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Research Article

Voice Quality in Italian Speaking Children with Autism

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Abstract

Purpose: This research aims to measure the voice quality of Italian-speaking children with autism. Previous studies on voice quality of individuals with autism reported abnormal characteristics like high pitch, great pitch excursions, large changes in volume, and creaky voice, hoarseness and harshness; also, great variability was found among the children. Previous studies were mostly based on perceptual evaluations and did not focus specifically on Italian-speaking children. The present study aims to gather acoustic data to identify features of dysphonia in autism, and to shed some light on the nature and causes of this dysphonia. The results would help create a pediatric assessment tool for early identification of autism.

Method: Participants were 13 native Italian-speaking boys and 1 girl (4-9 years old), with a diagnosis of High Functioning Autism. Acoustic voice parameters, relative to pitch, loudness and voice quality, were extracted from CAPE-V speech samples, and analyzed by Praat. A one-sample t-test was performed to verify whether the voice parameters were within normal limits, and an ANOVA was conducted to evaluate the variability in the voice parameters within the group.

Results: The results indicated that Italian-speaking children with autism used a normal voice quality (no hoarseness, roughness, or breathiness). However, high pitch, great pitch modulation, high loudness and wide dynamic range were found, probably determined by the use of sing-song intonation by some children.

Conclusion: The children with autism in this study did not show abnormal voice quality. However, they showed an abnormal use of pitch, pitch modulation, loudness and dynamic range, in sustained vowels and in the speech tasks.

Lay summary: The results provide evidence that Italian-speaking children with autism spoke with normal voice quality, but used high pitch, great pitch modulation, and high loudness and wide dynamic range. The abnormal levels and ranges of pitch and loudness were probably determined by the use of sing-song intonation by some children.

The pitch and loudness abnormalities found in Italian-speaking children correspond to features also reported in previous studies on children speaking other languages and might constitute a universal characteristic of voice production in autism.

Keywords: Voice disorders; Children with autism; Acoustic measurements of voice; Voice quality in autism

Introduction

Problem and its relevance

Abnormal features characterizing voice in children with autism spectrum disorder (ASD) have been previously identified, mainly in studies based on perceptual assessments, and only few studies provided an acoustic analysis of the voice samples from children with ASD. On the other hand, data from acoustic measurements can be very useful in order to better understand the nature of the dysphonia associated with ASD, and to establish normative values, which can be possibly used to create a voice assessment test for diagnostics of ASD in school-age children.

Another issue to be studied in analysis of voice quality in children with ASD, is whether there are uniform characteristics or whether there is variability across children; some variability has been previously found, and its causes have been debated. New data can bring more insight into the nature of the autism specific deficits that might cause this variability.

Finally, the problem of the language spoken by the children is addressed, investigating whether the deficits in pitch, loudness and voice quality would be typical of each language, or common to all children with ASD across languages and cultures. If the latter condition were true, evidence would be provided for universal dysphonic properties in children with ASD.

Previous studies

Previous perceptual studies highlighted the following characteristics of voice of children with ASD: “abnormal control of pitch and volume, and deficits in vocal quality” [1-3]; speech can be overly fast, jerky or loud, or it can be characterized by high pitch, large pitch excursions and increased pitch range, a loud voice, a quiet voice, inconsistent pauses, a creaky or nasal voice [1, 2, 4-17]; bouncing pitch, growling voice [18], quiet voice and lack of covariation between frequency and intensity in intonation [19].

In terms of prosodic features, the voice was described in some studies as “machine-like, “monotonic” or with “ flat” intonation and limited range of changes in F0 [7-9, 18], and with a flatter amplitude [20]. In other studies, the voice is described as “sing-song” [9, 18], or having “a larger pitch range [20, 21], as well as having a high incidence of “pitch excursions” [21]. Some studies focused on linguistic prosody deficits, like phrasing [22] and stress [23], where phrasal stress is reported as characterized by misplaced pitch peaks in the sentence [20] and occurring on new as well as on old information. Also, lack of speech pauses and stretched syllables were found [18].

Previous reviews and studies based on quantitative measurements reported: decreased range of accuracy of prosodic functions [24]; longer sentence duration [25-27], greater variability in pitch ranges [19, 20, 28, 29]; abnormal higher mean pitch and larger pitch range [30, 31 Filipe, et al. (2014)], compared to control groups. Bonneh, et al. (2011) [32] reported creaky voice, loud voice, large pitch excursions and increased pitch range.

Fusaroli, et al. (2022) [33] in a meta-analysis on studies on voice in autistic individuals, found higher pitch, longer pauses, increased hoarseness and creakiness of the voice, with respect to controls. However, great variability by age, sex, language, and clinical characteristics among the autistic participants, and small differences between ASD and control groups were found, indicating that a general acoustic profile typical of all autistic individuals, is difficult to outline.

Godel, et al. (2023) [34] analyzed voice features of ASD preschoolers by a new technique, automatized digital diarization, which extracts vocalizations from recordings of naturalistic social interactions.

Abnormal jitter, shimmer, and HNR parameters were found, as well as a faster rhythm (measured as syllable duration), which is indicated as a prognostic marker for developing ASD symptoms. However, the study did not have a control group and, due to the diarization method, there was no categorization of the vocalization or utterances produced by the children; so it is difficult to generalize interpretations relative to the association of specific prosodic traits expressed by voice parameters and speech productions in ASD.

Previous research analyzed children speaking Finnish [18], Hebrew [32], English [2, 35], Danish [33] and Swedish [36]. However, voice quality parameters in Italian-speaking children with ASD have not been studied.

The literature presented shows that further studies are needed, to be carried out on larger size groups of non-homogeneous autistic children and on more diverse cross-linguistic datasets.

Novelty and rationale of the study

The present study aims to provide new data about the dysphonic voice in autism, obtained by acoustic measurements, and focusing on both pitch, loudness, and voice quality parameters, differently from previous studies, mostly carried out by perceptual assessment of voice features.

The aim of this research is to analyze only quality of voice, independently of the pragmatic, affective, and grammatical prosody effects that would appear in spontaneous speech: therefore, the data for the present analysis was obtained from a standard voice assessment test, the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V); this analysis is different from that of most previous studies, which evaluated spontaneous speech or samples from prosody tests.

Also, the present study analyzes voices of children with ASD who are native speakers of Italian, differently from previous research, which analyzed children speaking Finnish [18], Hebrew [32], English [2, 35], Danish [33] and Swedish [36]. The new data might provide evidence of the presence of same signs of dysphonia across languages, so possibly indicating a universal nature of the disorder.

Goals of the study

The first goal of the present research is to test whether acoustic measures of pitch, pitch variability, loudness, loudness variability and voice quality in the productions by children with ASD, would be within normal limits or whether they would be different from reference thresholds.

The second goal of the study is to verify whether there is variability among children in voice parameters, or whether there are patterns of voice features typical of some children: these patterns might help identify some signs useful for assessment and diagnosis of ASD, and shed light on the nature or causes of the dysphonia in autism.

The results might be used to realize a diagnostic tool for a voice disorder, which is not at present included in the ADOS-2 autism assessment test: in fact, despite the fact that there is a general agreement on the presence of abnormal voice traits in these children, voice is not considered as a diagnostic indicator for ASD in the DSM-V and in the WHO definition of the disease [2, 30, 24, 37].

Also, the data from the Italian-speaking children were compared with those obtained from children speaking different languages, in order to verify whether the voice quality abnormalities differed from previous results, or whether same features were found across languages: in this case, the outcomes could indicate presence of universal features of abnormal voice production in autism.

Hypotheses

1) The values of voice quality parameters (jitter, shimmer and HNR) and of pitch and loudness from the children's speech samples will be different from the normal thresholds, and will indicate abnormal voice features in phonation and speech.

2) Some patterns will emerge from the analysis of voice parameters, possibly indicating same kind of abnormalities, common to the children with autism, in their voice quality, pitch and loudness.

3) The voice quality, pitch and loudness features produced in the recordings by the Italian-speaking children with ASD will be similar to those previously found in children who are native speakers of other languages.

Methods

Participants

The participants are 13 native Italian-speaking boys and 1 girl with autism between the age of 4 years and 9 years (mean 7.1 ± SD 16.9). The children had a diagnosis of High Functioning Autism (HFA), were verbal, had normal intelligence, and no other comorbid condition (like hearing impairment, Down syndrome, or ADHD). The diagnosis was obtained based on the ADOS-2 test. The children had therapy for autism spectrum disorder (ASD) for an average of 4.6 years (SD ± 17.4). The therapy administered to the children is the Developmental, Emotional Regulation and Body-Based Intervention (DERBBI) approach created by Dr. Magda Di Renzo at the Istituto di Ortofonologia, Rome [38].

The study is approved by the Hofstra IRB Committee (HU IRB Approval Ref#: 20220222-SLH-HPHS-BON-1). Informed consents in Italian were approved by both Hofstra University and the Istituto di Ortofonologia, and were provided to the parents of the children before the recordings.

Procedures

Data

Presence of abnormal voice quality features, like hoarseness and breathiness, was measured based on jitter, shimmer and Harmonics-to-Noise ratio values, and evaluated against normal reference thresholds.

The data for the present analysis were obtained from a standard voice assessment test, the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V): the CAPE-V tasks were selected, so to reduce interferences of the pragmatic and affective aspects of prosody that could have played a role in spontaneous speech samples, in changing the pitch, loudness and voice quality (as highlighted by [2, 17, 18, 20]: in fact, the present study focuses merely on an acoustic analysis of voice features, without testing the impact of pragmatic affective or grammatical prosody on the abnormal voice in children with ASD.

In particular, the observed data are voice parameters extracted from speech samples recorded from the Italian version [39, 40] of the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V). The CAPE-V is a perceptual test for assessment of voice quality, evaluating the following characteristics: Roughness (Perceived irregularity in the voicing source), Breathiness (Audible air escape in the voice), Strain (Perception of excessive vocal effort (hyperfunction)), Pitch (Perceptual correlate of fundamental frequency). The test includes a perceptual scale, to help rating whether the individual's pitch, loudness and vocal quality deviate from normal values (considering the person's age, and gender).

The CAPE-V includes different tasks: sustained vowels ([ah], [ih]) to be pronounced with clear voice at normal pitch and loudness for at least 3-5 sec each; sentences designed to elicit different laryngeal behaviors and signs of voice disorders (please, see list of sentences in Appendix A), and production of running speech for about 20 sec.

The sentences include phonetic characteristics, aiming to elicit different phonatory behaviors, and so to highlight possible voice abnormalities: occurrence of every vowel sound in the language, to identify possible phonatory issues relative to specific vowels; sequences enabling easy onset, to verify whether production of a smooth onset of phonation is possible; a sequence of all voiced sounds, to verify whether continuous vibration of the vocal folds is possible; presence of hard glottal attacks, to verify whether the person can alternate between hard and smooth onsets without spasms or excessive strain; some nasal sounds, to verify whether alterations of normal resonance are present (hypo- or hyper-nasality) and presence of several voiceless plosive sounds, to verify whether the person can alternate seamlessly between open and closed glottal states.

The CAPE-V test was used because it is designed to represent all the aspects of voice, both as used in phonation (represented by a sustained vowels task) and in continuous speech (as in read sentences and in spontaneous speech tasks). It is easy to elicit these voice samples from the children, and the results of the analysis would be easily comparable with reference data from other clinical studies.

The following voice parameters, representative of normal quality, were analyzed: Mean Speaking Fundamental Frequency (SFF), F0 range, average intensity and intensity range, jitter, shimmer, and Harmonics-to-Noise Ratio. The definitions of each parameter is reported here below:

- Mean speaking F0 (SFF) - Average F0 during conversation, or running speech, was measured on sentences, whereas a value of Mean F0 was calculated on the sustained vowels.
- Speaking Max Frequency Range (MFR) in conversation: (Max F0 - Min F0) - Change in F0 level during speech, indicating emotions, syllables stress, types of sentences or syntactic structures.
- Average intensity - Overall level of amplitude during a speech task (like oral reading, conversation or sustained vowel).
- Dynamic range - Amplitude variation during a conversation, due to speaker's feelings, or situation.
- Jitter - Average absolute difference between two consecutive periods, divided by the average period (Jitter percent).
- Shimmer - Average absolute difference between the amplitude of three consecutive periods, divided by the average amplitude (Shimmer percent).
- Harmonics-to-Noise Ratio (HNR) - the ratio between periodic and non-periodic components in the voice.

In particular, the voice in the sentences productions has been analyzed examining all parameters: values for Mean SFF, Max F0 range, average intensity, intensity range, jitter, shimmer and HNR.

The productions of sustained vowels have been analyzed separately from the sentences, and only values of Mean F0, Average intensity, jitter, shimmer and HNR have been considered. In fact, the voice fundamental frequency and intensity variation in the production of sustained vowels is considered to be minimal with respect to that occurring in spoken sentences.

The normal thresholds selected to evaluate whether the measured values were in a normal range, were obtained from the literature on voice measurements [41-43]. Table 1 reports the parameters observed, with the normal thresholds adopted, the literature they were derived from, and the type of abnormal voice quality that a value not within normal limits might indicate.

The thresholds adopted for the statistical analysis are adapted from the values of the literature to represent the group of participants in this study. All thresholds refer to male boys between the age of 4 and 10 years, as our sample included 13 boys and 1 girl, reflecting the 4:1 male to female ratio which has been a part of the description of ASD since the first characterisation of the disorders [44].

Table 1: Normal thresholds for voice parameters and relative references.

Voice quality measures	Thresholds from the literature and references	Voice quality if value beyond threshold	Threshold used for One-sample t-test
Mean SFF (measured on sentences)	240Hz for 5-6 years old boys (Awan and Mueller 1996) 237Hz for 7-10 years old boys (Ferrand and Bloom, 1996; Bennett, 1983)	Too high pitch productions	240 Hz
Speaking Max Frequency Range (MFR) in speech (Max F0 - Min F0) (measured on sentences)	214 Hz for 5-6 years boys 158 Hz for 7-8 years old boys (Ferrand ad Bloom 1996)	Excessive variation in pitch during speech	186 Hz (calculated as average between 214Hz and 158 Hz)
Average intensity (measured on sentences)	70 dB (Ferrand, 2022; Baken, 1996; Lamarche et al., 2010)	Excessive variation in loudness during a speech task	70 dB (Average Intensity in dB)
Dynamic range (measured on sentences)	Range of 20-30 dB (between average intensity of 60-80 dB)	Lower or greater range might indicate monoloudness, too weak or too loud voice	25 dB
Jitter (Measured on vowels)	1.040%	If greater than threshold, might indicate hoarseness	1.04
Shimmer (Measured on vowels)	3.810%	If greater than threshold, might indicate hoarseness	3.81
Harmonics-to-Noise Ratio (HNR) (Measured on vowels)	15.3 dB (Ibrahim and Hassan, 2021)	If out of normal range, might indicate breathiness (if noise at higher frequencies), or hoarseness (if noise at lower frequencies)	15.3 dB

Data collection

The voices of the children with autism were recorded, in production of sustained vowels [ah] and [ih], and of 5 sentences from the Italian version of the CAPE-V voice assessment test.

The children were audio recorded at the speech pathology clinic Istituto di Ortofonologia, Rome, in a therapy room at the end of a therapy session. The speech by the children was recorded by a portable Sony voice recorder.

Data analysis

The data were analyzed by acoustic spectrography through Praat [45]: the parameters examined with Praat are listed in Table 1 above.

In order to test whether there are abnormal characteristics in the children's with ASD voices, a one-sample t-test was performed on the measures of voice quality, to verify whether the values relative to the pitch, intensity, hoarseness and breathiness are within normal limits in the speech of the children with ASD, or whether they significantly exceed the normal thresholds. The thresholds selected for the comparison are reported in Table 1.

Furthermore, in order to test whether there was variability across different children in voice characteristics, a one-way ANOVA was performed to compare the voice quality, pitch and loudness of all the children among them: the goal was to verify whether there were significant differences among the means of the voice parameters in all children, or whether some children used more similar voice quality patterns.

Results

COMPARISON OF THE VOICE QUALITY OF THE CHILDREN WITH REFERENCE THRESHOLDS, IN SENTENCES (1a) AND IN SUSTAINED VOWELS (1b)

The research question tested by this analysis is whether the voice quality, pitch and loudness parameters by all the children were within normal limits or if some of them exceeded the normal thresholds, indicating abnormal voice.

One-sample t-tests were performed to compare each voice parameter with a threshold value considered as a normal reference for that parameter, in order to test whether children's voices showed any feature outside of normal limits and whether some voice characteristics contributed more to the perception of dysphonia.

ONE-SAMPLE T-TEST RESULTS FOR SENTENCES

1a) Difference of the children's voices from the norm in sentences (please, refer to the thresholds used for the comparison in Table 1).

The results of t-tests comparing the voice parameters by all children, with the reference norms, in sentences productions, are reported in Table 2: children with autism showed an above average Speaking F0 (M = 287.9, SD = 43.9) than the population norm (t (69) = 9.1; p < .001). The threshold considered was 240 Hz.

Also, they showed a Speaking Max F0 range (M = 236, SD = 95.1) significantly higher than the norm (t (69) = 4.45; p < .001).

The threshold was considered as 186 Hz, calculated as the average of the two different values in the literature for children 5-6 years of age (214 Hz) and 7-9 years old children (158 Hz).

For intensity, the average intensity (M = 75.4; SD = 4.5) by the children with autism was significantly higher than the norm (t (69) = 10.13; p < .001), as well as their dynamic range (M = 34.2; SD = 13.2; t (69) = 5.84; p < .001).

In sentences, children with autism showed a jitter (M = 1.01, SD = 0.58) within normal limits (t (69) = -.134), n.s.

However, they showed an above-average shimmer (M = 7.76 , SD = 2.26) with respect to normal threshold (set at 3.81%) (t (69) = 14.65; p < .001), and slightly below average HNR values (M = 14.5, SD = 2.66) (t (69) = -2.45, p < .05) but still within normal range, if considering the SD reported in the literature for the reference norm adopted (15.3 dB, ± 10.65; [46]).

These results based on the analysis of the voices in the repeated sentences show that the Italian-speaking children with autism use, in connected speech, a higher than normal pitch and loudness, as well as a wider pitch range and dynamic range with respect to the relative normal thresholds.

The jitter and HNR values appear to be within normal limits, indicating an overall normal voice quality, but the shimmer is above threshold: this might depend on the wide changes in loudness in the speakers, which seem to be correlated to a high shimmer [47].

Table 2: Results of t-tests comparing the voice parameters by all children, with the reference norms, in sentences productions.

Voice parameters in sentences	M	SD	t (df)	P value
Average Speaking F0	287.9	43.9	t (69) = 9.1	p < .001
Speaking Max F0 range	236	95.1	t (69) = 4.45	p < .001
Average intensity	75.4	4.5	t (69) = 10.13	p < .001
Dynamic range	34.2	13.2	t (69) = 5.84	p < .001
Jitter	1.03	0.58	t (69) = -. 134	n.s.
Shimmer	7.76	2.26	t (69) = 14.65	p < .001
HNR	14.5	2.66	t (69) = -2.45	p < .05

ONE -SAMPLE T-TESTS RESULTS FOR VOWELS

1b) Difference of children's voices from the reference norms in sustained vowels productions (please, refer to the thresholds reported in Table 1).

Table 3: Results of t-tests comparing the voice parameters by all children, with the reference norms, in vowels productions.

Voice Parameters in vowels	Mean	SD	t (df)	P value
Mean F0	313.9	69.3	t (27) = 5.6	p < .001
Average intensity	78.1	4.8	t (27) = 8.9	p < .001
Jitter	0.26	0.2	t (27) = -19.7	p < .001
Shimmer	3.03	1.2	t (27) = -3.26	p < .01
HNR	20.9	3.6	t (27) = 8.1	p < .001

The results based on the analysis of the voice parameters in the sustained vowels (see Table 3) show that the Mean F0 and Average intensity were significantly above the norms, indicating an overall high pitch and loudness in the sustained vowels.

The F0 range and dynamic range were not measured for the sustained vowels repetitions, as the pitch and intensity are supposed not vary too much from the mean, since the children are instructed to pronounce vowels sustained for 3-5 sec, without changing the intonation.

The average HNR value found for vowels productions (20.9 dB) was significantly above the normal threshold, but within normal range, if considering the SD reported in the literature for the reference norm adopted (15.3 dB, ± 10.65; [44]).

The jitter and shimmer values actually were significantly lower than the reference threshold, therefore, within normal limits (see Table 1 for thresholds values).

COMPARISON OF THE VOICE QUALITY AMONG THE CHILDREN, IN (2a) SENTENCES AND (2b) IN SUSTAINED VOWELS

The second research question tested by this analysis is whether there is a significant difference in the abnormal voice parameters of the individual children's productions or whether we can find a pattern that might show similar dysphonic characteristics in the group of children with autism.

A one-way ANOVA was performed to compare each voice parameter that exceeded the normative values, among the children, to verify whether there were significant differences in voice quality, pitch or loudness, due to individual productions, or whether children used similar voice quality patterns.

Post-hoc Bonferroni tests for multiple comparisons were carried out on voice parameters in vowels and sentences productions, to verify which individual differences contributed more to the overall variability of the voice across the children.

2a) Comparison of abnormal voice parameters among the children in sentences (the parameters evaluated are reported in Table 1)

Table 4 reports the results of the one-way ANOVA comparing the voice quality in children with autism, in the sentences reading task: the Average F0, F0 range, average intensity, jitter, shimmer and HNR were found to be significantly different across the children, whereas only the dynamic range was similar across children.

Table 4: One-way ANOVA results indicating that children show similar dynamic range, in the production of sentences.

Voice parameters in sentences	F value	Sig.	Perceptual correlate
Average F0	F = (13, 56) = 7.1	p = <.001	Pitch
F0 range	F (13, 56) = 3.5	p = < .001	Pitch range
Average intensity	F (13, 56) = 10.5	p = <.001	Loudness
Dynamic range	F (13, 56) = 1	p = n.s.	Loudness range
Jitter	F (13, 56= 2.6	p = < .01	Hoarseness
Shimmer	F (13, 56) = 5.2	p =< .001	Hoarseness
HNR	F (13, 56)= 4.4	p< .001	Breathiness

The results of this One-way ANOVA test show that the voice quality parameters that differed from norms (Average F0, Average intensity and Max F0 range), are produced with variability across different children.

Only the dynamic range shows a similar pattern across all participants in sentences production.

2b) Comparison of abnormal voice parameters among the children in sustained vowels productions (the parameters evaluated are reported in Table 1)

The results of the One-way ANOVA comparing the voice quality in children with autism, in the sustained vowels, showed that only the abnormal pitch parameter 'Average F0' and the abnormal loudness parameter 'Average intensity' were found to be significantly different across the children, whereas all the other voice parameters were similar (see Table 5).

The F0 range and dynamic range were not measured for the sustained vowels repetitions, as the pitch and intensity are supposed not vary too much from the mean, since the children are instructed to pronounce vowels sustained for 3-5 sec, without changing the intonation.

Table 5: One-way ANOVA results indicating that children show similar Jitter, Shimmer and HNR, in the production of sustained vowels, but variability in the Mean F0 and Average intensity productions.

Voice quality Parameter in sustained vowels	F value	Sig.	Perceptual correlate
Average F0	F = (13, 14) = 10.8	p = <.001	Pitch
Average intensity	F (13, 14) = 4.68	p= < .01	Loudness
Jitter	F (13, 14)= .71	p = n.s.	Hoarseness
Shimmer	F (13, 14) = .76	p = n.s	Hoarseness
HNR	F (13, 14)= 1.6	p = n.s.	Breathiness

BONFERRONI TESTS

The results from the Post-hoc Bonferroni tests on voice parameters in vowels and sentences productions, revealed some variability for jitter, shimmer and HNR parameters, but only the results relative to dysphonic dimensions of F0 and intensity were reported here.

The Bonferroni tests found that, for the average F0 and average intensity in read sentences, the variability was mostly due to the fact that the mean values for average F0 and average intensity, were significantly different among 4 children of 4 ys, 6 ys and 9 ys respectively (Ch1 4.8 ys: M = 318 Hz, SD = 66.2; Ch2 6.3 ys: M = 247.2 Hz, SD = 14.6; Ch3 9 ys: M = 286 Hz, SD = 23.5), who used either a very accentuated sing-song intonation, or a very loud voice or a monotone voice, thus increasing or decreasing the average pitch level, the pitch modulation and the average F0 range.

The Bonferroni tests on children's F0 range in read sentences, found that 3 children of 5ys, and 6 ys and 9 yrs respectively, differed among them in this parameter, due to the fact that they were generally speaking very loud and changed their loudness while speaking, so inducing abrupt pitch changes (Ch1 5.11ys: M =138 Hz; SD = 35.1; Ch2 6.0 ys: M = 361.2 Hz; SD = 97.2; Ch3 9.6(1) ys: M = 142.6 Hz, SD = 66.6).

Bonferroni Tests for multiple comparisons on children's voice parameters in vowels pronunciations indicated that, for the Average F0, the variability was mostly due to the fact that the mean value for average F0 was significantly different among 3 children of 4ys, 6 ys and 8 ys respectively (4.8 ys: M =439 Hz, SD = 24; 6.2 ys: M = 402.5 Hz, SD = 3.5; 9.6 ys: M = 338Hz, SD = 29.6): a perceptual examination of the voices of the children indicated that they used a very accentuated sing-song intonation, with great pitch shifts from high to low values.

Likewise, the Bonferroni tests on children's abnormal average intensity in sustained vowels, found that three children, of age 4ys, 6ys and 8ys respectively, differed among them and from the normal threshold, in average intensity (4.8 ys: M = 85Hz, SD= 1.4; 6.3 ys: M = 71Hz, SD = 1.4; 8.5ys: M = 72Hz, SD = 2.8), due to the fact that they generally modulated the pitch during the vowel and spoke with a sing-song intonation, so causing a rhythmic alternation of high and low pitch levels, and a concurrent rhythmic change in the intensity.

Discussion

The results partially confirmed the Hypothesis 1: in fact, some aspects of voice, namely pitch and loudness, used by the children in vowels and sentences, appeared to be different from the normal thresholds, indicating abnormal voice features both in phonation and speech tasks.

However, the voice quality resulted normal in both tasks, i.e. no excessive hoarseness, breathiness or strain were detected.

Hypothesis 2 was also partially confirmed by the data, in fact, some patterns were found in children's voice features: in vowels, all voice quality parameters were similar, indicating similar normal voice in all children in this phonatory task. However, pitch and loudness appeared to vary among the children.

In sentences, all the voice quality and the pitch parameters differed among the children, so showing an extreme variability in voice quality in the speech tasks.

The nature of the variability among the children has been investigated further by Bonferroni tests on the measures that appeared to be different from the norms in the first analysis, i.e. pitch, loudness, pitch range and intensity range: the findings showed that the differences were due mostly to the voice of some children who modulated the pitch and spoke with a sing-song intonation, so generating a rhythmic alternation of high and low pitch levels, and a concurrent rhythmic change in the intensity. One child, on the other hand, used a monotone voice in sentences, so affecting the overall pitch range measures.

Finally, as to the third hypothesis, the similarities of the present results with previous data from different languages were qualitatively compared, and it appears that the present evidence confirms previous findings: in fact, the pitch was described as "monotonic" in studies on voice of Finnish and English-speaking children with autism [7, 8, 18] Baltaxe and Simmons (1980).

Also, the voice was described as "sing-song" [9, 18], or having "a larger pitch range [20, 21], or a high incidence of "pitch excursions" [21], or showing an abnormal mean pitch and pitch range [30] in Finnish- and English-speaking children.

The limitations of this study are the small sample size, the male bias n the selection of teh children with ASD, and the limited age range [48].

Conclusions and Future Studies

The children with autism in this study did not show abnormal voice quality (no excessive hoarseness, breathiness or strain were found). However, they showed an abnormal use of pitch, pitch modulation, loudness and dynamic range, in sustained vowels and in the speech tasks.

Evidence was provided that the children showed a high variability in the use of pitch and loudness and in the relative ranges, and that these effects were determined mostly by the use of sing-song intonation in speech tasks by some children: the wide modulations of pitch caused by this type of intonation induced also high variability in intensity.

Same findings resulted from studies on different languages, and the present data seem to confirm the existence of a sing-song intonation and relative wide excursions of pitch and intensity, as a universal feature of voice production in autism.

However, since these voice features seem to be correlated with the intonation used in speech, a further investigation is needed to identify what factors induce the use of prosodic contours by great F0 modulation in children with autism.

The good and normal voice quality appears to be a positive outcome of the DERBBI therapy, which was administered to the 13 children for an average of 4.6 years at the Istituto di Ortofonologia. The DERBBI approach is based on bodily expression to promote affective attunement processes as a basis for language, and does not focus specifically on voice; however, this treatment carried the children from a non-verbal condition, to a functional level of speech where they are able to pronounce and read sentences and to interact in a dialogue with a normal voice quality.

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Conflict of Interest

No Conflict of Interest.

References

1. Tager Flusberg H (1981) On the nature of linguistic functioning in early infantile autism. J Autism Dev Disord 11(1): 45-56.
2. Shriberg L, Paul R, McSweeney J, Klin A, Cohen D, et al. (2001) Speech and prosody characteristics of adolescents and adults with high functioning autism and Asperger syndrome. J Speech Lang Hear Res 44: 1097-1115.
3. Rapin I, Dunn M (2003) Update on the language disorders of individuals on the autistic spectrum. Brain & Development 25: 166-172.
4. Ghaziuddin M, Gerstein L (1996) Pedantic speaking style differentiates Asperger syndrome from high-functioning autism. Clinical Trial. J Autism Dev Disord 26(6): 585-595.
5. Lehtinen M (2010) Observations on the prosodic characteristics of Finnish-speaking youngsters with Asperger Syndrome In: Botinis, A. (Ed.), Proceedings of 'ExLing 2010-ISCA Tutorial and Research Workshop on Experimental Linguistics' (pp. 93-96). ISCA/University of Athens, Athens.
6. Pronovost W, Wakstein MP, Wakstein, DJ (1966) A longitudinal study of the speech behavior and language comprehension of fourteen children diagnosed atypical or autistic. Except Child 33: 19-26.
7. Baltaxe C, Simmons J (1985) Prosodic development in normal and autistic children. In: E. Schopler, G Mesibov (Eds.), Communication problems in autism. (pp. 95-125). New York, NY: Plenum Press.
8. Baltaxe C, Simmons JQ (1992) A comparison of language issues in high-functioning autism and related disorders with onset in childhood and adolescence. In Schopler E, Mesibov G (Eds.), High-functioning individuals with autism (pp. 201-225). New York, NY: Plenum Press.
9. Fay WH, Schuler AL (1980) Emerging language in autistic children: Language intervention studies. London: Edward Arnold.
10. Paul R, Shriberg LD, McSweeny J, Cicchetti D, Klin A, et al. (2005a) Brief report: Relations between prosodic performance and communication and socialization ratings in high functioning speakers with autism spectrum disorders. J Autism Dev Disord 35(6): 861-869.
11. Paul R, Augustyn A, Klin A, Volkmar F (2005b) Perception and production of prosody by speakers with autistic spectrum disorders. J Autism Dev Disord 35: 205-220.
12. Rutter M, Lockyer L (1967) A five to fifteen year follow-up study of infantile psychosis. I: Description of sample. Br J Psychiatry 113: 1169-1182.
13. Ornitz EM, Ritvo ER (1976) The syndrome of autism: A critical review. Am J Psychiatry 133(6): 609-621.
14. Paul R (1987) Communication. In Cohen D, Donnellan A (Eds.), Handbook of autism and pervasive developmental disorders (pp. 61-84). New York, NY: John Wiley.
15. McPartland J, Klin A (2006) Asperger's syndrome. Adolescent Medicine Clinics 17(3): 771-788.
16. Tager Flusberg H (2000) Understanding the language and communicative impairments in autism. International Review of Research in Mental Retardation 23: 185-205.
17. McCann J, Peppé S (2003) Prosody in autism spectrum disorders: A critical review. Int J Lang Commun Disord 38(4): 325-350.
18. Wiklund M (2016) Interactional challenges in conversations with autistic preadolescents: The role of prosody and non-verbal communication in other-initiated repair. Journal of Pragmatics 94: 76-97.
19. Baltaxe CAM, Simmons JQ, Zee E (1984) Intonation patterns in normal, autistic and aphasic children. In A. Cohen & M. van de Broecke (Eds.), Proceedings of the 10th International Congress of Phonetic Sciences (pp. 713-718). Dordrecht: Foris.
20. Hubbard K, Trauner D (2007) Intonation and emotion in autistic spectrum disorders. J Psycholinguist Res 36: 159-173.
21. Sharda M, Subhadra TP, Sahay S, Nagaraja C, Singh L, et al. (2010) Sounds of melody–pitch patterns of speech in autism. Neurosci Lett 478(1): 42-45.
22. Fine J, Bartolucci G, Ginsberg G, Szatmari P (1991) The use of intonation to communicate in pervasive developmental disorders. J Child Psychol Psychiatry 32: 771-782.
23. Baltaxe CA (1984) Use of contrastive stress in normal, aphasic, and autistic children. Journal of Speech & Hearing Research, 27(1): 97-105.

24. Peppé S, McCann J (2003) Assessing intonation and prosody in children with atypical language development: The PEPS-C test and the revised version. Clin Linguist Phon 17: 345-354.

25. Diehl JJ, Paul R (2012) Acoustic differences in the imitation of prosodic patterns in children with autism spectrum disorders. Res Autism Spectr Disord 6(1): 123-134.

26. Diehl JJ, Paul R (2013) Acoustic and perceptual measurements of prosody production on the profiling elements of prosodic systems in children by children with autism spectrum disorders. Applied Psycholinguistics 34(01): 135-161.

27. Grossman RB, Bemis RH, Skwerer DP, Tager Flusberg H (2010) Lexical and affective prosody in children with high-functioning autism. J Speech Lang Hear Res 53(3): 778-793.

28. Diehl JJ, Bennetto L, Watson D, Gunlogson C, McDonough J (2008) Resolving ambiguity: A psycholinguistic approach to understanding prosody processing in high-functioning autism. Brain Lang 106(2): 144-152.

29. Fosnot SM, Sun Ah J (1999) Prosodic characteristics in children with stuttering or autism during reading and imitation. Proceedings of the 14th International Congress of Phonetic Sciences, San Francisco 1-7 August. 1925-1928.

30. Fusaroli R, Lambrechts A, Bang D, Bowler DM, Gaigg SB (2017) Is voice a marker for Autism spectrum disorder? A systematic review and meta-analysis. Autism Res 10(3): 384-407.

31. Asghari SZ., Farashi S, Bashirian S, Jenabi E (2021) Distinctive prosodic features of people with autism spectrum disorder: a systematic review and meta-analysis study. Sci Rep 11: 23093.

32. Bonneh YS, Levanon Y, Dean Pardo O, Lossos L, Adini Y (2011) Abnormal speech spectrum and increased pitch variability in young autistic children. Front Hum Neurosci 4: 237.

33. Fusaroli R (2022) Toward a cumulative science of vocal markers of autism: A cross-linguistic meta-analysis-based investigation of acoustic markers in American and Danish autistic children. Autism Res 15: 653-664.

34. Godel M, Robain F, Journal F, Kojovic N, Latrèche K, et al. (2023) Prosodic signatures of ASD severity and developmental delay in preschoolers. NPJ Digit Med 6(1): 99.

35. Peppé S, McCann J, Gibbon F, O'Hare A, Rutherford M (2007) Receptive and expressive prosodic ability in children with high functioning autism. J Speech Lang Hear Res 50: 1015-1028.

36. Dahlgren S, Sandberg A, Strömbergsson S, Wenhov L, Råstam M, et al. (2018) Prosodic traits in speech produced by children with autism spectrum disorders-Perceptual and acoustic measurements. Autism & Developmental Language Impairments 3: 1-10.

37. World Health Organisation (1993) The ICD-10 classification of mental and behavioural disorders. Geneva: World Health Organisation.

38. Di Renzo M, Vanadi E, Petrillo M, Trapolino D, Racinaro L, et al. (2020) A therapeutic approach for ASD: method and outcome of the DERBBI-Developmental, Emotional Regulation and Body-Based Intervention. IJPE 2020, XII(1).

39. Schindler A, Ginocchio D, Ricci Maccarini A, Spadola Bisetti M, Ruoppolo G et al. (2006) CAPE-V (Consensus Auditory-Perceptual Evaluation of Voice): Italian version. Acta Phoniatrica Latina 28: 383-391.

40. Mozzanica F, Ginocchio D, Borgi E, Bachmann C, Schindler A (2014) Reliability and validity of the italian version of the consensus auditory-perceptual evaluation of voice (CAPE-V). Folia Phoniatrica et Logopaedica 65(5): 257-265.

41. Ferrand C (2022) Voice disorders: scope of theory and practice. London: Pearson Publishing.

42. Baken R, Orlikoff F (2000) Clinical Measurement of Speech and Voice (2nd edn.). San Diego, CA: Singular Publishing.

43. Zemlin WR (1998) Speech and hearing science: Anatomy and physiology (4th edn.). Boston, MA: Allyn and Bacon.

44. Kirkovski M, Enticott PG, Fitzgerald PB (2013) A review of the role of female gender in autism spectrum disorders. J Autism Dev Disord 43(11): 2584-2603.

45. Boersma P, Weenick D (2019) Praat: Doing phonetics by computer.

46. Ibrahim RA, Hassan EM (2021) Normative vocal acoustic parameters for preschool and elementary school Egyptian children. Int J Pediatr Otorhinolaryngol 143: 110662.

47. Brockmann M, Storck C, Carding PN, Drinnan MJ (2008) Voice loudness and gender effects on jitter and shimmer in healthy adults. J Speech Lang Hear Res 51: 1152-1160.

48. Tager Flusberg H (1995) Dissociations in form and function in the acquisition of language in autistic children. In: H Tager-Flusberg (Ed.), Constraints on language acquisition: Studies of atypical children. (pp. 175-194). Hillsdale, NJ: Erlbaum.