Relations Among Detection of Syllable Stress, Speech Abnormalities, and Communicative Ability in Adults With Autism Spectrum Disorders

Niko Kargas, a Beatriz López, b Paul Morris, b and Vasudevi Reddy b

Purpose: To date, the literature on perception of affective, pragmatic, and grammatical prosody abilities in autism spectrum disorders (ASD) has been sparse and contradictory. It is interesting to note that the primary perception of syllable stress within the word structure, which is crucial for all prosody functions, remains relatively unexplored in ASD. Thus, in the current study, we explored syllable stress perception sensitivity and its relationship to speech production abnormalities and communicative ability in adults with ASD.

Method: A same–different syllable stress perception task using pairs of identical 4-syllable words was delivered to 42 adults with/without high-functioning ASD, matched for age, to investigate primary speech perception ability in ASD. Speech production and communicative ability in ASD was measured using the Autism Diagnostic Observation Schedule (Lord et al., 2000).

Results: As predicted, the results showed that adults with ASD were less sensitive in making judgments about syllable stress relative to controls. Also, partial correlations revealed a key association of speech production abnormalities with stress perception sensitivity, rather than communicative ability.

Conclusions: Our findings provide empirical evidence for deficits on primary syllable stress perception in ASD and its role on sociocommunicative difficulties. This information could facilitate the development of effective interventions for speech and language therapy and social communication.

A typical prosody production is one of the most noted deviant characteristics of language in individuals with autism spectrum disorders (ASD; for a review, see McCann & Peppé, 2003). Despite the overwhelming evidence showing that many individuals with ASD demonstrate atypical prosodic perception skills and atypical-sounding prosody, a speech element that could become a stigmatizing barrier to social acceptance (Shriberg et al., 2001), little is known about the associations of these two abilities (see McCann & Peppé, 2003; O’Connor, 2012, for reviews). Thus, the focus of this article is, first, to explore the relationship between basic speech perceptual skills and speech production abnormalities and, second, to explore if their relationship contributes to the sociocommunicative difficulties observed in individuals with high-functioning ASD.

Speech perception has multiple functions. In particular, speech sounds may convey information on the content, the emotional connotation, and the identity of the speaker (e.g., Blake & Sekuler, 2006). In linguistics, the term prosody refers to the suprasegmental properties of the speech signal and plays an important role in a range of communicative functions that have been categorized as affective, pragmatic, and grammatical (Panagos & Prelock, 1997; Roach, 2000; Shriberg et al., 2001). These functions help the speaker to enhance or change the meaning of what is said (Couper-Kuhlen, 1986; Cruttenden, 1997), hence facilitating communication. In an acoustic manner, prosody is defined by variations in loudness (amplitude), duration, pitch (fundamental frequency), intonation (changes in pitch over time), rhythm (duration, rate, and pauses), and stress (the relative prominence of particular units within the speech signal; Lehiste, 1970; Shriberg, Kwiatkowski, & Rasmussen, 1990; Stephens, Nickerson, & Rollins, 1983).

Affective prosody refers to changes in the speech register used with different social situations or communicative

Disclosure: The authors have declared that no competing interests existed at the time of publication.

aUniversity of Lincoln, Lincolnshire, United Kingdom bUniversity of Portsmouth, Hampshire, United Kingdom
Correspondence to Beatriz López: beatriz.lopez@port.ac.uk


DOI: 10.1044/2015_JSLHR-S-14-0237

Downloaded From: http://jslhr.pubs.asha.org/ by a ReadCube User on 09/01/2016
Terms of Use: http://pubs.asha.org/ss/rights_and_permissions.aspx
partners (e.g., speech toward children or work colleagues) and to convey general emotional states (e.g., relaxed or annoyed; Bolinger, 1989; Hargrove, 1997). Pragmatic prosody refers to different ways an utterance is expressed to deliver the intentions of the speaker and to provide additional social information that goes beyond the syntax of the sentence (e.g., Bates & McWhinney, 1979; Winner, 1988). For example, stress can be used pragmatically to emphasize the unit of information within an utterance that requires the receiver’s focus of attention. Grammatical prosody is used to indicate whether someone makes a question or a statement and to highlight syntactic information within utterances or sentences (e.g., Gerken, 1996; Warren, 1996). Grammatical stress, for instance, indicates whether a word is a noun (e.g., PREsent) or a verb (e.g., preSENT).

In comparison with prosodic expressive abilities, fewer investigations have explored the processing skills of receptive prosody in individuals with ASD (Globerson, Amir, Kishon-Rabin, & Golan, 2014; McCann & Peppé, 2003; O’Connor, 2012). Most of the studies in this area have focused primarily on the perception of pragmatic/afffective prosody (Chevallier, Noveck, Happé, & Wilson, 2011; Globerson et al., 2014; Golan, Baron-Cohen, & Hill, 2006; Golan, Baron-Cohen, Hill, & Rutherford, 2007; Grossman, Bemis, Plesa Skwerer, & Tager-Flusberg, 2010; Heikkinen et al., 2010; Järvinen-Pasley, Wallace, Ramus, Happé, & Heaton, 2008; Jones et al., 2011; Kleinman, Marciano, & Ault, 2001; Lindner & Rosén, 2006; Peppé, McCann, Gibbon, O’Hare, & Rutherford, 2007; Rutherford, Baron-Cohen, & Wheelwright, 2002). In several of these studies using complex vocal expressions (i.e., when an understanding of mental states is needed for making a judgment) or complex experimental paradigms (i.e., tasks that demand enhanced cognitive load), findings were reported for atypical perception of pragmatic and affective prosodic cues in individuals with ASD (e.g., Chevallier et al., 2011; Golan et al., 2006, 2007; Kleinman et al., 2001; Rutherford et al., 2002). In contrast, the processing of basic voice expressions and vocalizations (e.g., laughing–happy, crying–sad) appear to be intact in children, adolescents, and adults with ASD (Grossman et al., 2010; Heikkinen et al., 2010; Jones et al., 2011) although some studies failed to replicate these findings (Lindner & Rosén, 2006; Mazefsky & Oswald, 2007; Philip et al., 2010).

Research on the perceptual abilities of grammatical prosody in ASD also provides contradictory findings. To be specific, some research groups reported that individuals with ASD exhibited deficits in the comprehension of grammatical cues of word stress (Paul, Augustyn, Klin, & Volkmar, 2005; Peppé et al., 2007) whereas others have not (Chevallier, Noveck, Happé, & Wilson, 2009; Grossman et al., 2010; Järvinen-Pasley, Peppé, King-Smith, & Heaton, 2008). A similar pattern of inconsistencies in the results is evident in studies exploring the ability to use stress to perceive phrase structures in individuals with ASD. To be specific, in some studies, evidence was reported for impaired performance in individuals with ASD relative to controls (Dielh, Bennetto, Watson, Gunlogson, & McDonough, 2008; Jarvinen-Pasley, Peppé, et al., 2008), and other studies have not found significant group differences on performance (Paul, Augustyn, et al., 2005; Peppé et al., 2007).

In summary, current research on prosody perception and comprehension in ASD presents a complex picture, characterized by contradictory findings in all areas of prosodic function. Two main potential explanations for these inconsistencies are suggested in the literature. One explanation is that these contradictions are the result of differences among prosodic paradigms (e.g., Diehl et al., 2008; McCann & Peppé, 2003), and the other explanation suggests that previous inconsistencies reflect heterogeneity in ASD samples (e.g., Järvinen-Pasley, Peppé, et al., 2008; McCann & Peppé, 2003). For example, research shows that there is considerable variability in skills found in several domains in people with ASD (e.g., Kargas, López, Reddy, & Morris, 2015; Valla & Belmonte, 2013).

Literature on prosody ability in ASD has focused predominantly on prosodic expression, indicating deficiencies in vocal quality that are characterized by inappropriate use of stress (i.e., atypical placement of stress cues within the utterance), pitch variation (i.e., “robotic” or exaggerated intonation), phrasing, and rhythm (e.g., Baltaxe & Guthrie, 1987; Baltaxe, 1984; Bonneh, Levanon, DeNardo, Lossos, & Adini, 2011; DePape, Chen, Hall, & Trainor, 2012; Diehl & Paul, 2013; Kujala, Lepistö, & Näätänen, 2013; McCann & Peppé, 2003; Paul, Augustyn, et al., 2005; Paul, Bianchi, Augustyn, Klin, & Volkmar 2008; Paul, Shriberg, et al., 2005; Shriberg et al., 2001). These verbal behaviors are present at infancy and highly persistent with relatively little change over time (Kanner, 1971; Simmons & Baltaxe, 1975). Also, previous findings indicate that the receptive and expressive prosodic deficits are closely related (e.g., Diehl & Paul, 2013; McCann & Peppé, 2003; Paul, Augustyn, et al., 2005; Peppé et al., 2007).

Overall, pragmatic, affective, and grammatical stress perception and production are suggested to represent an area of particular difficulty for people with ASD (e.g., Diehl & Paul, 2013; Paul, Augustyn, et al., 2005; Paul et al., 2008; Shriberg et al., 2001). However, in previous studies on prosody perception in ASD, primary detection of syllable stress within the word structure independent of meaning has not been investigated. This is important because correct perception of syllable stress is necessary for the development of cognitive reconstructions that link different acoustic versions of an utterance with different affective, pragmatic, and grammatical functions and social meaning. On the basis of previous related findings reporting impaired perception of pragmatic, affective, and grammatical prosody cues in ASD (see Kujala et al., 2013; McCann & Peppé, 2003; O’Connor, 2012, for reviews), it is predicted that the group with ASD would exhibit reduced performance on our syllable stress perception task compared with the comparison group. Deficits in the primary perception of syllable stress could have negative consequences in learning how different acoustic versions of utterances convey different meanings, which in turn could result in atypical receptive
and expressive prosodic abilities, communication skills, and overall language acquisition (Cutler, Oahan, & van Donselaar, 1997; Mehta & Cutler, 1988; Pierrehumbert, 2003; Wood & Terrell, 1998). In addition, this study aimed to investigate the associations between stress perception and communicative abilities in individuals with ASD. On the basis of related findings showing a relationship between receptive and expressive prosodic skills in higher-level experimental tasks (see O’Connor, 2012, for a review), we predicted a similar relationship between primary perceptive skills of syllable stress and speech production abnormalities in ASD (e.g., Paul, Augustyn, et al., 2005; Peppé et al., 2007). Last, it was also hypothesized that both speech perception and production skills would be related to communicative abilities in individuals with ASD (Diehl & Paul, 2013; Paul, Shriberg, et al., 2005).

**Method**

**Participants**

Forty-two native adult English speakers participated in this study. Participants’ details are shown in Table 1. The participants were 21 individuals with ASD and 21 typically developing (TD) adults (three women and 18 men in each group). Participants with ASD were recruited from the database of the Autism Research Network (Portsmouth) and through a local adult support group for people with ASD. All participants in the ASD group had a formal diagnosis of Asperger’s syndrome by experienced clinicians according to the Diagnostic and Statistical Manual of Mental Disorders clinical criteria (American Psychiatric Association, 1994, 2000). In order to confirm their diagnoses and to ensure consistency across participants, the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) was administered. All participants fit the criteria for ASD. The comparison group was selected through the university’s participant pool and local social groups. Ethical approval was provided by the university’s research ethics committee. On the basis of self-reports, it was confirmed that all participants in the comparison group did not have a psychiatric diagnosis, or developmental diagnosis.

All participants completed the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). Verbal IQ (VIQ), performance IQ (PIQ), full-scale IQ (FIQ), and chronological age characteristics of the participants in the ASD and TD groups did not differ significantly (all ps > .1). It is suggested that group-matching designs have a number of methodological limitations, particularly when studying cognitive and language abilities in ASD (Kover & Atwood, 2013; Mervis & Klein-Tasman, 2004); therefore, we do not consider our groups equally matched. Thus, in order to be confident that any significant group differences found on syllable stress perception, speech abnormalities, and social communication abilities do not reflect differences in intelligence, we also ran analyses controlling for VIQ, PIQ, and FIQ. Participants received a short hearing test for the standard range of frequencies (250–8000 Hz) using an audiometer. All of the participants had normal auditory acuity, which was a condition for being included in the study.

**Syllable Stress Perception Task**

A stress perception task was used to test the hypothesis that primary perception of syllable stress is reduced in the group with ASD. The task was based on 10 four-syllable words with lexical templates that have first syllable stress, such as auditory and dandelion, and 10 four-syllable words with lexical templates that have second syllable stress, such as capacity and democracy. The words were selected from the linguistics databases of MRC Psycholinguistic Database and CELEX. The selection criteria for the words included written and spoken frequency, familiarity, and syllable structure. Full details about the selection criteria for the words and the experimental paradigm can be found in Leong, Hämäläinen, Soltész, and Goswami (2010).

All words were produced by a native female speaker of British English and recorded using Audacity software. Two samples for each word were made, one with stress emphasis on the first syllable position such as AUditory (i.e., SUU), and another one with stress emphasis on the second syllable position, such as auDitory (i.e., USUU). This factor was labeled as first/second stress position. In general, in the English language, stress syllables are louder, longer, and higher in pitch than unstressed syllables. The two word samples were matched for total duration, and the first two syllables were analyzed for mean intensity, fundamental frequency (f0), and duration using Praat software. The total duration of the two tokens among the word pairs ranged from 800 ms to 1200 ms. Mean values for stressed and unstressed first syllables, such as AU or au in AUditory and

<table>
<thead>
<tr>
<th>Table 1. Participants’ mean scores and standard deviations for chronological age and IQ scores across groups.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
</tr>
<tr>
<td>ASD</td>
</tr>
<tr>
<td>Range</td>
</tr>
<tr>
<td>TD</td>
</tr>
<tr>
<td>Range</td>
</tr>
</tbody>
</table>

**Note.** ASD = autism spectrum disorder; TD = typically developing.
auditory, and stressed and unstressed second syllables as, for example, di in *Auditory* and DI in *auditory*, are shown in Table 2. Pair samples *t* tests were used to confirm that the auditory parameters differed between stressed (S) and unstressed (U) syllables and among words. Word pairs were matched in all four possible ways (SUUU–SUUU, USUU–USUU, SUU–SUU, USU–SUU), producing two different types of judgments, same and different (e.g., same: *Auditory*–*Auditory*/*auditory*–*auditory*; different: *Auditory*–*auditory*/*Auditory*). This factor is referred to as Discrimination type. Therefore, by combining the two factors together, two blocks of 40 trials were created. The experimental design we used is explained in Leong et al. (2010).

Word pairs were presented one after the other (500-ms interstimulus interval) with a 2000-ms intertrial interval. Participants were requested to make same–different judgments about the position of syllable stress in the pair, (e.g., same: SUUU–SUUU or different: SUU–SUU). Moreover, participants were asked to give their response as accurately and quickly as possible after a question mark appeared on the computer screen (at the end of the second word of each pair). During presentation of the stimuli, the computer screen remained blank. Their responses were given by pressing left or right buttons via a computer keyboard with the preferred hand. Last, the experimenter clarified to the participants that their task was to decide whether the word pairs sound the “same or different” and not whether they were correctly or incorrectly pronounced (Leong et al., 2010). All participants reported that the instructions were clear. Prior to testing, participants were given four practice trials and feedback of the accuracy of their responses (text on the screen and verbally), and they did not appear to have any problems executing the task.

### Speech Abnormalities and Communication Skills

The ADOS (Lord et al., 2000) was used to measure speech abnormalities and communication skills in the group with ASD. ADOS Module 4 provides accurate assessment and diagnosis of autism for verbally fluent adolescents and adults suspected of having ASD and is commonly used by clinicians and in research. An ADOS assessment takes approximately 40 min to complete. The ADOS consists of semi-structured situations and standardized activities, which allow the examiner to observe behaviors important to the diagnosis of ASD, such as communication, social interaction and play, or imaginative use of materials. “Language and communication” is one of the five ADOS measures. The ADOS language and communication measure assesses the participant’s language production skills and style of communication and comprises 10 items. Ratings on Item 2 of the ADOS language and communication score reflect speech abnormalities or, in other words, atypical vocal characteristics, which are specific to autism. For example, coding involves elements of speech that are unusually slow or rapid or have odd intonation and/or inappropriate stress. Thus, we used the ADOS total scores (excluding Item 2) to measure communicative ability and ADOS language and communication Item 2 as a measure of speech abnormalities in ASD.

### Procedure

The study was carried out in a 3-hr testing session. To begin, participants were seen individually by the first and second authors in order to complete the ADOS interview and the intelligence test. After administration of the ADOS and intelligence test, each participant was tested individually on the syllable stress perception task, and spoken stimuli were presented via closed-cup headphones (HD-3030). Participants were informed that they could terminate their participation at any time and without any negative consequences. Testing took place in a quiet room. Between each experimental procedure, rest breaks were given in order to ensure that performance on the tasks was not reduced due to tiredness and fatigue or loss of interest. Last, all participants reported that they had no problems performing the tasks; they also appeared to be interested and motivated.

### Results

Sensitivity and response bias in making judgments about syllable stress were measured using d prime (‘d’) and criterion (c). Calculated ‘d’ and c values as well as mean percentage of correct responses in each condition are shown in Table 3.

Independent sample *t* tests revealed significant group differences for sensitivity (‘d’) but not for criterion bias. To be specific, the group with ASD demonstrated significantly lower sensitivity on detecting lexical stress than the TD group task, *t*(40) = 2.7, *p* = .01. This finding indicates that

---

### Table 2. Acoustic parameters of stressed and unstressed syllables (mean across 20 words).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Stressed</th>
<th>Unstressed</th>
<th><em>t</em>(19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First syllable manipulated</td>
<td>e.g., AU in <em>Auditory</em></td>
<td>e.g., au in <em>auditory</em></td>
<td></td>
</tr>
<tr>
<td>Mean intensity in dB (SD)</td>
<td>78.4 (2.7)</td>
<td>69.4 (4.6)</td>
<td>10.0*</td>
</tr>
<tr>
<td>Mean f0 in Hz (SD)</td>
<td>222.3 (27.0)</td>
<td>182.8 (36.3)</td>
<td>5.23*</td>
</tr>
<tr>
<td>Mean duration in ms (SD)</td>
<td>288.2 (78.0)</td>
<td>148.7 (38.1)</td>
<td>6.91*</td>
</tr>
<tr>
<td>Second syllable manipulated</td>
<td>e.g., DI in <em>auditory</em></td>
<td>e.g., di in <em>Auditory</em></td>
<td></td>
</tr>
<tr>
<td>Mean intensity in dB (SD)</td>
<td>77.1 (3.5)</td>
<td>72.4 (4.2)</td>
<td>5.97*</td>
</tr>
<tr>
<td>Mean f0 in Hz (SD)</td>
<td>235.4 (19.0)</td>
<td>182.5 (22.2)</td>
<td>11.6*</td>
</tr>
<tr>
<td>Mean duration in ms 236.3 (SD)</td>
<td>162.4 (63.3)</td>
<td>4.52* (52.9)</td>
<td></td>
</tr>
</tbody>
</table>

*p < .001.
individuals with high-functioning ASD have difficulties in the detection of acoustic prominence in speech. However, as suggested by the nonsignificant group difference in the response bias, both groups were equally biased toward giving a same or different response.

A mixed-factorial analysis of variance, 2 (First/Second syllable stress) × 2 (Group), using $d'$ as the dependent variable, was conducted to statistically test the effects of varying the syllable template. This revealed a significant main effect of Group, $F(1, 40) = 6.9$, $p = .012$, partial $\eta^2 = .147$, but no significant main effect of First/Second syllable stress ($p = .235$) and no significant interaction between Group × First/Second syllable stress ($p = .114$). The same pattern of results was observed even after controlling for FIQ and VIQ. Overall, the aforementioned results indicate that the participants with ASD made significantly less accurate judgments about shared syllable stress regardless of the syllable template (i.e., SUUU or USUU).

Due to the heterogeneity of the ASD population and previous findings suggesting considerable variability in performance on acoustic discrimination paradigms (e.g., Jones et al., 2009; Kargas et al., 2015), we further explored the mean scores of $d'$ to assess if there were concealed subgroups with either exceptionally good or poor sensitivity performance on stress perception in the ASD group. The criteria for good and poor sensitivity performance were defined correspondingly as 2 SD above and below the mean of the TD group with higher $d'$ indicative of better performance. There were two exceptional good performers in each group. However, seven (33%) individuals in the ASD group had sensitivity values 2 SD below the comparison mean compared with two (10.5%) individuals in the TD group. This difference in distribution was significant, $X^2(df = 2) = 3.53; p = .038$. All other individuals in both groups performed within 2 SD.

### Associations Among Stress Perception, Speech Production, and Communication Skills in ASD

In order to explore if sensitivity in making judgments about shared syllables is associated with the quality of speech production in individuals with ASD, Pearson correlations were performed between $d'$ average values on performance in the stress perception task and ADOS speech abnormalities scores. These results revealed significant negative correlations ($r = -.75; p = .001$) between stress perception and speech abnormalities scores, indicating that lower $d'$ values—that is, less sensitivity on syllable stress—were associated with higher scores in the ADOS speech abnormalities item or, in other words, with atypical quality of vocal production. Also, the correlations remained significant even after partialing out all three measures of IQ (VIQ: $r = -.67, p = .001$; PIQ: $r = -.66, p = .002$; FIQ: $r = -.67, p = .002$). However, in contrast to predictions, the correlations between performance on the stress perception task and ADOS communication total scores were not significant ($r = -.19, p = .401$), indicating that impaired sensitivity on stress perception cannot fully account for communication deficits in the group with ASD. Last, consistent with our hypothesis, there was a moderately large, significant, positive correlation between ADOS speech abnormalities scores and ADOS communication total scores ($r = -.39, p = .028$), indicating that atypical speech production was associated with lower communication skills in ASD. Further, the relationship remained significant even after controlling for VIQ ($r = -.19, p = .036$).

To investigate the contribution that sensitivity on syllable stress perception and communicative ability had to speech production abnormalities in ASD, two partial correlations were calculated (see Figure 1). First was a partial correlation between ADOS speech production abnormalities scores and performance on the syllable stress perception task, controlling for ADOS communication total scores. These correlations revealed that the relationship between syllable stress perception sensitivity and quality of speech production remained highly significant ($r = -.68, p = .001$) even when controlling for communicative ability. The second partial correlation was between ADOS speech production abnormalities scores and ADOS communication total scores partialing out performance on the syllable stress perception task. It is interesting to note that the correlation between communicative ability and speech production abnormalities after partialing out performance on the speech perception task was no longer significant ($r = -.36, p = .110$) although still moderately large. This pattern of results suggests that it is impairments in detecting syllable stress rather than communicative ability that influence quality of speech in ASD.

### Discussion

The principle aim of the present study was to investigate if the perception of primary syllable stress in the absence of word meaning judgments is intact in individuals with high-functioning ASD. A secondary aim was to explore the relationships among perception of syllable stress, quality of speech production, and communicative ability in ASD. Four main findings emerged from the study. First, it was found that the ASD group was significantly less sensitive in the detection of syllable stress relative to controls. Second, even within a relatively homogeneous group with
ASD (i.e., autism diagnosis and level of IQ), performance on the syllable stress perception task varied considerably across individuals. Third, correlational analyses revealed that poor perceptual sensitivity of syllable stress was associated with atypical quality of speech production in ASD. Fourth, performance on the stress perception task was not significantly related to communicative ability in ASD, indicating that perceptual difficulties in primary prosodic information cannot fully account for differences in overall language and communication skills. However, it was shown that perception of syllable stress, rather than communicative ability, influences quality of speech production in ASD.

Our results on the syllable stress perception task add to previous research reporting impaired receptive abilities across a wide range of prosody functions in ASD (e.g., Chevallier et al., 2011; Diehl et al., 2008; Järvinen-Pasley, Peppé, et al., 2008; Paul, Augustyn, et al., 2005; Peppé et al., 2007) and are consistent with previous findings indicating that stress is an area of particular difficulty (e.g., Diehl & Paul, 2013; Paul, Augustyn, et al., 2005; Paul et al., 2008; Paul, Shriberg, et al., 2005; Shriberg et al., 2001). For example, several studies using the Profiling Elements of Prosodic Systems in Children (Peppé & McCann, 2003), the most widely used standard measure of receptive and expressive prosodic skills in the ASD literature (Peppé, 2009), have concluded that children with ASD have difficulties interpreting pragmatic, affective, and grammatical prosodic cues accurately (e.g., Diehl & Paul, 2013; Peppé & McCann, 2003). Our findings extend previous research by showing that adults with ASD appear to have difficulties detecting syllable stress regardless of whether meaning is important for making the decision.

The prosody impairments in ASD are predominantly thought to stem from either increased attention to perceptual cues of the speech signal (e.g., Mottron, Dawson, Soulières, Hubert, & Burack, 2006), which results in decreased attention to linguistic information (Happé & Frith, 2006), or due to higher-order processing impairments at the level of interpretation, such as understanding mental or affective states of others (e.g., Baron-Cohen, Leslie, & Frith, 1985). These explanations indicate that low-level perceptual processes are, to a great extent, intact in ASD. However, early prosodic deficits have been suggested to be a possible explanation for the later impairments in the comprehension of the pragmatic and socioemotional meanings and prosody production observed in individuals with ASD (e.g., Diehl et al., 2008; Diehl & Paul, 2013; McCann & Peppé, 2003; Ploog, Banerjee, & Brooks, 2009). For example, correct perception of syllable stress is necessary for the development of cognitive reconstructions that link different acoustic versions of an utterance with different affective, pragmatic, and grammatical functions and social meanings. Therefore, the current findings showing that the primary perception of syllable stress is impaired in ASD suggest that basic perceptual acoustic deficits may have a negative effect on all prosody functions, at least partly, and consequently might limit the repertoire of higher-order sociocommunicative skills.

Another potential explanation for the inconsistencies in previous findings on prosody perception abilities in ASD might lie in the considerable variability in skills that is frequently reported in several domains (Valla & Belmonte, 2013), such as in low-level auditory discrimination ability (e.g., Kargas et al., 2015), language and communication skills (e.g., Kjellmer, Hedvall, Fernell, Gillberg, & Norrellgen, 2012), and sensory behaviors (e.g., Bogdashina, 2003). Autism is a heterogeneous neurodevelopmental condition. Therefore, conceiving of ASD as a homogeneous group of disorders and conceptualizing perceptual abilities and sociocommunicative skills as stable over time seems unjustified and may also lead to contradictory findings (see also Kargas et al., 2015; Mayer, Hannent, & Heaton, 2014; Valla & Belmonte, 2013). For example, even within the relatively homogeneous sample in our study (i.e., autism diagnosis and levels of IQ), we found a meaningful subgroup with ASD (33%; see also Heaton, Williams, Cummins, & Happé, 2008; Jones et al., 2009; Kargas et al., 2015) that exhibited markedly poor sensitivity to syllable stress perception (above 2 SD from the control mean) and clear atypical speech.

It is interesting that in the current study performance on perception of syllable stress was associated with speech production abnormalities in ASD, supporting previous evidence showing a correlation between receptive and expressive prosodic skills (e.g., Diehl & Paul, 2013; McCann &
Peppé, 2003; Paul, Augustyn, et al., 2005; Paul et al., 2008; Peppé et al., 2007). However, it is worth pointing out that perception of syllable stress was not associated with communicative ability in ASD, indicating that factors other than perceptual prosody sensitivities may contribute to the development of communication deficits. Previous studies have shown that children with ASD do not emulate the speech of their peers as TD children do (Baron-Cohen & Staunton, 1994; Paul et al., 2008). For example, their stress production ability is not qualitatively comparable with the level of their peers (Diehl & Paul, 2013; Paul, Augustyn, et al., 2005). This lack of speech emulation is thought to be an important contributing factor to the social communication deficits observed in speakers with ASD (Baron-Cohen & Staunton, 1994; Paul et al., 2008). Receptive prosody precedes and influences the development of expressive prosody. In fact, in typical development, prosody processing ability is associated with early language acquisition and the development of communicative ability and social skills (e.g., Demuth & Morgan, 1996; Jusczyk, 2003; Pierrehumbert, 2003). Again, the exact perception of the acoustic prominence in speech is necessary for the precise emulation of speech. Therefore, on the basis of our findings, we propose the possibility that atypical sensitivity to acoustic cues of speech may influence the development of speech production in people with ASD. If this suggestion has any kernel of truth, it could facilitate the development of easy-to-implement and effective interventions for speech and language therapy in ASD (see also Diehl & Paul, 2013; Paul, Augustyn, et al., 2005; Paul, Shriberg, et al., 2005).

On the other hand, previous research has also highlighted that interest in sociocommunicative cues plays a crucial role in language acquisition in TD infants (e.g., Fernald, 1985; Fernald & Kuhl, 1987). Studies on infants and children with ASD have shown that interest in social cues is significantly less salient relative to TD individuals (e.g., Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Klin, 1991). For example, preschool children with ASD prefer to attend to nonspeech stimuli more than to childhood-directed speech, and their cortical mechanisms responsible for speech processing are underdeveloped (Kuhl, Coffey-Corina, Padden, & Dawson, 2005; see also Boddaert et al., 2004; Gervais et al., 2004; Lepistö et al., 2005). Therefore, social motivational reasons may also account for the failure to emulate the speech of peers and the speech production abnormalities observed in children with ASD. Thus, at least to some extent, lack of typical social communication and interaction experiences in ASD could have detrimental effects in learning significant linguistic and prosodic features important for effective communication.

Partial correlations revealed a key association of speech abnormalities with stress perception sensitivity rather than communicative ability in ASD. This pattern of results is consistent with accounts emphasizing the important role of prosody perception in language acquisition and the development of communication and social skills (e.g., Demuth & Morgan, 1996; Jusczyk, 2003; Pierrehumbert, 2003). These findings indicate that atypical speech perception is the primary contributing factor for speech abnormalities in ASD, such as inappropriate use of stress, which in turn could hinder the development of communication skills. To be specific, we propose that initial atypicalities in the perception of primary acoustic cues in speech may be responsible for speech production abnormalities that contribute to atypical social communication and interaction experiences, which result in the communication deficits observed in ASD. Future research is needed in order to test this hypothesis and to develop adequate theories mapping the development of social communication and interaction skills in ASD.

Previous research shows that adults with developmental dyslexia also have difficulties in the primary detection of syllable stress, which could result in severe phonological deficits (Leong et al., 2010). However, in contrast to people with ASD, individuals with developmental dyslexia do not have difficulties in interpreting pragmatic, affective, and emphatic stress cues or in social communication. It is worth pointing out that although our study used the same syllable stress task as in Leong et al. (2010), the acoustic differences of stressed versus unstressed syllables were more differentiated in our task than in the study on developmental dyslexia. In other words, it was easier to make a correct judgment in our task than in the previous study. Yet, by inspecting the percentages of correct responses between the two studies, it appears that adults with ASD made more errors than adults with developmental dyslexia, and the control groups in both studies performed similarly (see Leong et al., 2010, for full details). Thus, it is possible that there is a similar but more pervasive basic perceptual prosodic deficit in ASD than in developmental dyslexia, in which different degrees of severity may result in different types of prosodic impairments. We suggest that further research is needed to explore the specificity of these impairments.

It is worth mentioning the limitations for assessing speech abnormalities in ASD in the current study. The ADOS speech abnormalities score is a composite of different types of vocal atypicalities and does not differentiate between subtypes of speech features and thus is not the best measure for speech abnormalities. Therefore, although our principal aim was to explore if there is an association between syllable stress perception and speech production, we were not able to determine in what way individual differences in sensitivity to primary acoustic cues of syllable stress may differentially affect subtypes of speech abnormalities. Furthermore, future studies are needed to assess the extent to which different prosody functions are influenced by individual differences in primary perception of speech. Moreover, future research should attempt to utilize a battery of experimental paradigms in which the linguistic and perceptual dimensions of syllable cues are independently manipulated. Also, more research is needed to understand the role that atypical low-level auditory discrimination abilities in ASD (e.g., Kargas et al., 2015; O’Connor, 2012) play on prosody perception. This information would be of great significance for assisting speech and language therapists to identify particular targets for intervention.
Conclusion

The present study is comprised of two fundamental aspects. First, it provides a direct demonstration for impaired basic perception of acoustic cues for syllable stress within the word structure, regardless of meaning, in ASD. Second, it provides empirical evidence showing an association between primary detection of syllable stress and speech production atypicalities. However, it is noted that this may relate to high variability of perceptual abilities that is frequently reported in several domains in ASD (e.g., Kargas et al., 2015; Vallà & Belmonte, 2013). Furthermore, the current study provides evidence indicating that the relationship between perception of syllable stress and speech abnormalities may contribute to the development of communication deficits observed in ASD. However, it is suggested that perceptual atypicalities cannot fully account for the social communication and interaction impairments in ASD.

Our results support previous reports indicating that studies on basic speech perception could help us to better understand in what way verbal information is processed in individuals with ASD. This information could lead to a better comprehension of the social communication and interaction difficulties individuals with ASD encounter (e.g., Alcantara, Cope, Cope, & Weisblatt, 2012; Diehl & Paul, 2013; McCann & Peppe, 2003; Paul, Shriberg, et al., 2005), which could facilitate the development of effective interventions for speech and language therapy and social communication interventions.

Acknowledgments

A doctoral bursary to the first author from the Department of Psychology, University of Portsmouth, funded this research. The authors gratefully acknowledge the participants who took part in the research. We would also like to thank the Autism Research Network, University of Portsmouth, and a local support group for adults with autism for their invaluable help. We would also like to thank the three reviewers for their helpful and constructive feedback on an earlier version of this manuscript.

References


Mayer, J. L., Hammett, I., & Heaton, P. F. (2014). Mapping the developmental trajectory and correlates of enhanced pitch...


