Short Report

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Voice pitch and gender in autism

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Abstract

Autistic adults are often perceived as having an atypical speech. The acoustic characteristics of these impressions prove surprisingly difficult to delineate, but one feature that does robustly emerge across different studies is higher pitch (F0 values) in autistic versus neurotypical individuals. However, there is no clear explanation why autistic individuals should have higher-pitched voices. We propose that the solution lies in the gender imbalance still prevalent in autism, which entails an overrepresentation of male participants in research on speech in autism. We analyse speech samples from a gender-balanced group of 40 autistic and 40 neurotypical adults, controlling for potential stress levels through electrodermal activity recordings. We find that autistic males tend to have higher pitch than neurotypical males, but that autistic females tend to have lower pitch than neurotypical females. The interpretation we put forth for our finding – that the autistic versus neurotypical group difference in pitch goes in opposite directions between males and females – is that autistic individuals tend to be less influenced by neurotypical gender stereotypes.

Lay abstract

It is has often been observed that autistic individuals have higher-pitched voices than non-autistic ones, but no clear explanation for this difference has been put forth. However, autistic males are still dramatically over-represented in published research, including the acoustic studies that report higher pitch in autistic participants. In this study, we collected speech samples from a group of autistic and neurotypical adults that, unlike in most studies, was perfectly balanced between groups and genders. In this gender-balanced sample, pitch was significantly higher in autistic versus neurotypical men, but *lower* in autistic versus neurotypical women. Overall, women tend to have higher-pitched voices than men, but the magnitude of this difference is culture dependent and may be significantly influenced by the internalisation of normative expectations towards one's gender. We propose that higher pitch in autistic males and lower pitch in autistic females could be due, at least in part, to a lesser integration of sociolinguistic markers of gender. Our report shows that speech atypicality should not be operationalised in terms of systematic and unidirectional deviation from the neurotypical baseline.

Keywords

atypicality, gender, pitch, voice, autism

Atypical speech is a frequent characteristic of autism, present in the very first clinical descriptions (e.g Asperger, 1991; Goldfarb et al., 1956; Simmonds & Sukhareva, 2020) and perceived as such by both experienced clinicians and naive raters, even for autistic adults whose language skills are within the typical ranges (de Marchena & Miller, 2017; Grossman, 2015; Nadig & Shaw, 2012). However, a clear-cut delineation of the objective correlates of these impressions proves rather elusive (McCann & Peppé, 2003), including at the level of acoustic analyses (Fusaroli et al., 2022; Fusaroli et al., 2017). One result that does repeatedly emerge across acoustic studies is that autistic individuals tend to have a higher pitch, as reflected by higher fundamental frequency values (F0), than neurotypical ones. The F0 corresponds to the frequency of vibration of the vocal folds, which correlates with the perceived pitch.

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Although higher F0 has been robustly documented in studies on speech in autism, no clear explanation exists for this trend – perhaps because it is difficult to come by. Higher pitch values in autism have been independently observed across different samples, age ranges and languages as different as English, Danish, Hebrew, Mandarin, Portuguese and French (Bonneh et al., 2011; Chen et al., 2022; Filipe et al., 2014; Fusaroli et al., 2022; Fusaroli et al., 2017; Kissine & Geelhand, 2019). It is tempting to link atypical speech to the difficulties in using language in social contexts, which is a key diagnostic feature of autism. However, even though some difficulties with intonation have been reported, there is no clear-cut evidence that, independently of their linguistic skills, autistic individuals have systematic difficulties in identifying and even wielding linguistic and pragmatic functions of prosody (McCann & Peppé, 2003). Furthermore, higher pitch has been observed in autistic versus neurotypical adults independently of the elicitation task and conversational demands (Kissine & Geelhand, 2019; Kissine et al., 2021).

There are well-known anatomic differences between biological males and females, which tend to yield higher F0 values in the latter. However, it is equally well documented that the internalisation of normative expectations towards one's gender may significantly accentuate this difference. There are no sex differences in the F0 of baby cries, but higher-pitched cries are consistently (mis)attributed by adults to girls and lower-pitched ones to boys (Cornec et al., 2024). Older children have been found to adjust their voice towards a gender dimorphism before puberty, that is, before significant sex differences in the vocal tract length and larynx may emerge (Cartei et al., 2014). Finally, the magnitude of the difference in F0 between men and women is dependent on social norms and sexual orientation (e.g. Simpson, 2009; van Bezooijen, 1995, among many others).

The (official) sex ratio in autism is generally around one female for four males (e.g. Loomes et al., 2017). Even though there is growing evidence that this gender imbalance partly owes to diagnostic and social biaises (e.g. Geelhand et al., 2019; Loomes et al., 2017), it still extends to much published research, including to studies on acoustic characteristics of speech in autistic adults. For instance, there were only 7 females out of 77 autistic participants in Fusaroli et al.'s (2017), 7 out of 20 in Kissine and Geelhand's (2019), and none in Kissine et al.'s (2021) studies. It is therefore likely that the tendency for autistic speech samples to display a higher F0 is in fact limited to productions by autistic males: in other words, the autistic speakers who tend to display a higher pitch than non-autistic ones are mostly males.

No clear biological or physiological explanation currently exists for why the speech of autistic males tend to have higher F0 values. However, it also makes sense to speculate that higher F0 has been observed in autistic males, at least in part, because they are less likely to integrate sociolinguistic markers associated with male-gendered stereotypes. This hypothesis would gel well with the social atypicalities, inherent in the autism diagnosis, but also with higher rates of gender diversity in autism (Warrier et al., 2020) and lower rates of gendered play in autistic boys (Hull et al., 2023). A straightforward corollary hypothesis is that autistic females are also less prone than non-autistic to integrate female gender sociolinguistic markers, such as high-pitched voice. But if so, one should expect F0 to be *lower*, and not higher, in autistic versus neurotypical females.

We hypothesise that higher F0 in autistic speech samples previously documented in the literature owes to the combination of predominantly male participant samples in autism research with a lower gender dismorphism in the speech of autistic individuals. To this end, we analyse a large quantity of speech samples, elicited in a semi-controlled environment, from a gender-balanced sample of 80 French-speaking adults: 40 autistic, 40 neurotypical, with 20 females in each group. Speech samples are drawn from a task where participants had to define common words in front of an experimenter (Clin & Kissine, 2023b). Stress may result in higher F0 values, and it remains possible that in some studies the elicitation tasks (e.g. picture naming by Bonneh et al., 2011; or reading by Green & Tobin, 2009) imposed higher stress levels on autistic participants, yielding the reported group differences. Potential stress peaks were controlled by collecting sensory responses through electrodermal sensors attached to the participant's hand. Moreover, we also exclude any speech disfluency that might be stress induced.

Methods

Participants

The speech samples were collected during an independent experimental study, with completely different objectives and research questions; for details, see Clin and Kissine (2023b). The autistic group was composed of 40 adults (20 females), group-wise matched by full-scale (FIQ) and verbal intellectual quotients (VIQ) to a neurotypical group consisting of 40 adults (20 females). See Table 1 for participant characteristics. Groups did not differ in age, educational level, full scale IQ, and verbal IQ (all $p > .135$; see Supplementary materials). All autistic participants received an official diagnosis of autism or Asperger syndrome from a multidisciplinary team officially habilitated to issue autism diagnoses; neurotypical participants had no history of developmental delays, psychiatric diagnoses or neurocognitive impairments. Inclusion criteria were being a native French speaker, being verbally fluent, having no intellectual delay and having normal or corrected-to-normal vision and audition.

Table 1. Participant characteristics: means and standard deviations.

Group	Gender[a]	*n*	Age (y)	FIQ[b]	VIQ[b]	AQ[c]	ADOS[d]	Education[e]
Autistic	Female	20	35.75 (8.97)	119.7 (12.21)	125.05 (12.61)	38.25 (5.66)	12.08 (4.15)	3.4 (1.47)
Autistic	Male	20	36.75 (11.12)	117.2 (18.78)	123 (18.25)	39.05 (5.45)	11.75 (4.46)	3.05 (1.31)
Neurotypical	Female	20	35.2 (10.68)	116.25 (8.81)	125.1 (11.24)	15.05 (6.49)	/	3.8 (0.95)
Neurotypical	Male	20	37.25 (12.14)	121.35 (9.09)	127.75 (14.43)	18.9 (5.61)	/	3.5 (1.15)

[a]Self-reported.
[b]Full scale and verbal IQ, WAIS-IV (Wechsler, 2008).
[c]Autism Quotient (Baron-Cohen et al., 2001).
[d]ADOS total score (Lord et al., 2012).
[e]Education level (see Clin & Kissine, 2023b, for details). *Missing data*: VIQ: one neurotypical male and one neurotypical female; ADOS: seven autistic females and four autistic males; Education level: one autistic male.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Erasmus Hospital-Université libre de Bruxelles Ethical Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Data collection

Each participant defined 20 words displayed on paper cards by the experimenter, with Shimmer3 GSR+ sensors attached on the palmar side of the proximal phalange of their index and medium fingers of their non-dominant hand. A value of 1 was assigned to every skin conductance difference comprised between 0.1 and 1 μS between two values separated by 1 s and followed by a recovery time, with a threshold a difference superior to 1 μS. The whole interaction was recorded with a camera (Sony FDR-AX33 4 K) and a professional microphone (Røde Videomic Pro).

To answer the research questions independent of those addressed here (see Clin & Kissine, 2023b, for details), for one half of the participants in each group (autistics versus non-autistic), throughout the task, the experimenter consistently looked at the participant's eyes; for the other half, the experimenter consistently looked away from the participant; furthermore, participants wore a Tobii Pro Glasses 2 wearable eye-tracker. This gaze manipulation did not affect the contrasts reported below (see Supplementary materials).

Speech data coding and acoustic analysis

Participant productions were coded as 'normal talk' (fluent speech) or a disfluency (Cohen's κ=0.92 for inter-coder agreement); see Clin and Kissine (2023a) for details. Using a Praat script, we extracted median F0 values per 5 ms bins using the auto-correlation method, only for segments coded as 'normal talk'; the maximum and the minimum F0 values were computed using the stepwise method described by Kissine and Geelhand (2019).

Community involvement

No autistic individual has been involved in the design of the study reported here. Some of our autistic participants contributed to recruiting by spreading the flyer on social media or directly talking to friends.

Results

All analyses were conducted in R (R Development Core Team, 2015). We analysed an average of 11,471 data points per participant; see Table 2. There was no difference in the number of data points between groups or genders (both $p > .302$).

Table 2 also shows that mean F0 values are numerically lower in autistic versus neurotypical females, but higher in autistic versus neurotypical males. A linear regression with F0 values as dependent variable and Group (Autistic vs Neurotypical) and Gender (Female vs Male) as fixed factors revealed a significant Gender X Group interaction ($\beta=-3.96$; $se=0.1$; $p<.001$). Post hoc pairwise Tukey comparisons conducted with the emmeans package (Lenth et al., 2020) confirmed that the difference went in the expected direction: lower F0 in autistic versus neurotypical females ($\beta=-12.39$; $se=0.28$; $p<.001$) and higher F0 in autistic versus neurotypical males ($\beta=3.46$; $se=0.32$; $p<.001$). These contrasts remained unaffected when per-participant average skin conductance response was added to the model (see Supplementary material for details and other robustness checks).

Fig. 1 displays individual F0 density distributions, arranged by mode. Remarkably, while in the neurotypical group this ranking introduces a strict gender split, in the autistic group there is more variation, with one male

Table 2. Average number of datapoints and average F0 values per participant, by group and gender.

Group	Gender	Datapoints (range)	F0 in Hz (sd)
Autism	Female	12989.35 (43945-1314)	184.49 (33.84)
Autism	Male	8466.3 (24755-723)	151.1 (63.73)
Neurotypical	Female	13394.15 (40275-3051)	207 (50.56)
Neurotypical	Male	17416.40 (11034.8-6711.12)	139.16 (22.15)

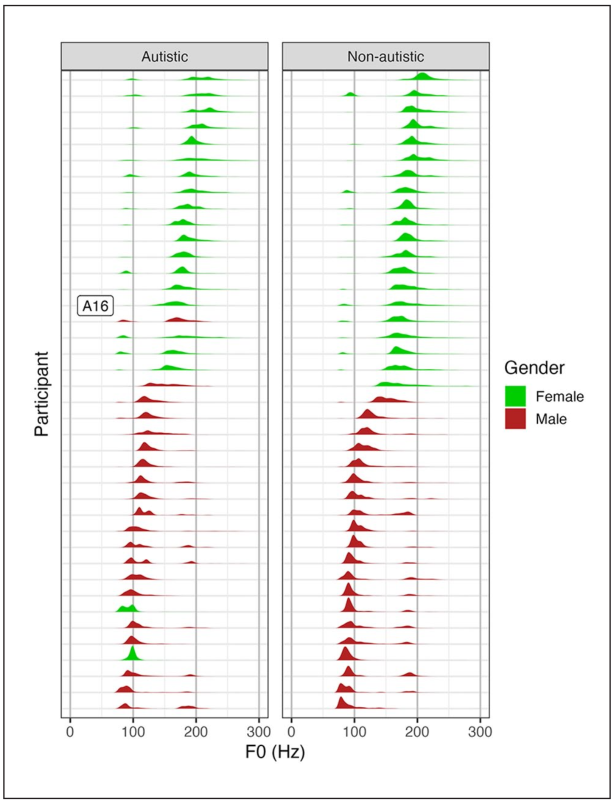

Figure 1. Density graphs of F0 values collected for each participant (every 5 s), arranged by decreasing value of mode (by 10 Hz bins) and split by group. All participants reported to be cis-gender, except A16, in the autism group, whose gender assigned at birth was male.

ranking above three females, and two females ranking towards the lower mode ranges. Furthermore, the distributions of F0 values of autistic individuals are less peaked than those of neurotypical ones.

Discussion

Decade-long efforts to delineate clear acoustic characteristics of speech in autism presuppose that perceptions of atypicality should be operationalised in terms of systematic and unidirectional deviation from the neurotypical baseline. Yet, what research on language in autism makes rarely explicit is that there are no obvious physiological or cognitive characteristics across the autism spectrum that can be expected to yield consistent phonetic atypicalities – that is, independently of the languages, cultures, and social milieux. Motor (see Maffei et al., 2023) or biological (e.g. Borysiak et al., 2017) explanations of atypical pitch in autism may of course emerge in future research. However, reduced gender dismorphism in F0 in the speech of autistic adults that we document here is also consistent with the idea of lower sociolinguistic marking of gender in autism, sketched in the Introduction.

Collecting speech samples from a gender-balanced group of autistic adults confirms previously reported F0 differences between autistic and neurotypical adults, but shows that this difference is asymmetric across genders. In our study, speech samples from autistic men tend to have higher F0 values than those collected from neurotypical men, whereas speech samples from autistic women tend to have lower F0 values than those produced by neurotypical women. In other words, one of the most prominent linguistic marker of gender, pitch, seems to be less marked in autistic adults. Consistently with this interpretation, gender introduces a strict split in neurotypicals, with higher F0 modes for females, but not in autistic participants. Furthermore, the individual F0 distributions of autistic individuals were flatter, which could be explained by lower peaks around more gender typical values.

Our study clearly emphasises the importance of including female autistic participants in research designs. It would be interesting to replicate this study in other languages and cultures, but also to investigate whether the same tendency applies to other indexes of gender, linguistic or not. An obvious limitation, to be addressed in future research, is that we did not have any independent measure of our participants' adherence to gender stereotypes.

Non-autistic individuals form rapid impressions of atypicality when listening to the speech of autistic individuals, which may lead to negative judgements and stigma (Geelhand et al., 2021; Grossman, 2015). Our results suggest that such impressions of atypicality are not necessarily triggered by the presence of distinctive acoustic properties or articulatory disabilities, but by the absence of phonetic details that neurotypical listeners may map on gender stereotypes. In addition to gender, (neuro-typical individuals') speech carries rich extra-linguistic information about their age, socio-economic status and geographic origin, along with stereotypes that may be attached to these. Better understanding how sociolinguistic markers interact with impressions of atypicality should help move beyond a disability-based perspective on speech in autism and prompt a more holistic approach to language atypicality.

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Author contribution

MK formulated the research goals, carried out the analyses and wrote the paper. EC created the material, recruited the participants, organised the sessions and administered part of them, trained and supervised the research assistants, and carried out electrodermal data coding and extraction.

Declaration of conflicting interests

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Ethical approval statement

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (Erasme-ULB Ethics Committee, approval code: P2018/625/CCB B406201838210) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Participants gave their written consent to be involved in this study after having been informed of their rights and all aspects of the sessions (number, length, content and collected data).

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Supplemental material

Supplemental material for this article is available online.

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