RESEARCH ARTICLE

Comparing Growth in Linguistic Comprehension and Reading Comprehension in School-Aged Children with Autism versus Typically Developing Children

Ryan P. Grimm, Emily J. Solari, Nancy S. McIntyre, Matthew Zajic, and Peter C. Mundy

Many children with autism spectrum disorders (ASD) struggle with reading comprehension. Linguistic comprehension is an important predictor of reading comprehension, especially as children progress through elementary school and later grades. Yet, there is a dearth of research examining longitudinal relations between linguistic comprehensions in school-age children with ASD compared to typically-developing peers (TD). This study compared the developmental trajectories of linguistic and reading comprehension in samples of children with ASD and age-matched TD peers. Both groups were administered measures of linguistic and reading comprehension multiple times over a 30-month period. Latent growth curve modeling demonstrated children with ASD performed at significantly lower levels on both measures at the first timepoint and these deficits persisted across time. Children with ASD exhibited growth in both skills comparable to their TD peers, but this was not sufficient to enable them to eventually achieve at a level similar to the TD group. Due to the wide age range of the sample, age was controlled and displayed significant effects. Findings suggest linguistic comprehension skills are related to reading comprehension in children with ASD, similar to TD peers. Further, intervention in linguistic comprehension skills for children with ASD should begin early and there may be a finite window in which these skills are malleable, in terms of improving reading comprehension skills. ***Autism Res** 2017, 0: 000–000.* © 2017 International Society for Autism Research, Wiley Periodicals, Inc.

Lay Summary: There is relatively little research concerning reading comprehension development in children with ASD and how they compare to TD peers. This study found children with ASD began at lower achievement levels of linguistic comprehension and reading comprehension than TD peers, but the skills developed at a similar rate. Intervening early and raising initial levels of linguistic and reading comprehension may enable children with ASD to perform similarly to TD peers over time.

Keywords: autism spectrum disorder; reading comprehension; linguistic; comprehension; reading development; reading intervention

Introduction

The majority of the research concerning skill acquisition in individuals with autism spectrum disorder (ASD) has focused on non-academic skills such as functional life skills, play, and social skills [Machalicek et al., 2008]. While the literature base on academic skill development in school-aged children with ASD is growing [Simpson & Myles, 2016], there remains a dearth of research examining the development of reading comprehension and its component skills in this population. Successful reading comprehension undergirds success across all academic content areas and poor reading comprehension has been linked to later deleterious outcomes such as conduct problems and school dropout [Connor, Alberto, Compton, & O'connor, 2014]. Many children with ASD are enrolled in regular education classrooms [de Bruin, Deppeler, Moore, & Diamond, 2013; Fleury et al., 2014] and are therefore expected to learn and access information from the general education curriculum. There is evidence to suggest that reading difficulties in school-aged children with ASD may be related to diagnostic status and symptom severity [Åsberg, Kopp, Berg-Kelly, & Gillberg, 2010; Estes, Rivera, Bryan, Cali, & Dawson, 2011; Jones et al., 2009; McIntyre et al., 2017; Norbury & Nation, 2011; Ricketts, Jones, Happé, & Charman, 2013]. Thus, the development of reading comprehension and its component skills in children with ASD may differ from that of typically developing (TD) children, and it is possible that students with ASD may not be receiving maximal benefit from instructional methods primarily targeting TD

From the Reading and Academic Development Center, University of California, Davis (R.P.G., N.S.M., M.Z.); MIND Institute, Reading and Academic Development Center, University of California, Davis (E.J.S., P.C.M.)
Received July 11, 2017; accepted for publication December 06, 2017
Address for correspondence and reprints: Ryan P. Grimm, Reading and Academic Development Center, School of Education, University of California, Davis, 1 Shields Ave., Davis, CA 95616. E-mail: rpgrimm@ucdavis.edu
Published online 00 Month 2017 in Wiley Online Library (wileyonlinelibrary.com)
DOI: 10.1002/aur.1914

students. This study compares the development of reading comprehension and one of its subcomponent skills, linguistic comprehension, between school-age children with ASD and TD children in order to examine if differential reading attainment and growth are detected between ASD and TD students. Findings from this study have potential to impact treatment protocols for targeted reading instruction for students with ASD.

The Role of Decoding and Linguistic Comprehension in Reading Comprehension

Reading comprehension has been described as the product of word decoding and linguistic comprehension; both essential to develop the ability to gain meaning from written text [Gough & Tunmer, 1986]. Word reading, or decoding, is an early predictor of reading comprehension. In research with TD students, automaticity of decoding individual graphemes and blending them to form words develops in the early grades; there is evidence to support that this is also true for individuals with ASD who have average IQ [Castles, Crichton, & Prior, 2010; Flores & Ganz, 2009; McIntyre et al., 2017]. A second subcomponent skill of reading comprehension, in late elementary and beyond, is the ability to comprehend oral language, or linguistic comprehension [Nation & Snowling, 2004; Ouellette & Beers, 2010]. Linguistic comprehension skills are multifaceted and consist of semantic knowledge [Ouellette & Beers, 2010; Perfetti, 2007], syntactic and grammar knowledge [Cain & Oakhill, 2006; Nation, Clarke, Marshall, & Durand, 2004], narrative recall [Leslie & Caldwell, 2009], and incorporating background knowledge when reading [Hannon & Daneman, 2001] to generate inferences. An important developmental shift occurs specific to linguistic comprehension, in which it becomes an increasingly more important in the prediction of reading comprehension as children progress through school [Hoover & Gough, 1990; Kershaw & Schatschneider, 2012]. As children's texts become more complex, variance in linguistic comprehension skills becomes a stronger predictor of reading comprehension. There are two potential explanations for this. First, fewer cognitive resources need to be dedicated to decoding individual words. Second, as the texts that students engage in become more complex they require greater proficiency in the facets of linguistic comprehension.

Decoding, Linguistic Comprehension and Reading Comprehension in Samples with ASD

Theories of reading comprehension development highlight the contribution of linguistic comprehension to reading comprehension as students mature. Extant research suggests linguistic comprehension makes important contributions to reading comprehension in samples of students with ASD. The Simple View of Reading [Gough & Tunmer, 1986; Hoover & Gough, 1990] theorizes that reading comprehension is the result of a multiplicative interaction between word reading and linguistic comprehension. Perfetti, Landi, and Oakhill [2005] proposed a reading comprehension framework and reviewed research showing the importance of specific aspects of linguistic comprehension to reading comprehension, as well as higher-order processes such as generating inferences. A study by Norbury and Nation [2011] compared the contributions of word reading and linguistic comprehension to reading comprehension. These authors examined a sample of adolescents (aged 14–15) with ASD (with and without language impairment) and a comparison sample of TD children. Using regression analyses, the authors concluded that linguistic comprehension deficits were strongly linked to reading comprehension difficulties among the adolescents with ASD, which parallels results found in studies with non-ASD samples [Clarke, Snowling, Truelove, & Hulme, 2010; Kershaw & Schatschneider, 2012]. Norbury and Nation [2011] also examined ASD diagnostic status as it related to a measure of inferencing, a component of linguistic comprehension [Kim, 2016]. They found diagnostic status predicted an additional 10% of variance in inferencing after controlling for word-level reading and an oral language composite. They theorized that the functional relation between inferencing skills and reading comprehension in children with ASD may differ from that of TD children. Other studies have also found differences in the inferencing skills of readers with ASD compared to TD readers [Jolliffe & Baron-Cohen, 1999a,b].

There are also studies demonstrating conflicting results. For example, Saldaña and Frith [2007] found differences in reading comprehension between adolescents with ASD and TD adolescents, but these were not attributable to inferences; they found both groups were able to activate world knowledge to generate inferences. However, they measured inferencing skills by the response time to answer a question based on activation of world knowledge. A faster response time indicated world knowledge was activated. Operationalizing inferencing skills in this manner may explain differences with the prior studies that measured inferencing skills with explicit questions. Tirado and Saldaña [2016] provided a more nuanced examination of inferencing skills among adolescent groups of readers with ASD, poor comprehension, and TD. First, they presented participants with passages containing target phrases that were or were not coherent with the rest of the passage. Faster reading time of coherent target passages indicated activation of inferencing skills. They found ASD and TD individuals performed similarly when inferencing skills were measured in this fashion. However, the ASD group performed significantly worse than both the TD group and poor comprehenders when presented with explicit questions regarding inferences. This led the authors to conclude adolescents with ASD are able to produce inferences similarly to TD children, but experience difficulty applying this to answering inferential questions. Oral language competence may also be associated with inferencing skills and help explain performance on some inference tasks. Lucas and Norbury [2015] found that vocabulary and verbal working memory, not ASD symptomatology, predicted inference skill in a sample of children with ASD and those with TD.

The studies cited above examining linguistic comprehension, inferencing, and reading comprehension were cross-sectional, and less is known about the rate of development of linguistic comprehension skills in children with ASD when compared with TD children. There is also a dearth of research examining the longitudinal relations between linguistic comprehension and reading comprehension in children with ASD. Additionally, many of the studies reported wide variation in participants' scores, which may be attributable to age, given evidence of the dynamic nature of linguistic comprehension skills with regard to reading comprehension [Gough & Tunmer, 1986; Kershaw & Schatschneider, 2012]. A lack of attention to age may have biased results and is one potential explanation for conflicting results. The present study builds upon these works by longitudinally examining higher-order linguistic comprehension skills (including inferencing) and reading comprehension measures commensurate with a given participant's age. Furthermore, this study presents data from a wide age range of school-aged children, but controls for age at each timepoint, providing a robust picture of linguistic comprehension and reading comprehension development over time.

The Present Study

Educational practitioners design interventions based on the current needs of their students given their students' individual histories and the future learning goals. This necessitates longitudinal empirical evidence that incorporates age appropriate measures and is sensitive to a student's current level of functioning. This longitudinal study examined the development of linguistic and reading comprehension skills in a sample of 8–16-year-old students with ASD, and followed them for 3 years, at 15-month intervals for a total of 30 months (15 months between year 1 and year 2; 15 months between year 2 and year 3). Linguistic and reading comprehension skill developments were compared to a sample of age-matched TD controls.

Research Questions

This study had three research questions: (a) What were the developmental trajectories of linguistic comprehension and reading comprehension skills for the samples of school-aged children with ASD and TD peers?, (b) Were there significant differences in linguistic comprehension and reading comprehension developmental trajectories between the subgroups?, and (c) How did the relations between the developmental trajectories of linguistic and reading comprehension differ between the subgroups of school-aged children with ASD and TD?

Methods

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. This study recruited 84 children, aged 8–16, at the first data collection timepoint, who had a diagnosis of ASD, and 44 age matched Typically Developing (TD) students. Due to missing data (see Data Analysis Plan below), the final analytic sample consisted of 65 children with ASD and 37 TD students. 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 ASD sample 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, 2011]; therefore, henceforth, we call the sample for this study higher functioning ASD (HFASD). Students in the HFASD sample exceeded parent report criterion scores on a combination of the Autism Symptom Screening Questionnaire [ASSQ; Ehlers, Gillberg, & Wing, 1999], the Social Communication Questionnaire, Lifetime version [SCQ; Rutter, Bailey, & Lord, 2003], and the Social Responsiveness Scale [SRS; Constantino & Gruber, 2005]. To be included in the TD sample, subjects did not meet criteria for ASD on any parent report measure. Exclusionary criteria 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 ($n = 55$) to girls ($n = 10$) in the HFASD sample,

Table 1. Demographic and Diagnostic Information for HFASD and TD Groups Collected at Timepoint 1

	HFASD			TD					
Variable	*M*	*SD*	%	*M*	*SD*	%	*t*	*P*	*d*
% Male			84.6			64.9			
Ethnicity									
Latino/a			10.8			0.0			
Asian			3.1			2.7			
Caucasian			66.2			78.4			
Decline to State			3.1			0.00			
Other			3.1			2.7			
Mixed			13.8			16.2			
Mother's Education Level									
Some High School			1.5			0.00			
Completed High School			3.1			0.00			
Some College			26.2			16.2			
Completed College			29.2			43.2			
Some Graduate School			7.7			5.4			
Completed Graduate School			30.8			29.7			
Decline to State			1.5			5.4			
IQ									
VIQ	95.45	15.59		110.54	14.53		4.82	<0.001	3.89
PIQ	101.97	16.44		117.22	15.43		4.60	<0.001	3.82
FIQ	98.34	14.91		115.30	13.63		5.69	<0.001	4.49
ADOS-2									
Social Affect	8.61	3.38		N/A	N/A				
RRB	2.48	1.27		N/A	N/A				
ADOS-2 Total	11.03	3.68		N/A	N/A				
SCQ Lifetime Total	21.23	7.37		2.43	2.13		19.22	<0.001	−8.63
ASSQ	18.68	5.66		1.97	2.88		19.72	<0.001	−8.09
SRS	81.63	10.83		45.05	9.03		17.30	<0.001	−11.61

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 = Austim Symptom Screening Questionnaire, total raw score; SRS = Social Responsiveness Scale, T-scores. ****P* < 0.001.

approximately 5:1, is similar to national prevalence rates [Christensen et al., 2016]. There were $n = 24$ boys and $n = 13$ girls in the TD sample. A chi-square test showed the proportions of boys and girls were significantly different between the HFASD and TD samples (χ^2 [1, $N = 102$] = 5.27). Table 1 presents demographic and diagnostic data for both samples.

Measures and Procedures

Members of a trained research group in a university-based child assessment laboratory collected the data reported here during two 2.5-hr sessions within a 2-week interval. Participants with a community ASD diagnosis were administered the ADOS-2 at their first visit. The ADOS-2 requires 40–45 min to administer. Reading and linguistic comprehension measures were administered at each of three time points at 15-month intervals.

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, Risi, Pickles, & Lord, 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]. Ehlers et al. [1999] suggest a cut-off score of 19 on the parent rating version as identifying likely ASD cases. 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. A cut-off score of 15 is recommended by the authors as an indication of possible ASD diagnosis. SCQ scores have been reported to strongly correlated with corresponding ADI-R scores, $r = .55$ to $.71$, $P < 0005$, $n = 200$ [Rutter et al., 2003]. The SRS [Constantino & 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 et al., 2004]. T-scores between 60 and 75 indicate deficiencies in reciprocal social behavior in the mild to moderate range. T-scores above 75 are in the severe range and are strongly associated with an ASD diagnosis.

Cognition. The Wechsler Abbreviated Scale of Intelligence [WASI-2; Wechsler, 2011] provided an estimate of nonverbal and verbal cognitive ability and was administered during participants' first study visit. 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.

Linguistic comprehension. The Auditory Reasoning subtest of the Test of Auditory Processing Skills, Third Edition [TAPS-3; Martin & Brownwell, 2005] was designed to tap higher-order linguistic processing related to making inferences and understanding implied meanings or idioms. An age-normed scaled score ($M = 10$, $SD = 3$) was calculated. Participants heard short vignettes and then were asked to respond to one question for each vignette. Cronbach's alpha from our study (.87) was generally consistent with publisher reported alphas [alphas = .91–.96; Martin & Brownwell, 2005].

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.

Reading accuracy. This measure was not included in analyses, but is included here to provide readers with descriptive information regarding the sample's reading skills. The Accuracy score from the GORT-5 is provided as a measure of this. Participants read passages of increasing length and difficulty. The accuracy score is based on the number of deviations from print the participant made while reading. Deviations from print include words read incorrectly, mispronunciations, omissions, substitutions, self-corrections, insertions or repetitions, words that needed to be provided to the participant, and skipped lines. Cronbach's alpha is reported as ranging from .86 to .94 in the normative sample and .93 in the ASD sample.

Data Analysis Plan

This study used latent growth curve modeling (LGC) to examine and compare the development of linguistic and reading comprehension in subgroups of school-aged children with ASD and TD children across three timepoints. Models were conducted in M*plus* 7.4 [Muthén & Muthén, 1998–1998] using full information maximum likelihood estimation. This estimator allowed participants to be included as long as they contained data on at least one of the linguistic or reading comprehension variables for at least one of the timepoints. This estimator excludes participants if they are missing data on any of the age covariates. This study used a flexible approach referred to as a latent basis model [McArdle & Epstein, 1987] or a level-shape model [Raykov & Marcoulides, 2006]. This approach freely estimated the shape of the linguistic and reading comprehension growth trajectories rather than imposing constrained trajectories, such as linear or quadratic shapes. The primary parameters of interest in LGC are latent intercept and slope factors. In this study, the intercept represents the average linguistic and reading comprehension scores at the first timepoint for each group. Raw scores were used as the use of standard scores can mask growth. For example, students may be making progress, but if they do not progress faster relative to their peers, their growth will appear flat when examining standard scores. The slope represents the average total amount of change in each set of variables across all three timepoints for each group. We set the loading for the first timepoint to 0, the loading for the second timepoint was freely estimated, and the loading for the third timepoint was set to 1. Since the loading for the second timepoint was freely estimated, this value represents the proportion of overall change that occurred between the first and second timepoints. Setting the time scores for the first and third timepoints to zero and one, respectively, defined the values of the

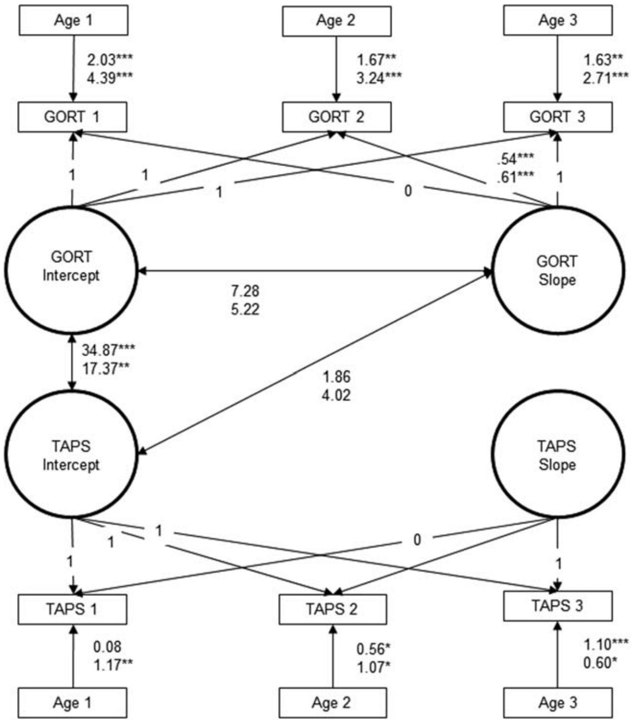

Figure 1. Conceptual diagram of the LGC model for both the HFASD and TD groups with unstandardized estimates. Estimates for the HFASD group are above estimates for the TD group. Parameters with a single estimate were constrained to equality across groups. TAPS = Test of Auditory Processing Skills Auditory Reasoning subtest; GORT = Gray Oral Reading Test Comprehension. $*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

slope factors as the total amount of change in each set of variables.

Though multiple latent growth curve models were fit with varying parameter specifications, only the final model is presented due to space restrictions. A conceptual diagram is shown in Figure 1. The intercept and slope factors for linguistic and reading comprehension are represented by circles. The arrows pointing from the circles to the GORT and TAPS variables (in rectangles) indicate the factors are measured by the observed variables. The arrows pointing from the age variables to the GORT and TAPS variables indicates regressions of GORT and TAPS on age, thereby controlling for age at each timepoint. In multiple group modeling, models are fit to each group separately, but simultaneously, to enable direct comparisons of the parameter estimates across groups. The parallel process aspect allowed us to model growth in linguistic comprehension and reading comprehension simultaneously. Finally, equality constraints were imposed to test for significant differences among the intercept and slope estimates across groups.

We used commonly employed fit statistics to judge the adequacy of the models. Specifically, we examined the chi-square goodness of fit test, root-mean-square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), and the standardized root mean square residual (SRMR). Based on recommendations by Hu and Bentler [1999], good fit was indicated by a non-significant chi-square value, RMSEA and SRMR values below .06 (values of .08 or below indicated adequate fit), and CFI and TLI values greater than .95. The chi-square fit statistic was given preference over the other fit statistics because it is a measure of absolute fit of the model to the data while the other fit indexes are measures of approximate fit.

Results

Descriptive Statistics

Descriptive statistics disaggregated by group are presented in Table 2 along with *t*-tests comparing the means of all observed variables. We accounted for multiple comparisons by employing a Bonferroni correction and used a *P*-value of 0.006 to indicate statistical significance. All mean comparisons for the TAPS and GORT comprehension variables were statistically significant at $P < 0.001$ for both raw and standard scores. Additionally, Cohen's *D* shows large effect sizes. The TD group scored significantly higher on all linguistic and reading comprehension measures compared to the children with ASD across time. There were also significant differences on all raw GORT accuracy scores, but the groups were not significantly different on the standard score at timepoint 2 ($P = 0.08$). However, Cohen's *d* showed that all differences had large effect sizes, including the non-significant difference. Thus, all differences appear to be, at least, clinically meaningful. There were no significant differences in age at any timepoint.

LGC Specification

A series of LGC models were fit with varying parameter constraints applied to the intercept and growth factors as well as the variance (and residual variance) and covariance specifications for the observed variables (i.e., linguistic and reading comprehension variables). With each iteration, optimal fit statistics were recorded and compared to arrive at the optimal model specifications for each subgroup. The most flexible approach—the latent basis model—provided the best fit to the data. Potential model constraints were considered by examining variances and residual variances to make the model more parsimonious given the small sample sizes of each group. Initially, the TAPS slope variance for the HFASD group caused a modeling problem, but was non-significant. The TAPS slope did not significantly covary with the intercept factor of either GORT or TAPS and it did not significantly covary with the GORT slope for either group. Therefore, the slope variance for the

Table 2. Descriptive Statistics and *t*-tests for the Children with ASD and TD Subgroups

		Raw Scores						
		ASD		TD				
	Variable	*M*	*SD*	*M*	*SD*	*t*	*P*	*d*
Raw Scores	AGE 1	11.26	2.17	11.68	2.26	1.04	0.302	0.28
	AGE 2	12.54	2.13	12.78	2.30	0.54	0.591	0.16
	AGE 3	13.79	2.16	14.05	2.37	0.57	0.570	0.17
	TAPS 1	6.91	4.89	13.32	6.65	5.13	<0.001	2.67
	TAPS 2	8.95	5.80	15.46	6.68	5.15	<0.001	2.61
	TAPS 3	8.77	6.01	16.86	7.22	6.08	<0.001	3.15
	GORTc 1	25.51	11.63	37.86	13.16	4.92	<0.001	3.51
	GORTc 2	29.83	12.49	43.68	11.48	5.54	<0.001	4.00
	GORTc 3	33.48	13.05	47.35	11.35	5.41	<0.001	3.97
	GORTa 1	26.92	13.49	40.16	17.70	4.25	<0.001	3.35
	GORTa 2	31.91	13.07	48.65	17.23	5.40	<0.001	4.30
	GORTa 3	37.05	15.91	57.97	26.31	5.01	<0.001	4.55
Standard Scores	TAPS 1	5.71	2.93	8.65	2.44	5.17	<0.001	1.79
	TAPS 2	5.80	2.66	8.97	2.87	5.62	<0.001	1.91
	TAPS 3	5.25	2.76	8.46	2.86	5.58	<0.001	1.91
	GORTc 1	7.14	2.84	10.27	2.39	5.66	<0.001	1.94
	GORTc 2	7.35	2.99	10.95	2.48	6.20	<0.001	2.18
	GORTc 3	7.62	3.03	10.91	2.55	5.59	<0.001	1.97
	GORTa 1	7.89	2.63	10.86	3.48	4.86	<0.001	1.70
	GORTa 2	9.45	8.79	12.14	3.68	1.77	0.080	1.08
	GORTa 3	8.60	3.03	12.54	3.24	6.16	<0.001	2.23

Note. TAPS = Test of Auditory Processing Skills - Auditory Reasoning Subtest; GORTc = Gray Oral Reading Test Reading Comprehension score; GORTa = Gray Oral Reading Test Accuracy score. ***$P < 0.001$.

HFASD group was constrained to zero. Various equality constraints of the residual variances of observed GORT and TAPS variables within groups were examined, however, these constraints degraded model fit to unacceptable levels and were not included in the final model.

The final model consisted of a latent basis specification in which the loading for the first timepoint was set to zero, the second timepoint was freely estimated, and the loading for the third timepoint was set to one. Participants' age was treated as a time-varying covariate by regressing each of the observed GORT and TAPS variables on age for each corresponding timepoint. The variance of the TAPS slope factor was constrained to zero in each group. The fit statistics of the final model were: $\chi^2 = (42, \quad n = 102) \quad 56.24, \quad P = 0.07;$ RMSEA = .08; SRMR = .08; CFI = .97; TLI = .96.

LGC for the HFASD Group

The intercept and slope results for each group are presented in Table 3, while the results for the loadings, covariates, and intercept and slope covariances are presented in Figure 1. Results in Table 3 indicate children in the HFASD group exhibited significant growth in both linguistic and reading comprehension over the three timepoints. There was also significant variation in the average score of both GORT and TAPS at the first timepoint, but not in the growth trajectory of either variable.

In Figure 1, results for the HFASD group are presented above those for the TD group. Instances in which only one value is provided represent parameters constrained to equality across groups for modeling purposes. The loading of .54 for GORT at the second timepoint indicates the HFASD group achieved approximately half of their progress by the second timepoint. However, concerning TAPS, the HFASD group peaked at the second timepoint and decreased slightly by the third timepoint. There was significant covariance between the GORT and TAPS intercepts, but not between the GORT intercept and slope, nor the TAPS intercept and GORT slope. Age was significantly related to GORT at each timepoint, with older children scoring higher. However, this was only true of TAPS at the second timepoint; moreover, for each timepoint, a 1-year increase in age was associated with approximately one-half or one-tenth of a point increase in TAPS score.

LGC for the TD Group

As seen in Table 3, the TD group scored significantly higher on the intercept parameters for both GORT and TAPS compared to the HFASD group. The TD group also exhibited slightly steeper slopes than the HFASD group, but these were not significantly different. Figure 2 provides plots comparing the estimated trajectories of GORT and TAPS of each group. There was also

Table 3. LGC Estimates for the HFASD and TD Groups

Parameter	HFASD	TD	Difference
Growth parameters			
GORT intercept	25.51***	37.86***	12.35***
GORT slope	7.97***	9.49***	1.52
TAPS intercept	6.91***	13.32***	6.42***
TAPS slope	1.86**	3.54**	1.68
Variance parameters			
GORT intercept	96.20***	47.01**	
GORT slope	12.41	7.05	
TAPS intercept	13.72***	10.46*	
TAPS slope[a]	N/A	N/A	

Note. TAPS = Test of Auditory Processing Skills Auditory Reasoning subtest; GORT = Gray Oral Reading Test Comprehension. [a]Constrained to zero. *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

significant variation in the intercepts of both GORT and TAPS, but not the slopes of either variable.

The loadings for the second timepoint for each variable in Figure 1 show the TD group made approximately 60% of their total growth between the first and second timepoints for each variable. The GORT and TAPS intercepts covaried significantly, but neither intercept significantly covaried with the GORT slope. Age was significantly associated with GORT at each timepoint, though the magnitude decreased over time. Similarly, age was also significantly associated with TAPS at the first and second timepoints, but was non-significant by the third timepoint.

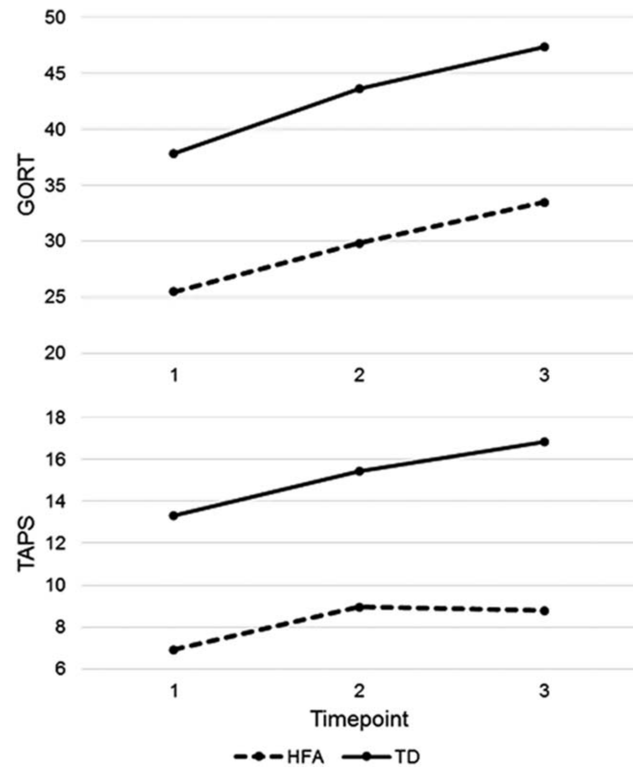

Figure 2. Growth plots of GORT (top) and TAPS (bottom) for the children with ASD and TD groups. TAPS = Test of Auditory Processing Skills Auditory Reasoning subtest; GORT = Gray Oral Reading Test Comprehension.

Discussion

Comparing Developmental Trajectories of the HFASD and TD Groups

This study compared the developmental trajectories of higher-order linguistic comprehension skills and reading comprehension between samples of school-age children with HFASD and TD peers. Regarding the first and second research questions, the shapes of the trajectories for GORT reading comprehension were nearly identical between the HFASD and TD groups. Approximately half of the total growth in reading comprehension occurred between the first and second timepoints. However, the HFASD group performed significantly lower than the TD at the first timepoint and this deficit persisted across time. Unlike reading comprehension, there were different shapes of the linguistic comprehension trajectories for each group. The TD group's trajectory was again characterized by nearly linear development, but the HFASD group's linguistic comprehension peaked at the second timepoint followed by a slight decline at the third timepoint. This supports the findings of Norbury and Nation [2011] who suggested diagnostic factors were related to differences in inferencing skills after accounting for word reading and oral language ability. If ASD diagnosis can be considered a risk factor by itself, it follows that ongoing monitoring of inferencing skills may be needed for some children with HFASD [Lucas & Norbury, 2014]. Interestingly, the present study found no significant differences in the amount of total growth in the two constructs achieved by each group. However, since the HFASD group's intercepts were significantly lower at the first timepoint, their growth was not sufficient to enable them to eventually reach achievement levels comparable to TD peers.

These findings indicate school-age children with HFASD are at risk of struggling with higher-order linguistic comprehension and reading comprehension compared to TD peers. The linguistic comprehension skills of the HFASD group declined at the third timepoint, therefore, early intervention in these skills is essential as there may be a point at which linguistic comprehension skills for students with HFASD may not continue to develop or that intervening at later ages may prove difficult. Though the reading comprehension skills of the HFASD group developed similarly to the TD group, recent research has found students with HFASD may not respond to general education reading curricula [McIntyre et al., 2017; Solari et al., 2017]. This may explain why the HFASD group's reading comprehension skills demonstrated significant growth, but they continued to lag behind the TD group. Thus, interventions targeting reading comprehension skills may need to be designed specifically for students with HFASD to meet their unique needs. For example, these students may require interventions that include components to address social cognition as these difficulties associated with the HFASD phenotype may also contribute to struggling with reading comprehension [Capps, Losh, & Thurber, 2000; McIntyre et al., 2017; Ricketts et al., 2013].

Comparing Relations between Linguistic Comprehension and Reading Comprehension

The relations between the development of linguistic comprehension and reading comprehension were similar across groups. Linguistic and reading comprehensions were significantly related at the first timepoint. But scores at the first timepoint were not significantly related to the rate of growth of either variable and this was true of both groups. This is likely due to the age range of the sample. There was wide variation in both groups at the first timepoint (ages 8–16), which would be expected to produce significant variation in linguistic and reading comprehension scores. However, regardless of age or diagnostic status, all children exhibited similar amounts of growth within each variable. Therefore, scores at the first timepoint did not predict the rate of change across timepoints. This further validates the inclusion of age as a time-varying covariate predicting each of the GORT and TAPS measures.

It is notable that linguistic and reading comprehension scores covaried significantly at the first timepoint for both groups. Previous studies have also identified links between linguistic and reading comprehension among children with HFASD and TD peers [Hoover & Gough, 1990; Kershaw & Schatschneider, 2012; McIntyre et al., 2017; Ricketts et al., 2013]. It is possible that had this study examined each timepoint cross-sectionally, there would have been significant relations between linguistic and reading comprehension, but this would not have provided information enabling the comparison of developmental trajectories. The findings demonstrated children with HFASD developed at a similar rate as the TD group, but was not sufficient to produce similar levels of achievement. It may also be possible that it becomes increasingly difficult to remediate linguistic comprehension skills as HFASD children mature, as evidenced by the slight decline in these scores at the third timepoint. Therefore, intervention should focus on increasing linguistic and reading comprehension skills among children with HFASD in the early grades. If their skills can be raised to a level commensurate with TD peers early in school, then their development may have the potential to continue on a similar trajectory.

Age Effects on Linguistic and Reading Comprehension

While examining the influence of age on each of the GORT and TAPS variables was not originally a research question of this study, there were notable effects. For both the HFASD and TD groups, age was significantly related to all GORT measures. This suggests reading comprehension skills are malleable for students with HFASD across the wide range (8–18) which has potential to inform targeted interventions. Age was only predictive of TAPS at the second timepoint for the HFASD group and only the first two timepoints for the TD group. Thus, there may be a smaller window to intervene in higher-order linguistic comprehension skills—operationalized here as inferences and implied meanings—for children with HFASD as compared to their TD peers. If so, other facets of linguistic comprehension, such as semantic or syntactic skills, have been shown to contribute to reading comprehension in children with HFASD [Norbury & Nation, 2011; Ricketts et al., 2013], and future research should investigate whether these skills are similarly constrained by age.

Out of necessity, many researchers collect data on convenience samples of children with HFASD from a wide age range. However, they do not always account for age in their analyses and this has the potential to bias results. The current findings suggest age should be considered when analyzing data from a wide age range of children with HFASD. This may be especially applicable to measures of academic achievement, which are often expected to provide varying results based on age differences. Accounting for age may provide more accurate and robust results.

Limitations

The primary limitation of this study is likely the small sample sizes of the HFASD and TD groups given that a latent variable modeling technique. However, the nature of LGC requires constraints, which decreases the number of estimable parameters relative to other latent variable modeling techniques. Even with small sample sizes, this study was able to detect significant effects in the intercepts and slopes, which were the primary parameters of interest in this study. Second, we examined higher-order linguistic comprehension and this skill may not have been well-developed in participants toward the lower end of the age range. It may be worth noting that similar analyses using receptive vocabulary were conducted and produced qualitatively similar results, but were a poorer fit to the data. Finally, the linguistic and reading comprehension constructs were each represented by a single variable. It has been documented this approach can underrepresent constructs [e.g., Shadish, Cook, & Campbell, 2002]. Thus, the present findings might have been altered had alternative variables been chosen or had multiple variables been used to represent each construct.

Conclusions and Future Research

The HFASD group achieved at significantly lower levels of linguistic and reading comprehension at the first timepoint compared to the TD group. Though both groups achieved similar rates of growth on both measures, this was not sufficient to enable the HFASD group to eventually match the achievement levels of their TD peers. Linguistic comprehension was related to reading comprehension at the first timepoint, but not the developmental trajectories of either group, which may be due to the large age range. Practitioners should monitor and intervene in both linguistic and reading comprehension skills of children with HFASD in an effort to prevent long-term underachievement. Intervention may need to occur over multiple years as these findings demonstrated significantly lower levels of linguistic and reading comprehension or the HFASD group over a 30-month period.

Future research should investigate whether other samples of children with HFASD follow similar trajectories of linguistic and reading comprehension as the present sample. For example, it may be that language phenotype plays a role such that children with HFASD and stronger language skills may follow a trajectory more similar to the TD sample. Additionally, children with HFASD and a language disorder may follow an entirely different trajectory. Finally, future research that utilizes a wide age range of students with HFASD should factor age into analyses to provide more accurate and robust results.

Acknowledgments

This work was supported by the Institute of Education Sciences through grant R324A120168.

References

Åsberg, J., Kopp, S., Berg-Kelly, K., & Gillberg, C. (2010). Reading comprehension, word decoding and spelling in girls with autism spectrum disorders (ASD) or attention deficit/hyperactivity disorder (AD/HD): Performance and predictors. International Journal of Language & Communication Disorders, 45, 61–71.

Cain, K., & Oakhill, J. (2006). Profiles of children with specific reading comprehension difficulties. British Journal of Educational Psychology, 76, 683–696.

Capps, L., Losh, M., & Thurber, C. (2000). "The frog ate the bug and made his mouth sad": Narrative competence in children with autism. Journal of Abnormal Child Psychology, 28, 193–204.

Castles, A., Crichton, A., & Prior, M. (2010). Developmental dissociations between lexical reading and comprehension: Evidence from two cases of hyperlexia. Cortex, 46, 1238–1247.

Charman, T., & Gotham, K. (2013). Measurement issues: screening and diagnostic instruments for autism spectrum disorders–lessons from research and practice. Child and Adolescent Mental Health, 18, 52–63.

Christensen, D., Baio, J., Van Naarden Braun, K., Bilder, D., Charles, J., Constantino, J., . . .Yeargin-Allsopp, M. (2016). Prevalence and characteristics of autism spectrum disorder among children aged 8 years - Autism and developmental disabilities monitoring network, 11 sites, United States, 2012. MMMR Surveillance Summary, 2016, No. SS-3, 1–23.

Clarke, P.J., Snowling, M.J., Truelove, E., & Hulme, C. (2010). Ameliorating children's reading comprehension difficulties: A randomized controlled trial. Psychological Science, 21, 1106–1116.

Connor, C.M., Alberto, P.A., Compton, D.L., & O'connor, R.E. (2014). Improving reading outcomes for students with or at risk for reading disabilities: A synthesis of the contributions from the Institute of Education Sciences Research Centers (NCSER 2014–3000). Washington, DC: National Center for Special Education Research, Institute of Education Sciences, U.S. Department of Education. Retrieved from http://ies.ed.gov/.

Constantino, J., & Gruber, C. (2005). Social responsiveness scale. Los Angeles, CA: Western Psychological Services.

Constantino, J.N., Gruber, C.P., Davis, S., Hayes, S., Passanante, N., & Przybeck, T. (2004). The factor structure of autistic traits. Journal of Child Psychology and Psychiatry, 45, 719–726.

de Bruin, C.L., Deppeler, J.M., Moore, D.W., & Diamond, N.T. (2013). Public school–based interventions for adolescents and young adults with an autism spectrum disorder: A meta-analysis. Review of Educational Research, 83, 521–550.

Ehlers, S., Gillberg, C., & Wing, L. (1999). A screening questionnaire for Asperger syndrome and other high-functioning autism spectrum disorders in school age children. Journal of Autism and Developmental Disorders, 29, 129–141.

Estes, A., Rivera, V., Bryan, M., Cali, P., & Dawson, G. (2011). Discrepancies between academic achievement and intellectual ability in higher-functioning school-aged children with autism spectrum disorder. Journal of Autism and Developmental Disorders, 41, 1044–1052.

Fleury, V.P., Hedges, S., Hume, K., Browder, D.M., Thompson, J.L., Fallin, K., . . . Vaughn, S. (2014). Addressing the academic needs of adolescents with autism spectrum disorder in secondary education. Remedial and Special Education, 35, 68–79.

Flores, M.M., & Ganz, J.B. (2009). Effects of direct instruction on the reading comprehension of students with autism and developmental disabilities. Education and Training in Developmental Disabilities, 44, 39–53.

Gotham, K., Risi, S., Pickles, A., & Lord, C. (2007). The Autism Diagnostic Observation Schedule: Revised algorithms for

improved diagnostic validity. Journal of Autism and Developmental Disorders, 37, 613–627.
Gotham, K., Risi, S., Pickles, A., & Lord, C. (2008). A replication of the Autism Diagnostic Observation Schedule (ADOS) revised algorithms. Journal of the American Academy of Child & Adolescent Psychiatry, 47, 642–651.
Gough, P.B., & Tunmer, W.E. (1986). Decoding, reading, and reading disability. Remedial and Special Education, 7, 6–10.
Hannon, B., & Daneman, M. (2001). A new tool for measuring and understanding individual differences in the component processes of reading comprehension. Journal of Educational Psychology, 93, 103–128.
Hoover, W.A., & Gough, P.B. (1990). The simple view of reading. Reading and Writing, 2, 127–160.
Hu, L., & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling, 6, 1–55.
Jolliffe, T., & Baron-Cohen, S. (1999a). A test of central coherence theory: Linguistic processing in high-functioning adults with autism or Asperger syndrome: Is local coherence impaired?. Cognition, 71, 149–185.
Jolliffe, T., & Baron-Cohen, S. (1999b). The strange stories test: A replication with high functioning adults with autism or Asperger syndrome. Journal of Autism and Developmental Disorders, 29, 395–406.
Jones, C., Happé, F., Golden, H., Marsden, A., Tregay, J., Simonoff, E., ... Charman, T. (2009). Reading and arithmetic in adolescents with autism spectrum disorders: Peaks and dips in attainment. Neuropsychology, 23, 718–728.
Kadesjö, B., Gillberg, C., & Hagberg, B. (1999). Brief report: autism and Asperger syndrome in seven-year-old children: a total population study. Journal of Autism and Developmental Disorders, 29, 327–331.
Kershaw, S., & Schatschneider, C. (2012). A latent variable approach to the simple view of reading. Reading and Writing, 25, 433–464.
Kim, Y.S.G. (2016). Direct and mediated effects of language and cognitive skills on comprehension of oral narrative texts (listening comprehension) for children. Journal of Experimental Child Psychology, 141, 101–120.
Leslie, L., & Caldwell, J. (2009). 19 formal and informal measures of reading comprehension. In S.E. Israel, & G.G. Duffy (eds), Handbook of research on reading comprehension (pp. 403–427). New York: Routledge.
Lord, C., Rutter, M., DiLavore, P., Risi, S., Gotham, K., & Bishop, S. (2012). Autism diagnostic observation schedule, second edition. Torrance, CA: Western Psychological Services.
Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic interview-revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. Journal of Autism and Developmental Disorders, 24, 659–685.
Lucas, R., & Norbury, C. (2015). Making inferences from text: It's vocabulary that matters. Journal of Speech, Language, and Hearing Research, 58, 1224–1232.
Lucas, R., & Norbury, C.F. (2014). Levels of text comprehension in children with Autism Spectrum Disorders (ASD): The influence of language phenotype. Journal of Autism and Developmental Disorders, 44, 2756–2768.
McArdle, J.J., & Epstein, D. (1987). Latent growth curves within developmental structural equation models. Child Development, 58, 110–133.
McIntyre, N.S., Solari, E.J., Grimm, R.P., Lerro, L.E., Gonzales, J.E., & Mundy, P.C. (2017). A comprehensive examination of reading heterogeneity in students with high functioning autism: Distinct reading profiles and their relation to autism symptom severity. Journal of Autism and Developmental Disorders, 47, 1086–1101 doi: 10.1007/s10803-017-3029-0.
Machalicek, W., O'reilly, M.F., Beretvas, N., Sigafoos, J., Lancioni, G., Sorrells, A., ... Rispoli, M. (2008). A review of school-based instructional interventions for students with autism spectrum disorders. Research in Autism Spectrum Disorders, 2, 395–416.
Martin, N., & Brownwell, R. (2005). Test of auditory processing skills (3rd ed.). Novato, CA: Academic Therapy Publications.
Muthén, L.K., & Muthén, B.O. (1998–2015). Mplus user's guide (7th ed). Los Angeles, CA: Muthén & Muthén.
Nation, K., & Snowling, M.J. (2004). Beyond phonological skills: Broader language skills contribute to the development of reading. Journal of Research in Reading, 27, 342–356.
Nation, K., Clarke, P., Marshall, C.M., & Durand, M. (2004). Hidden language impairments in children: Parallels between poor reading comprehension and specific language impairment?. Journal of Speech, Language, and Hearing Research, 47, 199–211.
Norbury, C., & Nation, K. (2011). Understanding variability in reading comprehension in adolescents with autism spectrum disorders: Interaction with language status and decoding skill. Scientific Studies of Reading, 15, 191–210.
Ouellette, G., & Beers, A. (2010). A not-so-simple view of reading: How oral vocabulary and visual-word recognition complicate the story. Reading and Writing, 23, 189–208.
Perfetti, C. (2007). Reading ability: Lexical quality to comprehension. Scientific Studies of Reading, 11, 357–383.
Perfetti, C.A., Landi, N., & Oakhill, J.V. (2005). The acquisition of reading comprehension skill. In M. J. Snowling, M. S. Seidenberg, & C. Hulme (Eds.), The science of reading: Handbook of reading research. Oxford: Blackwell.
Raykov, T., & Marcoulides, G.A. (2006). A first course in structural equation modeling. Mahwah, NJ: Erlbaum
Ricketts, J., Jones, C.R., Happé, F., & Charman, T. (2013). Reading comprehension in autism spectrum disorders: The role of oral language and social functioning. Journal of Autism and Developmental Disorders, 43, 807–816.
Rutter, M., Bailey, A., & Lord, C. (2003) The social communication questionnaire. Los Angeles, CA: Western Psychological Services.
Saldaña, D., & Frith, U. (2007). Do readers with autism make bridging inferences from world knowledge?. Journal of Experimental Child Psychology, 96, 310–319.
Shadish, W.R., Cook, T.D., & Campbell, D.T. (2002). Experimental and quasi-experimental designs for generalized causal inference. Boston: Houghton-Mifflin.
Simpson, R.L., & Myles, B.S. (2016). Educating Children and Youth with Autism: Strategies for Effective Practice, 3rd ed. Austin, TX: Pro-Ed.

Solari, E.J., McIntyre, N.S., Grimm, R.P., Swain-Lerro, L., Zajic, M., & Mundy, P.C. (2017).The relation between text reading fluency and reading comprehension for students with autism spectrum disorders. Research in Autism Spectrum Disorders, 41–42, 8–19.

Tirado, M.J., & Saldaña, D. (2016). Readers with autism can produce inferences, but they cannot answer inferential questions. Journal of Autism and Developmental Disorders, 46, 1025–1037.

Wechsler, D. (2011). Wechsler abbreviated scale of intelligence (2nd ed.). San Antonio, TX: NCS Pearson.

Wiederholt, J., & Bryant, B. (2012). Gray oral reading tests - fifth edition. Austin, TX: Pro-Ed.