 2009; Newman et al. 2007; Ricketts 2011). Like the differences observed between explicit and implicit reading on the QRI, the dissociation between word level processing and text level processing for meaning is likely another factor that, for educators, obscures the identification of developmental disturbances in reading comprehension in many students with HFASD.

The pattern of data in Fig. 3 also indicates that although variation in ASD-specific characteristics exhibited a non-significant association with reading comprehension in the HFASD sample, this association was mediated by variance in language measures. While structural language did not demonstrate a statistically significant direct association with reading comprehension in the final model, we did observe an expected, negative relation to ASD symptoms (Eigsti et al. 2011; Tager-Flusberg 2006) and a positive relation to performance on the higher order language measures. However, the mediating effects between ASD-specific characteristics and reading comprehension are primarily associated with higher order language, which reflected inference, narrative recall, and sentence-level processing abilities. When the latent measure of these higher order language abilities is not included in the model, ASD symptoms displayed a significant direct association with reading comprehension, even when considering covariance in structural language and reading accuracy abilities. Thus, a specific dimension of language, rather than all facets of language, appears to play a critical role in the connection between the social-communication phenotype of HFASD children and reading comprehension in this study.

The higher order language latent construct in this study may be validly perceived to be a measure of domain general cognitive factors that are involved in more advanced reading comprehension. In this study, these include inferential cognitive processes, measure of the ability to use sentence context (i.e., global coherence) to interpret word meaning, and the cognitive capacity to organize episodic recall of a text into an accurate or logical sequential (i.e., narrative) structure. The observation that this specific set of linguistic/cognitive measures mediated the relation between differences in ASD-specific characteristics and reading comprehension provides some of the strongest evidence to date that facets of the cognitive phenotype of ASD are specific to risk for reading comprehension disturbance in HFASD students.

An important reciprocal notion here is that effective interventions for reading comprehension development for HFASD students may stimulate the growth and development of abilities in cognitive dimensions that are often impaired in school-aged children with ASD. One illustration of this idea is provided by studies that indicate reading development may have a positive impact on social cognitive abilities (Dyer et al. 2000; Kidd and Castano 2013). Moreover, contemporary reading comprehension interventions are often designed to improve many areas of language and cognition that are often problematic for students with ASD. For example, one approach to reading comprehension instruction for elementary school children is a reciprocal teaching format that promotes student to student communication and social interaction while also focusing weeks of its curriculum on improving each of the following cognitive abilities: making connections to background knowledge, organizing narrative story elements and retelling, asking questions, making inferences, monitoring meaning, as well as several others (Solari and Gerber 2008). It seems plausible that interventions of this type may provide a foundation for future ASD intervention research. They offer the possibility of a targeted approach to intervention for academic achievement that fits well with the curriculum and expertise of regular education classrooms, and may have a cascading positive impact on the cognitive, and perhaps social-cognitive, development of school-aged children with ASD.

Study Limitations

The sample size in this study was relatively large for a low-incidence developmental disability such as ASD. However, the heterogeneity of development in ASD is also substantial. Thus, even larger samples of elementary and secondary students will be required in future studies to more fully understand reading development in students with ASD. Furthermore, using SEM with a relatively small sample size of 81 participants with HFASD is a limitation and the analyses should be interpreted conservatively. This report was also limited to concurrent data on the factors involved in reading comprehension. Longitudinal studies will be required to improve our understanding of the factors that influence reading development as well as our understanding of the patterns of development across the school-age years that are characteristic of students with HFASD. In the current study, covariance analyses controlling for IQ were used due to the difficulty of recruiting a representative sample of “higher functioning” school-aged children with ASD that can be matched to a typically developing sample on IQ. However, Miller and Chapman (2001) raised concerns about the limitations of covariance analyses, and future studies should address this potential confound.

The study was also limited in its appraisal of the issue of the specificity of reading comprehension problems in children with HFASD. The study design provided some data on this issue relative to children with high ADHD symptomatology as well those with typical development. However, more research is needed. For example, for both theoretical and practical reasons it would be very informative to conduct research with comparison samples of children with a specific learning disorder with impairment in reading (DSM-5, 2013), or with samples of children with a language disorder (DSM-5, 2013) to more completely appraise the specificity of the reading problems and the unique challenges for children with HFASD; these types of studies have potential to advance targeted interventions specific to the needs to children with HFASD. Additionally, rigorously identifying and grouping by specific language impairments, according to current diagnostic criteria in ASD samples, would extend the research in this regard.

Finally, a degree of common method variance may have played a role in the findings related to the association between the latent higher order language and reading comprehension variables in the HFASD sample. Both the QRI in the latent reading comprehension variable and the higher order language latent variable included measures of inferential ability. Nevertheless, the accurate assessment of reading comprehension proficiency logically includes measures of the capacity to construct inferences from text (Graesser et al. 1994). This common method issue is noteworthy, but does not necessarily confound the interpretation of the data in this study.

Conclusion

In summary, this study indicates that individuals with HFASD perform poorly on reading and language assessments as compared to their same-aged TD and ADHD peers. This finding suggests that the reading difficulties experienced by the HFASD students are different, and perhaps, more severe, on average, than individuals diagnosed with ADHD. The SEM models extended this finding to suggest that higher order language skills explain much of the difficulties in reading for this population of students. These findings have important implications for the design of interventions to improve reading comprehension in individuals with HFASD.

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Author Contributions NM participated in the design and coordination of the study, collected data, oversaw statistical analyses, interpretation, drafting and revision of the manuscript; ES participated in the design of the reading battery and interpretation of statistical analyses, and also contributed to drafting and revision of the manuscript; JG provided statistical support on SEM and group comparison analyses and collaborated on drafting and revision of methods section of manuscript; MS made a contribution to the design and coordination of the study and interpretation of study results; LL participated in the design, recruitment, and coordination of the study and collected data; SN participated in the design and coordination of the study, collected data and managed databases; TO participated in the coordination of the study, oversaw hiring and training of data collectors, and collected data; PM conceived of the study, directed its design and coordination, and participated in the drafting of the manuscript. All authors read and approved the final manuscript.

Compliance with Ethical Standards

Conflict of interest All the authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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