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Intact non-word repetition and similar error patterns in language-matched children with autism spectrum disorders: A pilot study

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ABSTRACT

Purpose: We investigated whether enhanced auditory short-term memory may contribute to the learning of novel word forms in children with Autism Spectrum Disorder. We also evaluated whether delayed but qualitatively normal, versus atypical, cognitive processes underlie non-word repetition in this population *via* a detailed error analysis.

Method: English-speaking children with Autism Spectrum Disorder (who had significant language delay) and typically-developing children matched pairwise on language ability were compared on the Syllable Repetition Task (Shriberg et al., 2009).

Results: All children exhibited better performance on stimuli of shorter vs. longer syllable length. In addition there was a significant interaction whereby children with Autism Spectrum Disorder performed better than typically-developing children at the longest syllable length. Repetition accuracy was significantly correlated with language level in both groups. In contrast, the relationship between Repetition accuracy and age was only marginally significant in the Autism Spectrum Disorder group and did not reach significance in the typically-developing group. This underscores the importance of language level to non-word repetition performance, and supports the practice of matching on language rather than age alone. An error analysis (Shriberg et al., 2012) showed many similarities between groups in terms of number of consonants deleted, encoding accuracy, and transcoding accuracy components of the task. However the Autism Spectrum Disorder group tended to display better auditory short-term memory with a medium effect size, though this did not reach significance given the small sample size.

Conclusion: These findings extend evidence of delayed but qualitatively normal non-word repetition previously described in preadolescents with Autism Spectrum Disorder (Williams et al., 2013) to younger kindergarten-age children with Autism Spectrum Disorder and language delay, indicating that non-word repetition is not an area of specific difficulty for this population. With respect to enhanced auditory short-term memory, we found preliminary evidence of better memory for longer nonwords in children with Autism Spectrum Disorder compared to younger typically developing children who were matched on language.

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1. Introduction

Autism spectrum disorders (ASD) are defined by impairments in social interaction and communication as well as repetitive interests and behaviors (American Psychiatric Association [APA], 2013). Early language delays are common but not universal in young children with ASD (*e.g.*, Luyster, Kadlec, Carter, & Tager-Flusberg, 2008; Weismer, Lord, & Esler, 2010). Yet, perhaps counterintuitively, aspects of auditory processing have been shown to be enhanced in adolescents and adults with Autism Spectrum Disorders (ASD), across a growing body of studies testing identification or discrimination of pitch of pure tones (*e.g.*, Bonnel et al., 2003; Jones et al., 2009), complex tones (*e.g.*, Heaton, 2003; Mottron, Peretz, & Ménard, 2000), as well as processing of pitch contour and rhythm in speech (Heaton, Hudry, Ludlow, & Hill, 2008; Järvinen-Pasley, Wallace, Ramus, Happé, & Heaton, 2008). A review of this literature in 2011 by Haesen, Boets, and Wagemans concluded that "identification and discrimination of isolated acoustic features (in particular pitch processing) is generally intact or enhanced in individuals with ASD, for pure as well as for complex tones and speech sounds." (p. 701). With respect to the mechanism that leads to enhanced local auditory processing, Bonnel et al. (2003, p. 230) suggest that high-functioning individuals with ASD may have more robust auditory short-term memory for pitch that is relatively resistant to the temporal decay and interference that affect neurotypical individuals. Two theories, Weak Central Coherence (Frith, 2003; Frith & Happé, 1994; Happe', 1999), and Enhanced Perceptual Functioning (Mottron and Burack, 2001; Mottron, Dawson, Soulières, Hubert, & Burack, 2006), predict enhanced local processing in ASD (along with either decreased or optional global processing, not investigated in the current study). However, we do not know if enhanced perception of acoustic features may hold implications for language learning.

Does enhanced local auditory processing extend to the initial learning of novel word forms in children with ASD? Findings from an experimental word-learning task conducted by Norbury, Griffiths, and Nation (2010) suggest that it does. These authors found that 6- to 8-year-olds with ASD were significantly better at producing the phonological forms of novel words soon after learning them than were typically-developing children matched for age, nonverbal IQ, and vocabulary ability, although this difference was not maintained four weeks later. Norbury et al. (2010) proposed that this heightened phonological skill may provide a mechanism by which children with autism learn new vocabulary, despite relying less on social cues. That is, while typically-developing (TYP) children may pay particular attention to social information in word learning situations (Norbury et al., 2010; Parish-Morris, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007), children with ASD may focus more of their attention on the sound structure of language (Järvinen-Pasley, Pasley, & Heaton, 2008; Norbury et al., 2010).

Non-word repetition tasks, where participants are asked to repeat a novel string of syllables in the absence of a referent, offer another window onto the initial processing of word forms. The aims of the current study are to better understand the nature of non-word repetition in younger children with ASD (mean age = 5;8) than those reported on previously by 1) comparing their non-word repetition accuracy to a typically-developing group matched on a global measure of receptive and expressive language 2) examining if repetition accuracy is more strongly associated with language level or with age in ASD, and 3) investigating different components of non-word repetition ability *via* an error analysis reflecting encoding, memory, and transcoding or production aspects of the task (Shriberg, Lohmeier, Strand, & Jackielski, 2012). Together these measures will provide evidence as to whether non-word repetition is delayed but in line with expressive language skills in ASD, or whether it is an area of particular impairment as reported for children with Specific Language Impairment (discussed in more detail below).

Prior work on non-word repetition reveals that *language impaired* children and adolescents with ASD (ASD + LI) perform poorly relative to standardized test norms (Kjelgaard and Tager-Flusberg, 2001) or age-matched TYP comparison groups (Gabig, 2008; Whitehouse, Barry, & Bishop, 2008). In contrast, children and adolescents with ASD and age-appropriate structural language are unimpaired in non-word repetition relative to TYP children of the same age (Kjelgaard and Tager-Flusberg, 2001; Whitehouse et al., 2008), highlighting that difficulties are tied to poor language ability rather than ASD per se. Notably, individuals with Specific Language Impairment demonstrate severe decrements in non-word repetition despite being matched on global measures of language ability to typically-developing groups, particularly when non-word stimuli are long (4 or 5 syllables in length, Riches, Loucas, Baird, Charman, & Simonoff, 2011; Whitehouse et al., 2008; Williams et al., 2013). Yet individuals with ASD, even those with significant language impairment, do not display the same pattern. The significantly better non-word repetition performance of participants with ASD + LI relative to those with Specific Language Impairment in several studies has provided evidence against overlap of these disorders, and for distinct underlying causes of non-word repetition difficulty in each case. These results are important in informing an active debate as to whether ASD and SLI share the same etiology (*e.g.*, Kjelgaard and Tager-Flusberg, 2001; Leyfer, Tager-Flusberg, Dowd, Tomblin, & Folstein, 2008), or whether the similarities observed in language profiles are superficial but stem from distinct underlying causes (*e.g.*, Whitehouse et al., 2008; Williams, Botting, & Boucher, 2008; Williams, Payne & Marshall, 2013).

As highlighted by Williams et al. (2013), a language-matched typically-developing comparison group is essential to understanding whether differences in performance stem from a qualitatively similar delay in a given ability, versus a deviant pattern of performance. Though this comparison is widely employed in the non-word repetition literature on SLI, Williams et al. (2013) were the first to conduct such a comparison among children (mean age 12 years) with ASD + LI, SLI, and typical development, as well as younger typically-developing children matched on verbal mental age. They developed 64 complex non-word stimuli (*e.g.*, krifyimp, boflisentim) to examine known difficulties with increased syllable length and the production of medial consonant clusters in SLI (Marshall and van der Lely, 2009). Strikingly, they found that children with

ASD + LI did not differ from language-matched typically-developing children on any measure or qualitative aspect of non-word repetition, whereas children with SLI performed significantly worse than the former groups and produced a different pattern of errors (Williams et al., 2013). This led the authors to conclude that children with ASD + LI exhibit delayed non-word repetition commensurate to their structural language skills. That is, they appear to employ qualitatively similar cognitive processes to younger typically-developing children.

In addition to illuminating the nature of differences in non-word repetition performance, matching on language ability is essential given the key role language level, particularly vocabulary size and related phonological knowledge, plays in non-word repetition performance (Gathercole 1995, 2006; Gupta & MacWhinney, 1997). For instance, non-word repetition ability is affected by the word-likeness and phonotactic probability of non-words, suggesting that stored lexical-phonological knowledge influences repetition accuracy (Dollaghan, Biber, & Campbell, 1995; Gathercole, Willis, Emslie, & Baddeley, 1991; Munson, 2006; Munson, Kurtz, & Windsor 2005). Multiple groups of researchers have proposed that vocabulary size and consequent phonological knowledge are in fact a causal determinant of non-word repetition performance (Edwards, Beckman & Munson, 2004; Snowling, Chiat, & Hulme, 1991). Given the importance of language level and related phonological knowledge for non-word repetition performance, we compare a kindergarten-age sample of children with ASD, the vast majority of whom had significant language delays, to typically-developing children matched on language ability. Moreover we examine relationships between language level or age on one hand, and non-word repetition accuracy on the other, which have not previously been examined in ASD. If we find that language level strongly associated with non-word repetition accuracy in ASD, as has been shown for typical development (Edwards et al., 2004) this would provide another source of evidence of typical phonological processes in this population.

We employed the Syllable Repetition Task (SRT) (Shriberg et al., 2009) as our measure of non-word repetition. The SRT consists of 18 non-words of 2-, 3-, and 4-syllable lengths, consisting entirely of five early-occurring speech sounds that are present in the phonetic inventories of most English speakers by the age of three (*i.e.*,/b, d, m, n/), thereby minimizing articulatory demands and avoiding possible confounds arising from misarticulations of later-developing target speech sounds (for the full set of stimuli and technical report please consult www.waisman.wisc.edu/phonology/techreports/TREP14.pdf).

The available evidence suggests that children with ASD may display similar non-word repetition accuracy to children matched on language level, as shown for the preadolescents tested by Williams et al. (2013) on much more complex non-word stimuli. However, given the very simple non-word stimuli we employed and findings of enhanced phonological processing of novel words (Norbury et al., 2010) and enhanced pitch processing of speech sounds (Heaton, Hudry et al., 2008; Heaton, Williams, Cummins, & Happe', 2008; Järvinen-Pasley, Pasley et al., 2008; Järvinen-Pasley, Wallace et al., 2008), it is possible that children with ASD in our study may perform better on longer stimuli. Therefore we predicted that children with ASD would perform at least as well as language-matched typically-developing children on the SRT.

Finally, to better understand the nature of non-word repetition ability in ASD we conducted an investigation of the task's component skills. Non-word repetition tasks involve listening to and repeating auditory non-word stimuli of increasing complexity (*e.g.*, dama, badama). Although initially conceived as a test of phonological short-term memory (Gathercole and Baddeley, 1989), it is widely acknowledged (see Coady and Evans, 2008 for a review) that these tasks tap multiple cognitive processes, of interest here 1) auditory-perceptual encoding, 2) matching to stored phonological representations, 3) retention of the auditory sequence in short-term memory, 4) articulatory planning, and 5) execution/repetition of non-word. In this study we reduce sources of variation due to step 2 by matching on language level, and minimize the demands of step 5 by using the SRT which was developed to remove the confound of articulation difficulty in non-word repetition. We examine the remaining component skills: auditory encoding, auditory short-term memory, and articulatory planning through an error analysis of SRT data, using the framework Shriberg et al. (2012) developed for the investigation of non-word processing in childhood apraxia of speech.

Encoding accuracy

We employ an analysis of the type of phoneme substitutions made (as proposed by Shriberg et al., 2009) to examine the first step of non-word repetition processing, auditory-perceptual encoding. Within-class substitutions are ones where the substituted phoneme does not change in manner of articulation (*e.g.*, substituting/m/for/n/in which both phonemes are nasals), whereas cross-class substitutions involve manner changes (*e.g.*, substituting/b/for/n/in which one phoneme is a stop and the other is a nasal). Within-class substitutions indicate that the target has been at least partially encoded (*i.e.,* the manner of articulation has been correctly encoded). *Encoding accuracy* is operationalized as the percentage within-class substitutions over all phoneme substitutions produced by that speaker. Riches et al. (2011) examined the encoding errors of adolescents with ASD + LI and typically developing adolescents on a longer and more complex test of non-word repetition and found no significant group differences. Therefore we predict that auditory-perceptual encoding will be intact in ASD as reflected in similar encoding accuracy across groups.

Auditory short-term memory

The auditory short-term memory component was analyzed following Shriberg et al. (2012) as a ratio of repetition accuracy on longer *vs.* shorter stimuli. The rationale of this measure, as opposed to simply examining accuracy on the longest stimuli, is that it isolates the contribution of memory in retaining longer items relative to the speaker's ability to encode shorter stimuli. We present 4 syllable to 2 syllable ratios as these best captured the variability in memory ability in our sample. We predict that memory will be enhanced in ASD, given the findings of Norbury et al. (2010), as well as findings from Walenski, Mostofsky, Gidley-Larson, and Ullman (2008), describing enhanced lexical memory in ASD.

Transcoding accuracy

For a complete treatment of repetition errors, we also examined additions to the target stimuli, which Shriberg et al. (2012) considered to reflect planning or programming deficits rather than difficulties with encoding or memory processes.

2. Methods

2.1. Participants

We report data from 9 ASD children and 9 TYP children. Participants were recruited in Montreal, Canada and were identified as English speakers by parent report based on the criterion that exposure to English across settings was greater than 75%. Inclusion criteria included the absence of physical disability that would interfere with completing the study procedures. Children with ASD were recruited through the local Children's Hospital and community flyers. They were assessed by a multidisciplinary team and were administered the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002) during diagnosis; all met criteria for ASD. TYP children were recruited from a university research database. Inclusion criteria for these children included no symptoms of ASD; no developmental, learning or behavioral disorder; no history of significant medical complications or conditions; no 1st or 2nd degree relatives with an ASD. Details on matching are provided below.

2.2. Procedure

Participants took part in a larger longitudinal study which included three time points over the course of a year. The data for the present study were obtained at the third and last study visit which took place in a university lab.

2.2.1. Language measure

Child language abilities were measured with the Mullen Scales of Early Learning (Mullen, 1995), which measures cognitive functioning in the domains of receptive and expressive language, visual reception (nonverbal skills), and fine and gross motor skills, in English-speaking children from birth to 68 months. For the purposes of this study, we report raw scores from the receptive and expressive language subscales of the Mullen. Standard scores were not available for all participants with ASD because some of them were older than age range of the norming sample. Therefore language impairment could not be characterized based on standard scores, but age equivalents, based on raw scores, were examined and are described below under *Group matching.*

2.2.2. Diagnostic measure

The ADOS (Lord et al., 2002) is a semi-structured assessment designed to assess children's social communication abilities and other behaviors associated with ASD. Children in our ASD group were administered Module 1 or 2, and all met criteria for ASD based on the cut-off scores for the respective module.

2.2.3. Group matching

ASD and TYP children were matched pair-wise to a child who had similar expressive language raw scores (within 5 points) on the Mullen Scales of Early Learning (Mullen, 1995). Table 1 shows participant characteristics as well as test results demonstrating no significant difference in expressive language, or receptive language, across diagnostic groups. As a result of matching on language ability the ASD group was significantly older (mean age of 5;8 as opposed to mean age of 3;1 for the TYP group). This reflects the fact that all but one ASD participant presented with a significant language delay. When chronological age was subtracted from each child's Mullen Expressive Language age equivalent this resulted in a mean delay of 23.44 months ($SD = 14.93$) in the ASD group. The same calculation in the TYP group resulted in a mean advantage of 6 months in expressive language age equivalent relative to chronological age ($SD = 9.90$). The ASD group also contained marginally significantly more male participants than the TYP group (8/9 males in the ASD group as opposed to 4/9 males in the TYP group), which is reflects the increased incidence of ASD in males.

Table 1
Participant characteristics.

	Autism Spectrum Disorder (n = 9)	Typically-Developing (n = 9)	Test statistic	*p* value	Effect Size *d*
Mullen Exp. Lang raw score	36.44 (11.65) Range: 15–50	36.00 (8.60) Range: 20–45	t = 0.09	0.928	0.04
Mullen Rec. Lang raw score	39.33 (9.25) Range: 27–48	36.11 (6.37) Range: 25–45	*t* = 0.86	0.404	0.41
CA in months	68.67 (12.09) Range: 50–85	36.78 (7.10) Range: 26–46	*t* = 6.82	<0.001	3.32
Number of males	8/9	4/9	$\chi^2 = 4.00$	0.046	–

2.2.4. Non-word repetition using the Syllable Repetition Task (SRT, Shriberg et al., 2009)

The SRT was administered following the instrumentation and scoring guidelines outlined in the SRT technical report (Shriberg and Lohmeier, 2008). The SRT audio stimuli were presented *via* a laptop with external speakers using the SRT Powerpoint presentation downloaded from http://www.waisman.wisc.edu/phonology. Participants were told “You are going to say some silly words. Every time you hear the woman say a word, you try to copy her. Say the word exactly the way she says it.” (Shriberg and Lohmeier, 2008). They then heard sequences of consonant-vowel syllables that made up non-words of increasing length (*e.g.*, bada, bamana, bamadana) and were asked to repeat them. We followed the administration instructions outlined the SRT technical report (Shriberg and Lohmeier, 2008) with one exception – if it proved necessary to continue testing, test items were administered again. Testing sessions were videotaped for later scoring and analysis.

2.2.5. Transcription and error analysis

Responses from the SRT were transcribed from video in the International Phonetic Alphabet (IPA) by the second author, and the 50 target consonants were scored as correct or incorrect. A second person (an SLP trained in phonetic transcription, who was blind to group membership and the hypotheses of the study) transcribed responses from 16 of the 18 participants. Interrater reliability calculated over all consonants was 91.5%. The total SRT score is the percent of correct consonants out of 50. The percent of correct consonants was also calculated separately for each syllable length (2, 3, and 4 syllables).

The component skills of auditory encoding, auditory short-term memory, and articulatory planning were examined *via* an analysis of errors, using the framework Shriberg et al. (2012). *Encoding accuracy* was measured as the percentage of consonant substitutions that were of the same manner of as the target sound, over all substitutions. Higher scores indicate greater competence in encoding the manner features of target sounds. The *auditory memory* component of the task was measured using the ratio of 4 syllable to 2 syllable accuracy, which best captured the variability in our sample. Higher scores indicate ability to repeat longer sequences while controlling for a speaker’s ability to encode and repeat shorter sequences. Finally, *transcoding accuracy* was measured as 100 minus the percentage of 18 target responses with one or more additions. Higher scores indicate greater accuracy in producing target sounds free from additions.

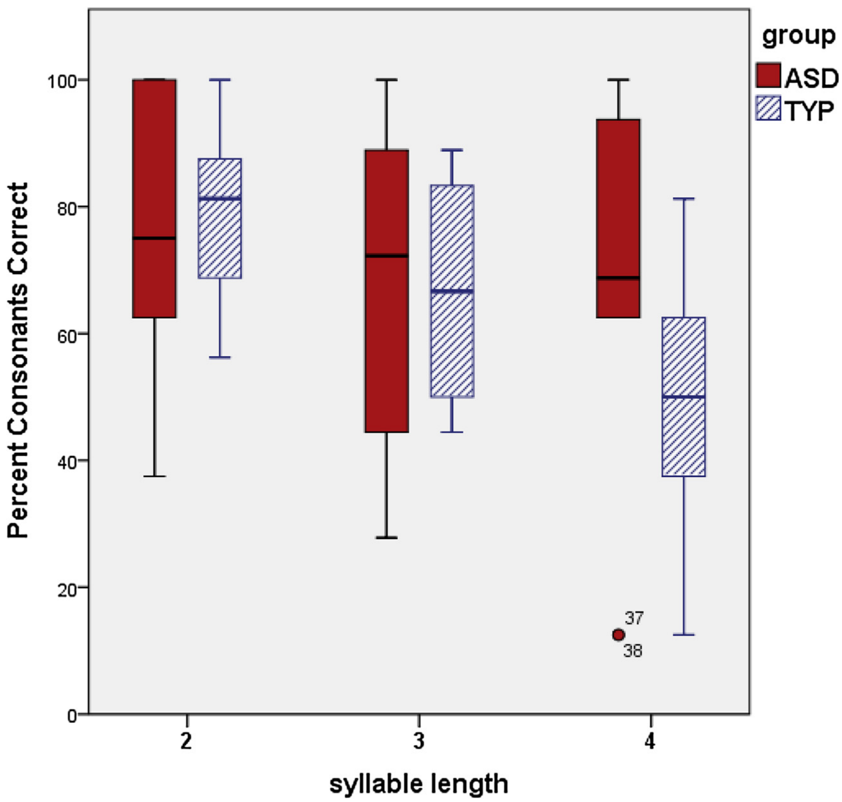

Fig. 1. Boxplot of accuracy on Syllable Repetition Task.

3. Results

3.1. Task administration

The matched groups did not differ in the number of items that needed to be administered a second time (ASD $M = 2.33$, $SD = 2.74$, TYP $M = 2.75$, $SD = 1.98$, t (15) = −0.355, $p = 0.728$, $d = -0.18$).

3.2. Repetition accuracy

To examine repetition accuracy the percent of consonants correct were submitted to a repeated-measures ANOVA with syllable length (2, 3, 4) as a within-subjects factor and group (ASD, TYP) as a between subjects factor. As expected there was a significant main effect of syllable length, F (2, 32) = 15.25, $p < 0.001$, $\eta_p^2 = 0.49$. Contrasts revealed significantly reduced repetition accuracy for 3 syllable relative to 2 syllable stimuli, F (1, 16) = 8.37, $p = 0.011$, and for 4 syllable relative to 3 syllable stimuli, F (1, 16) = 13.89, $p = 0.002$. Groups were not significantly different in their repetition accuracy, F (1, 18) = 0.35, $p = 0.560$, $\eta_p^2 = 0.022$. Finally, there was a significant interaction between group and syllable length, F (2, 32) = 4.08, $p = 0.026$, $\eta_p^2 = 0.20$. To break down this interaction repeated contrasts were performed comparing each step in syllable length. These revealed no significant interaction when comparing 3- to 2-syllable accuracy, F (1, 16) = 0.21, p = 0.654, but a strong significant interaction when comparing 4- to 3-syllable accuracy, F (1, 16) = 9.34, p = 0.008. This was due to the ASD group ($M = 67.4\%$, $SD = 34.6\%$) having higher 4 syllable scores than the language-matched TYP group ($M = 49.3\%$, $SD = 20.11$). Fig. 1 shows repetition accuracy for the language-matched groups tested in this study. As can be seen here, both groups were more accurate at shorter syllable lengths, with the ASD group showing elevated accuracy scores for the longest syllable length. For purposes of comparison with typically developing children similar in age to our ASD group, data provided in the SRT Technical Report (Shriberg and Lohmeier, 2008) indicates that typically-developing 4- to 6-year-olds (n = 20) had mean rates of 95% accuracy for 2-syllable, 81% accuracy for 3-syllable, and 76% accuracy for 4-syllable stimuli.

3.3. Relationships between repetition accuracy and expressive language or age

To examine the contributions of expressive language and age to SRT accuracy we conducted correlations within each group. Expressive language (Mullen expressive language raw scores) was significantly and positively related to SRT accuracy in both the ASD group ($r = 0.90$, $p = 0.001$) and the TYP group ($r = 0.67$, $p = 0.047$). In contrast, the relationship between age and SRT accuracy was only marginally significant in the ASD group ($r = 0.61$, $p = 0.083$) and was not significant in the TYP group ($r = 0.26$, $p = 0.494$). The relationship between expressive language and SRT accuracy remained significant when submitted to a partial correlation controlling for age in the ASD group ($r = 0.84$, $p = 0.009$), and remained marginally significant in the TYP group ($r = 0.69$, $p = 0.06$).

3.4. Component skills

Table 2 presents data and test results on raw number of errors on the SRT task (number of consonants deleted or substituted) as well as analyses of the encoding accuracy, auditory short-term memory and transcoding accuracy components of the non-word repetition task. A power analysis was conducted using data from Shriberg et al. (2012); who found significant differences between typically-developing children and children with apraxia of speech on the component skills of the SRT. We consider the sample size needed to find differences in the auditory short-term memory component, which was the one we predicted to differ between groups, specifically that children with ASD would perform better. Based on Shriberg et al. (2012's) data from children with apraxia of speech, a sample size of 15 in each group would be sufficient to detect a significant difference with alpha set at 0.05 and power at 0.80. Given that our pilot study sample size fell short of this (9 in each group) we pay particular attention to effect size in interpreting our results. Following Cohen (1988), effect sizes are interpreted as small (>0.2), medium, (>0.5) or large (>0.8). Consonant deletions were rare in both groups and were not

Table 2
Error Analysis/Components of performance on the Syllable Repetition Task.

	Autism Spectrum Disorder (n = 9) Mean (SD)	Typically-Developing (n = 9) Mean (SD)	Test statistic *t*	*p* value	Effect size *d*
Number of consonants deleted	1.78 (3.35)	1.22 (1.86)	0.44	0.669	0.21
Number of consonants substituted	10.67 (11.02)	14.89 (5.60)	−1.03	0.321	0.50
Encoding accuracy[a]	46.01% (29.27%)	42.05% (21.10%)	0.33	0.746	0.15
Auditory short-term memory[b]	0.81 (0.32)	0.62 (0.25)	1.42	0.176	0.66
Transcoding accuracy[c]	91.98% (7.91%)	91.36% (11.15%)	0.14	0.894	0.06

[a] Percent of substitutions produced with correct manner of articulation.
[b] Ratio of accuracy on 4 syllable vs. 2 syllable items.
[c] Percent of items produced without additions.

statistically different with a small effect size. The number of consonant substitutions also did not vary significantly between groups, although the typically developing group displayed more of these with a medium effect size. Turning to components of the non-word repetition task, the ASD and TYP groups did not reliably differ in the measure of encoding accuracy: when they substituted consonants both groups employed ones of the same manner of articulation as the target consonant a little less than half of the time. This suggests similar auditory-perceptual encoding ability across groups. Our measure of auditory short-term memory, the 4-syllable to 2-syllable repetition accuracy ratio, indicated better performance in children with ASD relative to language-matched typically developing children with a medium effect size, but this did not reach statistical significance. Finally, transcoding errors, where participants added non-target syllables or phonemes in their repetition, were exceedingly rare and did not differ significantly between groups.

4. Discussion

We compared the performance of kindergarten-aged English-speaking children with ASD with language delays to younger typically-developing children, on a test of non-word repetition using a limited set of early-acquired phonemes, the Syllable Repetition Task (Shriberg et al., 2009). Our main finding from this pilot study was a significant interaction between group and syllable length: the groups performed similarly on 2-syllable stimuli but the ASD participants were more accurate as stimulus length increased, and performed significantly better on 4-syllable stimuli. Contrary to reports suggesting that non-word repetition is globally impaired in ASD (*e.g.*, Gabig, 2008; Kjelgaard and Tager-Flusberg, 2001), our findings add to the evidence that non-word repetition skills are delayed in ASD but commensurate to or better than those of typically-developing children with similar language skills. Williams et al. (2013) demonstrated that preadolescents with ASD (mean age 12) had similar non-word repetition accuracy and qualitative error patterns to a language-matched comparison group on complex non-word stimuli involving consonant clusters. We have extended this finding to younger children (mean age 5;8) and shown that with the simple stimuli we employed, children with ASD actually had better repetition accuracy than a language-matched comparison group on 4-syllable stimuli. These findings stand in stark contrast to those reported elsewhere for children with SLI, who are not simply delayed but present a severely impaired and deviant pattern of non-word repetition accuracy and errors when compared to younger *or* same-age typically-developing children (Riches et al., 2011; Whitehouse et al., 2008; Williams et al., 2013).

Second, we found non-word repetition accuracy to be significantly correlated with expressive language level in both ASD and TYP groups, whereas this was not the case for age in our samples. This highlights the dominance of language level over age in contributing to differences in language processing skills in ASD, and the importance of matching on language level rather than age alone when evaluating delayed versus deviant performance. Importantly, this finding demonstrates for the first time that non-word repetition ability is related to expressive language skills in ASD. Future work should investigate in more detail how phonological aspects of vocabulary knowledge relate to non-word repetition performance in ASD, for example whether non-word repetition is affected by word-likeness and phonotactic probability to the same extent as it is in typical development (Dollaghan et al., 1995; Gathercole et al., 1991; Munson et al., 2005), and whether there is evidence of a causal role of vocabulary knowledge on non-word repetition performance.

Finally we conducted an error analysis to investigate key components of non-word repetition, including encoding, auditory short-term memory and transcoding/planning processes. Our data demonstrates similar encoding accuracy in children with ASD and language-matched typically developing children, as we predicted. This may appear inconsistent with prior reports of enhanced auditory perception in tasks examining the discrimination and identification of pitch contours and rhythm in speech (Heaton, Hudry et al., 2008; Heaton, Williams et al., 2008; Järvinen-Pasley, Wallace et al., 2008). This is likely because non-word repetition tasks involve multiple linguistic demands beyond auditory-perceptual identification. For instance our measure of encoding relies on producing the correct manner of articulation of a perceived speech sound. This highlights that enhanced local auditory processing in ASD, as reviewed in the introduction, may have limited transfer to the learning and use of language itself. With respect to auditory short-term memory, the ratio of accuracy on 4 syllable *vs*. 2 syllable items was elevated in the ASD group with a medium effect size but was not significantly different from the TYP group, likely due to small sample size and variability in both groups. We found no evidence of transcoding difficulty in children with ASD, in contrast to findings from apraxia of speech, where marked transcoding impairment as well as decrements in encoding and auditory memory components of non-word repetition (Shriberg et al., 2012).

In sum, our findings demonstrate that children with ASD have commensurate performance to typically-developing children matched for language ability on all component skills of a non-word repetition task using simple stimuli, and in fact demonstrate enhanced repetition accuracy on the longest test stimuli. There was also some indication of enhanced performance on the auditory memory component of the task in children with ASD, which will need to be replicated in a larger sample, and crucially, with an age-matched typically developing comparison group with equally mature short-term memory capacity. While these findings are in line with theories that propose enhanced local processing in ASD (Weak Central Coherence (Frith, 2003; Frith & Happé, 1994; Happe', 1999), and Enhanced Perceptual Functioning (Mottron and Burack, 2001; Mottron et al., 2006), it is important to note that they were found in children with ASD who were significantly older than the comparison group, given their language delays. It will be important for future work to investigate this question in with multiple groups of children who can be matched either on age or on language level. It will also be essential to evaluate the robustness of any advantages conferred by enhanced short-term auditory memory, *e.g.*, are longer word forms retained after a time delay, and furthermore, how does memory for word forms relate to global or semantic aspects of word learning.

Taken together with previous findings from older children using more complex non-word stimuli (Williams et al., 2013), this suggests that children with ASD handle the multiple linguistic skills tapped by non-word repetition tasks with qualitatively similar cognitive processes as those seen in typical development, though generally at a delay proportionate with their expressive language skills. Furthermore, language level was found to significantly correlate with non-word repetition accuracy after age was controlled for, indicating an interplay between language knowledge and the repetition of novel phonological forms in ASD, as has been demonstrated in typical development (Dollaghan et al., 1995; Gathercole et al., 1991; Munson et al., 2005; Munson, 2006).

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