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Atypical Prosody in Asperger Syndrome: Perceptual and Acoustic Measurements

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Abstract

The turn-taking prosodic ability in children with Asperger Syndrome (AS) was explored using perceptual and acoustic measurements. Eight- and nine-year-old children with AS (N = 12) were matched on age and non-verbal intelligence to typically developing peers. Although the turn-taking ability in children with AS was not functionally impaired, perceptual ratings revealed atypical prosodic features, and acoustic measurements showed alterations in the duration and pitch of one-word productions. Additionally, the children with AS had greater variability in fundamental frequency contours compared to typically developing peers. Naive adult listeners reported an impression of oddness in the prosody of children with AS, which may have consequences for social interactions. Clinical and scientific implications of these results are discussed.

Keywords: Asperger Syndrome, Atypical Prosody, Intonation, Turn-taking.

Atypical Prosody in Asperger Syndrome: Perceptual and Acoustic Measurements

Communication impairments in children, adolescents, and adults with autism spectrum disorders (ASD) are often marked by atypicalities in the production of prosody (e.g., Shriberg et al., 2001). Individuals with ASD may have difficulties in how they produce utterances (i.e., prosodic impairments), even when no problems are apparent regarding what they say (for instance, in lexical content). Although many studies have been conducted on prosody, no consensus has emerged on the prosodic characterization of ASD.

Prosodic cues are important for language processing at both word as well as phrase levels (e.g., Frazier, Carlson, & Clifton, 2006; Langus, Marchetto, Bion, & Nespor, 2012; Wagner & Watson, 2010). Prosody can be described as the level of language involved in the production of the speech melody and in chunking the speech continuum to convey or enhance meaning. When assessing prosody, the distinction between prosodic form and prosodic function is critical. Prosodic form corresponds to the variation in the acoustic and auditory-perceptual properties of the signal reflected in fundamental frequency, duration, and intensity (e.g., pitch of spoken syllables, their duration and perceived loudness), whereas prosodic function relates to lexical or phrasal meanings conveyed by prosody (Gussenhoven, 2004; Järvinen-Pasley, Peppé, King-Smith, & Heaton, 2008; Peppé, 1998).

The study of prosody is crucial in typically developing children since prosody processing is an integral part of language acquisition, in perception as well as in production (e.g., Cutler & Swinney, 1987; Morgan & Demuth, 1996). Decades of research, especially within the Prosodic Bootstrapping model, have shown that the development of prosodic sensitivity in the early years emerges before phonological, syntactic, and semantic developments (e.g., Christophe, Mehler, & Sebastian-Galles, 2001; Crystal, 1979; Mehler et al., 1988; Morgan & Demuth, 1996), and phonological and prosodic cues promote the development of word segmentation skills, as well as of grammatical categories and basic syntactic structures (e.g., Christophe, Guasti, Nespor, Dupoux, & Ooyen, 1997; Höhle, 2009). Thus, in typically developing children, prosody appears to develop first and faster than other components of language.

Given that prosody plays a very important role in speech perception and production, conveying explicit and implicit meanings, moods, and emotional interchange in language, when prosodic impairments occur, language acquisition can be disordered and problems in daily communication may appear. Consequently, prosody has been a topic of research in the context of clinical populations with specific language disorders, like deafness, Down syndrome, Williams syndrome, aphasia, schizophrenia, epilepsy, and ASD (e.g., Baltaxe & Simmons, 1985; Catterall, Howard, Stojanovik, Szczerbinski, & Wells, 2006; Heselwood, Bray, & Crookston, 1995; Parker & Rose, 1990; Pascual, Solé, Castillón, Abadía, & Tejedor, 2005; Sanz-Martín, Guevara, Corsi-Cabrera, Ondarza-Rovira, & Ramos-Loyo, 2006; Seddoh, 2004; Wells & Peppé, 2003).

About 20–30 in 10,000 individuals have a diagnosis within the autism spectrum disorders (Fombonne, 2009), including Autism, PDD-nos, Rett's Disorder, Child Disintegrative Disorder, and Asperger Disorder (AS). ASD is a neurodevelopmental disorder characterized by a complex group of conditions that involve some degree of difficulty with communication and interpersonal relationships, as well as obsessions and repetitive behaviors (American Psychiatric Association, 2000). Specifically, in AS there is no history of language delay and cognitive development is within normal range. However, there are significant impairments in social interaction, imagination, and communication, particularly involving pragmatics and prosody. Prosodic impairments are one of the earliest atypical features to appear in ASD and problems with the pragmatic use of language are a lifespan feature (e.g., Baltaxe & Simmons, 1985; Paul, Orlovski, Marcinko, & Volkmar, 2009; Schoen, Paul, & Chawarska, 2010; Tager-Flusberg, Paul, & Lord, 2005). These impairments may range from observable differences with no impact on comprehension to complete misunderstanding. Moreover, expressive prosody deficits persist even while other aspects of speech functioning improve, such as conversational skills (Simmons & Baltaxe, 1975). Therefore, the characterization of prosodic atypicalities in ASD is crucial, whether it indicates a severe pathology or minor problems in accuracy of communication.

Descriptions of prosodic impairments in ASD include specific difficulties with rhythm, speech rate, and intonation patterns (e.g., McCann & Peppé, 2003; Paul, Augustyn, Klin, & Volkmark, 2005; Shriberg et al., 2001). Additionally, it is known that children with ASD have at least some prosodic impairment and that the use of prosody to convey affect and phrase level stress are abilities harder to master (McCann, Peppé, Gibbon, O'Hare, & Rutherford, 2007). Despite previous studies, research has not yet provided a consistent characterization or typology of these prosodic disordered patterns and studies have not captured the extent of prosodic impairments in ASD. Moreover, a great amount of data from previous studies is contradictory. Researchers have reported both the presence of exaggerated intonation and monotone intonation, as well as of slow syllabic speech and fast articulatory rate (McCann & Peppé, 2003), to pinpoint a few examples. It is also true that many individuals with ASD (especially AS children) score very well on prosodic tasks. No convincing explanation is provided in the literature for this variability. Furthermore, very little is known about the comprehension and production of prosody in children with autism.

Many studies of prosody in ASD present methodological issues related with the assessment of prosody (e.g., McCann & Peppé, 2003). Therefore, improvements in the assessment of prosodic skills are required. The evaluation of expressive and receptive prosodic skills using perceptual measures, as well as acoustic analysis, could have significant clinical implications and improve differential diagnosis, assessment, and intervention for individuals with ASD.

In sum, prosody has been long considered an important topic of research both in typically developing children and in clinical populations, and it is consensual that atypical prosody is a common feature of ASD (e.g., Peppé, 2007). Nevertheless, no consensus has emerged on the characterization of the prosodic profile in ASD. In this study we analysed perceptual and acoustic measures and explored prosodic differences between individuals with AS and typically developing peers with the goal of characterizing potential prosodic impairments in children with AS. First, we analysed whether prosodic turn-taking is impaired in children with AS. Second, we examined if blind judges are able to identify atypical prosodic features for AS children through perceptual measurements. Finally, we studied the acoustic parameters of the children's productions in order to identify whether AS child speech exhibited differences in duration, pitch, and/or intensity. We described the acoustic parameters that can best define the atypicality of AS speech and presented some guidelines for parents and professionals to follow to reduce the effects of disordered prosody.

Method

Participants

Twenty-nine children participated in this study, 12 with AS and 17 typically developing peers (TD). The clinical group included 10 boys and 2 girls between 8 and 9 years old (M = 8.58, SD = 0.51), who met the ICD-10 (World Health Organization, 1992) and DSM-IV-TR (American Psychiatric Association, 2000) criteria for AS. The methods used in the diagnostic procedure were the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) and the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 1989). Exclusion criteria were schizophrenia, obsessive–compulsive disorders, attention deficit hyperactivity disorder, and learning difficulties. These children with AS were matched on age (M = 8.35, SD = 0.49) and non-verbal intelligence to typical developing peers (10 boys) (see table 1). Children with AS were attending special units for ASD within the mainstream school, and TD children were attending elementary school (first and second years). Informed consent was obtained from the parents of participating minors.

Insert Table 1

All children showed a level of non-verbal intelligence at to or higher than average, as assessed with Raven's Coloured Progressive Matrices (Raven's CPM, Raven, 1995; Simões, 2000).

Additionally, a group of 35 undergraduate students attending a master in education at the University of Aveiro, with a mean of age of 22.11 years (SD = 4.88), rated how natural the AS children's one-word productions sounded.

All participants were native speakers of European Portuguese, did not present any visual or hearing problems. The children were born and raised in monolingual homes in the region of Porto.

Material

Raven's CPM (Raven, 1995; Simões, 2000) that measures nonverbal abilities through 36 colored multiple-choice matrices organized in 3 sets (A, Ab, B). For each matrix there are six possible choices.

Turn-End subtest of the Profiling Elements of Prosody in Speech-Communication (PEPS-C; Peppé & McCann, 2003) adapted to European Portuguese (Filipe & Vicente, 2011). The PEPS-C assesses receptive and expressive skills in parallel in children aged 4 to 16. The tasks are at two levels: formal and functional. The formal level assesses auditory discrimination and voice skills, whereas the functional level evaluates four communicative categories (Turn-end, Affect, Chunking, and Focus). The Turn-End subtest has two tasks – receptive and expressive – each one with 20 items (2 examples + 2 training items + 16 experimental items). In the receptive task, participants have two image choices (one representing statements and the other representing interrogatives) and hear a word that could be produced as a question or as a statement (e.g., Carrot. vs. Carrot?). They are asked to choose if they heard a question or a statement by pointing to the appropriate picture. In the expressive task, if participants see a picture of a person reading in a book about food, they will produce the name of the food item with the statement intonation (e.g., Carrot); on the other hand, if participants see a picture of someone offering food, they will produce the name of the food item with a question intonation (e.g., Carrot?). A demonstration of the assessment procedure can be found on the following website: http://www.peps-c.com. In addition, a digital recorder was used to record participant's performance on the Turn-End expressive task.

For the atypicality rating of childrens' one-word speech productions in the Turn-End task, one audio-file for each child were created using all the Turn-end productions with a 4-second inter-stimulus intervals (N = 29 audio-files). The audio-files order was randomized and presented with an interval of 10 seconds. A 5-point Likert scale was used to rate the prosodic atypically.

We used IBM® SPSSTM version 20.0 for the statistical analyses and PRAAT (Boersma & Weenink, 2011) for the acoustic analysis.

Procedure

Participants were assessed in one individual session during approximately 30 minutes at local institutions with adequate comfort, sound, and lighting conditions. The tasks were presented in the same order for all the participants. First, for Raven's CPM the children saw a series of matrices with missing parts and had to point to the pattern piece that completed the matrix. Second, in the Turn-End subtest receptive task, the subject was asked to choose the picture (from the 2 presented) that matched with the intonation pattern he/she heard. In the expressive task, the participant saw one picture and had to produce the appropriate intonation. Subject performance in the tasks was audio-recorded for perceptual and acoustic characterization; the distance of the speaker from the recorder was approximately one foot.

For the perceptual characterization of prosodic atypically, judges listened to audio-files of all the children's productions in the expressive task of the Turn-end subtest. After heard each audio-file, judges rated atypicality in a 5 point Likert scale. They were told to judge whether the child sounded common or uncommon and to not value articulation errors or regional accent. Judges had no information about the study objectives.

For the acoustic characterization, the speech sample of children's productions was spliced into individual sound files (one per word). For each word item, duration, pitch (maximum, minimum, range, and mean), and intensity (maximum, minimum, and mean) were calculated.

Results

With the goal of analysing performance differences between the AS and TD groups on the Turn-end subtest, a comparative analysis was conducted. Results for the Turn-end subtest are shown in Table 2. The average results obtained in the receptive task for the AS group (M = 14.50, SD = 2.61) were close to those obtained by the TD group (M = 13.67, SD = 2.77). An analysis of variance (ANOVA one-way) on the test results, with Group as a factor (AS Group vs. TD Group), revealed that the two groups performance did not differ (F (1, 27) = 0.574; ns).

Insert Table 2

In the expressive task of the Turn-End subtest (see Table 2), the average scores for the AS group (M = 12.62, SD = 3.39) were also very similar to those obtained by the TD group (M = 11.76, SD = 3.81), and again performance did not differ between the two groups (F (1, 27) = 1.521; ns). Box plots of the two groups for the receptive and expressive tasks are shown in Figure 1.

Insert Figure 1

Since differences in turn-end prosodic skills (receptive and expressive) were not found between the two groups of children, perceptual and acoustic analyses of the one-word productions in the expressive task were conducted. Blind judges rated the children's productions in a 5-point Lickert scale with respect to the presence of atypical prosodic features. As a result, judges perceived AS children's productions as sounding significantly more atypical or uncommon than those of the TD children (M = 3.42 vs. 2.39, respectively for AS and TD; F (1, 27) = 10.98; p = 0.003). Figure 2 shows a box plot for the atypicality rating for the two groups.

Insert Figure 2

Acoustic measurements were performed on the speech sample of children's productions spliced into individual files, one for each word-item. For each word, duration, pitch (maximum, minimum, range, and mean), and intensity (maximum, minimum, and mean) were calculated. Results are given in Tables 3 and 4, respectively for declarative and interrogative items. Box plots for the acoustic measurements by modality (declarative and interrogative) for the two groups are shown in Figure 3.

Insert Table 3

Insert Table 4

Insert Figure 3

A multivariate analysis of variance (MANOVA) was carried out to assess whether the factor Group (TD Group vs. AS Group) had a significant effect on the multivariate composite that includes duration, pitch (maximum, minimum, range, and mean), and intensity (maximum, minimum, and mean). The MANOVA revealed a significant group effect and the power of the test was very good (Pillai's Trace = 2.857; $F(1, 27) = 0.533$; $p=0.027$; $\eta p2 = 0.533$; Power = 0,828).

Additionally, analyses of variance with Modality (declaratives vs. interrogatives) as a within-subject factor and Group (AS Group vs. TD Group) as a between-subject factor were conducted for each acoustic parameter, in order to identify which acoustic parameters were impaired.

Average duration results obtained for declaratives ranged from 0.86 to 1.40 seconds in the AS group, and from 0.70 to 1.12 seconds in the TD group. Average duration in interrogatives ranged between 0.84 to 1.34 seconds for the AS group, and from 0.70 to 0.99 seconds in the TD group ($M = 1.08$ vs. 0.88, $SD = 0.13$ vs. 0.88, respectively). The analysis of variance revealed that duration was significantly different for the two groups for both interrogatives and declaratives ($F (1, 27) = 19.72$; $p < 0.001$; without interaction).

Moreover, we found increased pitch range in the speech of AS children, when compared to TD peers for the declarative ($M = 108$ vs. 70, $SD = 40$ vs. 27, respectively), and for the interrogative prosodic patterns (M = 175 vs. 124, SD = 54 vs. 45, respectively; F (1, 27) = 13.06; p = 0.001).

Mean pitch was also significantly increased for the AS group, both in declarative (M = 243 vs. 224,) and interrogative (M = 286 vs. 261; F (1, 27) = 6.32; p = 0.018).

Finally, maximum pitch for the AS group was higher than for the TD group, both for declaratives (M = 255 vs. 222, SD = 36 vs. 28, respectively) and for interrogatives (M = 332 vs. 281, SD = 41 vs. 48, respectively; F (1, 27) = 14.71; p = 0.001). By contrast, no differences were found for minimum pitch between the AS and the TD group for declarative (M = 146 vs. 151, SD = 23 vs. 21, respectively) or interrogative conditions (M = 156 vs. 157, SD = 24 vs. 20, respectively; F (1, 27) = 0.159; ns). Also, no differences were found for the intensity parameters between the two groups for both conditions.

A standard multiple regression was used to assess the success of a model including the significant parameters as predictors of the perception of atypical prosody. All predictor variables were included in the backward stepwise method (see Table 5). The best-fit model (R^2 = 0.63, F (5, 23) = 10.484; p = <.001) for predicting the presence of atypical prosody was composed by interrogative maximum pitch (beta = .499), declarative maximum pitch (beta = -.586), interrogative mean pitch (beta = -.605), declarative mean pitch (beta = .525), and interrogative duration (beta = .749).

Insert Table 5

An inspection of the fundamental frequency contours (f0) revealed that the productions of the speakers with AS appeared to be characterized by heterogeneous contour patterns unlike the productions of the TD peers which showed more consistent patterns, in line with the higher variability shown by AS speech (as indicated by the SD values for pitch range and maximum pitch).

Discussion

The aim of the present study was to describe the prosodic profile of Portuguese speaking children with AS and to identify potential markers of prosodic impairment for this clinical population. As previous research findings on atypical prosody are inconsistent, in this study the focus was set on the perceptual analysis of prosody, as well as in fine details of the acoustic properties of the one-word children's productions with declarative and interrogative intonation. Twelve children with AS were matched to 17 typically developing peers on age and non-verbal intelligence, and they were evaluated with the Turn-end subtest of the PEPS-C. The results support the idea that the turn-taking ability in children with AS was not functionally impaired. However, perceptual ratings revealed atypical prosodic features, and acoustic measurements showed alterations in duration and pitch. Additionally, children with AS had a greater variability in fundamental frequency contours compared to typically developing peers.

Similar to Peppé, Cleland, Gibbon, O'Hare, and Mastínez-Castilla (2011), we did not find any differences between children with AS and typically developing peers in the turn-taking test, neither for receptive nor for expressive skills. The turn-taking prosodic ability seems to be functional in children with AS. However, in line with previous findings by Peppé (2007), judges identified atypical features in the productions of children with AS. These atypicalities in expressive prosody may induce the listener to perceive some strangeness in the utterances that could have implications in social interaction settings. In fact, atypical perception of prosody has severe consequences for social integration, as documented in the literature (e.g., Baron-Cohen & Stauton, 1994).

Diehl and Paul (2013) also found specific acoustic patterns in the speech of children with AS. As they pointed out, children with AS spoke more slowly and with more variable pitch (and higher pitch peaks) than their typically developing peers, but with no differences in minimum pitch and intensity. This pattern of results seems to match with the predictions of the hypothesis of a significant deficit in duration described by Bellon-Harn, Harn, and Meline (2007). The researchers found consistent deviances in rate and inappropriate pausing in the productions of children with AS. Shriberg and colleagues (2001) also found that there were no differences in intensity between children with high functioning autism and typically developing peers. More recently, Demouy and colleagues (2011) suggested some prosodic features that could be considered markers of ASD pathology, such as “rising intonation”. The results of our study support the hypothesis that increased pitch variability may be a marker for AS, and that alterations in utterance duration and maximum and mean pitch are good acoustic predictors for the atypicality found in the perception of AS speech. Interestingly, these acoustic predictors seem to be independent of the particular native language spoken by children with AS, given the convergent results found for English and European Portuguese children.

Furthermore, our results suggest that speakers with AS have characteristics generally different from typically developing peers in their fundamental frequency contours. These contours seem to show more consistent patterns for typically developing children which contrast with the high variability present in the AS children’s contours. Therefore, contrary to a common impression of monotonic speech in autism (Baltaxe & Simmons, 1985), children with AS have greater variability in pitch compared with typically developing peers. This same result was also found in children with high and lower functioning autism (Baltaxe, 1984; Diehl, Watson, Bennetto, McDonough, & Gunlogson, 2009).

These acoustic deviations in prosodic markers observed in autistic children's speech could be a signal for delay or for impairment. On the one hand, delay means that children will reach typical development stages at some point (like a train being delayed, but reaching its destination). On the other hand, the impairment hypothesis suggests a disordered profile with gaps in developmental milestones with progress occurring in a non-sequential pattern. How can the prosodic markers studied in the literature contribute to this debate? Are prosodic deviations a signal of delay or of impairment? Our findings showed that word duration (in ms) was significantly longer in the clinical population. Because duration diminishes with age (e.g., Harnsberger, Shrivastav, Brown, Rothman, & Hollien, 2008), we strongly suggest that this acoustic parameter is delayed in children with AS. In the case of fundamental frequency contours, it has been described that they are generally different from those of the typically developing peers. As variation in pitch decreases with age in typical development (Whiteside & Hodgson, 2000), it is quite possible that these differences may be also due to a relative delay in this prosodic cue. Prosodic markers are important whether they represent a delay or an impairment, and this particular distinction should be analyzed for intervention planning.

Although prosodic impairments in the autistic spectrum and their implications for the social context have been discussed in previous research (e.g., Baron-Cohen & Stauton, 1994), a systematic study about prosody rehabilitation, to our knowledge, does not exist. Therefore, research on prosody intervention is a current need, and the results of the present study have several clinical and scientific implications in that field. From a clinical point of view, prosodic intervention should focus both on functional and formal levels, specifically communicative goals and acoustic performance (comprehension/expression). Our results point out that although children with AS do not have difficulties with a functional prosodic ability, they can have impairments in the use of some acoustic cues related with the so-called formal level. Therefore, the distinction between formal and functional prosody is essential in the case of impaired prosody because it is important in order for a therapist to thoroughly identify an individual's strengths and weaknesses. For instance, the child can experience difficulties in pitch or timing control (formal level), while also struggling with the communicative function of questions (functional level). On the other hand, prosody is normally learned without a conscious effort, and it is difficult to teach to individuals with autism. Therefore, prosodic intervention should include the conscious training of acoustic properties within meaningful contexts, which may have an impact on the ability to use prosody effectively in speech. Specifically, duration and pitch are very important aspects to focus on to improve the social integration of children with AS. By and large, our findings open possibilities for further studies, which may complement the current language intervention techniques, and efforts might be directed for training the supra-segmental aspects of language.

From a more theoretical point of view, the present study contributes to the knowledge on communication deficits in ASD. The relationship between prosody and subgroups of ASD could provide insight into the nature and etiology of this disorder. Future studies should compare prosodic skills within and between ASD groups to identify acoustic profiles of prosodic functioning. As suggested by Demouy and colleagues (2011), there is a clinical necessity to assess prosodic markers (as well as other language domains) in all pathological groups in order to refine ASD diagnosis criteria and specify the language remediation axis. Also, the use of engineering technology in order to automatically assess prosodic ability has been shown to be able to distinguish among pathological subjects (Oller et al., 2010; Warren et al., 2010).

In conclusion, this study provides evidence of acoustic specificities in the speech of children with AS with no apparent functional correlates. As expressive prosody plays a vital role in the way listeners react to a speaker, knowing more about the prosodic profile of these individuals would help to design better intervention strategies. However, further methodological improvements are needed in order to address current limitations and achieve promising results. First, studies should incorporate larger sample sizes to obtain representative findings. Second, it is necessary to explore other pitch measures in more naturalistic settings, such as conversations. Fine, Bartolucci, Ginsberg, and Szatmari (1991) showed that naturalistic speech could be more sensitive to subtle characteristics of prosody production in particular for autism populations. Finally, the parameters analysed may not capture all the factors that could contribute to atypical expressive prosody (for example, a phonological analysis of intonation patterns in AS speech is still to be done). In order to capture the extent of prosodic impairments in ASD, future work should address these issues, by building on the practical and scientific implications of the present study.

References

American Psychiatric Association (2000). *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR)* (4th edition). Washington, DC: APA. doi: 10.1176/appi.books.9780890423349

Baltaxe, C. (1984). Use of contrastive stress in normal, aphasic and autistic children. Journal of speech and Hearing Research, 27, 97-105.

Baltaxe, C. A. M., & Simmons, J. Q. (1985). Prosodic development in normal and autistic children. In E. Schopler, & G. B. Mesibov (Eds.), Communication problems in autism (pp. 95-125). New York: Plenum Press. doi: 10.1007/978-1-4757-4806-2_7

Baron-Cohen, S., & Staunton, R. (1994). Do children with autism acquire the phonology of their peers? An examination of group identification through the window of bilingualism. First Language, 14, 241-248.

Bellon-Harn, M.L., Harn, W.E., & Meline, T. (2007, November). *Perceptual and acoustic correlates of duration in Asperger Syndrome*. Poster presented at the American Speech-Language- Hearing Association, Boston, MA.

Boersma, P., & Weenink, D. (2011). *Praat: doing phonetics by computer* [Computer program]. Version 5.3, retrieved 15 October 2011 from http://www.praat.org/.

Catterall, C., Howard, S., Stojanovik, V., Szczerbinski, M., & Wells, B. (2006). Investigating prosodic ability in Williams syndrome. Clinical Linguistics & Phonetics, 20(7-8), 531-538. doi: 10.1080/02699200500266380

Christophe, A., Guasti, T., Nespor, M., Dupoux, E., & Ooyen, B. V. (1997). Reflections on phonological bootstrapping: Its role for lexical and syntactic acquisition. Language and Cognitive Processes, 12(5/6), 585-612.

Christophe, A., Mehler J., & Sebastian-Galles, N. (2001). Perception of prosodic boundary correlates by newborn infants. Infancy, 2, 385-394. doi: 10.1207/S15327078IN0203_6

Crystal, D. (1979). Prosodic development. In P. Fletcher, & M. Garman (Eds.), Language acquisition (pp. 33-48). Cambridge: Cambridge University Press.

Cutler, A., & Swinney, D. A. (1987). Prosody and the development of comprehension. Journal of Child Language, 14(1),145-167.

Demouy, J., Plaza, M., Xavier, J., Ringeval, F., Chetouani, M., Périsse, D.,… Robel, L. (2011). Differential language markers of pathology in autism, pervasive developmental disorder not otherwise specified and specific language impairment. Research in Autism Spectrum Disorders, 5(4), 1402-1412. doi:10.1016/j.rasd.2011.01.026

Diehl, J. J., & Paul, R. (2013). Acoustic and perceptual measurements of prosody production on the PEPS-C by children with autism. Applied Psycholinguistics, 34, 135-161. doi: 10.1017/S0142716411000646.

Diehl, J. J., Watson, D., Bennetto, L., McDonough J., & Gunlogson, C. (2009). An acoustic analysis of prosody in high-functioning autism. Applied Psycholinguistics, 30, 385-404.

Filipe, M. G., & Vicente S. G. (2011). Teste de competências prosódicas para falantes do Português Europeu [A test of prosodic abilities for European Portuguese speakers]. In A. S. Ferreira, A. Verhaeghe, D. R. Silva, L. S. Almeida, R. Lima, & S. Fraga (Eds.), Proceedings of the VIII Iberoamerican Congress of Psychological Assessment (pp. 447-463). Lisboa: Sociedade Portuguesa de Psicologia. Retrieved from http://sigarra.up.pt/fpceup/publs_pesquisa.formview?p_id=75969

Fine, J., Bartolucci, G., Ginsberg, G., & Szatmari, P. (1991). The Use of Intonation to Communicate in Pervasive Developmental Disorders. Journal of Child Psychology and Psychiatry and Allied Disciplines, 32, 771-782. doi: 10.1111/j.1469-7610.1991.tb01901.x

Fombonne, E. (2009). Epidemiology of pervasive developmental disorders. Pediatric Research, 65, 591–598. doi: 10.1203/PDR.0b013e31819e7203

Frazier, L., Carlson, K., & Clifton, C. (2006). Prosodic phrasing is central to language comprehension. *Trends in Cognitive Science, 10*, 244-249.

Gussenhoven, C. (2004). The phonology of Tone and Intonation. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511616983

Harnsberger, J. D., Shrivastav, R., Brown, W. S., Jr., Rothman, H., & Hollien, H. (2008). Speaking rate and fundamental frequency as speech cues to perceived age. Journal of Voice, 22(1), 58-69. doi: 10.1016/j.jvoice.2006.07.004

Heselwood, B., Bray, M., & Crookston I. (1995). Juncture, rhythm and planning in the speech of an adult with Down's syndrome. Clinical Linguistics and Phonetics, 9, 121-137. doi: 10.3109/02699209508985328

Höhle, B. (2009). Bootstrapping mechanisms in first language acquisition. Linguistics, 47(2), 359-382. doi: 10.1515/LING.2009.013

Järvinen-Pasley, A., Peppé, S., King-Smith, G., & Heaton, P. (2008). The relationship between form and function level receptive prosodic abilities in autism. Journal of Autism and Development Disorders, 38, 1328-1340. doi: 10.1007/s10803-007-0520-z

Langus, A., Marchetto, E., Bion, R. A. H., & Nespor, M. (2012). The role of prosody in discovering hierarchical structure in continuous speech. Journal of Memory and Language, 66(1), 285–306

Lord, C., Rutter, M. L., Goode, S., Heemsbergen, J., Jordan, H., Mawhood, L., Schopler E. (1989). Autism Diagnostic Observation Schedule: A standardized observation of communicative and social behavior. Journal of Autism and Developmental Disorders, 19(2), 185–212. doi: 10.1007/BF02211841

Lord, C., Rutter, M. L., & Le Couteur, A. (1994). The 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(5), 659–685. doi: 10.1007/BF02172145

McCann, J., & Peppé, S. (2003). Prosody in autism spectrum disorders: A critical review. International Journal of Language & Communication Disorders, 38(4), 325-350. doi: 10.1080/1368282031000154204

McCann, J., Peppé, S., Gibbon, F. E., O'Hare, A., & Rutherford, M. (2007). Prosody and its relationship to language in school-aged children with high-functioning autism. International Journal of Language and Communication Disorders, 42(6), 682-702. doi: 10.1080/13682820601170102

Mehler, J., Jusczyk, P. W., Lamberts, G., Halstead, N., Bertoncini J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. Cognition, 29, 143-178. doi: 10.1016/0010-0277(88)90035-2

Morgan, J. L., & Demuth, K. (1996). Signal to Syntax: an overview. In J. L. Morgan, & K. Demuth (Eds.), Signal to syntax: Bootstrapping from speech to grammar in early acquisition (pp. 1-22). New York: Lawrence Erlbaum Associates.

Oller, D. K., Niyogi, P., Gray, S., Richards, J. A., Gilkerson, J., Xu, D., et al. (2010). Automated vocal analysis of naturalistic recordings from children with autism, language delay, and typical development. Proceedings of the National Academy of Sciences of the United States of America, 107(30), 13354–13359. doi: 10.1073/pnas.1003882107

Parker, A., & Rose H. (1990). Deaf children's phonological development. In A. G. Pamela (Eds.), Developmental speech disorders (pp. 83-108). New York: Wiley.

Pascual, S., Solé, B., Castillón, J. J., Abadia, M. J., & Tejedor, M. C. (2005). Prosódia afectiva y reconocimiento facial y verbal de la emoción en la esquizofrenia. Revista de

Psiquiatria de la Facultad de Medicina de Barcelona, 32, 179-183.

Paul, R., Augustyn, A., Klin, A., & Volkmark, F. R. (2005). Perception and production of prosody by speakers with autism spectrum disorders. Journal of Autism and Development Disorders, 35(2), 205-220. doi: 10.1007/s10803-004-1999-1

Paul, R., Orlovski, S. M., Marcinko, H. C., & Volkmar, F. R. (2009). Conversational behaviors in youth with Highfunctioning ASD and Asperger syndrome. Journal of Autism and Developmental Disorders, 39(1), 115–125. doi: 10.1007/s10803-008-0607-1

Peppé, S. (1998). Investigating Linguistic Prosodic Ability in Adult Speakers of English (Unpublished doctoral dissertation). University College London, London.

Peppé, S. (2007). Prosodic boundary in the speech of children with autism. In J. Trouvain, & W. Barry (Eds.), Proceedings of the 16th International Congress of Phonetic Sciences (p. 8). Saarbrücken: Universität des Saarlandes.

Peppé, S., Cleland, J., Gibbon, F., O’Hare, A., & Mastínez-Castilla, P. (2011). Expressive prosody in children with autism spectrum conditions. Journal of Neurolinguistics, 24, 41-53. doi: 10.1016/j.jneuroling.2010.07.005

Peppé, S., & McCann, J. (2003) Assessing intonation and prosody in children with atypical language development: the PEPS-C test and the revised version. *Clinical Linguistics & Phonetics, 17*(4/5), 345-354. doi: 10.1080/0269920031000079994

Raven, J. C. (1995). Manual for the Coloured Progressive Matrices (Revised). Windsor, UK: NFRE-Nelson.

Sanz-Martín, A., Guevara, M. A., Corsi-Cabrera, M., Ondarza-Rovira R., & Ramos-Loyo, J. (2006). Effecto diferencial de la lobectomía temporal izquierda y derecha sobre el reconocimiento y la experiencia emocional en pacientes con epilepsia. Revista de Neurologia, 42, 391-398.

Seddoh, A. (2004). Prosodic disturbance in aphasia: Speech timing versus intonation production. Clinical Linguistics & Phonetics, 18(1), 17-38. doi: 10.1080/0269920031000134686

Shriberg, L. D., Paul, R., McSweeny, J. L., Klin, A., Cohen, D. J., & Volkmar, F. R. (2001). Speech and prosody characteristics of adolescents and adults with high-functioning autism and Asperger syndrome. Journal of Speech, Language, and Hearing Research, 44(5), 1097-1115. doi: 10.1044/1092-4388(2001/087)

Simmons, J., & Baltaxe, C. (1975). Language patterns in adolescent autistics. Journal of Autism and Childhood Schizophrenia, 5, 333–351.

Simões, M. (2000). Investigações no âmbito da Aferição Nacional do Teste das Matrizes Progressivas Coloridas de Raven (M.P.C.R). Lisboa: Fundação Calouste Gulbenkian & Fundação para a Ciência e Tecnologia.

Schoen, E., Paul, R., & Chawarska, K. (2010). Vocal Production in Toddlers with Autism Spectrum Disorders. In R. Paul, & P. Flipsen (Eds.), Child Speech Sound Disorders: In Honor of Lawrence Shriberg (pp. 181-204). San Diego: Plural Publishers.

Wagner, M., & Watson, D. G. (2010). Experimental and theoretical advances in prosody: A review. Language and Cognitive Processes, 25, 905-945. doi: 10.1080/01690961003589492

Warren, S. F., Gilkerson, J., Richards, J. A., Oller, D. K., Xu, D., Yapanel, U., et al. (2010). What automated vocal analysis reveals about the vocal production and language learning environment of young children with autism. Journal of Autism and Developmental Disorders, 40, 555-559. doi: 10.1007/s10803-009-0902-5

Wells, B., & Peppé, S. (2003). Intonation abilities of children with speech and language impairment. Journal of Speech, Language, and Hearing Research, 46, 5-20. doi: 10.1044/1092-4388(2003/001)

Whiteside, S. P., & Hodgson, C. (2000). Some acoustic characteristics in the voices of 6 to 10 year-old children and adults: A comparative sex and developmental perspective. Logopedics Phoniatrics Vocology, 25, 122-132. doi: 10.1080/14015430050175851

World Health Organization. (1992). International Classification of Diseases, 10th revision (ICD-10). Genova: WHO.

Tager-Flusberg, H., Paul, R., & Lord, C. (2005). Communication in autism. In F. Volkmar, A. Klin, R. Paul, & D. Cohen (Eds.), *Handbook of Autism and Pervasive Developmental Disorders* (3rd Edition) (pp. 335- 364). New York: Wiley & Sons.

Table 1

Mean (M), Standard Deviation (SD), and Range for Age and Score in Raven's Coloured Progressive Matrices (RCPM) in the Asperger Syndrome (AS) and Typically Developing (TD) Children

Group		*M*	*SD*	Range
AS (*N* = 12)	Age	8.58	0.51	8 – 9
	RCPM score	23.42	3.72	17-29
TD (*N* = 17)	Age	8.35	0.49	8 - 9
	RCPM score	27	4.84	18-32

Table 2

Statements: Mean (M), Standard Deviation (SD), and Range of Acoustic Parameters in Asperger Syndrome (AS) and Typically Developing (TD) Children

Parameters		*M*	*SD*	Range
Duration*	AS	1.08	0.17	0.86 – 1.40
	TD	0.89	0.12	0.70 - 1.12
Pitch Range*	AS	108.63	40.58	50.59 – 179.74
	TD	70.67	27.14	19.67 – 126.37
Mean pitch*	AS	243.30	24.23	204.75 – 285.32
	TD	224.33	25.81	188.06 – 271.24
Maximum pitch*	AS	255.11	36.81	199.59 – 343.59
	TD	222.04	28.33	181.57 – 276.39
Minimum pitch	AS	146.55	23.78	102.45 – 176.54
	TD	151.11	21.86	108.39 – 186.85
Mean intensity	AS	72.87	3.07	68.82 – 77.89
	TD	70.52	4.86	61.89 – 76.05
Maximum intensity	AS	79.29	2.76	75.52 – 83.80
	TD	76.21	4.93	66.71– 82.63
Minimum intensity	AS	47.93	2.81	43.36 – 54.29
	TD	47.76	6.29	26.13 – 53.45

Note. * $p < .05$

Table 3

Questions: Mean (M), Standard Deviation (SD), and Range of Acoustic Parameters in Asperger Syndrome (AS) and Typically Developing (TD) Children

Parameters		*M*	*SD*	Range
Duration*	AS	1.08	0.13	0.84 – 1.34
	TD	0.88	0.88	0.70 – 0.99
Pitch Range*	AS	175.97	54.22	88.80 – 249.91
	TD	124.32	45.61	56.51 – 209.00
Mean pitch*	AS	286.14	22.15	249.32 – 322.77
	TD	261.14	31.36	211.02 – 327.00
Maximum pitch*	AS	332.26	41.81	256.19 – 395.22
	TD	281.71	48.61	204.26 – 378.79
Minimum pitch	AS	156.29	24.50	118.45 – 183.71
	TD	157.98	20.55	111.75 – 178.72
Mean intensity	AS	77.13	2.69	71.87 – 81.08
	TD	75.12	3.80	67.67 – 80.76
Maximum intensity	AS	83.00	2.82	79.50 – 87.05
	TD	81.03	3.69	75.07 – 87.25
Minimum intensity	AS	49.09	3.22	44.28 – 57.59
	TD	50.84	5.28	35.66 – 57.46

Note. * $p < .05$

Table 4

Regressions Predicting Atypical Prosody

	Beta	Standard Error	*p*-value
Model 1			
Maximum pitch interrogative	.712	.001	.296
Maximum pitch declarative	-.443	.001	.290
Mean pitch interrogative	-.644	.010	.066
Mean pitch declarative	.399	.012	.249
Span pitch interrogative	-.176	.001	.752
Span pitch declarative	-.106	.001	.758
Duration declarative	.079	.000	.816
Duration interrogative	.709	.000	.047
Adjusted *R2*	0.58		
Model 2			
Maximum pitch interrogative	.733	.001	.267
Maximum pitch declarative	-.475	.001	.220
Mean pitch interrogative	-.665	.010	.045
Mean pitch declarative	.440	.010	.134
Span pitch interrogative	-.200	.001	.708
Span pitch declarative	-.081	.001	.799
Duration interrogative	.775	.000	<.001
Adjusted *R2*	0.60		
Model 3			
Maximum pitch interrogative	.803	.001	.174
Maximum pitch declarative	-.557	.001	.008
Mean pitch interrogative	-.684	.009	.031
Mean pitch declarative	.475	.009	.063
Span pitch interrogative	-.266	.001	.560
Duration interrogative	.766	.000	<.001
Adjusted *R2*	0.62		
Model 4			
Maximum pitch interrogative	.499	.000	.050
Maximum pitch declarative	-.586	.000	.004

Mean pitch interrogative	-.605	.008	.030
Mean pitch declarative	.525	.008	.028
Duration interrogative	.749	.000	<.001
Adjusted $R2$	0.63		

Figure Captions

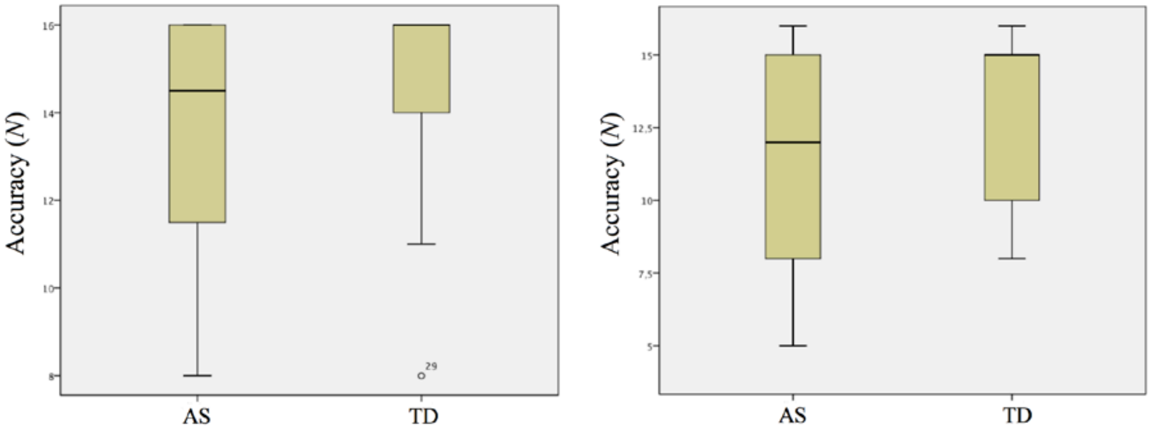


Figure 1. Box plots for the receptive (left) and expressive (right) Turn-End subtest in the Asperger Syndrome (AS) and typically developing (TD) children

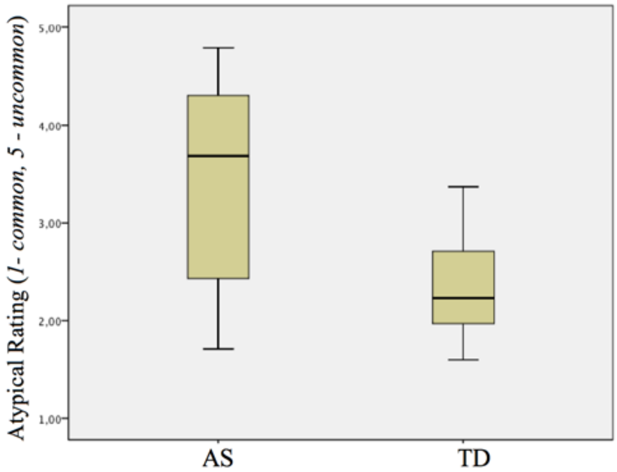
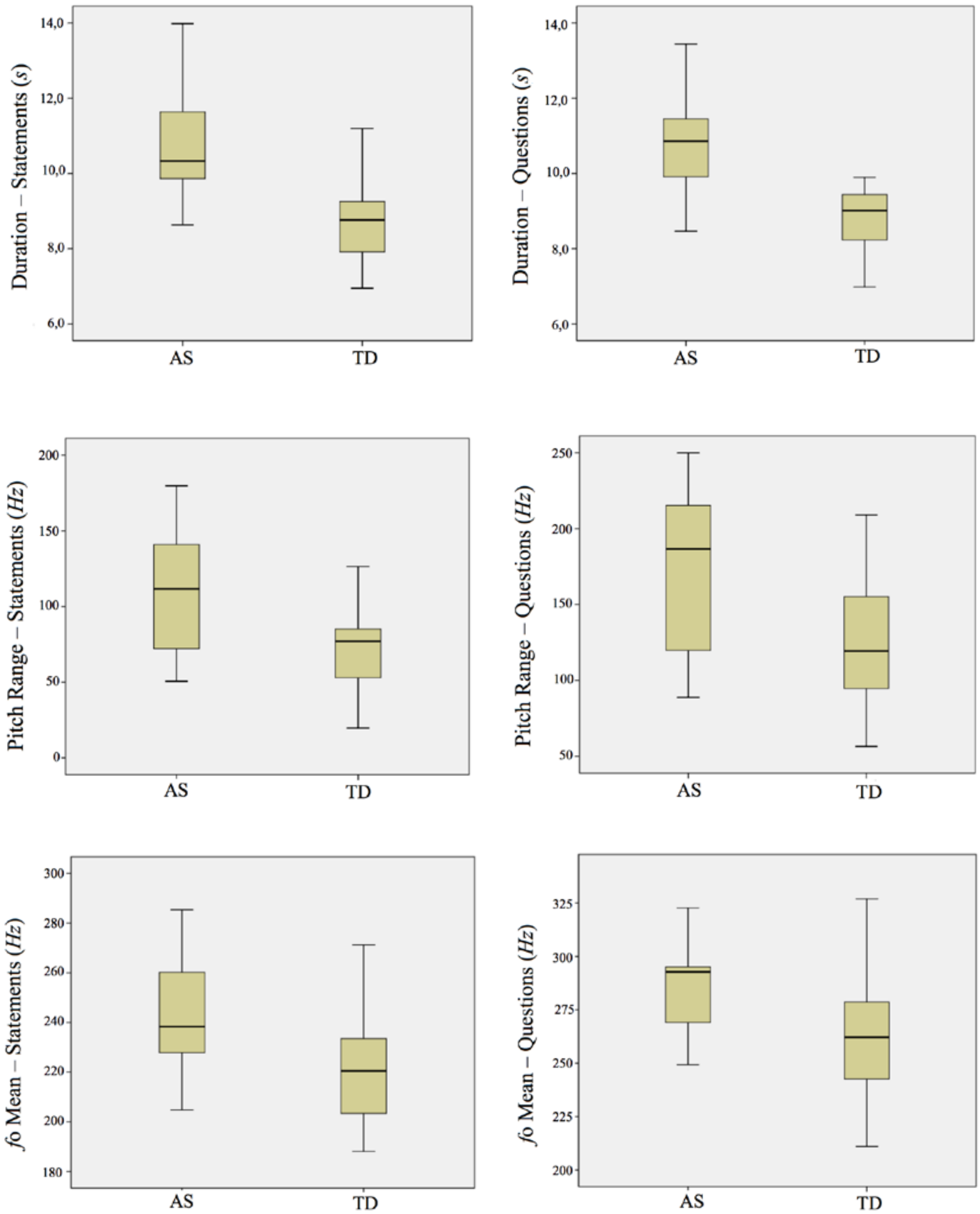


Figure 2. Box plots for the atypicality ratings given to utterances from Asperger Syndrome (AS) and typically developing (TD) children


Duration – Statements (s)
14,0
12,0
10,0
8,0
6,0
AS
TD
Duration – Questions (s)
14,0
12,0
10,0
8,0
6,0
AS
TD
Pitch Range – Statements (Hz)
200
150
100
50
0
AS
TD
Pitch Range – Questions (Hz)
250
200
150
100
50
AS
TD
fo Mean – Statements (Hz)
300
280
260
240
220
200
180
AS
TD
fo Mean – Questions (Hz)
325
300
275
250
225
200
AS
TD

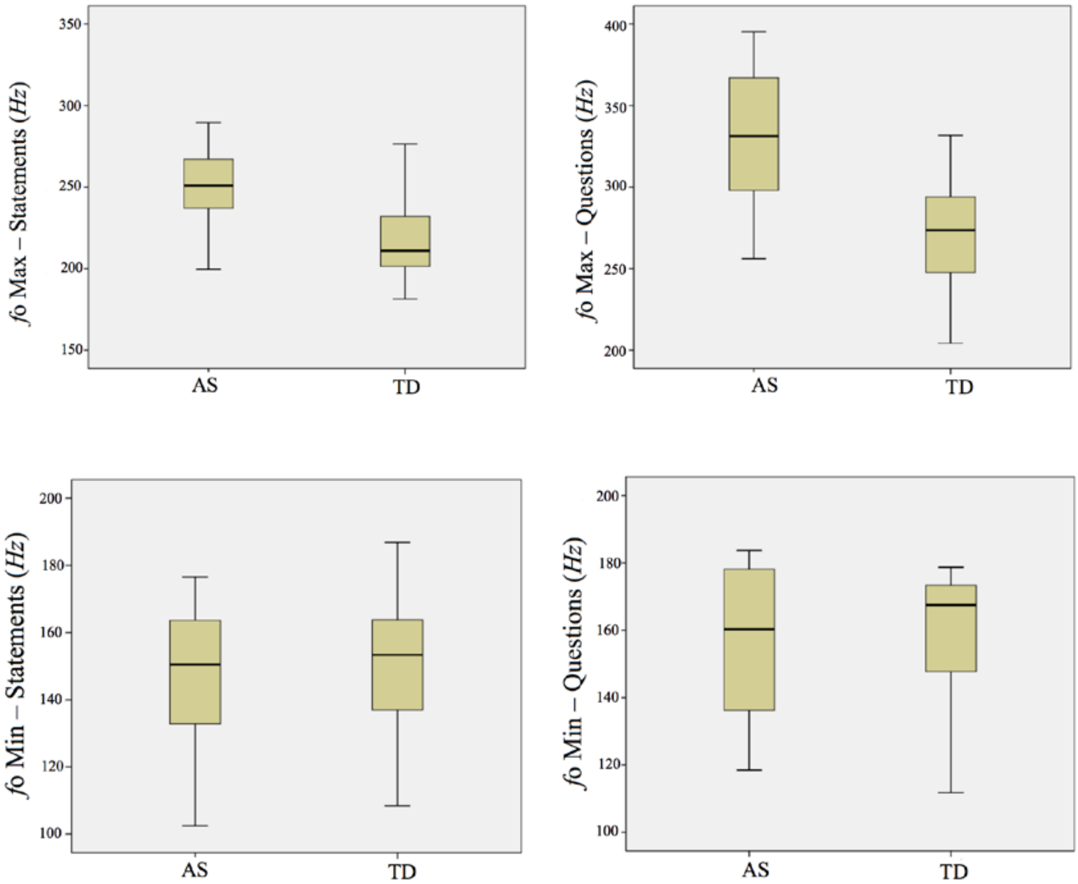


Figure 3. Box plots for acoustic measurements (duration, pitch range, *f*0 mean, *f*0 max, and *f*0 min) of utterances from Asperger Syndrome (AS) and typically developing (TD) children