Is grammar spared in Autism Spectrum Disorder? Data from judgments of verb argument structure overgeneralization errors.

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RUNNING HEAD: Grammar in ASD

Abstract

Children with Autism Spectrum Disorder (ASD) aged 11-13 (*N*=16) and an IQ-matched Typically Developing (TD) group aged 7-12 (*N*=16) completed a graded grammaticality judgment task, as well as a standardized test of cognitive function (WISC-IV). In a departure from previous studies, the judgment task involved verb argument structure overgeneralization errors (e.g., **Lisa fell the cup off the shelf*) of the type sometimes observed amongst typically developing children, as well as grammatical control sentences with the same verbs (e.g., *The cup fell off the shelf*). The ASD group showed a smaller dispreference for ungrammatical sentences (relative to the control sentences) than did the TD group. These findings are indicative of a subtle grammatical impairment in even relatively high-functioning children with ASD.

Keywords: language development; autism spectrum disorders; grammaticality judgment task; verb argument structure overgeneralization errors.

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Delayed language acquisition is common amongst children with ASD, though with a considerable degree of individual variation (Kjelgaard & Tager-Flusberg, 2001; Lord, Risi, & Pickles, 2004; Tager-Flusberg, Lord, & Paul, 1997; Thurm, Lord, Lee, & Newschaffer, 2007; but see Jarrold, Boucher & Russell, 1997). (Though, interestingly, in DSM-5, Autism Spectrum Disorder may be specified "with or without accompanying language impairment"). Young children with ASD show marked delays in both receptive and expressive language (Eaves & Ho, 2004; Luyster, Kadlec, Carter, & Tager-Flusberg, 2008; Luyster, Lopez, & Lord, 2007; Weismer, Lord, & Esler, 2010). These language deficits remain during childhood (Botting & Conti-Ramsden, 2003; Park, Yelland, Taffe, & Gray, 2012; Rapin & Dunn, 2003; Rescorla, 2002), though debate continues as to whether they continue into adolescence and adulthood (Howlin, 1984; Tager-Flusberg, 1985; Tager-Flusberg, et al, 1997; Boucher, 1976; 1988).

The present study focuses on the *grammar* of children with ASD. It is well known that children with ASD experience selective impairments in domains such as vocabulary learning, phonology, semantics and pragmatics (see Rapin & Dunn, 2003, for a review). The question of whether children with ASD also show selective grammatical impairments is less well understood, with studies often yielding contradictory findings.

On the one hand, some researchers have argued that grammar is spared in ASD. To be clear, the claim is not that grammar is *entirely* spared, such that children with ASD are on a par with age-matched controls. Rather the claim is that grammar is

relatively spared; that the grammar of children with ASD is as good as - perhaps even better than – would be expected given (a) the intellectual impairment that frequently accompanies (though is not a diagnostic criterion for) the disorder and (b) impairments in other areas of language (e.g., pragmatics, vocabulary and comprehension). For example, several researchers have found that children with ASD did not show impairments in grammar (or phonology) when compared to control groups matched for cognitive function, including a Down syndrome group (Tager-Flusberg, 1981, 1985; Tager-Flusberg, Calkins, Nolin, Baumberger, Anderson, & Chadwick-Dias, 1990; see also Roberts, Mirrett & Burchinal, 2001).

On the other hand, one particularly large study of children with ASD (*N*=300) found that the majority exhibited syntactic impairments, with such impairments more common than in a control group of children with dysphasia (Allen & Rapin, 1980; Rapin & Dunn, 2003). Eigsti, Bennetto, and Dadlani (2007) also found that children with ASD showed significant grammatical impairments when compared to groups matched for both nonverbal IQ and receptive vocabulary.

A third possibility is that children with ASD fall into two subgroups, one with impaired language (including, grammar, phonology and vocabulary), one without (i.e., with impaired social communication, rather than impaired language *per se*). Indeed, in DSM-5[1], while "deficits in nonverbal communicative behaviors used for social interaction" are a diagnostic criteria for Autism Spectrum Disorder, the disorder may be specified "with or without accompanying language impairment". This change from DSM-IV reflects the view that ASD and Specific Language Impairment, while frequently co-occurring (e.g., Conti-Ramsden, Simkin, & Botting, 2006; Fombonne, Bolton, Prior, Jordan, & Rutter, 1997; Tomblin, Hafeman, & O'Brien, 2003) and perhaps even co-morbid (e.g., Alarcón, Yonan, Gilliam, Cantor, &

Geschwind, 2005; Bradford et al., 2001; Kjelgaard & Tager-Flusberg, 2001), are distinct disorders (e.g., Whitehouse, Barry, & Bishop, 2007; 2008; Williams, Botting, & Boucher, 2008; see Tomblin, 2011, for a review).

One reason why it has proved difficult to choose between these three alternative possibilities is that studies that have yielded different results have often used different methods for language assessment (Eigsti et al, 2007). Another is that many of the methods used, particularly the analysis of spontaneous speech, make it difficult to disentangle "pure" grammatical impairments from impairments in other areas of language, such as phonology (which may impact upon, for example, morphological marking) and from more general impairments associated with ASD (e.g., social interaction).

A grammaticality judgment task, however, may constitute a "uniquely sensitive tool" (Eigsti & Bennetto, 2009: 1005) for investigating the grammatical abilities of children with ASD. One advantage is that this task – or at least the version used in the present study – does not require children to make any verbal response. This is an important advantage given that social interaction is a core deficit in ASD. Indeed, highly structured, analytical tasks of this nature play to the strengths of children with ASD, perhaps even more so than for typically developing children (e.g., Happé, 1999).

We are aware of only one previous study that has used a grammaticality judgment paradigm to investigate grammar in children with ASD. Eigsti and Bennetto (2009) compared the performance of an ASD group (aged 9-16) and a TD group matched for Full Scale IQ (*Wescher Intelligence Scale for Children*) on a binary *yes*/*no* grammaticality judgment task. Out of thirteen different types of morphosyntactic violation, children with ASD showed worse performance than IQ-

matched TD children on only three: 3sg *–s* marking (e.g., *play-s*), present progressive *–ing* marking (*play-ing*) and (marginally) past-tense marking (e.g., *play-ed)*. When the results were broken down by sentence length and error position, it was found that the ASD group showed impaired performance only for errors located at the ends of long sentences. The authors interpreted this finding as support for the claim that children with ASD have difficulties with executive function, including working memory (e.g., Bennetto, Pennington & Rogers, 1996).

It is interesting to note that all ungrammatical utterance types for which ASD children showed impaired performance in Eigsti and Bennetto's (2009) study were errors of morphology (*-s, -ing, -ed*). Indeed, when the results were broken down by error type, it was found that the ASD group showed impairment on errors involving omissions and substitutions, but not insertions or incorrect orderings (see also Blackwell & Bates, 1995; Roberts, Ricem & Tager-Flusberg, 2004; Wulfeck, 1993). Taken together with the finding for sentence-length and error position, this suggests that any selective grammatical deficit in children with ASD may reflect primarily a deficit in surface morphology – and perhaps ultimately phonology - rather than deeper syntax. An alternative possibility is that the measure used – a binary acceptability judgment – was not sufficiently sensitive to detect between-group differences in judgments of more "syntactic" errors.

Thus the aim of the present study was to investigate, using a more sensitive graded grammaticality judgment paradigm, whether children with ASD indeed show impairments at judging "pure" syntactic errors (as opposed to violations of surface morphology) when compared with typically-developing children matched for IQ. The use of a more sensitive graded (as opposed to binary) grammaticality judgment paradigm (e.g., Sorace & Keller, 2005) is particularly crucial, because – given that the

previous literature is inconclusive with regard to the issue of a syntactic impairment in ASD – if such an impairment does exist, it is presumably a very subtle one.

Given our focus on syntactic errors, we decided to investigate one of the types of error that has been most extensively studied amongst typically-developing children (e.g., Brooks & Tomasello, 1999; Brooks, Tomasello, Dodson & Lewis, 1999; Brooks & Zizak, 2002; Ambridge, Pine, Rowland, Jones, & Clark, 2009; Ambridge, Pine, Rowland, & Young, 2008): errors in which intransitive-only verbs such as *arrive* are incorrectly used in a transitive-causative construction (e.g., **Marge arrived the children at the party*). The hypotheses were as follows:

- Children will show a significant preference for grammatical sentences - intransitive uses of intransitive-only verbs (e.g., *arrive*) and both intransitive and transitive uses of alternating verbs (e.g., *break*) - over ungrammatical sentences – transitive uses of intransitive-only verbs (e.g., *arrive*). That is, we predict a main effect of grammaticality, such that grammatical sentences are rated as significantly more acceptable than ungrammatical sentences.
- On the assumption that grammar (as opposed to surface morphology/phonology) is spared in ASD, after matching for IQ, this pattern will **not** differ according to group (ASD/TD). That is, we predict no significant interaction of grammaticality (Yes/No) by group (ASD/TD). Note that, because this key prediction is a null effect, if such a pattern is observed, it would be necessary to verify that the study is sufficiently powered to detect this interaction, should it be present in the underlying data.

Method

Participants

The Autism Spectrum Disorder (ASD) group comprised 16 children aged 11;3-13;2 (*M*=12;2, SD=0;7), all of whom attended specialist schools or centres. All had received a diagnosis of Autism Spectrum Disorder based on DSM-5 criteria from two clinical psychologists working for the local NHS Social Communication Disorder Clinic. Post test, the Social Communication Questionnaire Current (Rutter, Bailey & Lord, 2003) was sent to parents. Questionnaires were received for 9 children, with scores ranging from 10-25 (*M*=18.33; *SD*=6.60) out of a maximum possible of 40. Thus it is clear that this constitutes a high-functioning ASD group[2]. A further four children were tested, but were discarded because their very low raw scores on the subcomponents of the IQ test made it difficult to match the ASD and TD groups on this measure.

The Typically Developing (TD) control group comprised 16 children aged 7;0-12;2 (*M*= 9;5, SD=2;4), and were significantly younger than the ASD group (t=4.51, p<0.001). These children were selected from an original pool of 30 tested, with the aim of matching the ASD group as closely as possible for raw scores on the subcomponents of the IQ test (in practice, this simply involved discarding the 14 TD children with the highest scores).

IQ Test

Children completed the *Wechsler Intelligence Scale for Children, Fourth Edition* (*WISC-IV*) (Wechsler, 2004), which comprises ten subtests and four subscales:

Working Memory Index, Processing Speed Index, Verbal Comprehension Index and Perceptual Reasoning Index (see Table 1). A series of independent *t*-tests (using Welsh's *df* modification for unequal variances) confirmed that the raw scores of the ASD and TD groups did not differ on any individual subtests[3], except matrix reasoning for which the ASD group outperformed the TD group. Indeed, for six of the ten tests, mean scores were numerically higher for the ASD than TD group. Thus if the ASD group do show a grammatical impairment relative to the TD group, we can be confident that this difference is not a consequence of lower IQ.

INSERT TABLE 1 ABOUT HERE

Grammaticality Judgment Test

Each child rated 20 sentences; one intransitive (e.g., *The plate broke into pieces*) and one transitive sentence (e.g., *Homer broke the plate into pieces*) for each of 10 different verbs. Five of the verbs were alternating verbs, meaning that both the intransitive and transitive variants were grammatical (e.g., *The plate broke into pieces; Homer broke the plate into pieces*). Half of the verbs were intransitive-only verbs, meaning that the intransitive variant was grammatical (e.g., *The cup fell off the shelf*) but the transitive variant was ungrammatical (e.g., **Lisa fell the cup off the shelf*). In order to ensure generalizability across verbs, whilst keeping the overall number of trials relatively low, two between-subjects item groups were used: For half of the children, the alternating verbs were *break, grow, cook, slide* and *shatter*, and the intransitive-only verbs were *fall*, *arrive*, *laugh*, *chuckle* and *appear*. For the remainder, the alternating verbs were *rip*, *smash*, *fold, open* and *bounce*, and the

intransitive-only verbs were *go*, *tumble*, *swim*, *disappear* and *vanish*. The full set of test sentences can be found in Appendix A.

The advantage of using argument structure overgeneralizations is that all errors are violations of deeper level syntax rather than surface morphology. Thus – unlike for Eigsti & Bennetto's (2009) *–s, -ing* and *–ed* errors, any impairment cannot be reducible to a possible phonological impairment (e.g., detecting and processing verb morphemes that have a short temporal duration).

For each test sentence, participants viewed a computer animation portraying the event described. The purpose of the animations was to ensure that participants interpreted the meaning of each sentence as intended, and that the truth value of the sentence was not in doubt, thus encouraging participants to rate according to grammatical acceptability (McDaniel & Cairns, 1996). Each animation was accompanied by a pre-recorded sentence spoken by a male native speaker of British English (the first author). Sentences were played through a loudspeaker attached to a laptop computer. The speaker was placed inside a stuffed 'talking dog'. This set-up allowed the experiment to be presented to participants as a game, which involved them helping a dog learn to speak English.

Children provided their judgments using a 5-point colour-coded smiley-face scale (e.g., Ambridge et al 2008). In order to make the scale more suitable for use with children with ASD, who may struggle to interpret the faces, the scale also included a numerical key (1-5).

Procedure

On Day 1, participants completed the grammaticality judgment test. First, participants were introduced to the grammaticality-judgement procedure through the use of seven

training trials (see Appendix B). The experimenter explained that "This dog is learning to speak English but sometimes he gets it wrong and says things a bit funny. We're going to help him, by telling him when he gets it right and when he says it wrong. When he says it right we're going to choose the green counter and put it here, on face number five. When he says it wrong we're going to choose the red counter and put it here on face number one. Don't worry about these other faces for now". The experimenter then completed the first and second training trials (5/5 and 1/5), and invited the child to complete the third and fourth trials, which also had expected responses of 5/5 and 1/5 respectively.

The experimenter then explained that "Sometimes the dog says it right but not perfectly. If it's good but not perfect, you can put the green counter here on face four. If it's a little bit right and a little bit wrong, or somewhere in between you can put it here on face three. Sometimes he says it wrong but it's not really terrible. If it's wrong but not terrible, you can put the counter here on face two. The child then completed the remaining three training trials. If the child did not give the expected responses (2-3, 3-4 and 4-5 respectively), the experimenter repeated the explanation of the scale. The child then completed the test trials in pseudorandom order (different for each child), with the constraint that no two consecutive trials used (a) ungrammatical sentences or (b) the same verb and a maximum of three consecutive sentences could be of the same sentence type (intransitive or transitive).Altogether, the judgment test took approximately 20 minutes per child.

The WISC-IV test, which generally took between 60 and 80 minutes per child, was completed in a separate session on Day 2 (usually the following day), and was scored according to the standardized procedures outlined in the test manual.

Results

Table 1 shows the mean raw scores for the TD and ASD groups on the Weschler Intelligence Scale for Children (WISC-IV) tests. Figure 1 shows the mean ratings (on the five-point scale) for grammatical ("Yes") and ungrammatical ("No") sentences (error bars show 95% CIs). Visual inspection of this figure suggests that, consistent with our first prediction, children – collapsing across group – correctly prefer grammatical over ungrammatical sentences. However, it also suggests that, counter to our second prediction, this preference is smaller for the ASD than the TD group.

In order to investigate these predictions, the data were analysed using mixed-effects models (lme4 package; Bates, Maechler, & Bolker, 2012) in R (R Core Team, 2014), with participant, verb and sentence as random effects on the intercept. We obtained *p* values for the main effects and interaction using the model comparison procedure (i.e., likelihood ratio test). The model (see Table 2) included age (as a control predictor), grammaticality (with ungrammatical as the reference level), group (with TD as the reference level) and the grammaticality x group interaction.

INSERT TABLE 2 ABOUT HERE

The main effect of grammaticality confirmed that, consistent with our first prediction, children gave significantly higher ratings to the grammatical sentences (M=4.01, SE=0.15) than the ungrammatical sentences (M=2.27, SE=0.20). No significant main effect of group was observed; indeed, the mean ratings observed for the TD (M=3.15, SE=0.18) and ASD group (M=3.13, SE=0.18) were almost identical. This finding is important, as it demonstrates that any difference between the groups

does not result from a simple tendency for the children in the ASD group to give inappropriately high or low ratings across the board. Crucially, the finding of a significant interaction of grammaticality x group indicates that, counter to our second prediction, the extent of dispreference for ungrammatical sentences was smaller for the ASD than the TD group. Thus, even when matching for IQ, at least one aspect of grammar – or, at least, performance on this particular judgment task – does not seem to be spared in ASD.

Discussion

The present study investigated the issue of whether, relative to domains such as vocabulary, phonology, semantics and pragmatics, grammar is spared in ASD, using a grammaticality judgment task that minimizes the concurrent demand on these other systems. Unlike a previous study that found impairments only in surface morphology, as opposed to syntax (Eigsti & Bennetto, 2009), the present study found that children with ASD showed a smaller dispreference for verb argument structure violations (e.g., **Lisa fell the cup off the shelf*) than their IQ-matched TD counterparts.

Before discussing the implications of these findings, it is important to consider potential objections to the present conclusion of impaired grammar in ASD. One is that the ASD group might be impaired not on grammar per se, but on the particular paradigm used to assess it in this study. While it is not possible to rule out this possibility, the same could be said of any investigation of the linguistic abilities of children with ASD. Any measure of judgments, comprehension or production – including spontaneous speech – has its own particular task demands that might mask underlying competence. If anything, as we argued in the introduction, a structured, analytical judgment task plays to the strengths of children with ASD more than most

comprehension or production tasks, which rely heavily on the social-communicative aspects of cognition known to be particularly impaired in ASD. That said, it would be instructive to compare, with the same group of children, the findings of a judgment task and a comprehension task that requires no deliberate response at all (e.g., eyetracking; Brock, Norbury, Einav, & Nation, 2008).

A second objection is that the present study investigated only one particular type of grammatical violation – transitive-causative uses of intransitive-only verbs – and has therefore failed to show that grammar more generally is impaired in ASD (though see Allen & Rapin, 1980; Eigsti et al, 2007; Eigsti & Bennetto, 2009; Rapin & Dunn, 2003). While it is, of course, important for future research to investigate whether other areas of grammar are similarly impaired, the fact remains that any impairment constitutes evidence against the claim that grammar is spared in ASD.

A third objection is that because this study necessarily focused on high functioning children with relatively well-developed language skills (see the relevant IQ subscale scores in Table 1), its findings do not generalize to all children with ASD. While this is true, it does not affect our conclusion that grammar is impaired relative to IQ in ASD, as, presumably, lower-functioning children would be expected to show greater grammatical impairment. Future research should address this possibility, including the question of whether an ASD group matched to the TD group for nonverbal IQ but with lower verbal language skills would show worse performance on the judgment task. Future research should also address the question of whether IQ-matched children with other developmental disorders show a similar profile to our ASD group.

These caveats aside, we now move on to consider the theoretical implications of the present findings. With regard to theories of language acquisition in ASD, the

present findings provide support for the view that – DSM-5 criteria notwithstanding – some degree of grammatical impairment is present even in relatively high functioning children with ASD. It is important to acknowledge that this conclusion is at odds with what is perhaps a growing consensus that children with ASD (or at least a high-functioning subgroup) show a similar trajectory to IQ-matched TD children. For example, Tek, Mesite, Fein, and Naigles (2014) used growth curve modelling to identify a high-verbal-skill ASD group who showed a pattern of growth in morphosyntactic complexity (14 grammatical morphemes and *wh*-question complexity) comparable to that shown by a TD control group (though these authors did also identify a low-verbal-skill ASD group with a flatter trajectory, perhaps because these children also show elements of SLI). Similarly, several researchers have found that, when given standard preferential-looking and elicited production tasks, English speaking children with ASD seem to acquire knowledge of SUBJECT VERB OBJECT word order in a similar way to typically-developing children (Naigles, Kelty, Jaffery, & Fein, 2011; Naigles & Tovar, 2012; Swensen, Kelley, Fein, & Naigles, 2007). Finally, Goodwin, Fein and Naigles (2011) showed that when assessed on their comprehension of *wh*-questions (a particularly complex syntactic structure), children with ASD performed similarly to language-matched (though not age-matched) controls.

Why then does the present study find evidence of grammatical impairment in ASD, while these other studies do not? Our suggestion, following Eigsti and Bennetto (2009: 1005), is that a grammaticality judgment task is a "uniquely sensitive tool" that is capable of detecting minor grammatical impairments that would most likely be missed by other measures. Consider, for example, the overgeneralization errors in the present study (e.g., **Lisa fell the cup off the shelf*). It seems unlikely that either ASD

or TD children would produce such errors at non-negligible rates in production; neither are they likely to differ in their ability to comprehend such sentences. Thus our conclusion is that high-functioning children with ASD show a grammatical impairment that is genuine, but sufficiently subtle to elude typical comprehension and production measures.

With regard to theories of language impairment more generally, the present findings raise the issue of the relationship between ASD and Specific Language Impairment, a disorder in which grammatical impairments are generally viewed as particularly central (e.g., van der Lely, 1996; Wexler & Rice, 1996). Indeed, as we saw in the introduction, although current diagnostic criteria mean that children with ASD do not qualify for a diagnosis of SLI, the two often seem to go hand in hand. This raises the possibility that the two disorders may share a common underlying cause, perhaps even at a genetic level (e.g., Alarcón et al, 2005). Because we did not include a group of children with SLI, our findings speak only indirectly to this debate. However, given that other grammaticality judgment studies have found a deficit in SLI, even when controlling for IQ (e.g., Wulfeck, Bates, Krupa-Kwiatkowski & Saltzman, 2004) our finding that children with ASD show a similar pattern are consistent with the possibility of a common etiology.

Turning now to implications for assessment and intervention, although it would not make sense to use a judgment task to diagnose ASD (since impaired language is no longer a diagnostic criterion for the disorder), the task may be useful for identifying those children with ASD who have an accompanying grammatical impairment that is too subtle to have been picked up by more traditional tests. Thus a judgment task may be useful for diagnosing underlying language difficulties that may not be particularly important in the early stages of language – when children's speech

is relatively simple – but which may adversely affect language and literacy in later childhood, and perhaps even adulthood. Indeed, as we noted above, because the social-communicative aspect of language is minimized, a judgment task is particularly well suited to investigating the strengths and weakness of different individuals with ASD *on language per se*. In order to meet this potential, however, it will be necessary to develop a judgment task that is both broader in scope (i.e., that does not include only in/transitive sentences) and that can be completed by lower functioning children with ASD.

In conclusion, the findings of the present study suggest that, counter to an emerging consensus in the literature, a relatively subtle grammatical impairment is present amongst even relatively high functioning children with ASD.

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Appendix A. Test sentences

Counterbalance Group A

Type	*Verb*	*Intransitive Sentence*	*Transitive Sentence*
ALT	Break	The plate broke into pieces	Homer broke the plate into pieces
ALT	Grow	The flowers grew in the greenhouse	Homer grew the flowers in the greenhouse
ALT	Cook	The bread cooked in the oven	Homer cooked the bread in the oven
ALT	Slide	The truck slid across the floor	Bart slid the truck across the floor
ALT	Shatter	The vase shattered into pieces	Bart shattered the vase into pieces
INT	Fall	The cup fell off the shelf	*Lisa fell the cup off the shelf
INT	Arrive	The children arrived at the party	* Marge arrived the children at the party
INT	Laugh	The audience laughed at the joke	* Bart laughed the audience at the joke
INT	Chuckle	The audience chuckled in anticipation	* Bart chuckled the audience in anticipation
INT	Appear	The coin appeared out of thin air	* Homer appeared the coin out of thin air

Counterbalance Group B

Type	*Verb*	*Intransitive Sentence*	*Transitive Sentence*
ALT	Rip	The dress ripped at the seam	Marge ripped the dress at the seam
ALT	Smash	The glass smashed into bits	Lisa smashed the glass into bits
ALT	Fold	The scarf folded double	Marge folded the scarf double
ALT	Open	The door opened in the hallway	Homer opened the door in the hallway
ALT	Bounce	The ball bounced down the street	Lisa bounced the ball down the street
INT	Go	The bus went along the pavement	* Homer went the bus along the pavement
INT	Tumble	The books tumbled off the table	* Homer tumbled the books off the table
INT	Swim	The fish swam in the tank	* Homer swam the fish in the tank
INT	Disappear	The money disappeared from the bank account	* Marge disappeared the money from the bank account
INT	Vanish	The card vanished into thin air	* Bart vanished the card into thin air

Appendix B. Training Sentences, and expected ratings on the 5-point scale

The cat drank the milk (5)

*The dog the ball played with (1)

The frog caught the fly (5)

*His teeth man the brushed (1)

*The woman said the man a funny story (2-3)

*The girl telephoned her friend the news (3-4)

The man whispered his friend the joke (4-5)

Footnote

[1] Incidentally, the introduction of DSM-5 has seen a decrease in the number of individuals diagnosed with Autism Spectrum Disorder, as compared with DSM-IV-TR Autistic disorder (AD) and pervasive developmental disorder-not otherwise specified (PDD-NOS); see Kulage, Smaldone and Cohn (2014) for a meta-analysis.

[2] Although we also administered the child version of the *Reading the mind in the eyes test revised version* (Baron-Cohen, Wheelwright, Scahill, Lawson & Spong, 2001) we did not analyse these results, as a reviewer raised concern regarding the use of this test as a diagnostic measure

[3] Composite scores were not calculated, as this requires the use of age-scaled scores, which is not appropriate, given that the aim is to match the two differently-aged groups on *raw* performance

Figure

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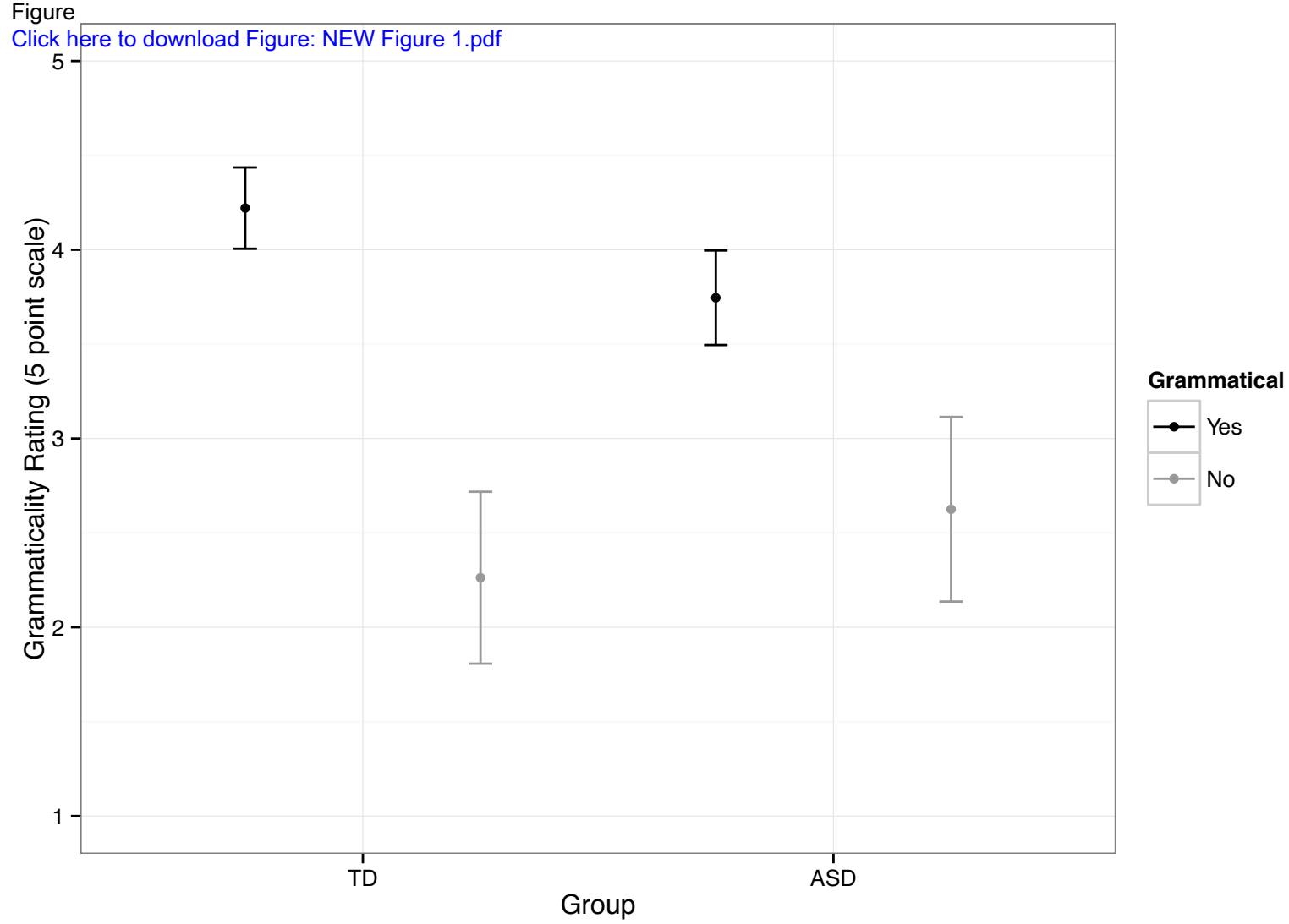

Table 1
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Table 1. Comparison of TD and ASD groups on individual components of the WISC-IV

		TD Group		ASD Group			
Index	**WISC-IV Subtests**	**M**	**SD**	**M**	**SD**	***t****	***p***
PRI	Block design (raw)	33.00	8.86	39.63	16.06	-1.44	0.16
VCI	Similarities (raw)	16.94	5.04	18.69	11.86	-0.54	0.59
MWI	Digit Span (raw)	16.94	3.66	15.81	5.65	0.67	0.51
PRI	Picture Concpts (raw)	14.62	5.28	15.56	4.70	-0.53	0.60
PSI	Coding (raw)	40.75	18.22	39.19	8.98	0.31	0.76
VCI	Vocabulary (raw)	27.31	9.13	29.88	13.99	-0.61	0.54
WMI	Letter-Number Seq (raw)	13.63	5.29	13.75	6.23	-0.06	0.95
PRI	**Matrix Reasoning (raw)**	**15.50**	**5.27**	**20.13**	**6.05**	**-2.31**	**0.03**
VCI	Comprehension (raw)	19.88	4.57	15.81	8.42	1.69	0.10
PSI	Symbol Search (raw)	22.56	5.45	22.19	7.73	0.16	0.88
	Age	**9.42**	**2.40**	**12.21**	**0.59**	**-4.51**	**0.00**

PRI=Perceptual Reasoning Index
VCI=Verbal Comprehension Index
WMI=Working Memory Index
PSI = Processing Speed Index

*Welsh's df correction for unequal variances applied

Table 2. Mixed effects models

Factor	***M***	***SE***	***df***	***t***	***Chi Sq***	***p (Chi sq)***
(Intercept)	2.22	0.50	37.90	4.46		
Age	-0.01	0.05	27.30	-0.30	1.64	0.20 n.s.
Grammaticality (Yes vs No)	2.17	0.21	44.10	10.24	37.28	<0.001
Group (ASD vs TD)	0.40	0.26	70.20	1.53	1.28	0.26 n.s
Grammaticality x Group	-0.84	0.22	569.50	-3.86	14.73	<0.01

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