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Research Article

Sentence Comprehension in Boys With Autism Spectrum Disorder

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Purpose: Previous research has suggested that language comprehension might be particularly impaired in children with autism spectrum disorder (ASD), but this profile has been only broadly characterized. In the current study, the authors examined sentence comprehension in school-age boys with ASD, including a subgroup with intellectual disability (ID), with particular attention paid to errors that might differentiate between lexically and syntactically based difficulties.
Method: Participants were boys with ASD (n = 45, ages 4–11 years) and younger typically developing boys (n = 45, ages 2–6 years). Comprehension was assessed with the Test for Reception of Grammar—Version 2 (Bishop, 2003). Error types were analyzed for a subset of items.
Results: Boys with ASD did not differ from younger typically developing boys matched on receptive vocabulary in overall sentence comprehension on the Test for Reception of Grammar—Version 2 or the number of lexical errors committed. In contrast, the subgroup of boys with ASD and ID (n = 16) had poorer overall performance and committed more lexical errors than younger typically developing boys matched on nonverbal cognition.
Conclusions: On average, comprehension was delayed in school-age boys with ASD but not beyond receptive vocabulary expectations. Boys with ASD and ID, however, had a weakness in sentence comprehension beyond nonverbal cognitive expectations.

Key Words: autism, grammar, syntax, receptive language, intellectual disability

Delayed language development is often the first symptom of autism spectrum disorder (ASD) noticed by caregivers and is an associated feature supporting an ASD diagnosis (American Psychiatric Association, 2013; De Giacomo & Fombonne, 1998). Relative to social and behavioral impairments, however, little research has addressed the strengths and weaknesses that define the language profile associated with ASD. Previous studies suggest that language comprehension might be particularly impaired in children with ASD (Hudry et al., 2010). Given the importance of language comprehension for continued development in adaptive and academic skills (Dockrell, Lindsay, & Palikara, 2011; Park, Yelland, Taffe, & Gray, 2012), it is important to determine the nature and sources of greatest challenge in language comprehension for children with ASD. Identifying factors that contribute to sentence comprehension performance can also provide insight into the mechanisms underlying the language impairments associated with ASD and point toward intervention targets (Boucher, 2012).

In typical development, vocabulary and syntax are closely linked, such that strengths and weaknesses in one domain can influence the other (Bates, Dale, & Thal, 1995), yet it is unclear how children with ASD are able to make use of lexical information for sentence comprehension (e.g., the extent to which lexical knowledge supports syntactic processing relative to typical development; Eigsti, de Marchena, Schuh, & Kelley, 2011). The current study was designed to assess the comprehension of several key sentence-level grammatical constructions, with the additional goal of delineating the extent to which lexical difficulties contribute to comprehension impairments in children with ASD. One approach to understanding the contributions of lexical knowledge to language development in children with ASD is to examine the comprehension of sentences that vary in the extent to which they tax lexical or syntactic knowledge. In addition, examining the types of errors committed during comprehension could clarify whether children with ASD employ atypical strategies that lead to misinterpretations of sentence meanings (Thomas et al., 2009). These approaches were used in the present research.

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Previous Research on Sentence Comprehension and Related Skills in Children With ASD

Research on sentence comprehension in children with ASD is sparse; however, a few studies have examined related skills, including aspects of syntax and its link to lexical learning. Roberts, Rice, and Tager-Flusberg (2004) found that a subgroup of children with ASD had deficits in both receptive vocabulary and expressive syntactic skills, with poor production of third person singular and past tense finite markers. Eigsti, Bennetto, and Dadlani (2007) identified syntactic deficits in the spontaneous expressive language of young children with ASD relative to children with Down syndrome and children with typical development, who were matched on receptive vocabulary. In addition, Eigsti and Bennetto (2009) found that children with ASD had deficits in grammatical judgment abilities compared to children with typical development, matched on chronological age and IQ. Whether and how these syntactic problems may manifest in sentence comprehension remains to be determined.

One mechanism by which syntactic knowledge is known to support lexical acquisition in typical development is *syntactic bootstrapping,* in which the meaning of a novel verb is inferred, in part, from the sentence frame in which it appears (Gleitman, 1990; Naigles, 1990). Syntactic bootstrapping has been studied in children with ASD. Naigles, Kelty, Jaffery, and Fein (2011) found that 17 young children with ASD displayed syntactic bootstrapping in that they interpreted novel verbs in transitive sentences as having causative meanings. Naigles et al. provided evidence for the presence of abstract syntactic knowledge in children with ASD and demonstrated that the development of vocabulary and syntax comprehension are related in these children, as in typical development. Nonetheless, their study failed to offer clues as to the ways in which vocabulary or syntax affect language comprehension for children with ASD.

Sentence comprehension in children with ASD. Contrasting performance on reversible and nonreversible sentences can yield insight into the relative contributions of lexical and syntactic processing. *Reversible sentences* are ones in which the lexical constituents can play the role of either agent or patient equally well (e.g., "The girl pushes the boy," or vice versa), such that syntactic knowledge of word order constraints must be used to correctly assign thematic roles to the subject and object when discerning the meaning of the sentence. In *nonreversible sentences* semantic cues alone may be sufficient to scaffold interpretation independently of syntax (e.g., "The mother holds the baby"). For many children with language impairments, comprehension of reversible forms might be uniquely challenging (Oakes, Kover, & Abbeduto, 2013). Oakes et al. (2013) found that adolescents with Fragile X syndrome or Down syndrome had poorer performance than typically developing children matched on nonverbal cognitive ability for reversible subject–verb–object (SVO) sentences (e.g., "The boy chased the girl"), but not for nonreversible four-element sentences (e.g., sentences with a compound object composed of two inanimate nouns, as in "The boy threw the ball and the glove"), suggesting that they had special difficulty using syntactic, but not lexical, cues. Assessment of nonreversible and reversible sentences in children with ASD could likewise indicate whether lexical or syntactic difficulties lead to problems in sentence comprehension.

Early work on the sentence comprehension abilities of children with autism pointed to impairments over and above receptive vocabulary level. Prior and Hall (1979) reported that the comprehension of nonreversible sentences by children with autism was poorer than that of typically developing children matched on receptive vocabulary. Children with autism also tended to have poorer comprehension on reversible sentences than expected on the basis of their receptive language (Paul, Fischer, & Cohen, 1988; Tager-Flusberg, 1981). It is interesting, however, that children with autism have demonstrated the requisite syntactic knowledge of word order but failed to make use of semantic strategies (i.e., not attaining better performance for probable vs. neutral events; "The mom holds the baby" vs. "The duck chases the goose"), indicating that deficits in lexical knowledge might be contributing to sentence comprehension difficulties (Paul et al., 1988; Tager-Flusberg, 1981). In a similar vein, Swensen, Kelley, Fein, and Naigles (2007) found that 10 boys with ASD could interpret reversible transitive SVO sentences in an eye gaze paradigm, again documenting the use of word order as a comprehension strategy. On the whole, these studies suggest that sentence comprehension is a challenge for children with ASD but that the underlying impairment may be lexical rather than syntactic.

Children with ASD and intellectual disability. The limited research on sentence comprehension in children with ASD has largely focused on individuals with intellectual abilities in the typical range. Moreover, the few studies that have examined individuals with ASD and comorbid intellectual disability (ID; i.e., an IQ of 70 or below) have failed to take nonverbal cognitive ability into account, despite the fact that it is an important correlate of language ability in children with ASD (Ellis Weismer, Lord, & Esler, 2010). These practices have led to a critical gap in the literature because about 25% of children with ASD have a co-occurring ID (Chakrabarti & Fombonne, 2001; Kim et al., 2011). In addition, scholars have estimated that 8%–28% of children with ID also have ASD (Bryson, Bradley, Thompson, & Wainwright, 2008; De Bildt et al., 2004). The little research that does exist suggests that language skills in children with ASD and ID tend to be lower than nonverbal cognitive expectations, with greater deficits in receptive than expressive language (Ellis Weismer et al., 2010; Maljaars, Noens, Scholte, & van Berckelaer-Onnes, 2012). In the present study, therefore, we examined sentence comprehension in a heterogeneous sample of boys with ASD and separately studied the performance of the subgroup of boys with ASD whose cognitive abilities were in the ID range.

Current Study

We examined lexical and syntactic aspects of sentence comprehension by testing overall sentence comprehension;

the number of lexical errors made during sentence comprehension; and the types of errors committed for nonreversible and reversible SVO sentences, which differ in the extent to which syntactic knowledge is necessary for successful comprehension. Based only on a small subset of items, this latter analysis was exploratory in nature with the goal of providing some initial evidence as to whether a profile of relative weakness in lexical or syntactic knowledge might better characterize children with ASD. We compared the performance of a relatively large, heterogeneous sample of school-age boys with ASD to typically developing boys matched on receptive vocabulary. Only boys were included because of the increased prevalence of ASD in males and the desire to match the groups on gender. Given the dearth of research on sentence comprehension in children with ASD and ID, we also separately report on a subgroup of participants with ASD and ID. In summary, we addressed the following four research questions:

> *Research Question 1*: Do boys with ASD have deficits in sentence comprehension relative to boys with typical development matched on receptive vocabulary ability?
> *Research Question 2*: Do boys with ASD make more lexical errors than boys with typical development?
> *Research Question 3*: Are differences in error patterns for boys with ASD and boys with typical development displayed on nonreversible and reversible sentences?
> *Research Question 4*: How do boys with ASD and ID differ from boys with typical development matched on nonverbal cognitive ability in their sentence comprehension?

Method

Participants

Participants (45 boys with ASD, ages 4–11 years, and 45 boys with typical development, ages 2–6 years) were selected from a larger study on word learning and language development in boys with neurodevelopmental disorders (Kover, McDuffie, Hagerman, & Abbeduto, 2013; McDuffie, Kover, Hagerman, & Abbeduto, 2013), which included 61 boys with ASD and 59 boys with typical development. Participants with ASD were recruited both nationally and locally to each of two sites (one on the West coast and one in the Midwest) using university recruitment registries, postings to Internet websites and Listservs, magazine advertisements, and postings at conferences and meetings. Participants with typical development were largely recruited locally using university research registries, community postings, flyers at local early childhood centers, and family referrals. All participants were native English speakers and lived with their biological mothers. According to parental report, all participants used speech as their primary means of communication; had a minimum of 10 spoken words; no more than a mild hearing loss; and no uncorrected visual, sensory, or physical impairment that would affect performance. Parents of each participant with ASD provided documentation confirming a clinical or educational community diagnosis of ASD as well as molecular genetic testing ruling out Fragile X syndrome. Parents of participants with typical development reported that their child was not receiving special education services at the time of enrollment. Approximately 75% of participants with ASD and participants with typical development were Caucasian. The largest remaining categories were Hispanic (8%), African American (6%), and Asian (5%), with an additional 6% of participants described as African American/Hispanic, American Indian or Alaskan Native, or Other. In terms of education, 64% of mothers of participants with ASD had an associate, technical, or higher degree compared to 88% of mothers of participants with typical development. Median family income on a rating scale defined in $25,000 increments was $75,000–$100,000 for both participants with ASD and for typically developing participants. Written informed consent was obtained.

The two inclusionary criteria for typically developing boys were (a) having a score at or below 11 on the Social Communication Questionnaire to screen for autism symptoms (Corsello et al., 2007), which led to the exclusion of two boys, and (b) achieving a standard score between 85 and 130 on measures of nonverbal cognition and receptive vocabulary (described below), which led to the exclusion of 12 boys. Boys with ASD received a classification of autism on the Autism Diagnostic Interview—Revised (Rutter, Le Couteur, & Lord, 2003) and an autism severity score of at least 4 on the Autism Diagnostic Observation Schedule (Lord, Rutter, DiLavore, & Risi, 2002) at their initial assessment in the project, supporting the research classification of ASD. Six boys with a community diagnosis of ASD were excluded from the present analyses because they failed to meet these Autism Diagnostic Interview—Revised and Autism Diagnostic Observation Schedule criteria. We also excluded boys who had missing data on any of the measures of interest in the present analysis. One boy with ASD was excluded because of missing data for nonverbal cognition and receptive vocabulary; nine boys with ASD were excluded because of missing data for sentence comprehension. Scores from the initial assessment for two participants in each group were missing because of noncompliance or examiner error for one or more measures and, as such, scores for all measures from a follow-up assessment, 18 months later, were used instead. Participant characteristics (at the time of the relevant assessment) are shown in Table 1. **T1**

Materials and Procedure

As part of the larger study, participants completed a variety of standardized and experimental measures of language and cognition over the course of several sessions, usually within a period of a few days. Every effort was made to use comparable strategies for facilitating the completion of the testing protocol across participants and groups, including visual schedules, breaks as needed, and so on.

Nonverbal cognition. The Brief IQ subtests of the Leiter International Performance Scale—Revised (Leiter–R; Roid & Miller, 1997) were administered to all participants. These subtests (Figure Ground, Form Completion, Sequential

Table 1. Participant characteristics. AQ1

Measure	Overall sample of boys with ASD (*n* = 45)			Boys with typical development (*n* = 45)			Subsample of boys with ASD and ID (*n* = 16)		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Chronological age	7.69	1.91	4–11	3.75	1.07	2–6	8.03	1.73	5–11
Leiter–R nonverbal IQ	77.62	19.51	40–117	109.29	11.42	91–129	57.25	9.28	40–68
Leiter–R growth score	467.62	16.56	439–510	455.09	11.24	429–482	456.38	10.53	441–471
PPVT–4 standard score[a]	71.98	22.49	20–113	114.92	10.18	89–130	52.38	19.95	20–77
PPVT–4 growth score	123.07	28.00	58–186	122.53	20.50	82–164	102.69	23.35	58–149
TROG–2 standard score[b]	66.71	16.59	55–111	104.44	15.26	81–132	57.00	5.20	55–74
TROG–2 items correct	28.67	21.19	2–76	32.53	19.39	4–73	13.25	9.60	2–36
Autism severity/screener	7.89	1.64	4–10	3.76	2.64	0–9	8.31	1.45	5–10

Note. Autism severity scores were based on the Autism Diagnostic Observation Schedule (Gotham, Pickles, & Lord, 2009) for boys with autism spectrum disorder (ASD); autism symptom screener scores were based on the Social Communication Questionnaire for typically developing boys. ID = intellectual disability; Leiter–R = Leiter International Performance Scale—Revised; PPVT–4 = Peabody Picture Vocabulary Test—Fourth Edition; TROG–2 = Test for Reception of Grammar—Version 2.

[a]Standard scores for the PPVT–4 were available only for boys 2;6 (years;months) or older (i.e., 39 of the typically developing boys). [b]Standard scores for the TROG–2 were available only for boys 4;0 or older (i.e., 16 of the typically developing boys).

Order, and Repeated Patterns) measure fluid reasoning and visualization skills. Examiners use pantomime and nonverbal cues (i.e., facial expression) to introduce each task. No spoken responses are required from the participant; instead, answers are given by either pointing or placing shapes or cards in the correct location. The Leiter–R Brief IQ subtests yield raw scores, standard scores, and growth scores.

Receptive vocabulary. We used the Peabody Picture Vocabulary Test—Fourth Edition (PPVT–4; Dunn & Dunn, 2007) as a measure of receptive vocabulary. The PPVT–4 was administered to all participants beginning with the item consistent with the participant's estimated developmental level for participants with ASD and chronological age for typically developing participants. Participants received either the A or B version, alternating among participants in the larger study. The PPVT–4 yields raw, standard, and growth scores.

Sentence comprehension. The Test for Reception of Grammar—Version 2 (TROG–2; Bishop, 2003) is a standardized measure of receptive syntax that examines 20 specific AQ2 syntactic constructions in their entirety. Each construction is tested with a block of four items. The participant's task is to select the one drawing out of four choices that corresponds to a sentence read aloud by the examiner. Foil drawings differ from the target drawing by either a lexical element (noun, verb, adjective) or a grammatical element (word order, function word, inflection), yielding the possibility of either lexical or syntactic errors, respectively. Consistent with the instrument's standardization, testing began at the first item (A1) and was discontinued after five consecutive failed syntactic constructions (i.e., blocks). Failure is defined as one or more incorrect responses in a block. Performance on the TROG–2 is quantified in terms of the number of blocks passed; an age-equivalent score; and, for children age 4;0 (years; months) and older, a standard score. We also summed the number of items answered correctly as the dependent variable for Research Question 1 as a way to capture variability in performance among participants who passed the same number of blocks but displayed different response patterns (e.g., failed a block due to incorrectly answering one vs. four items).

We defined and identified lexical errors following the TROG–2 manual for Blocks A, B, D, and E (Appendix D of the manual lists lexical errors for all items in Blocks A, B, D, E, F, J, and K; see Bishop, 2003, p. 68). Lexical errors were defined as the selection of a foil that depicted a noun, verb, or adjective that differed from one in the target sentence. For Blocks A, B, D, and E, these foils showed an irrelevant noun in the subject or object position or an irrelevant verb. The subset of blocks examined for lexical errors (i.e., A, B, D, and E) was one for which data were available for all participants in the current study. We chose to focus on this subset of four blocks because it allowed us to retain all participants from the matched groups, described below, maintaining our emphasis on a heterogeneous sample of boys with ASD. This set of four blocks contains simple two-element sentences, negatives, and nonreversible and reversible three-element sentences (see Table 2). We summed T2 the number of lexical errors committed in Blocks A, B, D, and E to serve as the dependent variable for Research Question 2. Table 3 contains descriptive statistics for all T3 analyzed error types.

On the basis of their performance for Blocks A, B, D, and E, we also classified participants in terms of whether they made a "statistically abnormal (approximately 5th percentile or below)" number of lexical errors given their chronological age, as defined by the TROG–2 (Appendix C of Bishop, 2003, p. 59). In addition to the sum of lexical errors, we used this classification of participants to address Research Question 2 regarding the extent to which lexical errors were committed across groups. Note that we also replicated this dichotomy using age-equivalent scores from the PPVT–4; however, no participant from either group was ever classified as committing a statistically elevated number of lexical errors given their receptive vocabulary age-equivalent score.

Table 2. Syntactic constructions from Blocks A, B, D, and E of the TROG–2.

Block description	Example
Two-element simple sentence	The sheep is running.
Negative (i.e., *not*)	The man is not sitting.
Three element nonreversible SVO	The girl pushes the box.
Three element reversible SVO	The man is chasing the dog.

Note. Items are from *The Test for Reception of Grammar—Version 2,* by D. Bishop. Copyright 2003 by the Psychological Corporation/ Pearson, Clinical Assessment. Reprinted with permission. SVO = subject–verb–object.

To address Research Question 3, we focused on the comprehension of nonreversible and reversible sentences. Nonreversible sentences (Block D) were ones in which the agent was animate and the patient was inanimate, with the exception of one item with an animate patient. All foils for nonreversible items were lexical (i.e., they portrayed the wrong lexical item in the subject, verb, or object position). Reversible sentences (Block E) contained animate agents and patients; potential incorrect responses were selections of either the word order foil (i.e., they portrayed the agent and patient in the reversed relationship) or a lexical error with respect to the verb or the patient. We dichotomized participants on the basis of whether they had committed one or more lexical errors in Block D or Block E and one or more word order errors in Block E. Again, we considered analyses using these variables to be exploratory because of the very small number of items on which they were based.

Analysis Plan

We tested differences in overall sentence comprehension performance (i.e., total items passed) and the number of lexical errors committed (i.e., total lexical errors for Blocks A, B, D, and E) with independent-samples *t* tests. We then compared groups using a χ^2 test to determine whether a greater proportion of participants with ASD or typical development demonstrated statistically elevated numbers of lexical errors. Finally, using χ^2 tests, we examined the number of lexical and syntactic errors committed in Blocks D and E by comparing the number of participants who committed at least one lexical or word order error in Blocks D or E across groups. Two-tailed *p* values are reported throughout.

Results

Establishing Group Equivalence

The participants who met the inclusionary criteria were 45 boys with ASD and 45 typically developing boys. As we describe in greater detail below, our comparison sample of typically developing boys was matched to the overall sample of boys with ASD on receptive vocabulary growth scores and to a subgroup of boys with ASD and ID on nonverbal cognitive growth scores, using guidelines proposed by Kover and Atwood (2013) and Mervis and colleagues (Mervis & Klein-Tasman, 2004; Mervis & Robinson, 1999). Although the groups matched on receptive vocabulary were necessarily mismatched on nonverbal cognition and vice versa, we chose the current matching strategy in favor of statistical control so that results would be interpretable in the context of the ASD cognitive and linguistic phenotypes. Because of our matching strategy, the findings for the overall sample of boys with ASD must be interpreted relative to receptive vocabulary expectations, and the findings for the subsample of boys with ASD and ID must be interpreted in terms of nonverbal cognitive expectations.

Overall sample of boys with ASD. Receptive vocabulary was chosen as the primary matching variable, as has been done in previous studies (e.g., Eigsti et al., 2007), because vocabulary ability is foundational to sentence comprehension in typical development. The overall sample of boys with ASD and the boys with typical development had similar receptive vocabulary growth scores, $t(88) = 0.10$, $p = .918$, $d = 0.02$, variance ratio = 1.87 (Kover & Atwood, 2013). Note that the effect size for the group difference in receptive vocabulary is very small; however, the variance ratio between groups is large.

Although the groups were well matched in terms of central tendency for receptive vocabulary ability, boys with ASD had higher Leiter–R Brief IQ growth scores than the typically developing boys, $t(88) = 4.20$, $p < .001$, $d = 0.89$, variance ratio = 2.17. However, the difference between groups for nonverbal cognition favored the participants with

Table 3. Errors committed in Blocks A, B, D, and E of the TROG–2.

	Overall sample of boys with ASD (*n* = 45)			Boys with typical development (*n* = 45)			Subsample of boys with ASD and ID (*n* = 16)		
Variable	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Lexical errors for A, B, D, and E	2.67	3.34	0–12	1.73	2.05	0–11	4.63	3.88	0–12
Lexical errors in Block D	0.98	1.10	0–4	0.98	0.97	0–3	1.38	1.26	0–3
Lexical errors in Block E	0.60	0.96	0–3	0.31	0.70	0–4	1.31	1.20	0–3
Word order errors in Block E	0.60	0.94	0–4	0.64	0.80	0–3	1.00	1.15	0–4

Note. Only lexical errors were possible in Block D.

ASD, meaning that any weaknesses in sentence comprehension or increased lexical errors by participants with ASD cannot be accounted for by lower nonverbal cognitive skills relative to the boys with typical development.

Subgroup comparison. We examined the performance of the subgroup of participants with ASD who had Leiter–R Brief IQs of 70 and below (i.e., at least 2 *SD* below the mean; $n = 16$). Descriptive statistics for this subsample are presented in the far right column of Table 1. Compared to the 45 boys with typical development, these 16 boys with ASD and ID did not differ in Leiter–R Brief IQ growth scores, $t(59) = 0.40$, $p = .691$, $d = 0.12$, variance ratio = 0.88. Thus, these groups can be considered matched on nonverbal cognitive ability. In contrast, the subsample of participants with ASD and ID had significantly lower PPVT–4 growth scores than the boys with typical development, $t(59) = –3.21$, $p = .002$, $d = –0.93$, variance ratio = 1.30. This difference indicates a weakness in receptive vocabulary relative to nonverbal cognitive ability in the boys with ASD and ID; however, this is not unexpected given the suggestion of a relative impairment in receptive language and the relationship between vocabulary and cognition in children with ASD (Hudry et al., 2010; Kover et al., 2013).

Sentence Comprehension Ability

Overall sample of boys with ASD. In terms of total TROG–2 performance, boys with ASD ($n = 45$) and boys with typical development did not differ on total blocks passed or number of items answered correctly, indicating similar general sentence comprehension ability given their receptive vocabulary, $t(88) = –0.42$, $p = .674$, $d = –0.09$, and $t(88) = –0.90$, $p = .369$, $d = –0.19$, respectively. However, boys with ASD did have significantly lower standard scores on the TROG–2 ($M = 66.71$, $SD = 16.59$) than the norming population ($M = 100$, $SD = 15$), indicating an overall delay relative to their same-age peers, $t(44) = –13.46$, $p < .001$, $d = –2.22$. Boys with ASD also had lower standard scores relative to the subset of typically developing boys old enough (i.e., age 4 and above, $n = 16$) for computation of TROG–2 standard scores, $t(59) = 7.97$, $p < .001$, $d = –2.32$.

Subsample of boys with ASD and ID. In terms of total TROG–2 performance, boys with ASD and ID ($n = 16$) obtained significantly lower scores than boys with typical development matched on nonverbal cognitive ability for total blocks passed and total items passed, $t(59) = –3.20$, $p = .002$, $d = –0.93$, and $t(59) = –3.80$, $p < .001$, $d = –1.11$, respectively.

Lexical Error Analysis: Blocks A, B, D, and E

Overall sample of boys with ASD. In terms of total lexical errors committed in Blocks A, B, D, and E, the overall sample of boys with ASD ($n = 45$) and boys with typical development did not differ, $t(88) = 1.60$, $p = .114$, $d = 0.34$. Of the 45 boys with ASD, however, 13 committed a statistically elevated number of lexical errors for their chronological age, whereas no typically developing boys committed a statistically elevated number of lexical errors for their chronological age. The difference between groups for the number of participants with statistically elevated numbers of lexical errors for chronological age was significant ($p = .015$).

Subsample of boys with ASD and ID. The subsample of participants with ASD and ID ($n = 16$) committed more lexical errors in Blocks A, B, D, and E relative to the boys with typical development, $t(59) = 3.77$, $p < .001$, $d = 1.10$. Of the 16 boys with ASD and ID, 10 committed a statistically elevated number of lexical errors for their chronological age relative to no boys with typical development ($p < .001$).

After having observed increased lexical errors in boys with ASD and ID relative to typical development, we completed a qualitative analysis of their errors, following the guidelines provided in the TROG–2 manual. The qualitative error analysis focuses on the last five blocks administered to the participant. The goal of these analyses was to gain further insight into the nature of the processing strategies that the participants were bringing to bear on the task of sentence comprehension. We began with an analysis of systematic errors. According to the TROG–2 manual, *systematic errors* are defined as failing every item within a given block, indicating that the child does not understand the construction and may be trying to interpret it in terms of a more familiar syntactic frame. Of the 16 boys with ASD and ID, 12 displayed a pattern of systematic errors for at least one of the last five blocks they completed. We also summed the number of errors committed in the last five blocks completed to differentiate between what the TROG–2 manual describes as *sporadic error patterns* and *random error patterns*. According to the manual, 12 or fewer errors indicate a sporadic pattern, and 13 or more errors indicate a random pattern. A sporadic pattern suggests above-chance performance and potential processing limitations; a random pattern (i.e., one that does not differ from chance) may suggest poor knowledge of the syntactic constructions tested (Bishop, 2003). Of the 16 boys with ASD and ID, seven displayed a sporadic error pattern and nine displayed a random error pattern.

Nonreversible and Reversible Sentences

For nonreversible sentences, we dichotomized participants as having committed at least one lexical error or no lexical errors; for reversible sentences, we dichotomized participants in two ways: as having committed (a) at least one lexical error or no lexical errors and (b) at least one word order error or no word order errors.

Overall sample of boys with ASD. For nonreversible sentences, the number of participants who committed lexical errors did not differ between groups (25 with ASD, 27 with typical development; $p = .670$). For reversible sentences, the number of boys with ASD who committed lexical errors did not differ from the comparison group (16 with ASD, 11 with typical development; $p = .250$). The number of boys with ASD who committed syntactic word order errors also did not differ from the comparison group (18 with ASD, 21 with typical development; $p = .523$).

Subsample of boys with ASD and ID. For nonreversible sentences, the number of participants with ASD and ID who

committed at least one lexical error (i.e., 10) did not differ from the comparison group ($p = .860$). Participants with ASD and ID also did not differ from those with typical development with respect to word order errors for reversible sentences ($p = .277$). In contrast, 11 of the 16 boys with ASD and ID committed at least one lexical error during reversible sentence comprehension, leading to a significant difference from the typically developing boys ($p = .002$).

Discussion

This study was designed to examine the extent of delay in sentence comprehension for boys with ASD relative to younger typically developing boys. We were also interested in the types of errors committed by boys with ASD and the implications of those types of errors for understanding underlying deficits. In our sample, variability among boys with ASD was large, with scores ranging from impaired to typical for receptive vocabulary, nonverbal cognition, and sentence comprehension. We view this heterogeneity as representative of the disorder and a strength of the study.

Sentence Comprehension

Sentence comprehension was delayed in the overall sample of boys with ASD, as evidenced by standard scores lower than their chronological age peers in the norming population as well as the subset of typically developing boys in the comparison group for whom standard scores could be computed. However, the overall sample of boys with ASD and younger typically developing boys matched on receptive vocabulary did not differ in their overall performance on the TROG–2 in terms of raw scores for blocks passed or items answered correctly. This differs from Prior and Hall's (1979) findings. In contrast, the subgroup of boys with ASD and ID passed fewer blocks and answered fewer items correctly than the younger typically developing boys. Taken together, these findings indicate a weakness in sentence comprehension relative to nonverbal cognition for boys with ASD and ID, but not relative to receptive vocabulary when considering a broader range of the ASD phenotype. We should emphasize that vocabulary is an area of weakness for children with ASD relative to age expectations on average (Charman, Drew, Baird, & Baird, 2003); thus, we are suggesting not that sentence comprehension is a strength for boys with ASD but rather that impairments in this domain do not exceed receptive vocabulary expectations. Future longitudinal research is needed to gain an understanding of the emergence and trajectory of sentence comprehension skills across individuals with ASD.

Errors in Comprehension

To address the potential interplay between vocabulary and syntax in language comprehension, we examined the number of lexical errors committed during the interpretation of a subset of sentences, including simple two-element sentences, negatives, and three-element nonreversible and reversible sentences. We found that boys with ASD and ID incorrectly chose more lexical foils than did nonverbal cognition–matched typically developing boys; the overall sample of boys with ASD did not differ from the comparison group of typically developing boys in the number of lexical foils chosen. However, both the overall sample of boys with ASD and the sample of boys with ASD and ID included more boys who made a statistically elevated number of lexical errors for chronological age than did the comparison group. On the whole, given their receptive vocabulary ability, many participants from the overall sample of boys with ASD displayed some success in avoiding lexical distractors in support of sentence comprehension. Boys with ASD and ID either did not have the necessary lexical knowledge for sentence comprehension or were not able to use their extant lexical knowledge effectively.

Additional research on language development in children with ASD and ID is warranted considering that language abilities may be influenced by different foundational skills than for children with unimpaired cognitive skills (van der Schuit, Segers, van Balkom, & Verhoeven, 2011). Indeed, van der Schuit et al. (2011) found that vocabulary knowledge was related to both concurrent and later syntactic knowledge in children with ID, but the relationship between vocabulary and syntactic knowledge was not significant for 4- and 5-year-old typically developing children, matched on chronological age. They suggested that children with ID demonstrate a prolonged reliance on lexical knowledge to facilitate syntactic performance. Eigsti et al. (2011) also highlighted that language acquisition in children with ASD might be driven by a protracted developmental pattern such that biases or mechanisms for learning come into play later than would be expected on the basis of typical development or nonverbal cognition. The possibility that a stronger foundation of lexical abilities is needed to support sentence comprehension in children with ID, including those with ASD, relative to typical development is worthy of further research.

An alternative explanation is that boys with ASD and ID were challenged to a greater degree than boys with typical development matched on nonverbal cognition in terms of the processing demands of the TROG–2, including demands on memory and attention. The TROG–2 manual indicates that poor performance due to lexical errors could indicate more difficulty with memory or attention than syntactic comprehension per se; however, the TROG–2 was not designed to differentiate between impaired processing, on the one hand, and lexical and syntactic impairments on the other. Thus, the qualitative analysis of errors on the last five blocks completed by each boy with ASD and ID can only hint at the reasons for their poorer performance and increased lexical errors. Approximately half of the boys with ASD and ID displayed sporadic errors, indicative of processing limitations, whereas half displayed random errors, indicative of poor interpretation of the syntactic constructions being tested. Two thirds of these boys systematically failed all items of at least one block, also indicating a lack of mastery

for some constructions. On the basis of our results, we can conclude that boys with ASD and ID have weaker sentence comprehension and increased lexical errors than expected based on their nonverbal cognitive ability. A lack of syntactic knowledge and processing limitations contributed to their problems, although the relative contributions of these factors may differ across individuals and syntactic constructions. Pending future research, optimally integrating lexical and syntactic information during sentence comprehension might be an appropriate target for language interventions for children with ASD and ID.

Errors for Nonreversible and Reversible Sentences

In exploratory analyses we found that the subgroup of boys with ASD and ID were more likely to commit at least one lexical error during the comprehension of reversible sentences than were boys with typical development; this was not true for nonreversible sentences or for the overall sample of boys with ASD. Reversible SVO sentences present high processing demands because of the need to use syntactic knowledge about word order to distinguish between the correct interpretation and an incorrect interpretation involving the same lexical items but reversed word order (e.g., "The man is chasing the dog" vs. "The dog is chasing the man"). As also suggested by our findings of an increased overall number of lexical errors in boys with ASD and ID, children with ASD may revert to less advanced comprehension strategies (e.g., failing to use lexical knowledge), in particular during reversible sentence comprehension, leading to lexical errors (Tager-Flusberg, 1981).

It is interesting that neither the overall group with ASD nor the subgroup of boys with ASD and ID differed from typically developing boys in rate of word order errors. These findings are in line with the notion that children with ASD are able to use syntactic knowledge to support comprehension (Paul et al., 1988; Swensen, 2007; Tager-Flusberg, 1981). The finding that boys with ASD and ID had overall impaired sentence comprehension and more lexical errors, especially on reversible SVO comprehension, could be taken to align with the proposal that deficits in declarative learning and memory create linguistic challenges for this subgroup of children with ASD by negatively affecting lexical development (Boucher, Mayes, & Bigham, 2008). Declarative (explicit, associative) memory is that which is accompanied by a feeling of effortful recollection and includes semantic and episodic memory (Boucher et al., 2008). Boucher et al. (2008) hypothesized that impaired comprehension and semantic knowledge result from limited categorical world knowledge due to declarative memory deficits in the form of poor integration of episodic memories. Children with ASD and ID may adequately acquire words and apply word knowledge on simple tests of receptive vocabulary, such as the PPVT–4, but fail to generalize or use that knowledge across tasks, perhaps especially when lexical and syntactic processing must be integrated (Boucher et al., 2008). The effects of memory and learning impairments associated with the declarative system on language development are in need of further research, including how these impairments affect the integration of knowledge across language domains (Boucher, 2012). Given the exploratory nature of our findings regarding this topic, experimental tasks are needed to test whether children with ASD or subgroups of children with ASD have difficulty integrating lexical and syntactic knowledge and whether such difficulty may be exacerbated by and detectable only in the context of syntactically challenging constructions, such as reversible sentences.

Limitations and Future Directions

Despite its strengths, this study has several limitations. Although the comparison groups were well matched in terms of central tendency, there was more variability in receptive vocabulary scores among participants with ASD in the overall sample than among those with typical development. This heterogeneity in levels of language ability among the participants with ASD is an asset in terms of representation and generalization; however, it also challenges researchers to find appropriate comparison groups who might still be considered "typically developing." Furthermore, our subgroup of participants with ASD and ID was small and matched to the comparison group on a different cognitive dimension (i.e., nonverbal cognition) than was the overall sample (i.e., receptive vocabulary). It is important to note that we cannot distinguish between the possibility that lexical errors occurred because of limitations with memory or attention rather than lexical knowledge per se because the study did not include measures of processing, such as phonological memory. Nonetheless, this work provides the basis for future studies that can address the developmental trajectories of sentence comprehension in children with ASD as it relates to lexical and syntactic knowledge. Connecting what is known about explicit and implicit learning in individuals with ASD (Barnes et al., 2008; Mayo & Eigsti, 2012; Watanabe, Ikeda, & Miyao, 2010) to the profiles of language impairment associated with ASD and ASD and ID will also be important in future research.

Conclusion

This study yields insight into the comprehension difficulties of children with ASD. In particular, these findings serve as initial work in systematically examining lexical errors in the context of sentence comprehension in individuals with ASD and ID, a population on which very little research on language development has been conducted. In the face of high linguistic demands, syntactic knowledge might be used as a foundation for comprehension by children with ASD. If the current findings are replicated with experimental measures, appropriate targets for language intervention for children with ASD may include improving attention to lexical items and increasing use of lexical knowledge. We have drawn attention to the fact that aspects of sentence processing beyond syntactic knowledge, perhaps including lexical abilities, are likely to be critical components of language comprehension processes for children with ASD.

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AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES

AQ1: In the Table 1 note, you cite Gotham, Pickles, & Lord (2009). Please supply a complete reference list entry for this. Thank you.

AQ2: Please confirm that the first sentence in the *Sentence comprehension* section is correct as modified; if it is not, please reword. Thank you.

AQ3: Please consider clarifying the words *agent* and *patient* in the last paragraph before the *Analysis Plan* heading (I assume the terms are specific to the TROG–2).

AQ4: In the sentence that "These findings are in line with the notion …", you cite Swenson (2007). Should this be Swenson et al. (2007)? If not, please supply a complete reference list entry for Swenson (2007).

END OF AUTHOR QUERIES