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"This Is What a Mechanic Sounds Like": Children's Vocal Control Reveals Implicit Occupational Stereotypes

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Abstract
In this study, we explored the use of variation in sex-related cues of the voice to investigate implicit occupational stereotyping in children. Eighty-two children between the ages of 5 and 10 years took part in an imitation task in which they were provided with descriptions of nine occupations (three traditionally male, three traditionally female, and three gender-neutral professions) and asked to give voices to them (e.g., "How would a mechanic say . . . ?"). Overall, children adapted their voices to conform to gender-stereotyped expectations by masculinizing (lowering voice pitch and resonance) and feminizing (raising voice pitch and resonance) their voices for the traditionally male and female occupations, respectively. The magnitude of these shifts increased with age, particularly in boys, and was not mediated by children's explicit stereotyping of the same occupations. We conclude by proposing a simple tool based on voice pitch for assessing levels of implicit occupational-gender stereotyping in children.

Keywords
occupational-gender stereotypes, implicit stereotypes, children, voice imitation

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Occupational-gender stereotyping is present from early childhood (Ruble, Martin, & Berenbaum, 2006). However, developmental research in this area typically uses explicit judgments (e.g., "Can girls be doctors?" or "Who can do this job? Only men? Only women? Both women and men?"; Signorella, Bigler, & Liben, 1993), and such judgments can be subject to expectancy and social-desirability biases (as they are in adults; White & White, 2006).

However, investigating spontaneous or automated manifestations of occupational stereotypes in children is more challenging. For example, the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998), which is commonly used with adults, requires that participants maintain two sets of representations simultaneously and have a certain level of reading proficiency—for example, assigning words in a stereotype-compatible manner (i.e., boy–truck) or stereotype-incompatible manner (i.e., girl–truck) by pressing different buttons—which can be too cognitively demanding for children younger than 8 years old (McKeague, O'Driscoll, Hennessy, & Heary, 2015). Although child-friendly variants of the IAT (e.g., target categories represented as images, as in the action-interference paradigm; Banse, Gawronski, Rebetez, Gutt, & Morton, 2010) and other behavioral-interference paradigms (e.g., Strooplike tasks; Most, Sorber, & Cunningham, 2007) have been developed, a further limitation of these measures is that they prime children with gender information (e.g., by asking children to assign attributes to boys or girls), and responses might be influenced by the task demands.

In the present study, we developed and tested a simple tool to investigate behavioral manifestations of

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spontaneous gender stereotyping in children. This tool overcomes the above limitations by exploiting the volitional characteristics of the human voice.

Besides being a medium of linguistic communication, the human voice has been shown to signal various aspects of one's identity, including gender (masculinity and femininity). Indeed, adults routinely and volitionally adjust the fundamental frequency (F0, or pitch) of their voice and the spacing between vocal-tract resonances, or formants (ΔF), which are sexually dimorphic in adults (lower in men than in women), to vary the expression of their masculinity and femininity in gendered contexts (e.g., dating scenarios and job interviews; Pisanski, Cartei, McGettigan, Raine, & Reby, 2016). These vocal behaviors are likely to be acquired early in childhood: From around 4 years of age, boys speak with lower formants than girls despite the absence of significant overall anatomical differences in the vocal apparatus between the two sexes (Vorperian & Kent, 2007). More recently, two imitation studies have shown that primary-school children spontaneously masculinize their voices (by lowering F0 and ΔF) and feminize their voices (by raising F0 and ΔF) when imitating the opposite gender (Cartei, Cowles, Banerjee, & Reby, 2014) and when giving voice to stereotypically masculine or feminine child characters of the same gender as themselves (Cartei et al., 2019).

Given that sex-related voice cues (F0 and ΔF) can be flexibly and dynamically controlled from childhood and that their variation can be quantified, we propose that voice-imitation tasks can be extended to implicitly access and monitor changes in individuals' gender constructs, such as role stereotyping. More specifically, in the present study, we used a voice-imitation paradigm to explore children's implicit beliefs about gender-typed occupations. Children were asked to give voices to male-typed, female-typed, and gender-neutral occupations. We predicted that children would raise their F0 and ΔF (thus feminizing their voices) for the female-typed occupations and lower their F0 and ΔF (thus masculinizing their voices) for the male-typed occupations; their F0 and ΔF should be somewhere in the middle for the gender-neutral occupations. We also evaluated the extent to which these acoustic variations were made independently of children's explicit beliefs about occupational stereotypes by controlling for children's explicit ratings of occupational stereotypes (given via a questionnaire asking "Who does the job of being . . . ?" on the same occupations). Finally, we tested the extent to which F0 and ΔF manipulations can be operationalized into a measure of stereotypicality that could be used to quantify implicit occupational stereotyping in children.

Method

Participants

The sample consisted of 82 children from Years 1 through 6 in the United Kingdom (UK) system—twenty-eight 5- to 6-year-olds (from UK Years 1 and 2; 16 girls; age: M = 5.9 years, range = 5.22–7.1), twenty-seven 7- to 8-year-olds (from UK Years 3 and 4; 12 girls; age: M = 7.4 years, range = 7.4–9), and twenty-seven 9- to 10-year-olds (from UK Years 5 and 6; 14 girls; age: M = 9.2 years, range = 9.3–10.8). The children were all native British-English speakers recruited from four primary schools in Sussex, UK. Written consent was obtained from teachers and parents prior to testing, and children also gave their verbal assent on the day of testing. The study received ethics approval from the Sciences & Technology Cross-Schools Research Ethics Committee at the University of Sussex (Certificate ER/VC44/13).

Procedure

Children were individually tested in a quiet room at their school. They first completed an occupation-imitation task and then an occupations questionnaire.

Imitation task. Children were first recorded as they read four sentences out loud in their own voice until they were familiar with them ("The cat is on the box," "Jane runs up a hill," "The sheep is blue," and "Where were you yesterday?"). These sentences were selected from primary-school phonics teaching material because they contain the main vowels in British English, they are gender neutral in content, and they are relatively easy to read. After reading the sentences in their natural voices, the children were told to read the sentences aloud as if they were someone in a specific occupation. There were nine occupations in total, three male-typed (builder, lorry driver, mechanic), three female-typed (babysitter, beautician, nurse), and three gender neutral (doctor, student, writer). The occupations were compiled from a questionnaire study on UK primary-school children (Miller & Budd, 1999) and from archival data on true gender ratios from the UK Office of National Statistics (2019). The instructions also explained what each occupation entailed (e.g., "Imagine that you are a doctor. A doctor is someone who cures people who are ill. Imagine how a doctor sounds when they talk and read the following sentences . . .").

Recordings were made with the child sitting in front of a desk. The child spoke into a Zoom H1 recorder (Zoom, Hauppauge, NY) positioned on the desk at approximately 30 cm from the child's mouth. A Sound Shield vocal-reflection filter (Marantz, Mahwah, NJ) was positioned on the desk around the recorder to minimize environmental noise. The sentences were presented in a child-friendly font and size (Comic Sans Serif, font size 20) on a laminated A4 sheet positioned at eye level behind the recorder so that children could read the sentences without tilting their heads. If a child had difficulty reading the sentences in the practice stage, the researcher played a prerecorded female voice reading the sentence out loud and asked the children to repeat the sentence after listening to the recording. Sound files were recorded at 44.1 kHz, 16 bits, and saved in WAV format.

Occupations questionnaire. After the imitation task, children were asked to complete a questionnaire. The questionnaire asked children, "Who does the job of being . . . ?" and then listed each of the same nine occupations in a random order. To determine explicit sex stereotyping, we asked children to rate the occupations on a 5-point scale (1 = *only women*, 2 = *mostly women, some men*, 3 = *both men and women*, 4 = *mostly men, some women*, 5 = *only men*). Each occupation had a picture (an icon related to the occupation but without gender-related information; e.g., a spanner and a car for "mechanic") and a nongendered description of the occupation to improve clarity. The researcher read each question and the scale, and she marked the child's choice on the answer sheet.

Sound analyses

Recordings were edited to remove noise (e.g., child's short inspiration bouts, humming, researcher's instructions) and long pauses. To extract F0 and ΔF from each recording, we used a dedicated batch-processing script in Praat (Boersma & Weenink, 2019). The script extracted mean F0 using the "To Pitch (cc)" command (pitch-range parameters: 60–600 Hz). Additionally, the script estimated the center frequencies of the first four formants (F1 to F4) of each recording (formant parameters: number of formants = 6, max formant = 7,800 Hz, dynamic range = 30 dB, length of the analysis window = 0.03 s). The difference between any two adjacent formant frequencies, also defined as formant spacing, was then calculated ($\Delta F = Fi_{i+1} - F_i$), following Cartei, Cowles, and Reby (2012). ΔF is determined by, and inversely correlated to, the length of the vocal tract of the speaker: Longer vocal tracts produce narrower formant spacing. This measure is a more accurate estimate of global vocal-tract adjustments than individual formant values (Pisanski et al., 2014). The computed values for F0 and individual formants were double-checked by visual inspection of the spectrogram, and analysis parameters were adjusted to correct erroneous estimates. The means and standard deviations for each acoustic parameter are reported in Table S1 in the Supplemental Material available online.

Statistical analyses

All analyses were conducted using the statistical program SPSS Version 24. We first tested the effect of age group (5- to 6-year-olds, 7- to 8-year-olds, and 9- to 10-year-olds) and occupation type (stereotypically male, stereotypically female, and gender neutral) on the measured acoustic variables, F0 and ΔF, by running two linear mixed models separately for each sex. Age group, occupation type, and their interaction were entered in the models as fixed factors, whereas children's F0 and ΔF from the recordings of the imitated occupations were defined as the outcome variables. Linear mixed models also included participant identity as a subject term and occupation (within occupation type) as a nested random factor term. Children's explicit ratings on the questionnaire were added to the model as a covariate, given that, on average, children rated the stereotypically male occupations as done mostly by men, the stereotypically female occupations as done mostly by women, and the gender-neutral occupations as done by both sexes (for statistical analysis and results of the questionnaire ratings, see Appendix S1 in the Supplemental Material). All pairwise comparisons were Bonferroni corrected.

We also devised an *index of stereotypicality* (IoS) for each acoustic variable, and we tested its use as a simple tool to quantify occupational stereotyping in children. The F0 IoS was obtained for each participant by dividing F0 across the feminine occupations by F0 across the masculine occupations. Similarly, the ΔF IoS was obtained by dividing mean ΔF across the feminine occupations by ΔF across the masculine occupations.

One-sample *t* tests were used to analyze the extent of occupational stereotyping within each age group: Absence of stereotyping would be reflected by index values equal to 1, and increasing levels of stereotyping would be reflected by index values above 1. Standard estimates of effect sizes (Cohen's *d*s) with values of 0.2, 0.5, and 0.8 represent small, medium, and large effects (Cohen, 1988). Our sample size was based on those used in previous research (Cartei et al., 2012; Cartei et al., 2019), and a power analysis in G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) confirmed that our sample size ($N = 82$) would allow us to detect an effect as small as 0.15 with a power of .80, which was smaller than most effects reported in this article.

Results

Results from the linear mixed models for F0 and ΔF are presented in Table 1.

Table 1. Results From Linear Mixed Models Testing the Effect of Experimental Factors on Fundamental Frequency (F0) and Formant Spacing (ΔF) of Girls and Boys

	F0		ΔF	
Sex and predictor	*F*	*p*	*F*	*p*
Girls (*n* = 42)				
Intercept	$F(1, 167.44) = 1{,}253.72$	< .001	$F(1, 73.99) = 14{,}304.23$	< .001
Age group	$F(2, 36.473) = 0.06$	.936	$F(2, 36.87) = 19.59$	< .001
Occupation type	$F(2, 290.94) = 23.04$	< .001	$F(2, 288.96) = 27.51$	< .001
Occupation rating	$F(1, 298.77) = 0.02$	.869	$F(1, 291.45) = 1.98$	.16
Age Group × Occupation Type	$F(4, 288.04) = 4.51$	.001	$F(4, 288.05) = 2.08$	.082
Boys (*n* = 40)				
Intercept	$F(1, 177.16) = 1{,}489.10$	< .001	$F(1, 73.33) = 12{,}715.94$	< .001
Age group	$F(2, 40.09) = 1.05$	.359	$F(2, 39.745) = 9.28$	< .001
Occupation type	$F(2, 305.53) = 4.25$	.015	$F(2, 303.40) = 15.52$	< .001
Occupation rating	$F(1, 309.97) = 4.34$	.038	$F(1, 304.64) = 1.637$	.202
Age Group × Occupation Type	$F(4, 303.92) = 6.15$	< .001	$F(4, 302.96) = 1.273$	.281

Fundamental frequency (F0)

There was a significant main effect of occupation type on F0 for both boys and girls, both *p*s < .001. Pairwise comparisons (Table 2) revealed that, across age groups, children's F0 followed the expected sex-stereotypical pattern: Both sexes significantly raised their F0 for the stereotypically female occupations compared with the other two occupation types, and they lowered their F0s for the stereotypically male occupations compared with the other two occupation types. However, in boys, the difference between F0s in the gender-neutral and stereotypically male occupations was not significant, $p > .05$ (also see Fig. 1). Explicit ratings of occupations (via questionnaire) had a significant main effect on boys' F0, $p = .038$. However, a simple linear regression between boys' F0 and explicit ratings revealed that the ratings accounted for only 3% of the variance in boys' F0, $F(1, 352) = 11.84$, $p = .001$, $R^2 = .03$.

Because the main effect of occupation type on F0 was qualified by a significant interaction effect with age group in both sexes, we ran linear mixed models for each sex and age group. Pairwise comparisons (Table 3, Fig. 2a) revealed that the girls' F0 in the youngest age group (5- to 6-year-olds) was significantly higher for the stereotypically female occupations compared with the stereotypically male occupations. In the older age groups, girls' F0 was significantly higher and lower, respectively, for stereotypically female and male occupations compared with the gender-neutral occupations, reaching the highest value by 7 to 8 years of age. All effect sizes for the significant comparisons increased with age from medium (*d*s > 0.5) to large (*d*s > 0.8).

In boys (Table 3, Fig. 2b), F0 was not significantly different across occupation types in the youngest age group (5- to 6-year-olds). Boys' F0 in the older age groups was significantly higher for stereotypically female occupations compared with the neutral or stereotypically

Table 2. Pairwise Comparisons for Fundamental Frequency (F0) Among Occupation Types (Stereotypically Male, Stereotypically Female, and Gender Neutral) Across Age Groups (Bonferroni Corrected)

Sex	Occupation type (I)	Occupation type (J)	Mean difference (I – J)	*SE*	*df*	*p*	95% CI	Cohen's *d*
Girls (*n* = 42)								
	Female	Male	32.80	4.87	293.78	< .001	[21.06, 44.55]	0.932
	Neutral	Female	−19.06	3.93	290.25	< .001	[−28.53, −9.59]	0.552
	Neutral	Male	13.74	3.97	290.43	.002	[4.18, 23.30]	0.399
Boys (*n* = 40)								
	Male	Female	−12.8	4.78	307.03	.022	[−24.39, −1.38]	0.383
	Neutral	Female	−9.92	3.83	305.08	.03	[−19.15, −0.69]	0.302
	Female	Male	2.96	3.73	305.41	.100	[−6.02, 11.95]	0.091

Note: CI = confidence interval.

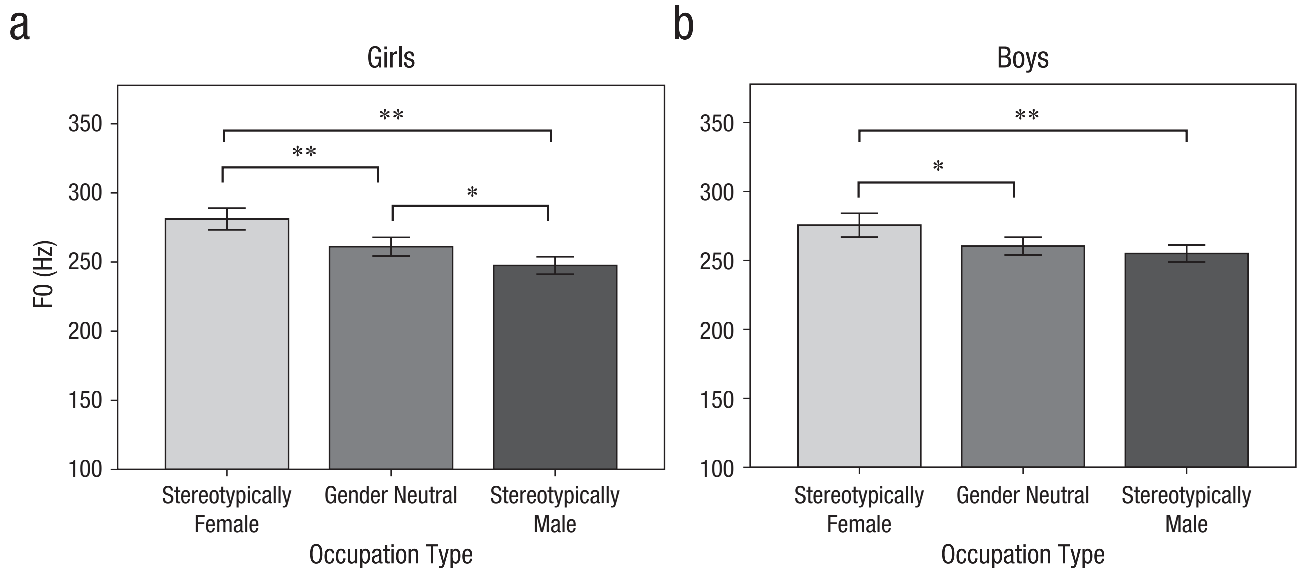

Fig. 1. Fundamental frequency (F0) of girls (a) and boys (b) according to occupation type (stereotypically female, gender neutral, stereotypically male). Asterisks indicate significant differences between occupation types (*$p < .05$, **$p < .001$). Error bars represent 95% confidence intervals.

male occupations ($p < .05$), and this difference increased with age. No significant differences in F0 between the neutral and stereotypically male occupations were found ($p > .05$).

Formant spacing (ΔF)

There was a significant main effect of occupation type on ΔF for both boys and girls, *p*s < .001. Pairwise comparisons (Table 4) revealed that, across age groups, children's ΔF followed the expected sex-stereotypical pattern: Both sexes significantly lowered their ΔF for the stereotypically male occupations compared with the gender-neutral and stereotypically female occupations, and they raised their ΔF for the stereotypically female occupations compared with the other two occupation types (also see Fig. 3).

There was a significant main effect of age group on ΔF, *p*s < .001. In line with the age-related growth in anatomical vocal-tract length, across occupation types (Table 5), 5- to 6-year-old children spoke with a wider ΔF compared with the two older age groups, *p*s < .001, and 7- to 8-year-old boys spoke with a wider ΔF than 9- to 10-year-old boys, $p = .041$. However, the ΔF of 7- to 8-year-old girls was narrower than the ΔF of 9- to 10-year-old girls, $p = .001$. The interaction effect between age group and occupation type was not significant in either sex, $p > .05$.

Indexes of stereotypicality (IoSs)

One-sample *t* tests were conducted within each sex and age group to investigate whether the F0 IoS and the ΔF IoS were significantly different from 1, thus reflecting the presence of stereotyping. We found that both girls' and boys' F0 IoS in all age groups was different from 1, *p*s < .05, with large effect sizes increasing with age (all Cohen's *d*s > .5), with the exception of 5- to 6-year-old boys, $p > .05$ (Table 6; also see Fig. 4). The mean ΔF IoS was also different from 1 in all age groups for both sexes, *p*s < .05 (Table 6). To further investigate the main effect of age group on the two IoSs, we conducted two analyses of variance (ANOVAs), separately for boys and girls, investigating the effect of age group on F0 IoS and ΔF IoS. Pairwise comparisons revealed that children's F0 IoS was significantly lower in the 5- to 6-year-olds than in the 9- to 10-year-olds (girls: $p = .010$, $d = 0.15$; boys: $p = .017$, $d = 0.11$). No significant differences were found for ΔF IoS between age groups, *p*s > .05.

Discussion

In line with our hypotheses, children spontaneously altered their voices according to their sex-stereotyped expectations of adult occupations: they feminized their voices (by raising F0 and ΔF) when imitating individuals in stereotypically female occupations, and they masculinized them (by lowering F0 and ΔF) when imitating individuals in stereotypically male occupations. The observed voice shifts were significant even when analyses accounted for children's explicit ratings of the same occupations. The only study (White & White, 2006) conducted so far comparing implicit stereotypes (using the IAT) and explicit stereotypes (using a questionnaire) in relation to occupations was conducted with

Table 3. Results of Pairwise Comparisons for Fundamental Frequency (F0) Among Occupation Types (Stereotypically Male, Stereotypically Female, and Gender Neutral; Bonferroni Corrected)

Age group	Occupation type (I)	Occupation type (J)	Mean difference (I – J)	*SE*	*df*	*p*	95% CI	Cohen's *d*
Girls (n = 42)								
5- to 6-year-olds								
	Female	Male	13.80	5.04	115.07	.021	[1.56, 26.04]	0.46
	Female	Neutral	10.01	5.17	115.26	.17	[−2.54, 22.57]	0.33
	Neutral	Male	3.79	5.04	115.07	1.00	[−8.45, 16.03]	−0.13
7- to 8-year-olds								
	Female	Male	40.79	7.32	67.06	< .001	[22.81, 58.77]	0.94
	Female	Neutral	23.86	7.41	67.11	.006	[5.67, 42.04]	0.55
	Neutral	Male	16.94	7.32	67.06	.07	[−1.05, 34.92]	−0.39
9- to 10-year-olds								
	Female	Male	45.27	6.01	106.97	< .001	[30.65, 59.89]	1.61
	Female	Neutral	23.84	6.06	107.15	< .001	[9.10, 38.58]	0.85
	Neutral	Male	21.43	6.10	107.21	.002	[6.59, 36.27]	−0.76
Boys (n = 40)								
5- to 6-year-olds								
	Female	Male	5.82	5.79	83.16	.95	[−8.33, 19.96]	0.17
	Female	Neutral	−9.47	5.71	83.16	.30	[−23.42, 4.48]	−0.28
	Neutral	Male	15.29	5.51	83.13	.02	[1.83, 28.74]	−0.45
7- to 8-year-olds								
	Female	Male	17.91	5.31	122.53	.003	[5.03, 30.80]	0.61
	Female	Neutral	20.46	5.56	123.37	.001	[6.97, 33.95]	0.02
	Neutral	Male	−2.55	5.20	122.41	1.00	[−15.18, 10.09]	0.09
9- to 10-year-olds								
	Female	Male	35.36	6.49	100.11	< .001	[19.56, 51.17]	1.13
	Female	Neutral	28.92	6.40	100.03	< .001	[13.34, 44.50]	0.93
	Neutral	Male	6.44	6.49	100.11	.97	[−9.37, 22.25]	−0.21

Note: CI = confidence interval.

adults, and it revealed that correlations between these explicit and implicit measures were modest. Our findings add to those of White and White by showing that the imitation priming task used in this study could also be used to assess relatively automatic mental associations in children in relation to occupational stereotyping beyond the effects obtained via explicit self-report measures.

Although overall F0 and ΔF shifts followed the expected stereotypical patterns, we also observed sex- and age-related differences in the manipulation of these voice cues. In relation to ΔF, we found that the youngest children (5- to 6-year-olds) displayed the highest ΔF values and that boys' ΔF continued to linearly decrease with age, as expected, because of the age-related lengthening of the vocal tract (Kent & Vorperian, 2018). The ΔF of girls showed a slight, but significant, increase after age 8, contrary to the growth in the underlying vocal-tract anatomy (Fitch & Giedd, 1999) but in line with acoustic data (Cartei et al., 2019). Given the presence of sex differences in formant values reported in the literature and the absence of underlying sex differences in vocal-tract length (Kent & Vorperian, 2018, for a review), our results support the hypothesis that sex differences in ΔF before puberty are largely due to sex-specific differences in vocal behavior. Specifically, girls may dynamically shorten their tract by speaking with spread lips (or a raised larynx), which would raise the formants and widen their spacing. Interestingly, one study on facial expressions reports that girls start to smile more than boys from about age 9, and this behavior continues throughout adulthood (Dodd, Russell, & Jenkins, 1999). It is also possible that boys' age-related decline in ΔF values may be further accentuated by boys rounding their lips, as suggested in previous studies (Cartei et al., 2019; Perry, Ohde, & Ashmead, 2001). Robust, noninvasive methods for lip tracking have now been developed (e.g., the Optotrack motion-tracking system; NDI, Waterloo, Ontario, Canada) which would make it possible to test these hypotheses (e.g., by

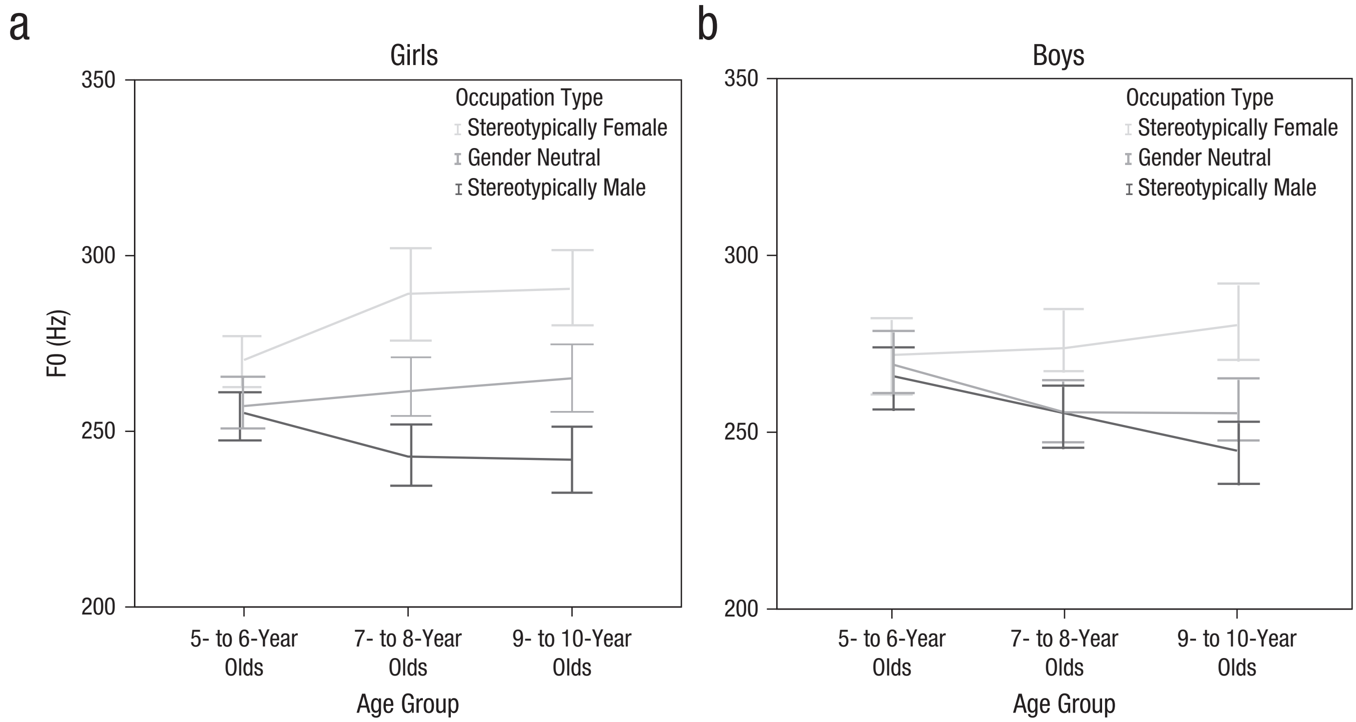

Fig. 2. Fundamental frequency (F0) of girls (a) and boys (b) as a function of age group and occupation type. Error bars represent Cousineau's (2005) 95% confidence intervals.

replicating the present study while measuring the amount of lip spreading and rounding during children's imitations of occupations).

In relation to F0, the shifts between the three occupation types did not reach significance in the youngest group (5- and 6-year-olds). One possibility for this pattern of results is that the youngest children held stereotypical beliefs regarding adult occupations to a lesser degree than the older children. This is unlikely, however, given the absence of an age-group effect in the questionnaire ratings, indicating that 5- and 6-year-old children exhibited the same level of occupational stereotyping as the older children, at least explicitly. Moreover, previous studies have revealed that before 7 years of age, children apply gender stereotypes more rigidly than older children do, until they begin to acquire more complex categorization skills (Bigler & Liben, 1992). A more likely explanation relates to restrictions in vocal physiology and behavior. For example, in studies of children aged 5, 7, 9, and 11 years, some authors (Busby & Plant, 1995; Cappellari & Cielo, 2008) have reported that the F0 for males aged 5 years was significantly higher compared with all the other age groups, with no statistical difference among

Table 4. Pairwise Comparisons for Formant Spacing (ΔF) Among Occupation Types (Stereotypically Male, Stereotypically Female, and Gender Neutral) Across Age Groups (Bonferroni Corrected)

Sex	Occupation type (I)	Occupation type (J)	Mean difference (I – J)	*SE*	*df*	*p*	95% CI	Cohen's *d*
Girls (*n* = 42)								
	Female	Male	40.76	5.51	289.84	< .001	[27.48, 54.03]	0.613
	Neutral	Female	−18.03	4.43	288.73	< .001	[−28.70, −7.35]	0.273
	Neutral	Male	22.73	4.47	288.79	< .001	[11.95, 33.51]	0.345
Boys (*n* = 40)								
	Female	Male	31.33	5.68	303.81	< .001	[17.66, 45.00]	0.447
	Neutral	Female	−13.46	4.54	303.27	.01	[−24.41, −2.51]	0.193
	Neutral	Male	17.86	4.43	303.37	< .001	[7.19, 28.53]	0.258

Note: CI = confidence interval.

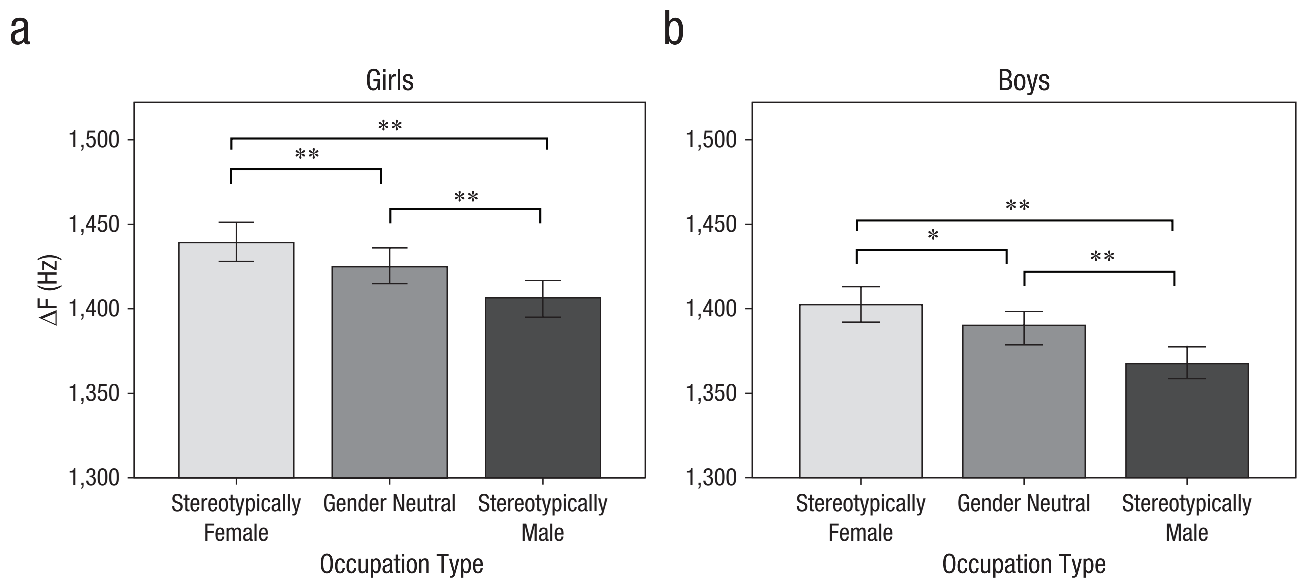

Fig. 3. Formant spacing (ΔF) of girls (a) and boys (b) for each occupation type (stereotypically female, gender neutral, stereotypically male). Asterisks indicate significant differences between occupation types (*$p < .05$, **$p < .001$). Error bars represent 95% confidence intervals.

children aged 7, 9, and 11 years. This would suggest that the youngest children had a narrower F0 range at their disposal compared with the older children. It is also possible that the youngest children were less able to finely control F0, given that the neuromotor structures involved with phonation develop with age (Behlau, Madazio, Feijó, & Pontes, 2001).

We also found that although girls' F0 values for the feminine and masculine occupations reached a high and low plateau, respectively, after age 7, boys' F0 continued to increase for the feminine occupations and decrease for the masculine occupations with age. This pattern suggests that children differentially evaluate males and females engaging in stereotypic and counterstereotypic occupations and that boys in particular are sensitive to gender-role boundaries and norm violations, as also found in previous studies of occupational stereotyping (Blakemore, 2003; Wilbourn & Kee, 2010). To determine the origin and development of these gender differences, researchers could deploy the voice-imitation paradigm presented here in conjunction with explicit measures, such as children's beliefs about competency (e.g., whether both genders "can" perform various jobs and social roles) and gendered personality attributions (e.g., whether female- or male-dominated occupations may require stereotypically feminine or masculine traits, respectively), as well as children's own gender-role flexibility.

In order to suggest a simple voice-based measure of implicit stereotyping, we calculated two IoSs on the

Table 5. Results of Pairwise Comparisons for Formant Spacing (ΔF) Among the Three Age Groups (Bonferroni Corrected)

Sex	Age group (I)	Age group (J)	Mean difference (I – J)	*SE*	*df*	*p*	95% CI	Cohen's *d*
Girls								
	5- to 6-year-olds	7- to 8-year-olds	136.11	24.53	36.96	< .001	[74.61, 197.62]	2.13
	5- to 6-year-olds	9- to 10-year-olds	110.64	22.24	36.78	< .001	[54.85, 166.42]	1.82
	7- to 8-year-olds	9- to 10-year-olds	–25.48	25.18	36.90	.96	[–88.63, 37.68]	0.40
Boys								
	5- to 6-year-olds	7- to 8-year-olds	90.60	25.57	39.84	.003	[26.68, 154.52]	1.38
	5- to 6-year-olds	9- to 10-year-olds	110.15	27.45	39.72	.001	[41.54, 178.76]	1.61
	7- to 8-year-olds	9- to 10-year-olds	19.55	24.95	39.67	.001	[–42.81, 81.92]	0.30

Note: CI = confidence interval.

Table 6. One-Sample Tests for Indexes of Stereotypicality (Test Value = 1)

Sex	Age group	*t*	*p*	Mean difference	95% CI	Cohen's *d*
		Fundamental frequency (F0) index of stereotypicality				
Girls						
	5- to 6-year-olds	$t(15) = 2.69$	.017	.06	[.01, .11]	0.67
	7- to 8-year-olds	$t(9) = 3.12$	.012	.16	[.04, .27]	0.99
	9- to 10-year-olds	$t(13) = 4.31$	.001	.19	[.10, .29]	1.15
Boys						
	5- to 6-year-olds	$t(11) = 0.38$	.71	.01	[−.05, .07]	0.11
	7- to 8-year-olds	$t(16) = 2.94$	.01	.07	[.02, .12]	0.71
	9- to 10-year-olds	$t(12) = 3.43$	.005	.14	[.05, .23]	0.95
		Formant spacing (ΔF) index of stereotypicality				
Girls						
	5- to 6-year-olds	$t(15) = 3.95$	.001	.02	[.01, .04]	0.99
	7- to 8-year-olds	$t(9) = 4.12$	.003	.02	[.01, .03]	1.30
	9- to 10-year-olds	$t(13) = 7.09$	< .001	.04	[.02, .05]	1.89
Boys						
	5- to 6-year-olds	$t(11) = 3.47$	.005	.02	[.01, .04]	1.00
	7- to 8-year-olds	$t(16) = 5.55$	< .001	.03	[.02, .04]	1.35
	9- to 10-year-olds	$t(12) = 2.10$	.047	.02	[.00, .04]	0.58

Note: Mean differences are between the sample means and the test value of 1 (absence of stereotyping). CI = confidence interval.

basis of the ratios of either F0 (F0 IoS) or ΔF (ΔF IoS) across the stereotypically female and male occupations. The F0 IoS was a more sensitive proxy than the ΔF IoS in the case of the voice adjustments performed by the children for the different occupation types in this study. Indeed, the index based on F0, but not ΔF, significantly increased with age, reflecting the age-related shifts in children's F0 along the expected gender-stereotypical lines. We would argue that the F0 IoS also offers a more direct measure of implicit stereotyping compared with

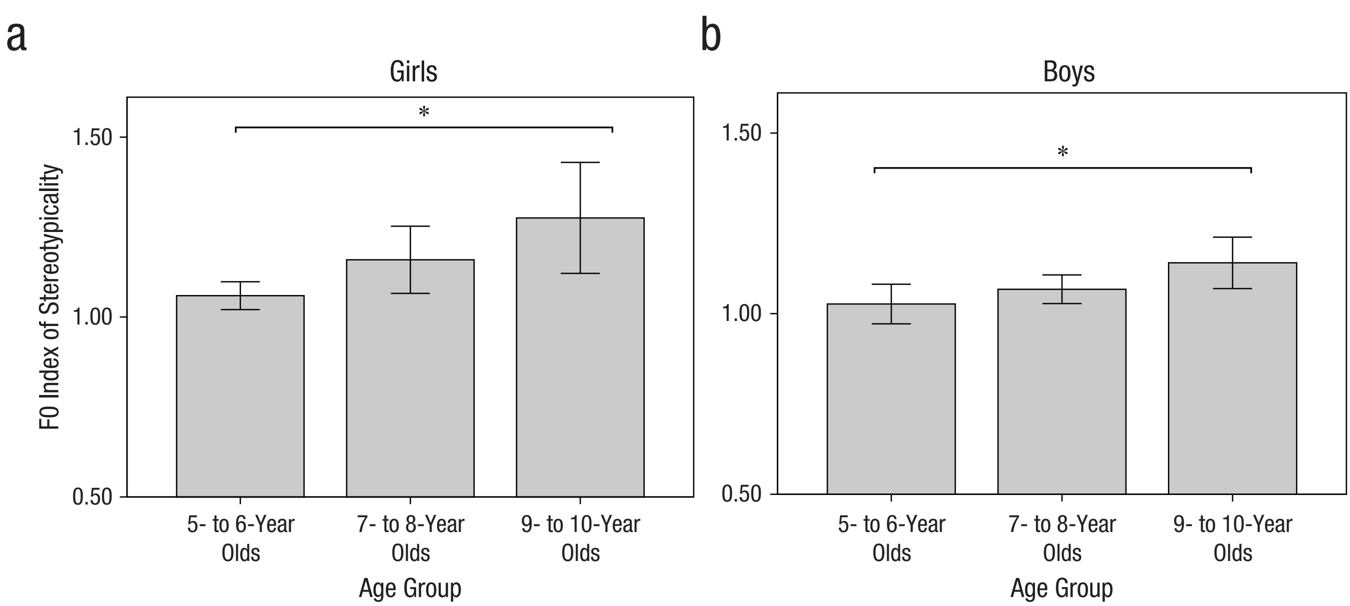

Fig. 4. Fundamental frequency (F0) index of stereotypicality (F0 across the feminine occupations divided by F0 across the masculine occupations) for girls (a) and boys (b) within each age group. Absence of stereotyping is reflected by index values equal to 1, and increasing levels of stereotyping is reflected by index values above 1. Asterisks indicate significant differences between age groups ($p < .05$). Error bars represent 95% confidence intervals.

the ΔF IoS, given that the latter measure can interact with age-related variation in the articulatory gestures (e.g., lip and laryngeal movements) affecting vocal-tract length, as children start expressing their voice gender behaviorally (Cartei et al., 2014). Children's F0 can also be measured much more easily by researchers who have undertaken basic training in bioacoustics, and many open-source audio-software programs today (e.g., Praat; Boersma & Weenink, 2019) can robustly track children's F0 from relatively quiet audio recordings. On the other hand, children's formants are more difficult to measure automatically than adults' because of the widely spaced harmonic components generated by children's high-pitched voices (Lieberman & Blumstein, 1988). We thus propose that the index based on F0 (F0 IoS) could be particularly useful as a simple tool for assessing and monitoring stereotypes in children across multiple gender-typed occupations, as in the present study, as well as in relation to individual occupations (e.g., by pairing single gender-typed occupational terms with gender-neutral ones). Given the lack of observed differences in the pitch-based index for 5- and 6-year-olds, we recommend using this measure for children aged 7 onward. We also propose that in order to isolate effects of maturation in the vocal apparatus and motor control from actual changes in stereotypes, the F0 IoS would be best used in experiments with children of similar age or as a before-and-after measure following stereotype-reducing interventions (e.g., a reduction in the F0 IoS signifying greater efficacy of interventions). This type of measure would also be useful to control for extraneous influences on F0, such as those connected to specific phonological features (e.g., prevoicing and aspiration; Cho, Whalen, & Docherty, 2019).

In summary, the imitation paradigm whereby children are asked to give voices to stereotypical and counterstereotypical occupations not only supports notions that the activation of gender associations proceeds relatively automatically (even when gender is not explicitly a salient feature of a task) but also is a relatively direct and simple tool to be used with children. Thus, our paradigm not only may be used as a stand-alone measure but also may allow researchers to verify or challenge the results of IAT studies or priming studies with children, as well as with adolescents and adults.

Transparency

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Author Contributions
All authors designed the study. Testing and data analysis were performed by V. Cartei. Data interpretation was performed by V. Cartei and D. Reby. V. Cartei drafted the manuscript, and the other authors provided critical revisions. All the authors approved the final version of the manuscript for submission.
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The data set supporting this article has been uploaded to the Sussex Research Online (SRO) repository at https://doi.org/10.25377/sussex.12073665. The design and analysis plans for the study were not preregistered.

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Supplemental Material

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