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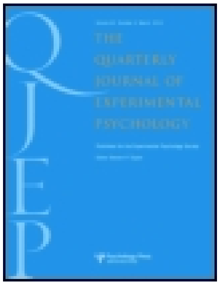
Joanne Arciuli
University of Sydney

Rhea Paul
Sacred Heart University, paulr4@sacredheart.edu



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Joanne Arciuli [a] & Rhea Paul [b]

[a] Faculty of Health Sciences, University of Sydney, Sydney, NSW, Australia

[b] Child Study Center, Yale School of Medicine, Yale University, New Haven, CT, USA

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Sensitivity to probabilistic orthographic cues to lexical stress in adolescent speakers with autism spectrum disorder and typical peers

Joanne Arciuli[1] and Rhea Paul[2]

[1]Faculty of Health Sciences, University of Sydney, Sydney, NSW, Australia
[2]Child Study Center, Yale School of Medicine, Yale University, New Haven, CT, USA

Lexical stress refers to the opposition of strong and weak syllables within polysyllabic words and is a core feature of the English prosodic system. There are probabilistic cues to lexical stress present in English orthography. For example, most disyllabic English words ending with the letters "-ure" have first-syllable stress (e.g., "pasture", but note words such as "endure"), whereas most ending with "-ose" have second-syllable stress (e.g., "propose", but note examples such as "glucose"). Adult native speakers of English are sensitive to these probabilities during silent reading. During testing, they tend to assign first-syllable stress when reading a nonword such as "lenture" but second-syllable stress when reading "fostpose" (Arciuli & Cupples, 2006). Difficulties with prosody, including problems processing lexical stress, are a notable feature of autism spectrum disorder (ASD). The current study investigated the ability of adolescents with ASD (13–17 years of age) to show this sensitivity compared with a group of typically developing peers. Results indicated reduced sensitivity to probabilistic cues to lexical stress in the group with ASD. The implications of these findings are discussed.

Keywords: Lexical stress; Prosody; Autism spectrum disorder; Autism; Probabilistic cues; Reading; Orthography.

Autism spectrum disorder (ASD) is a neuropsychological condition characterized by deficits in social communication and the presence of restricted and repetitive behaviours (American Psychiatric Association, APA, 1994). Although individuals with ASD can show expressive communication skills that range from no functional speech to advanced vocabulary and syntax, current estimates suggest that 70–80% of individuals with a diagnosis of ASD have functional use of spoken language (Rogers, 2006). Since the first delineation of the autistic syndrome (Kanner, 1943), abnormal prosody has been identified as a core feature of the syndrome for individuals with autism who speak.

Prosody plays a pivotal role in human interaction. All of the world's languages exhibit a characteristic pattern of prosodic rules, which provide suprasegmental cues to convey lexical, grammatical, pragmatic, and affective information.

Correspondence should be addressed to Joanne Arciuli, Faculty of Health Sciences, University of Sydney, PO Box 170, Lidcombe, NSW 1825, Australia. E-mail: joanne.arciuli@sydney.edu.au

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The term *prosody* refers to: (a) the assignment of relative prominence or stress to various units within the speech signal; (b) changes in pitch of the speech sound wave over time that make up its intonation contour; and (c) the rhythm and timing patterns that make up the phrasing of the utterance, expressed through fluency, rate, duration, and pauses within speech events. Acoustically, prosody is a composite of pitch (fundamental frequency), intensity (amplitude), and duration, as well as the covariation of these variables (Stephens, Nickerson, & Rollins, 1983).

Atypicalities in prosody production are among the most commonly reported social-communicative features of ASD (see Shriberg et al., 2001, for review) and also one of the earliest characteristics to appear (Paul, Fuerst, Ramsay, Chawarska, & Klin, 2011; Wetherby et al., 2004). Prosodic atypicalities have been reported at all levels of ability in ASD, including high-functioning autism (Peppé, McCann, Gibbon, O'Hare, & Rutherford, 2007), although prosodic production deficits are not seen universally in this population. Paul, Shriberg et al. (2005) reported abnormal prosody in the spontaneous speech of 47% of the 30 speakers with ASD studied. A range of prosodic production deficits have been reported in speakers with ASD, including problems with stress, phrasing, and intonation (See Shriberg et al., 2001, for review). However, many of these early studies were plagued by methodological difficulties, including small sample sizes, absence of normative data and contrast groups, and poorly defined prosodic categories.

In an attempt to address some of these problems, Shriberg et al. (2001) reported on a range of suprasegmental characteristics in continuous speech samples from adult speakers with high-functioning autism, using a standard assessment method, the Prosody-Voice Screening Profile (PVSP; Shriberg et al., 1990). They found significant differences between ASD and typical speakers, most notably regarding the use of stress and the presence of hypernasal voice quality. In an experimental paradigm, Paul and colleagues (Paul, Augustyn, Klin, & Volkmar, 2005) found that children with ASD matched for reading level to a group of typical peers showed deficits in stress production in response to written material at both the lexical (e.g., "REcall" versus "reCALL") and phrasal levels (e.g., "CHOCOLATE ice cream" versus "chocolate ICE CREAM"). Paul, Bianchi, Augustyn, Klin, and Volkmar (2008), using an imitation task, reported acoustic differences in the production of stressed versus unstressed nonsense syllables in adolescents with ASD, when compared to typical peers. In addition, analyses of both spontaneous and imitative production of lexical stress for both real and nonsense words in speakers with ASD revealed small but significant differences in both perceptual ratings of stress and acoustic measures of duration of syllables (Diehl & Paul, in press). Taken together, these findings suggest that producing appropriate stress patterns is one of the primary features of prosodic difficulty in speakers with ASD.

The term *lexical stress* refers to the contrast between strong and weak syllables within words. Stress-timed languages exhibit patterns of lexical stress that vary from word to word and are not predictable in a straightforward way. There is considerable debate regarding the classification of languages as stress- versus syllable-timed. Such differences may be more accurately viewed in terms of a continuum. Still, there are prototypical examples, and English is often cited as an example of stress-timing. In English over 90% of words contain more than one syllable and, thus, exhibit lexical stress. Lexical stress is critical for intelligibility (Klopfenstein, 2009) and contributes to the perception of a speaker's communicative competence (Paul, Shriberg et al., 2005).

Stress assignment during reading

There are probabilistic cues to lexical stress present within English orthography. Arciuli and Cupples (2006) undertook a large-scale corpus analysis of over 7,000 disyllabic words within the CELEX database. The endings of these words were analysed to determine probabilistic relationships with lexical stress patterns. "Ending" was defined as the letter string beginning at the second phonemic vowel and including any following letters (i.e., the "body" or "rime" of the second syllable regardless of the presence of inflections). The analysis revealed 340 distinct word endings, which were reported by Arciuli and Cupples (2006) in their Appendix C. Some endings were found to be strongly associated with first-syllable stress, while different endings were found to be strongly associated with second-syllable stress. For example, around 70% of disyllabic English words ending with the letters "-ure" have first-syllable stress (e.g., "pasture", but note "endure"), whereas around 70% of words ending with "-ose" have second-syllable stress (e.g., "propose", but note "glucose"; Arciuli & Cupples, 2006). Adults are sensitive to these probabilities during silent reading. Using carefully constructed disyllabic nonwords that contain probabilistic cues to lexical stress, it was found that participants tended to assign first-syllable stress when reading a nonword such as "lenture" but second-syllable stress when reading "fostpose" (Arciuli & Cupples, 2006).

Additional research has confirmed the value of word endings in assigning lexical stress during reading. A triangulation of corpus analyses of age-appropriate children's reading materials, behavioural testing, and computational modelling demonstrated that sensitivity to these kinds of probabilistic cues to lexical stress during reading aloud follows a developmental trajectory in typically developing children aged 5–12 years (Arciuli, Monaghan, & Ševa, 2010). As children are exposed to an increasing volume and variety of written language in their reading materials, sensitivity to probabilistic cues to lexical stress increases. This appears to happen without having to draw children's attention to these cues explicitly. See Ševa, Monaghan, and Arciuli (2009) for additional modelling work comparing probabilistic versus rule-based approaches to stress assignment during reading aloud.

The current study

There is speculation that the difficulty in producing stress in speakers with ASD may stem from subtle motor impairments that impact the ability to reproduce precisely the prosodic patterns of other speakers in their environment (Diehl & Paul, in press). In contrast, Shriberg, Paul, Black, and van Santen (2011) recently reported data suggesting that both perceptual and acoustic measures of the prosody of young children with ASD were more likely to stem from a failure to attune to speech patterns in the environment, rather than from motor disorders. One way to test the hypothesis that it is a lack of attunement to ambient speech patterns rather than motor difficulties that leads to prosodic production differences in those with ASD is to employ an experimental lexical stress task that does not require overt speech.

The current study investigated how adolescents with ASD respond to the lexical stress assignment task reported by Arciuli and Cupples (2006) in their Experiment 4, in which participants are given a written list of disyllabic nonwords that contain probabilistic biases towards either first- or second-syllable stress and are asked to underline the part of the word (either the beginning or the end) that they think should receive emphasis. This task has the potential to elucidate participants' underlying knowledge about lexical stress patterns in English, without the requirement that they replicate these patterns in their own speech. Since adults, rather than adolescents, had been tested in the Arciuli and Cupples (2006) study, a group of typically developing students was matched for age and verbal IQ to our group of adolescent speakers with ASD. The Arciuli and Cupples task was then administered to these two groups of participants.

Method

Participants

A total of 22 typically developing (TD) adolescents and 25 with high-functioning ASD, all native monolingual speakers of English with normal or corrected-to-normal eyesight and normal hearing, participated in the study. All participants had verbal IQ scores above 70 and spoke in full sentences. The age range of participants was 13–17 years. Descriptive information on the two participant groups appears in Table 1. There were no significant differences between the two groups in terms of age, verbal IQ, language, or reading

Table 1. *Characteristics for diagnostic groups*

Characteristic	*TD (n = 22)*	*ASD (n = 25)*	*t(45)*	*p*	*Cohen's d*
Age (years)	15.0 (1.2)	15.0 (1.5)	0.27	.79	0.08
Verbal IQ[a]	105.0 (12.3)	110.0 (22.8)	1.18	.25	0.35
CELF total score[b]	107.1 (10.1)	100.8 (17.7)	1.47	.15	0.44
GORT score[c]	107.3 (16.9)	100.5 (23.3)	1.13	.27	0.33

Note: Means are shown, with standard deviations in parentheses. TD = typically developing. ASD = autism spectrum disorder.
[a]Verbal IQ score on Differential Abilities Scale (Elliott, 2007) for ASD group, and on Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999) for TD group. [b]Composite standard score on CELF (Clinical Evaluation of Language Fundamentals–IV; Wiig, Secord, & Semel, 2004). [c]GORT (Gray Oral Reading Test; Gray, 1996) Developmental Quotient.

scores (see Table 1). The group with TD contained more girls (8) than the group with ASD (3).

The group with typical development was screened for ASD using the Social Communication Questionnaire (Rutter, Bailey, & Lord, 2003). The participants in the ASD group had all been diagnosed previously by medical professionals or multidisciplinary teams as showing this syndrome. The Autism Diagnostic Observation Schedule–G (ADOS–G; Lord, Rutter, DiLavore, & Risi, 2000) and Autism Diagnostic Interview–Revised (ADI–R; Lord, Rutter, & LeConteur, 1994) were used to confirm diagnoses. All participants in the ASD group met criteria for ASD on both the ADOS–G and the ADI–R. None of the TD participants scored above threshold on the Social Communication Questionnaire screener. For the TD group, family history questionnaire responses also confirmed that no immediate family members had any history of autistic symptoms or a diagnosis of ASD.

Procedure

This study employed the same stimuli and task as those reported by Arciuli and Cupples (2006), with a reduced set of stimuli to avoid fatigue in these younger participants, who were also undergoing a larger battery of testing as part of their participation in an ongoing research project. The 40 stimuli from the Arciuli and Cupples report were divided into four lists. Each participant completed one of the four lists, and list presentation was rotated randomly among participants. The Appendix displays the lists of stimuli.

The task was administered during individual testing. The written stimuli were presented on a sheet of paper. Written instructions were read to the participant by a trained research assistant, who also gave them practice stimuli and made sure participants understood the task. The research assistant was available throughout the task to answer any questions the participant had. Participants were instructed to underline parts of the written words to indicate whether they thought emphasis should be placed closer to the beginning (first syllable) or to the end (second syllable) of each word on the list, after explanation and demonstration of what was meant by "emphasis".

Results

Data for the TD group and ASD group were examined separately for outliers. The mean scores of 3 participants (2 ASD and 1 TD: 6% of the data) were found to be more than 2 standard deviations from the mean of their group for that condition and were excluded from further analysis.[1] A 2×2 analysis of variance (ANOVA) was conducted. Group (TD versus ASD) was between subjects, and nonword type (nonwords with cues to first-syllable stress versus nonwords with cues to second-syllable stress) was within subjects. Percentage of words assigned first-syllable stress was the

[1] Excluding these participants did not affect the significance of the *t* tests conducted to examine matching (Table 1).

dependent variable. There was no main effect of group, $F(1, 42) = 0.30$, $p = .59$, $\eta_p^2 = .007$; however, there was a main effect of nonword type, $F(1, 42) = 18.39$, $p < .001$, $\eta_p^2 = .304$. Nonwords with cues to first-syllable stress were more often assigned first-syllable stress than were nonwords with cues to second-syllable stress (means of 63.6% and 43.4%, respectively). Importantly, there was a significant interaction between group and nonword type, $F(1, 42) = 5.85$, $p = .02$, $\eta_p^2 = .122$.

As in Arciuli and Cupples (2006), we then conducted paired t tests. TD and ASD data were analysed separately. A Bonferroni corrected alpha level of .025 (.05/2) was used to determine significant differences. As expected, typically developing adolescents showed sensitivity to probabilistic orthographic cues to lexical stress. On average, they assigned first-syllable stress to disyllabic nonwords that contained cues to first-syllable stress 70.8% of the time. In contrast, they assigned first-syllable stress to disyllabic nonwords containing cues to second-syllable stress only 39% of the time. A paired-samples t test revealed that this difference was significant, $t(20) = 4.69$, $p < .001$, Cohen's $d = 1.23$. This result indicates that typically developing adolescents show the same sensitivity to probabilistic orthographic cues to lexical stress as the adults reported by Arciuli and Cupples (2006).

On average, adolescents with ASD assigned first-syllable stress to disyllabic nonwords that contained cues to first-syllable stress 56.5% of the time. In contrast, they assigned first-syllable stress to disyllabic nonwords containing cues to second-syllable stress 47.7% of the time. A paired-samples t test showed that this difference was not significant, $t(22) = 1.34$, $p = .194$, Cohen's $d = 0.43$. Thus, adolescents with ASD did not appear to show the same level of sensitivity to probabilistic orthographic cues to lexical stress as the typically developing adolescents we tested or the adults reported in Arciuli and Cupples (2006).

Discussion

Previous research has found a rich source of probabilistic cues to lexical stress in English orthography and has shown that adults, children, and connectionist computational models are sensitive to these regularities (e.g., Arciuli & Cupples, 2006; Arciuli et al., 2010; Ševa et al., 2009). In particular, Arciuli and Cupples (2006) showed that adults respond to probabilistic cues to lexical stress in disyllabic nonwords in predictable ways during silent reading. A separate body of research indicates that many individuals with ASD exhibit difficulties with prosody, and especially stress patterns, although whether the source of these problems is motor difficulties or lack of attunement to ambient language has not been clear.

The present study revealed that adolescents with ASD do not appear to show the same level of sensitivity to probabilistic lexical stress cues as their typically developing peers. In view of Arciuli et al.'s (2010) findings that sensitivity to probabilistic orthographic cues to lexical stress increases with age, it might be argued that perhaps the participants with ASD that were included in our study had not yet reached age-appropriate levels of sensitivity, even though they were older than the participants reported in the earlier Arciuli et al. study. The counterargument to this possibility is that our ASD and TD groups were matched in terms of language, reading, and verbal IQ. This matching suggests that participants in each of our groups probably received similar levels of exposure to oral and written language that would enable sensitivity to probabilistic orthographic cues to emerge if it were going to emerge.

Since there was no requirement for participants to produce the words, it seems unlikely that motor explanations can account for this difficulty. While the findings do not allow us to definitively rule out motor deficits (as motor plans may be implicated even when an overt response is not produced), the findings lend weight to the suggestion of Shriberg et al. (2011) that it may be a lack of attunement to the fine details of ambient language conventions that underlie this deficit.

It is possible that "attunement" and, more specifically, sensitivity to probabilistic cues in language (be they in oral or written language) might be underpinned by the capacity for implicitly detecting regularities—known as statistical learning. One possibility is that impaired prosodic processing in individuals with ASD might be associated with deficits in statistical learning. Neuroscientific evidence from typically developing adults shows that statistical learning starts to operate almost as soon as an individual is exposed to stimuli that contain regularities and without any form of instruction to do so, and that it proceeds in the absence of conscious awareness (Turk-Browne, Scholl, Chun, & Johnson, 2009). A recent functional magnetic resonance imaging (fMRI) study has revealed a lack of statistical learning during exposure to artificial language containing probabilistic cues in children and adolescents with ASD aged 9–16 years (Scott-Van Zeeland et al., 2010). Interestingly, the study also revealed a relationship between the degree of communication impairment (measured via the ADI–R communication subscale) and neural processing during the statistical learning task in those with ASD. A study by Brown, Aczel, Jiminez, Kaufman, and Grant (in press) incorporated a range of behavioural tests of implicit learning, including artificial grammar learning, a contextual cueing task, and a serial reaction time task. In contrast with the Scott-Van Zeeland et al. study, their results suggest that implicit learning is intact in children and adolescents with ASD aged 8–14 years. In addition, Brown et al. reported that there was no correlation between the degree of communication impairment (measured via the Social Communication Questionnaire) and performance on the implicit learning tasks. These studies reflect a growing interest in implicit learning processes in individuals with ASD, and additional research is required to further elucidate the learning profiles of children with and without ASD and how these profiles might (or might not) relate to various aspects of language impairment.

Future research could explore the possibility that prosodic difficulty in individuals with ASD is related to a limited capacity for statistical learning by including the task we used in the current study alongside independent tests of statistical learning. As far as we are aware no previous study has undertaken this kind of investigation. Yet, it seems that the incorporation of language-based tasks that specifically rely on the processing of probabilistic cues (as opposed to more general measures of language ability such as the ADI–R or the Social Communication Questionnaire) alongside independent tests of statistical learning may be particularly well suited to the exploration of subtle covariation in proficiency with natural language and statistical learning abilities.

If it can be demonstrated that reduced sensitivity to probabilistic lexical stress cues is unrelated to statistical learning in those with ASD, then alternative explanations for the results of the current study need to be explored. One possibility is that individuals with ASD are sensitive to probabilistic cues to lexical stress in English orthography but that this sensitivity is somehow overridden by impaired monitoring and checking processes during the act of silent reading—perhaps via faulty inner speech (sometimes referred to as the inner voice). Additional future research might also examine participants' stress assignment during both a silent reading task and a reading aloud task using the nonwords we used in the current study. It is possible that our participants with ASD may have had metacognitive difficulties reflecting on prosody or perhaps struggled with the decision elements of the task. This may relate to the question of implicit learning in ASD. Use of a more implicit prosody assignment task may reveal a lack of group differences if implicit learning is intact in the ASD population.

Regardless of the source of the observed differences, it seems possible that they have consequences for language function in speakers with ASD. Difficulty in using orthographic regularities to assign stress in polysyllabic words may lead to slower processing of written texts. For example, this difficulty could result in reduced or delayed activation of semantic networks for processing word meaning, leading to slower or less appropriate spreading activation within semantic networks, which supports depth of association in language processing. Potentially, this effect could play some role in the reading comprehension deficits present in many readers with ASD (Nation, Clarke, Wright, & Williams, 2006). As there are other factors known to be associated with poor comprehension in individuals with ASD, reduced sensitivity to probabilistic orthographic cues to lexical stress, alone, cannot account for comprehension difficulties in this population. Future research might investigate the (relative) impact of reduced sensitivity to orthographic regularities upon reading outcomes.

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REFERENCES

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Arciuli, J., & Cupples, L. (2006). The processing of lexical stress during visual word recognition: Typicality effects and orthographic correlates. *Quarterly Journal of Experimental Psychology*, *59*(5), 920–948.

Arciuli, J., Monaghan, P., & Ševa, N. (2010). Learning to assign lexical stress during reading aloud: Corpus, behavioural and computational investigations. *Journal of Memory and Language*, *63,* 180–196.

Brown, J., Aczel, B., Jiminez, L., Kaufman, S., & Grant, K. (2010). Intact implicit learning in autism spectrum conditions. *Quarterly Journal of Experimental Psychology*, *63*(9), 1789–1812.

Diehl, J., & Paul, R. (in press). Acoustic and perceptual measurements of prosody production on the PEPS-C by children with autism spectrum disorders. *Applied Psycholinguistics*.

Elliott, C. D. (2007). *DAS–II administration and scoring manual*. San Antonio, TX: Pearson Assessments.

Gray, W. (1996). *Gray Oral Reading Test–III*. Austin, TX: Pro-Ed.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, *2,* 217–250.

Klopfenstein, M. (2009). Interaction between prosody and intelligibility. *International Journal of Speech-Language Pathology*, *11*(4), 326–331.

Lord, C., Rutter, M., DiLavore, P., & Risi, S. (2000). *Autism Diagnostic Observation Schedule–G*. Los Angeles, CA: Western Psychological Services.

Lord, C., Rutter, M., & LeConteur, A. (1994). Autism Diagnostic Interview–Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, *24,* 659–685.

Nation, K., Clarke, P., Wright, B., & Williams, C. (2006). Patterns of reading ability in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *36*(7), 911–919.

Paul, R., Augustyn, A., Klin, A., & Volkmar, F. (2005). Perception and production of prosody by speakers with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *35,* 201–220.

Paul, R., Bianchi, N., Augustyn, A., Klin, A., & Volkmar, F. R. (2008). Production of syllable stress in speakers with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *2,* 110–124.

Paul, R., Fuerst, Y., Ramsay, G., Chawarska, K., & Klin, A. (2011). Out of the mouths of babes: Vocal production in infant siblings of children with ASD. *Journal of Child Psychology and Psychiatry*, *52,* 588–598.

Paul, R., Shriberg, L. D., McSweeny, J., Cicchetti, D., Klin, A., & Volkmar, F. (2005). Brief report: Relations between prosodic performance and communication and socialization ratings in high functioning speakers with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *35*(6), 861–869.

Peppé, S., McCann, J., Gibbon, F., O'Hare, A., & Rutherford, M. (2007). Receptive and expressive prosodic ability in children with high-functioning autism. *Journal of Speech, Language, and Hearing Research*, *50*(4), 1015–1028.

Rogers, S. (2006). Evidence-based intervention for language development in young children with autism. In T. C. W. Stone (Ed.), *Social and communication development in autism spectrum disorders: Early identification, diagnosis, and intervention*. New York, NY: Guilford.

Rutter, R., Bailey, A., & Lord, C. (2003). *Social Communication Questionnaire*. Los Angeles, CA: Western Psychological Services.

Scott-Van Zeeland, A., McNealy, K., Wang, A., Sigman, M., Bookheimer, S., & Dapretto, M. (2010). No neural evidence of statistical learning during exposure to artificial languages in children with autism spectrum disorders. *Biological Psychiatry*, *68*(4), 345–351.

Ševa, N., Monaghan, P., & Arciuli, J. (2009). Stressing what is important: Orthographic cues and lexical stress assignment. *Journal of Neurolinguistics*, *22*(3), 237–249.

Shriberg, L., Kwiatkowski, J., & Rasmussen, C. (1990). *The Prosody-Voice Screening Profile*. Tucson, AZ: Communication Skill Builders.

Shriberg, L., Paul, R., Black, L., & van Santen, J. (2011). The hypothesis of apraxia of speech in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *41,* 405–426.

Shriberg, L., Paul, R., McSweeney, J., Klin, A., Cohen, D., & Volkmar, F. (2001). Speech and prosody characteristics of adolescents and adults with high functioning autism and Asperger syndrome. *Journal of Speech, Language, and Hearing Research*, *44,* 1097–1115.

Stephens, K., Nickerson, R., & Rollins, A. (1983). Suprasegmental and postural aspects of speech production and their effect on articulatory skills and intelligibility. In I. Hochberg, H. Levitt, & M. Osberger (Eds.), *Speech of the hearing impaired: Research, training and personnel preparation* (pp. 35–51). Baltimore, MD: University Park Press.

Turk-Browne, N. B., Scholl, B. J., Chun, M. M., & Johnson, M. K. (2009). Neural evidence of statistical learning: Efficient detection of visual regularities without awareness. *Journal of Cognitive Neuroscience*, *21,* 1934–1945.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence*. San Antonio, TX: Pearson Assessments.

Wetherby, A., Woods, J., Allen, L., Cleary, J., Dickinson, H., & Lord, C. (2004). Early indicators of autism spectrum disorders in the second year of life. *Journal of Autism and Developmental Disorders*, *34,* 473–493.

Wiig, E. G., Secord, W., & Semel, E. (2004). *Clinical evaluation of language fundamentals–IV*. San Antonio, TX: The Psychological Corporation, Harcourt Brace Jovanovich.

APPENDIX

Stress assignment task: Experimental stimuli in each list

List 1	*List 2*	*List 3*	*List 4*
breckage	fostpose	baldron	aject
curban	troduct	regan	lanage
hunstroke	secline	lenture	mucrose
hatrine	onsect	refend	feduct
setect	ventose	savern	ongage
undure	masern	ampose	dorphine
partel	hatchel	nevoke	tanure
fantern	dummon	hispel	vorsage
antend	rancel	vegend	espect
fontage	brefect		plosure
			viscern