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Sounds of melody—Pitch patterns of speech in autism

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ABSTRACT

The objective of this study was to find a pattern in vocalizations of children with Autism Spectrum Disorder (ASD). We compared the intonational features of 15 children with ASD who showed speech, aged 4–10 years, with 10 age-matched typically developing controls. Exaggerated pitch, pitch range, pitch excursion and pitch contours were observed in speech of children with autism, but absent in age-matched controls. These exaggerated features, which are distinctive characteristics of motherese, were also seen in interactions of an independent group of 8 mothers of typical infants using child-directed speech. Our findings provide the first evidence of a distinct pattern in vocal output from children with autism. They also demonstrate that speech patterns might follow a delayed developmental trajectory in these children.

Autism Spectrum Disorder (ASD) is a pervasive developmental brain disorder that manifests in the first 3 years of life. It is characterized by abnormal social behaviour, reduced ability or interest in communicating with others, language dysfunction and rigidities of behaviour and thought [2]. Communicative dysfunction is a characteristic feature of ASD [2] and in many cases, manifests through absent or deviant vocalizations. Although past research on vocal atypicalities has shed some light on the nature of communicative abnormalities in autism [3], no clear patterns have emerged to characterise vocalizations from ASD populations due to the heterogeneity of the disorder and variability in tasks and measurements used. As a result, speech therapists continue to struggle with methods and approaches to improve and induce spoken language in children with autistic. It is clinically important to develop easy-to-implement interventions that might facilitate verbal development in autism.

Earlier statistics report more than 50% of the ASD population to be nonverbal [8]. It has been established, by advances in the past decade, that there is an early brain dysfunction in autism which intensive intervention can alter, leading to optimistic outcomes. Additionally, it has now been shown that more than 75–95% children, who receive early intervention, develop useful speech [8]. Given this premise of abnormal early development, it is possible that children with ASD have a delayed developmental trajectory. As a result, communication milestones followed by typical children might appear at later time points manifesting as atypical developmental traits. Among the most commonly reported atypical feature of speech and communication in autism is unusual prosody [17]. Prosody is a broad term that encompasses affective, pragmatic, syntactic as well as intonational functions in communication and is used to refer to the manner of speaking rather than the content. The acoustic measures of prosody include mean voice pitch (perceptual correlate of fundamental frequency, F0), pitch range, intensity, speaking rate, pause duration and intonation contours [4].

Distinctive intonational patterns are known to aid maturation of speech and communication skills in typically developing children [10]. Speech directed to infants commonly known as 'motherese' has distinct prosodic patterns characterized by higher pitch, slower tempo and exaggerated intonation. Early intonation patterns of typically developing children also exhibit motherese-like features, which they outgrow by 2–3 years of age [9]. We hypothesize that children with ASD in the age group of 4–10 years may exhibit delays in their verbal communication strategies, when compared with age-matched typically developing children. This hypothesis is motivated by some evidence from past research that has shown that receptive prosodic skills develop late in children with ASD as compared to age-matched controls [19]. In addition, the DSM and ICD criteria cite delayed development of speech as a key feature of language in autism, and delay is acknowledged in many descriptions

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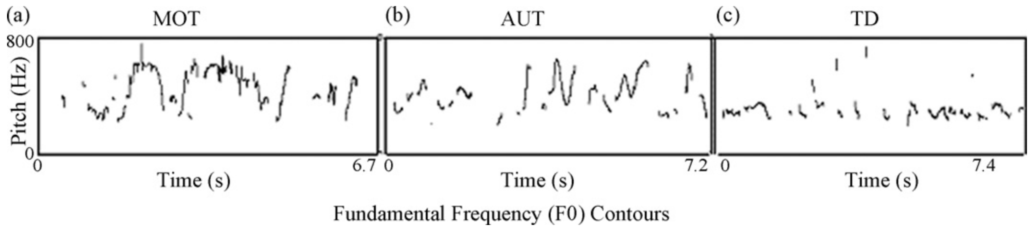

Fig. 1. (a–c) Fundamental frequency contours.

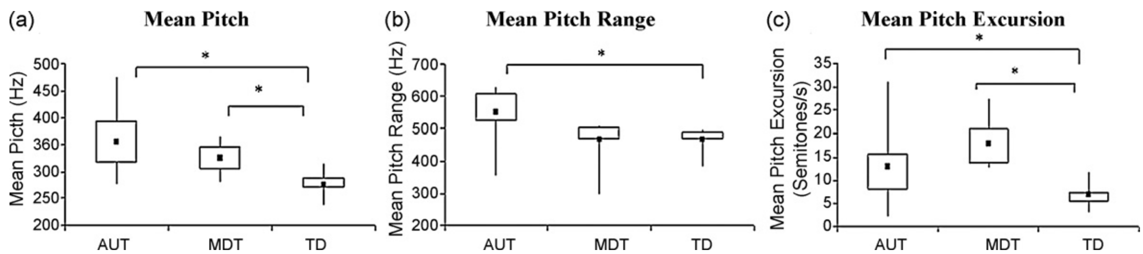

Fig. 2. (a–c) Box plots of mean pitch, pitch range and pitch excursion.

of the language characteristics of individuals with autism [20]. We predict that the motherese-like intonation patterns, that typically developing children outgrow by 2–3 years of age [9], will be exhibited in children with ASD in the age-group of 4–10 years due to a developmental delay in their verbal communication strategies. We tested the manifestation of this delay using methods of acoustic analysis to compare characteristic intonation patterns of vocalizations from three groups: children with ASD aged 4–10 years, age-matched typical controls and vocalizations from mothers of typical infants.

Thirty-three subjects were recruited for this study: 15 children (14M, 1F) with ASD (AUT), 10 (9M, 1F) age-matched typically developing (TD) control children and 8 mothers (MOT) of typically developing infants aged 6–18 months. The AUT group was recruited from child and adolescent psychiatry units of hospitals and met the diagnostic criteria of Autism/PDD-NOS with speech in the Diagnostic and Statistical Manual for Mental Disorders, DSM IV [2] and assessment using CARS (Childhood Autism Rating Scale) [21] in some cases. Since the incidence of ASD is much higher in boys it was not possible to balance the groups for gender [24]. The AUT group had mean age 6.25 years (SD 1.5) and the TD group had mean age 7.3 years (SD 2.0), the age range being 4–10 years for both groups. All subjects were English-Hindi bilinguals. The verbal ability of the ASD group was confirmed by parents report and psychological assessment by clinicians. The criteria for selecting children was a minimum vocabulary of 20 words by age 4 and ability to elicit a minimum of 2 min of vocalizations in interactive speech conditions. No quantitative judgements were made about the verbal IQ of these children as the parameters measured in the study looked only at the qualitative aspects of the utterances independent of content of vocalizations. Members of all groups had no known speech or hearing deficits as confirmed by a thorough clinical workout. Informed consent was obtained for each individual's participation as approved by the Human Ethics Committee of the Institute.

Speech samples were elicited using a spontaneous speech task. In preparation for the task, children from both the groups, AUT and TD, were instructed to name twenty pictures presented sequentially on a computer screen. Some pictures in the task were of a car, a television and an ice cream. The interviewer made a note of the objects, which most of the AUT group appeared to display an interest in (ice-cream, television and car). Those pictures were then displayed on the computer screen and discussed with the children using opening questions like 'Do you like ice cream?' and 'Which is your favourite car?'. The spontaneous responses obtained were simultaneously recorded and were used to carry out all the acoustic analysis. All the mothers of the typically developing infants (MOT) who participated in the study were also instructed to talk to their infants (between 6 and 18 months) describing the objects ice cream, television and car. This was done to elicit comparable samples of conversational speech revolving around a common topic. All recordings were made using a noise cancellation microphone attached to a laptop computer. Extraneous noise was manually edited out.

The longest uninterrupted sample in spontaneous speech for the AUT group was 80 s, thus 80 s long sequences were also excerpted from the TD and MOT group for acoustic analysis. Each sample was 16-bit digitized at a sampling rate of 22,050 Hz using GoldWave software. We used a pragmatic approach of chunking the speech into speech segments which were demarcated by pauses no longer than 300 ms. The following acoustic measurements were made using the cross-correlation algorithm in Praat [5]:

1. ***Pitch (F0) Measures:*** Measurements of mean, maximum and minimum pitch were made.
2. ***Pitch Range:*** In order to quantify the dynamics of pitch change, a pitch range measure was calculated as the difference between maximum and minimum pitch used by the subject measured in Hertz.
3. ***Pitch Excursion:*** An expanded pitch contour is described in terms of a long, continuous pitch glide, with pitch excursions of 13 semitones/s or more [10]. Since the perception of changes in pitch is more proportional than absolute, the conversion from absolute frequency to semitone ratio allows more meaningful comparisons across talkers with different mean F0 [12]. Pitch excursion was calculated using the formula proposed by de Pijper [7]. Each spontaneous speech sample was broken down into speech chunks separated by pauses of 300 ms.

Table 1
Regression matrix.

Group	Pitch	Pitch range	Pitch excursion	*p* value
Regression effects with age (r^2)				
ASD	0.197	0.452	0.043	>0.05
TD	0.481	0.03	0.531	>0.05

$$\underset{\text{(semitones/s)}}{\text{Pitch Excursion}} = \left[\frac{39.863 \log \left[\frac{F0_{max}}{F0_{min}} \right]}{\text{speech chunk duration}} \right]$$

Fig. 1(a–c) shows fundamental frequency contours. The AUT contours are similar to MOT speech and show expanded prosodic features, evidenced by more dynamic contours.

Fig. 2(a–c) shows box plots representing quantitative measurements of mean pitch, pitch range and pitch excursion.

Table 1 shows a regression matrix to rule out effects of age on all measured parameters for both AUT and the TD groups.

Fig. 2(a) shows mean pitch for each of the three groups: AUT = 355.8 Hz SD 61.7, MOT = 326.3 Hz SD 31.2 Hz, TD = 275.4 Hz SD 22.5 Hz. One-way ANOVA showed significant differences between the groups ($F(1,32) = 9.013$, $p < 0.001$). A post-hoc SNK (Student–Neuman–Keuls) test of multiple pair-wise comparisons between groups showed significant differences between AUT and TD ($p < 0.001$), and also between MOT and TD ($p = 0.028$) but no significant difference between mean pitch of AUT and MOT ($p = 0.157$) although the effect was medium (Cohen's $d = 0.6$, $r = .288$).

The pitch range for the three groups is presented in Fig. 2(b), with AUT = 550.6 Hz SD 84.9, MOT = 466.07 Hz SD 70.7, TD = 465.7 Hz SD 41.2. As the pitch range data were not part of a normal distribution, a non-parametric Kruskal–Wallis one-way ANOVA on ranks was used, and showed significant differences between groups ($H(1,2) = 9.947$, $p = 0.007$). A post-hoc Dunn's test of multiple comparisons showed significant difference between AUT and TD ($p < 0.05$), but no difference between AUT and MOT ($p > 0.05$) with a large effect size (Cohen's $d = 1.08$, $r = 0.475$).

Fig. 2(c) shows the average pitch excursion for each group (−AUT = 13 semitones/s, SD 7.8, MOT = 18 semitones/s SD 5.88, TD = 6.8 semitones/s SD 2.4). A one-way ANOVA showed significant differences between groups ($F(1,32) = 7.314$, $p = 0.003$). A post-hoc SNK (Student–Neuman–Keuls) test of multiple pair-wise comparisons between groups showed significant differences between AUT and TD ($p = 0.002$), and also between MOT and TD ($p = 0.022$), but no significant difference between mean pitch excursion of AUT and MOT ($p = 0.076$), with a medium-sized effect (Cohen's $d = -.72$, $r = -0.3$).

Our findings show that pitch patterns of verbal children with ASD in the age group of 4–10 years are different from age-matched typically developing children. Pitch patterns of the AUT group are characterized by exaggerated intonation contours manifested in terms of elevated pitch, higher pitch range and pitch excursion as compared to TD. No significant effects of age were seen on any of the measured parameters in both groups of children as confirmed by the regression analysis (Table 1). This demonstrated that the differences in the patterns of speech in the AUT and TD groups reflected a developmental delay of verbal skills in the AUT group. It is noteworthy, that exaggerated pitch patterns are also distinguishing features of motherese as demonstrated by analysis of child-directed vocalizations of mothers in the MOT group [10]. Our results showed that pitch patterns of the AUT and MOT group had no significant differences. Although there was a difference in group sizes (AUT = 15, MOT = 8), we see a medium-sized effect. This might be due to two reasons. The AUT group demonstrated considerable variability in their pitch patterns. Second, since we compare vocalizations from mothers and children, it is possible that there might be other confounding factors like age and experience, which might have led to a larger effect. However, despite these factors, our preliminary findings show interesting pitch patterns in ASD speech, which can be explored further.

Longitudinal studies on the development of speech have shown that in typically developing children between 0 and 5 years, mean pitch decreases as a function of age [1]. Additionally, in typically developing children, pitch range decreases with age and pitch variability approaches zero between 7 and 9 years [9]. Pitch characteristics of the AUT group in the age group 4–10 years, are exhibited by typically developing children between 2 and 3 years, suggesting that these features might follow a delayed developmental trajectory [9].

For typically developing infants, mothers use specific tonal and temporal patterns of infant-directed speech in order to enhance language development [11]. It is through melodic qualities (higher pitch, pitch range, and expanded intonation), embedded in the prominent intonation contours of motherese, that speech first becomes meaningful to infants [16]. Our finding that the pitch patterns of the AUT group are similar to the MOT group suggests a role for motherese-like speech in verbal development of children with ASD. The close relationship between receptive and expressive language skills forms a basis for understanding the importance of motherese-like speech in environments of older children with ASD [18]. Even when verbal development is delayed, the role of parent-child interaction in enhancing communication cannot be ignored and motherese provides one such platform of interaction. Literature on parental responsiveness has shown that the impact of mothers on children's development is determined by the 'style' and persistent nature of mother-child interaction [6]. It has also been shown that children are more responsive to conversational rather than monotonic interactions [15]. The use of motherese might not induce speech in children who never develop language, but might aid verbal language in children who suffer developmental delays. The relation between motherese and expression of affect may be another crucial aspect for children with autism. Affect or emotional content in speech is a well-known characteristic of exaggerated contours also seen in motherese. The classic view of autism [14] places a "biological disturbance of affective contact" as a primary deficit. Yet, this does not necessarily imply a prosodic disturbance. A recent study [13] investigated the production of affective speech in children with autism and found that they are probably able to process large pitch and intensity variations, but they tend to overshoot the intonational target and are deficient in correlating the pitch and intensity variations with the appropriate emotions. This is further corroborated by our findings of dynamic pitch ability in children with ASD.

Although not many studies on vocalizations of children with autism have found consistent results, there is a hypothesis that these individuals display atypical phonological and prosodic features in early vocalizations [22]. Past literature on prosody in autism has primarily been focussed on affective and pragmatic aspects. Studies by Baltaxe et al. [4] analysed frequency range patterns in spontaneous utterances of children with autism compared TD controls but did not find significant differences suggesting that the mean of the ranges did not adequately capture the deviances in speech of the autism group. Other studies by Paul et al. [18] and Shriberg et al. [23] have looked at stress patterns in autism and have reported atypicalities. While all these studies report atypical prosodic patterns in children with autism, their findings have been variable making it difficult to draw consistent conclusions about the nature of prosodic deficits in ASD productions. Our study is the first attempt to identify a distinct pattern in vocalizations of individuals with ASD using a simple speech-eliciting task. The identification of exaggerated speech in older children with ASD might provide an impetus for designing intervention strategies that might work more effectively in these high-functioning subgroups.

Although we look at a small proportion of the ASD spectrum, the results of our study provide the first evidence of a consistent pitch pattern in a group of individuals with ASD. Further research will aim at studying more control populations of children who have not been exposed to motherese and correlate expressive language measures with motherese exposure.

Preliminary as our findings are, they could to be explored further to establish a basis for continued use of motherese-like speech in enhancing verbal communication in sub-populations of ASD individuals.

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References

[1] S. Amano, T. Nakatani, T. Kondo, Fundamental frequency of infants' and parents' utterances in longitudinal recordings, J. Acoust. Soc. Am. 119 (2006) 1636–1647.
[2] American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders, 4th ed. (DSM IV), American Psychiatric Association, Washington, DC, 1994.
[3] C.A.M. Baltaxe, J.Q. Simmons, E. Zee, Intonational patterns in normal, autistic and aphasic children. In A. Cohen, M. van de Broecke (Eds.), Proceedings of the 10th International Congress of Phonetic Sciences, Dordrecht, Foris, 1984.
[4] R. Banse, K.R. Scherer, K.R. Acoustic, Profiles in vocal emotion expression, J. Pers. Soc. Psy. 70 (1996) 614–636.
[5] P. Boersma, P. Weenink, Praat: Doing phonetics by computer, Version 4.3.14, 2005.
[6] M.H. Bornstein, Maternal responsiveness: characteristics and consequences, New Dir. Child Dev. 43 (1989) 75–87.
[7] J.R. De Pijper, Modelling British English Intonation, Dordrecht, Foris, 1983.
[8] G. Dawson, S. Faja, Autism spectrum disorders: A developmental perspective. In: T.P. Beauchaine, S.P. Hinshaw (Eds.), Child and Adolescent Psychopathology. Wiley, Hoboken, NJ, in press.
[9] S. Eguchi, I.J. Hirsh, Development of speech sounds in children, Acta Oto-Laryngol., Suppl. 257 (1969) 1–51.
[10] A. Fernald, T. Simon, Expanded intonation contours in mothers' speech to newborns, Dev. Psych. 20 (1984) 104–113.
[11] A. Fernald, P.K. Kuhl, Acoustic determinants of infant preference for motherese speech, Infant Behav. Dev. 10 (1987) 279–293.
[12] D.L. Grieser, P.K. Kuhl, Maternal speech to infants in a tonal language: support for universal prosodic features in motherese, Dev. Psych. 24 (1988) 14–20.
[13] K. Hubbard, D.A. Trauner, Intonation and emotion in autism spectrum disorders, J. Psycholing. Res. 36 (2007) 159–173.
[14] L. Kanner, Autistic disturbances of affective contact, Nervous Child 2 (1943) 217–250.
[15] K. Lamers, L.J. Hall, The response of children with autism to preferred prosody during instruction, Focus Autism Other Dev. Disab. 18 (2) (2003) 95–104.
[16] M.M. Lewis, Infant Speech: A Study of the Beginnings of Language, Routledge and Kegan Paul, London, 1951.
[17] J. McCann, S. Peppé, Prosody in autism spectrum disorders: a critical review, Int. J. Lang. Commun. Dis. 38 (2003) 325–350.
[18] R. Paul, A. Augustyn, A. Klin, F. Volkmar, Perception and production of prosody by speakers with autism spectrum disorders, J. Autism Dev. Dis. 35 (2005) 205–220.
[19] S. Peppe, J. McCann, F. Gibbon, A. O'Hare, M. Rutherford, M. Receptive, Expressive prosodic ability in children with high-functioning Autism, J. Speech Lang. Hear. Res. 50 (2007) 1015–1028.
[20] I. Rapin, M. Dunn, Update on the language disorders of individuals on the autistic spectrum, Brain Dev. 25 (2008) 166–172.
[21] E. Schopler, R.J. Reichler, B.R. Reiner, The Childhood Autism Rating Scale for Diagnostic Screening and Classification of Autism, Irvington, New York, 1986.
[22] S.J. Sheinkopf, Peter Mundy, D. Kimbrough Oller, Michele Steffens, Vocal atypicalities of preverbal autistic children, J. Autism Dev. Dis., 30, 2000.
[23] L.D. Shriberg, R. Paul, J.L. McSweeny, A.M. Klin, D.J. Cohen, F.R. Volkmar, Speech and prosody characteristics of adolescents and adults with high-functioning autism and Asperger syndrome, J. Speech Lang. Hear. Res. 44 (2001) 1097–1115.
[24] P.E. Tanguay, Pervasive developmental disorders: a 10-year review, J. Am. Acad. Child Adol. Psych. 39 (9) (2000) 1079–1095.