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Vocal Fundamental and Formant Frequencies Affect Perceptions of Speaker Cooperativeness

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Title: Vocal Fundamental and Formant Frequencies Affect Perceptions of Speaker
Cooperativeness

Running Head: Vocal Traits Affect Perceived Cooperativeness

Authors: Kristen K. Knowles, University of Edinburgh, UK

Anthony C. Little, University of Stirling, UK

Corresponding Author: Kristen K. Knowles, School of Social and Political Science,
University of Edinburgh, 15a George Square, Edinburgh EH8 9LD.

kristen.knowles@ed.ac.uk

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Abstract

In recent years, the perception of social traits in faces and voices has received much attention. Facial and vocal masculinity are linked to perceptions of trustworthiness, however, while feminine faces are generally considered to be trustworthy, vocal trustworthiness is associated with masculinised vocal features. Vocal traits such as pitch and formants have previously been associated with perceived social traits such as trustworthiness and dominance, but the link between these measurements and perceptions of cooperativeness have yet to be examined. In Study 1, cooperativeness ratings of male and female voices were examined against four vocal measurements: fundamental frequency (F_0), pitch variation (F_0 - SD), formant dispersion (D_f) and formant position (P_f). Feminine pitch traits (F_0 and F_0 - SD) and masculine formant traits (D_f and P_f) were associated with higher cooperativeness ratings. In Study 2, manipulated voices with feminised F_0 were found more cooperative than voices with masculinised F_0 among both male and female speakers, confirming our results from Study 1. Feminine pitch qualities may indicate an individual who is friendly and non-threatening, while masculine formant qualities may reflect an individual that is socially dominant or prestigious, and the perception of these associated traits may influence the perceived cooperativeness of the speakers.

Key Words: voice pitch; formant frequencies; cooperation; prosociality

Introduction

Previous research has shown that a variety of personality attributions are made based on facial appearance, including trustworthiness, competence, aggressiveness and dominance (Little, Roberts, Jones, & DeBruine, 2012; Oosterhof & Todorov, 2008; Todorov, Pakrashi, & Oosterhof, 2009; Todorov, Said, Engell, & Oosterhof, 2008). Further, these attributions are linked to morphological aspects of facial appearance. Pro-social traits tend to be associated with faces that are feminine and babyish, while negative and anti-social traits are associated with masculine, mature faces (Montepare & Zebrowitz, 1998; Oosterhof & Todorov, 2008; Perrett *et al.*, 1998).

Similarly, voices also elicit personality attributions. Voice pitch (F_0) influences the perception of personality traits such as truthfulness, persuasiveness, nervousness and friendliness (Apple, Streeter, & Krauss, 1979; Kramer, 1977). More recently, voice pitch has been associated with perceptions of trustworthiness (Klofstad, Anderson, & Peters, 2012; Tigue, Borak, O'Connor, Schandl, & Feinberg, 2012) and sexual infidelity (O'Connor, Re, & Feinberg, 2011). Voice pitch is sexually dimorphic in humans, and lower pitch in men is commonly associated with masculinity and attractiveness (Feinberg, 2008). As with masculine facial traits, masculine vocal traits are also associated with negative traits, such as physical dominance and threat potential (Puts, Apicella, & Cárdenas, 2012; Wolff & Puts, 2010). However, whether feminine voices or masculine voices are associated with pro-social personality traits remains somewhat unclear. While feminine faces are generally found to be more trustworthy than masculine faces, a number of studies have shown that masculine voices are more trustworthy than feminine voices (Apple *et al.*, 1979; Klofstad *et al.*, 2012; Oosterhof & Todorov, 2008; Tigue *et al.*, 2012; Todorov, Baron, & Oosterhof, 2008). This seemingly contradictory pattern of results suggests that further examination of the factors influencing perceptions of vocal prosociality is warranted.

Trustworthiness

Voice pitch has been associated with perceptions of trustworthiness. Voices with low F_0 are considered more truthful and trustworthy than voices with high F_0 , in both male and female voices (Apple *et al.*, 1979; Klofstad *et al.*, 2012; Tigue *et al.*, 2012). Masculine (i.e. low-pitch) voices are considered attractive in men, and feminine (i.e. high-pitch) voices are considered attractive in women (Feinberg, 2008; Feinberg, Jones, DeBruine, *et al.*, 2005). Attractiveness is often associated with positive personality attributions via a “halo” effect (Eagly, Ashmore, Makhijani, & Longo, 1991; Zuckerman, Miyake, & Elkin, 1995). The halo effect may explain why low-pitched male voices are considered trustworthy (Klofstad *et al.*, 2012; Tigue *et al.*, 2012), however, masculinised pitch also makes men seem likely to engage in sexual infidelity (O’Connor *et al.*, 2011), which is not in line with a straightforward halo effect. These seemingly paradoxical findings suggest that perceptions of prosociality may have a more complex link with vocal masculinity. Additionally, Tigue *et al.* (2012) found that lower-pitched voices were considered more trustworthy than their higher-pitched counterparts in voices of both sexes, suggesting that trustworthiness may not be exclusively related to vocal attractiveness, at least among female speakers. Rather, there may be a generalised effect of vocal masculinity being considered trustworthy in voices of both men and women. Additionally, Klofstad *et al.* (2012), Tigue *et al.* (2012) and O’Connor *et al.* (2011) each used manipulated versions of stimuli (raised and lowered F_0). Because listeners chose between very masculine and very feminine male voices, as opposed to measuring impressions based on normal variation in a naturalistic sample, this may have led to choosing masculine voices because the feminised voices sounded too high-pitched by direct comparison to masculinised voices. Furthermore, these studies did not examine acoustic traits other than F_0 .

F_0 variation is another vocal attribute which may affect the perception of prosociality. In contrast to jitter or F_0 tremor, which are perceived as voice roughness, F_0 variation is captured by measuring the standard deviation in voice pitch throughout an utterance. As such, the pitch variation (F_0 -SD) captures the amount of within-utterance variation in pitch, and low values of F_0 -SD are perceived as monotony. A high variation in F_0 (F_0 -SD) is considered a pleasant vocal attribute (Apple *et al.*, 1979; Scherer, 1974) and its presence in both play behaviour in non-human primates and in human child-directed speech suggests that it may be used as a signal of affiliation (Goedeking, 1988; Trainor, Austin, & Desjardins, 2000). Variation in F_0 may then also be related to perceptions of prosociality. Formant measures (formant dispersion, D_f , and formant position, P_f) may also influence listeners' attributions of prosociality, due to their relationships with dominance and intrasexual competition (Puts *et al.*, 2012; Puts, Hodges-Simeon, Cárdenas, & Gaulin, 2007).

Dominance

The link between low voice pitch and trustworthiness is a surprising one, due to the association between masculinity, anti-social behaviour and dominance (Mazur & Booth, 1998). Masculine-sounding male voices are considered to be cues to dominance which could aid intra-sexual competition (Puts *et al.*, 2012, 2007; Wolff & Puts, 2010), and low F_0 is associated with dominance both cross-culturally in humans and within non-human species (Morton, 1977; Ohala, 1983, 1984). Thus, if a speaker wishes to sound submissive, they may wish to affect higher-pitched vocalisations, with the goal of sounding small and nonthreatening (Ohala, 1984). Low F_0 , D_f and P_f are related to body size, and it has been suggested that these traits serve as cues to threat potential (Feinberg, Jones, Little, Burt, & Perrett, 2005; Puts *et al.*, 2012, 2007). Speakers with naturally higher measurements of these vocal traits may be perceived as submissive, which could give the impression to listeners as being naturally more prosocial and cooperative.

A high F_0 may be related to increased perceptions of submissiveness because nervousness (such as that brought about by lying or fear) has an impact on vocal fold tension. An autonomic nervous response via vagus nerve stimulation tightens the vocal folds, which increases F_0 (Charous, Kempster, Manders, & Ristanovic, 2001). F_0 variation may also be influenced by emotional arousal, and may reveal emotional traits of the speaker, such as whether they feel confident or threatened (Banse & Scherer, 1996; Hodges-Simeon, Gaulin, & Puts, 2011), and a low F_0 variation has been suggested as a means of intimidation (Hodges-Simeon, Gaulin, & Puts, 2010). Because low F_0 and F_0 -SD are related to threat potential and intimidation, and because high measures of these traits may be related to nervousness and fear, individuals with naturally higher pitch and pitch variation may accordingly be perceived as submissive, which in turn could positively influence perceptions of prosociality. Low measures of these traits may negatively influence ratings of cooperativeness, as dominant individuals may use threat or physical strength to get their way, while cooperation requires working in tandem to a common, mutually-beneficial end. Thus, voices that sound masculine and dominant may be considered attractive, or even trustworthy, but an inverse relationship between masculinity and cooperativeness may be expected because masculine individuals may behave in a more selfish way or be less likely to acquiesce to the needs of others (Booth & Osgood, 1993; Dabbs & Morris, 1990).

A listener's own dominance may additionally influence the way they attribute prosociality to others. Watkins, Jones & DeBruine's (2010) finding that dominant men are less sensitive to facial dominance cues in other men lends support to the idea that social trait attribution may be modulated in part by the individual differences of the listeners. This is also supported by research showing that taller (i.e. more dominant) men are less sensitive to dominance cues in masculinised faces and voices than shorter men (Watkins, Fraccaro, *et al.*, 2010), however this study also found that height was not associated with self-rated dominance, nor was self-rated dominance associated with dominance attributions in faces and voices. A possible explanation for the differing results presented in the two aforementioned

studies may be in the way dominance was measured. Watkins, Jones, *et al.* (2010) measured dominance as a personality trait using an 11-item questionnaire (Goldberg, 1999) while Watkins, Fraccaro, *et al.* (2010) utilised a single scaled question about the participants' dominance, which may be more reflective of the participants' conceptions of their own physical dominance rather than capturing dominant personality characteristics. Research by Wolff & Puts (2010) did not find that self-rated physical dominance, physical aggressiveness, or morphometric measures of strength predicted dominance attributions of others, however the measures taken by these researchers focus on traits which reflect physical formidability rather than dominant personality traits such as those measured by Watkins, Jones, *et al.* (2010). It may thus be reasonable to suspect that individual differences in dominance as a personality characteristic may interact with the way social traits are perceived in the others.

The Present Research

In the present study, we examined ratings of cooperativeness for male and female voices based on a naturalistic sample (Study 1). Here, we examined measurements of pitch (F_0) and pitch variation (F_0 -SD), as well as two measures of formants (formant dispersion, D_f , and formant position, P_f). In Study 2, we examined the effect of manipulated F_0 on ratings of cooperativeness. In both Study 1 and Study 2, we additionally measured the dominance of the subjects who rated the stimuli, in order to determine if this factor affected how cooperative they found the voices of others.

STUDY 1*Methods*Stimuli

16 men and 16 women were recruited as stimulus donors (male ages 18-30, mean age 20.4 years, *SD* 2.73 years; female ages 18-23, mean age 19.4 years, *SD* 1.46 years). All were undergraduate psychology students at the University of Stirling. Recordings were obtained using an Audio-Technica AT-4041 microphone with a cardioid pickup pattern, at a distance of approximately 65cm using a preamp (M-Audio Audiobuddy). Audio was recorded directly to hard disk as .wma files using Windows Movie Maker v.2.1.4027.0, with a 48kHz sampling rate and 16-bit quantisation. The room was quiet and partially soundproofed with 1.5-inch thick sound-dampening foam. Participants were recorded while reading a scripted text. This text was selected due to its neutrality of content (see Cowan & Little, 2013). For the purposes of this experiment, 5 seconds of speech was extracted from this scripted recording: "October frequently brings the first frost of the season over the greater part of the UK." Extraction was completed using Audacity (v.2.0.2). We excluded participants whose first language was not English, and those who exhibited difficulties reading from a script (*e.g.* omitting words, stuttering, long pauses, or repeating words). Additionally, participants over the age of 30 were excluded from our stimulus set so that perceived age would not play a role in participants' ratings (Linville & Fisher, 1985; Mulac & Giles, 1996).

For analysis and playback, audio files were converted to single-channel .mp3 at 320kbps/48kHz using Switch v.2.04. All voice measurements were obtained using Praat v.5.3.03 (Boersma & Weenink, 2013). F_0 was measured using Praat's autocorrelation algorithm. Pitch was searched for between 65-300Hz for male voices, and between 100-600Hz for female voices, according to the manufacturer's recommendations (Boersma & Weenink, 2013). Measurements of the first four formants were taken ($F_1 - F_4$) using Linear

Predictive Coding with the BURG algorithm, using 10 poles and pre-emphasis. Maximum frequencies were set at 5500Hz for female voices and 5000Hz for male voices, again per manufacturer recommendations. These formant measures were used to calculate both formant dispersion (D_f , see Fitch, 1997), which is the average distance between the four formants in Hz, and formant position (P_f , see Puts, Apicella, & Cárdenas, 2012), which is obtained by assigning each formant a z -score and taking the mean of these four standardised measures. F_0 - SD (the within-utterance standard deviation of F_0) was also recorded. All measurements were obtained using voiced segments of speech only. These four measurements were chosen in order to capture vocal masculinity, due to the sexual dimorphism exhibited by each of these measures. Additionally, these four measures have all been related to attributions of social traits in previous studies.

Subjects

Participants ($N = 79$) were psychology undergraduates at the University of Stirling. Females ($n = 57$) were aged 18-35 ($M = 19.56$ years, $SD 2.8$ years); males ($n = 22$) were aged 18-30 ($M = 19.95$ years, $SD 2.5$ years). All took part in the study to fulfill a course requirement. All phases of this experiment were approved by the University of Stirling Ethics Committee.

Procedure

Following Havlicek, Roberts, & Flegr (2005) and Watkins, Jones, & DeBruine (2010), participants completed the 11-item dominance subscale of the IPIP (Goldberg, 1999, ipip.ori.org) resulting in a range of scores from 18 to 43, with a mean score of 31.9 ($SD 5.2$). This questionnaire was administered prior to stimuli exposure. Male and female voices were presented in separate blocks, and randomised within each block. Participants were asked to rate the voices for how cooperative they thought the person sounded. For the purposes of this study, we defined cooperativeness as “a measure of how likely you think a person might be to

work with you toward a mutually beneficial goal - *e.g.* writing a presentation or contributing to group work. In these situations, cooperative people will do their fair share of the work required. A person who is uncooperative is not likely to contribute their fair share of work or resources, but will still enjoy the rewards of effort provided by others.” This definition stresses mutual-benefit cooperation and highlights the possible existence of defectors/free-riders. Voices were rated on a 7-point Likert scale, with 1 indicating low cooperativeness, and 7 indicating high cooperativeness.

Data Treatment

For ANOVA analyses, the 16 voice stimuli for each sex were placed into high- or low- F_0 groups (separated evenly into two quantiles of the 8 highest- and 8 lowest- F_0 in the sample). This median split was performed in order to maximise statistical power due to the low number of voices sampled ($N = 16$ for each sex), and to make the results more comparable to experiments which use manipulated stimuli. This same method was used to create high and low quantiles based on the other traits measured (F_0 - SD , D_f , P_f). Voices which fell into one high group did not necessarily fall into high groups of other measurements, *e.g.* voices with high F_0 were not entirely the same as voices with high D_f , etc. While this method of collapsing the data into two separate groups is not without its disadvantages, similar methods have been usefully applied by previous researchers to examine differences between groups based on high and low measures of other traits (*e.g.* Cowan & Little, 2013; Little, Burt, Penton-Voak, & Perrett, 2001; Penton-Voak & Chen, 2004; Penton-Voak *et al.*, 2003; Stanton, Liening, & Schultheiss, 2011). Linear mixed effects models were performed in R (R Core Team, 2014) with the *lmerTest* package (Kuznetsova, Brockhoff, & Christensen, 2014).

Results

For tests using the stimulus as the unit of analysis, mean cooperativeness ratings were calculated by averaging the ratings of all listeners. Mean ratings were also calculated separately for male and female listeners in order to determine whether male and female listeners use different cues for perceiving cooperativeness. For tests using the listener as the unit of analysis, we calculated each participant's mean cooperativeness rating given to all stimuli, and also calculated separate mean ratings of male and female voices. Additionally, we calculated the rating given by each participant to high- F_0 and low- F_0 voices separately; the same method was used to calculate ratings based on high/low F_0 - SD , D_f , and P_f .

The mean acoustic measurements of all parameters are similar to the averages of those examined in previous research, barring mean female voice F_0 , which is lower than the population-level average. While the minimum and mean F_0 are lower, the upper limit is on par with those measured by other researchers (*e.g.* Feinberg, DeBruine, Jones, & Perrett, 2008; Puts *et al.*, 2012), which indicates that we have simply captured a wider range of female F_0 , and not an unrepresentative sample. Based on the types of analyses we use, there are no reasons to suspect that these lower-than-average female voices should elicit a pattern of results that would differ in directionality from a more restricted stimulus set, as we have captured a wider range of F_0 than is typically utilised.

Vocal Measurements & Cooperativeness Ratings

All four vocal measurements obtained (F_0 , F_0 - SD , D_f , P_f) were sexually dimorphic, with all measures significantly lower for male voices than for female voices (independent-samples t-tests; all $t > 5.24$, all $p < .001$). See Table 1. None of the vocal measurements obtained revealed significant correlations with cooperativeness ratings (Table 2), however many of the correlation coefficients are notable: F_0 was positively but non-significantly related to cooperativeness for both male and female voices; when male voices were rated by other men, the correlation approached significance, $r(16) = .48$, $p = .059$. P_f was negatively

related to cooperativeness ratings for both male and female voices; when female voices were rated by other women, this negative correlation also approached significance, $r = -.48$, $p = .059$. See Figure 1.

Male voice F_0 was significantly positively correlated with F_0 - SD , $r(16) = .77$, $p < .001$, and F_0 - SD was significantly negatively correlated with D_f , $r(16) = -.54$, $p = .03$. No other measurements for male voices were intercorrelated, all $r < .15$, all $p > .57$. Female voice F_0 was significantly negatively correlated with P_f , $r(16) = -.70$, $p = .003$, and F_0 - SD was significantly negatively correlated with D_f , $r(16) = -.50$, $p = .05$. No other measurements for female voices were intercorrelated, all $r < .29$, all $p > .28$.

(Figure 1 about here)

(Table 1 about here)

(Table 2 about here)

(Table 3 about here)

A 2x2 ANOVA (sex of voice; high/low F_0 ; sex of listener as a between-subjects factor) revealed a significant main effect of F_0 only, $F(1, 77) = 34.36$, $p < .001$, with high-pitched voices being found more cooperative than low-pitched voices, in both male and female stimuli, when rated by both male and female listeners. See Table 3. There was also a significant interaction between speaker sex and F_0 , $F(1,77) = 6.33$, $p = .01$. No other significant effects or interactions were observed (all $F < 3.19$, all $p > .08$). Repeating the analysis separately for male and female voices revealed that the main effect of F_0 on cooperativeness ratings was stronger for female voices, $F(1,77) = 38.16$, $p < .001$, than for male voices, $F(1,77) = 5.41$, $p = .02$. See Figure 2a.

For the measure F_0 - SD , the 2x2 ANOVA (sex of voice; high/low F_0 - SD ; sex of listener as a between-subjects factor), a significant main effect of F_0 - SD was revealed, $F(1, 77) = 48.00$, $p < .001$, indicating that a high F_0 - SD was found more cooperative than low F_0 -

SD in both male and female voices. Similarly, a 2x2 ANOVA for D_f (sex of voice; high/low D_f ; sex of listener as a between-subjects factor) revealed a significant main effect of D_f , $F(1, 77) = 34.85$, $p < .001$, with low D_f being found more cooperative in voices of both men and women. The 2x2 ANOVA for P_f (sex of voice; high/low P_f ; sex of listener as a between-subjects factor) returned no significant main effect of P_f , $F(1, 77) = 0.03$, $p = .87$. A significant interaction between P_f and sex of listener was observed, $F(1, 77) = 12.23$, $p < .001$, as well as a three-way interaction between P_f , sex of listener and sex of voice, $F(1, 77) = 5.25$, $p = .03$. Analysing male and female stimuli separately revealed a main effect for female voices, $F(1, 77) = 5.40$, $p = .02$, such that voices with a higher P_f received higher ratings of cooperativeness, however amongst male voices, those with a lower P_f were rated as more cooperative. Furthermore, post-hoc t-tests show that while male listeners respond to P_f when making cooperativeness judgements of both men and women (male voices: $t(21) = -2.04$, $p = .05$; female voices: $t(21) = 2.21$, $p = .04$), female listeners are less affected by this metric (male voices: $t(56) = -0.95$, $p = .35$; female voices: $t(56) = 0.63$, $p = .53$).

(Figure 2 about here)

Mixed Effects Models

We performed additional analyses of what vocal traits influence ratings of cooperativeness using linear mixed effects models. Random effects in all of the models were the listener and voice stimulus. For male listeners of male stimuli, our model was significant, $\chi^2(4) = 16.38$, $p = .003$. There were significant fixed effects of F_0 , $F = 8.29$, $p = .004$, and listener dominance, $F = 11.08$, $p < .001$, on voice cooperativeness ratings. There was also a significant interaction between F_0 and listener dominance, $F = 9.41$, $p = .002$, and a near-significant effect of D_f , $F = 4.01$, $p = .07$. The model shows that men with higher voice pitch and low formant dispersion were rated by other men as more cooperative, and that male listeners who were low in dominance gave higher cooperativeness ratings than high-

dominance listeners. The interaction between F_0 and dominance suggests that high-dominance men found high F_0 to be cooperative, while low-dominance men favoured voices which were low in F_0 .

Our model for female listeners was also significant, $\chi^2(6) = 32.39, p < .001$. Women rated male stimuli as cooperative based on three fixed factors. F_0 was positively associated with cooperativeness, $F = 15.10, p < .001$. A high F_0 - SD was also associated with cooperativeness ratings, $F = 5.41, p = .04$. There was also a significant effect of women's age on cooperativeness ratings, such that older women gave higher cooperativeness ratings, $F = 17.42, p < .001$. We also observed a significant interaction between listener age and speaker F_0 , $F = 13.81, p < .001$, indicating that older women found low-pitched voices cooperative, while younger women found high-pitched voices cooperative. A non-significant interaction between speaker F_0 and F_0 - SD , $F = 3.61, p = .08$ was also present. Although not a significant factor within the model, the inclusion of this interaction term significantly improved the overall model, $\chi^2(1) = 4.15, p = .04$. The direction of the interaction indicates that a high pitch variation positively influenced cooperativeness ratings, particularly when voices were low in pitch; the positive effect of pitch variation was less pronounced for voices which were high in F_0 . Voices with a low pitch and also a low pitch variation were found the least cooperative, while voices with a low pitch and high pitch variation were found the most cooperative.

For male listeners of female stimuli, there was a significant fixed effect listener dominance on cooperativeness ratings, $F = 8.82, p = .003$, and a non-significant main effect of F_0 , $F = 3.01, p = .08$, indicating that men who were high in dominance found women to be less cooperative than low-dominance men, and high F_0 was generally found more cooperative than low F_0 . As with men listening to male voices, a similar significant interaction between dominance and F_0 was found, $F = 5.00, p = .03$. This interaction suggests that high-dominance men found high-pitched female voices to be more cooperative, and low-dominance men favoured lower-pitched female voices. Our overall model was significant, $\chi^2(3) = 13.67, p = .003$.

For women listening to the voices of other women, we found a significant model with two fixed effects, $\chi^2(2) = 9.46, p = .009$, indicating that higher cooperativeness ratings were predicted by both a high F_0 , $F = 5.05, p = .04$, and a high F_0 -SD, $F = 4.35, p = .057$. While the significance value for F_0 -SD approached significance within the model, the inclusion of the term did significantly improve the overall model, $\chi^2(1) = 4.57, p = .03$. In these four models presented, the addition of further factors, including vocal measurements and listener age and dominance, and interactions between these, did not significantly improve the models beyond the results presented.

Individual Differences

Among female listeners, age was positively correlated with cooperativeness ratings of male voices, such that older listeners gave higher cooperativeness scores to men, $r(57) = .327, p = .013$, but not to women, $r(57) = .185, p = .17$. Age was unrelated to cooperativeness ratings among male listeners when rating men, $r(22) = .271, p = .22$ and when rating women, $r(22) = .240, p = .28$.

Among male listeners, scores on the dominance questionnaire were negatively correlated with mean cooperativeness ratings, such that low dominance was related to higher ratings of cooperativeness in others, $r(22) = -0.47, p = .026$. This was mainly true for voices of women, $r(22) = -.506, p = .016$, though a similar directionality was present for male voices as well, $r(22) = -.346, p = .115$. Dominance scores for female listeners were not related to mean cooperativeness ratings in voices of either sex (male $r(57) = .097, p = .47$; female $r(22) = .085, p = .53$).

STUDY 2

The results from Study 1 indicated that F_0 and F_0 - SD were strongly linked to cooperativeness judgments. F_0 has been manipulated in numerous experiments by other researchers examining subjective traits such as attractiveness, dominance, and trustworthiness (e.g. Feinberg, Jones, Little, Burt, & Perrett, 2005; Puts *et al.*, 2007; Tigue *et al.*, 2012). Thus, we further examine the relationship between F_0 and cooperation by repeating Study 1 using a stimulus set consisting of voices with manipulated F_0 .

Methods

Stimuli

8 male and 8 female voices were randomly selected from the stimuli used in Study 1 (male ages 19-30 years, $M = 21.0$ years, $SD 3.74$ years; female ages 18-23 years, $M = 19.6$ years, $SD 1.92$ years). Pitch manipulations were made using Praat v.5.3.56 (Boersma & Weenink, 2013). Using Praat's pitch-synchronous overlap add (PSOLA) method, each voice was manipulated in Hz by ± 0.5 equivalent rectangular bandwidths (ERBs), which is perceptually equivalent to a manipulation of ± 20 Hz (Traunmüller, 1990). This created a raised and lowered version of each voice, resulting in a total of 16 male and 16 female voices. The PSOLA method alters the pitch of the voice, while leaving other aspects (e.g. formants) unchanged. Numerous other experiments have successfully used the PSOLA method in experiments examining perceived attractiveness, dominance and trustworthiness (e.g. Feinberg *et al.*, 2006; Jones, Feinberg, DeBruine, Little, & Vukovic, 2008; Jones, Feinberg, DeBruine, Little, & Vukovic, 2010; Klofstad *et al.*, 2012; Puts, 2005; Tigue *et al.*, 2012; Vukovic *et al.*, 2008), allowing this experiment to be directly comparable to a large amount of previously published literature. Amplitude was scaled to create a constant presentation volume using RMS (root-mean-squared) method.

Participants

Participants ($N = 101$) were psychology undergraduates at the University of Stirling. Females ($n = 70$) were aged 16-40 years ($M = 20.3$ years, $SD = 4.66$ years); males ($n = 31$) were aged 17-49 years ($M = 20.7$ years, $SD = 5.81$ years). All took part in the study to fulfill a course requirement.

Procedure

Apart from the stimuli, the procedure for Study 2 was identical to Study 1. Stimuli were again presented in separate blocks of male/female voices. Each block consisted of 8 voices, which had been both raised and lowered in F_0 , resulting in 16 voice stimuli per block. Within each block, the order of presentation was randomised.

Results

As in Study 1, we calculated each participant's mean cooperativeness rating given to all stimuli, and also calculated separate mean ratings of male and female voices. Additionally, we calculated each participant's mean rating of high- F_0 and low- F_0 voices for both male and female voices separately.

Listeners rated both male and female voices which had been raised in pitch as significantly more cooperative than voices which had been lowered (male voices: raised $M = 4.26$, $SD = 0.64$, lowered $M = 3.97$, $SD = 0.70$, $t(100) = 4.71$, $p < .001$, 95% CI [0.17, 0.42]; female voices: raised $M = 4.22$, $SD = 0.71$, lowered $M = 3.96$, $SD = 0.70$, $t(100) = 4.36$, $p < .001$, 95% CI [0.14, 0.37]). See Figure 3. A 2x2 ANOVA (pitch, sex of voice, sex of rater as a between-subjects factor) revealed a significant main effect of F_0 on cooperativeness ratings, $F(1,99) = 38.07$, $p < .001$. No other significant main effects or interactions were observed (all other $F \leq 2.66$, all other $p \geq .11$).

(Figure 3 about here)

Age was positively correlated to cooperativeness ratings for female raters, $r(70) = .26$, $p = .028$. When further examined by sex of speaker, the correlation remained for male voices, $r(70) = .27$, $p = .023$, but not for female voices, $r(70) = .20$, $p = .104$, though the directionality of the effect is the same. There was no significant correlation found between age and cooperativeness ratings by male listeners, $r(31) = -.18$, $p = .33$. No significant correlations between dominance scores and cooperativeness ratings were found among male listeners (rating women: $r(31) = -.08$, $p = .66$; rating men: $r(31) = .03$, $p = .86$).

Using ANCOVA, we investigated whether self-measures of dominance were related to listeners' sensitivity to masculinity cues when judging the pro-sociality of others (within-subjects factor: mean cooperativeness rating [masculinised, feminised]; between-subjects factor: sex of listener; covariates: age, dominance score). No significant effect of listener dominance was found for men listening to voices of other men, $F(1, 67) = 0.17$, $p = .68$, suggesting that listeners' own dominance did not affect men's sensitivity to dominance cues of other men while assessing cooperativeness. We did observe a non-significant interaction between listener age and masculinity cues, $F(1, 67) = 3.46$, $p = .074$, which suggests that older men may have been more sensitive to dominance cues than younger men, and rated masculinised voices as less cooperative than younger men. There was no effect of age or dominance on men's sensitivity to cues of female masculinity, all $F < 1.30$, all $p > .26$. We also found no significant effects of age or dominance on women's sensitivity to masculinity cues when assessing the cooperativeness of other women, all $F < 2.69$, all $p > .11$, or of other men, all $F < 0.92$, all $p > .34$.

While we found no relationship between dominance scores and cooperativeness judgments among female listeners in Study 1, we did observe a significant negative correlation in Study 2, irrespective of F_0 manipulation. Here, dominance was negatively

correlated with cooperativeness ratings of women rating female voices, $r(70) = -.26, p = .03$, but not when women rated male voices, $r(70) = -.08, p = .52$.

General Discussion

Results from Study 1 indicated that feminine pitch traits (high F_0 and high F_0 - SD) and masculine formant traits (low D_f and P_f) were considered more cooperative-sounding in male voices than those with masculine pitch traits and feminine formant traits. In female voices, feminine pitch traits (high F_0 and high F_0 - SD) were also considered more cooperative than masculine pitch traits. A masculine D_f was also considered more cooperative than a feminine D_f , while femininity in P_f was found more cooperative for female speakers.

Study 2 confirmed our findings from Study 1 regarding a positive association between F_0 and cooperativeness ratings, with feminised voice pitch being found more cooperative in the voices of both men and women. Individual differences of the listeners also influenced cooperativeness ratings. Among female listeners, age was positively correlated with cooperativeness ratings given to other women in both Study 1 and Study 2. In Study 1 only, dominance in male listeners was negatively correlated with cooperativeness ratings given to women, and men who were low in dominance found male voices with masculine F_0 cooperative, while high-dominance men found feminine F_0 cooperative.

What makes a voice sound cooperative?

Both Study 1 and Study 2 illustrate that a high F_0 is associated with perceptions of cooperativeness. Male listeners also displayed a tendency to rate voices with a high F_0 - SD as more cooperative than voices with a low F_0 - SD . Additionally, voices with low formant measures were rated as more cooperative than voices with high formant measures (both D_f and P_f for men, and D_f for women); however, our mixed model analyses confirmed this

relationship between a low D_f and increased ratings of cooperativeness for men listening to other men's voices only. It is important to note that while D_f is a measure of the spacing between the formants, P_f is a measurement of the mean frequency of the formants. So, while cooperative male voices had little space between the formants (a low D_f), those formants also have a low mean measured value (a low P_f), according to our ANOVA results. For women's voices, a low D_f was considered cooperative, as well as voices with a high mean measured formant value (a high P_f).

Feminine pitch and pitch variation, combined with masculine formants, appear generally to be vocal traits that influence perceptions of cooperativeness. Our results regarding the relationship between high pitch traits (F_0 and F_0-SD) and ratings of cooperativeness were the most clear, and our mixed models also support the relationship between masculine D_f and ratings of cooperativeness. While our results concerning P_f were not conclusive based on the mixed effects model presented in Study 1, the relationships we uncovered using the median-split technique are intriguing, especially considering the differing directionality for male and female voices, and this is worth examining further. Future research may wish to examine the relative importance of pitch and formant traits more thoroughly.

Pitch and Pitch Variation

High voice F_0 positively influenced perceptions of a speaker's cooperativeness in voices of both sexes, in both a naturalistic (Study 1) and manipulated sample (Study 2). In both studies, a higher voice pitch elicited increased ratings of cooperativeness in male and female voices. Low F_0 is associated with masculinity (Feinberg, DeBruine, Jones, & Little, 2008; Feinberg, 2008; Pisanski, Mishra, & Rendall, 2012; Pisanski & Rendall, 2011; Puts et al., 2012) and is related to high testosterone levels among men (Dabbs & Mallinger, 1999). Given that men with high testosterone are prone to numerous antisocial and risk-taking behaviours (Apicella et al., 2008; Archer, Biring, & Wu, 1998; Booth & Osgood, 1993;

Coates & Herbert, 2008; Dabbs & Morris, 1990; Mazur & Booth, 1998; D. B. O'Connor, Archer, & Wu, 2004; Rowe, Maughan, Worthman, Costello, & Angold, 2004; Stanton et al., 2011; Studer, Aylwin, & Reddon, 2005), the perception of masculinity may suggest a general air of uncooperativeness or lack of prosociality. This finding underscores the importance of F_0 as a male intra-sexual signal, with low F_0 indicating physical dominance (Hodges-Simeon *et al.*, 2010; Vukovic *et al.*, 2011; Wolff & Puts, 2010). Given that physically dominant persons may use their physical strength to get what they want, and less dominant individuals may be less likely to physically challenge others, persons with lower perceived masculinity and dominance may be considered desirable as potential cooperators. Additionally, vocal femininity may be associated with a certain degree of compliance, which may also be captured by the construct of “cooperativeness.”

Voices with high F_0 - SD (i.e. more dynamic, less monotone voices) were rated as more cooperative than voices with low F_0 - SD . While some of the apparent effect of F_0 - SD in our ANOVA results may be attributed to its correlations with other measured traits, our mixed model analyses present a more fine-tuned picture of how this trait stands alone as a main effect, particularly for female listeners, for whom F_0 - SD was positively related to cooperativeness ratings of both male and female voices. Hodges-Simeon *et al.* (2010) found that low F_0 - SD predicted higher ratings of physical dominance, which may be an undesirable trait in potential cooperators. F_0 - SD is sexually-dimorphic, with high F_0 - SD being a feminine trait. This trait in men, then, may sound friendlier and less dominant than monotone voices. Given that we also found high F_0 - SD to be associated with cooperativeness in female voices (for female listeners only) lends further credence to F_0 - SD 's inverse relationship with perceived dominance in voices of both sexes. Our results support the suggestion that variation in F_0 may serve to elicit and maintain positive emotional states in the listener (Traunmüller & Eriksson, 1995). Hodges-Simeon *et al.* (2010) liken F_0 variation to a “smile,” positing high F_0 - SD as a submissive social gesture. Our data support such an association.

We also found an interaction between pitch and pitch variation in male voices, when judged by female listeners. Men's voices with a high pitch variation were considered more cooperative generally, but also influenced cooperativeness ratings to a greater degree when the voices were also low in F_0 . The positive effect of pitch variation on cooperativeness ratings was less extreme for voices which had a high F_0 , suggesting that negative perceptions of a low F_0 may be ameliorated if the speaker also has a high pitch variation.

Formants

Low D_f is generally considered a masculine trait (Feinberg, Jones, Little, *et al.*, 2005; Wolff & Puts, 2010) and is associated with a larger body size (Feinberg, Jones, Little, *et al.*, 2005) due to the allometric relationship between body height and vocal tract length (Evans, Neave, & Wakelin, 2006; Fitch, 1997). While we may not expect a masculine trait to be associated with cooperativeness, it has previously been suggested that formants have a greater effect on dominance judgments than on judgments of masculinity (Hodges-Simeon *et al.*, 2010; Pisanski & Rendall, 2011), suggesting a link between the formants and perceptions of social traits. If the formants are a somewhat reliable indicator of speaker size or height, listeners may find taller individuals to be more cooperative, possibly because height could confer prestige. While voices with low D_f are considered dominant, Puts *et al.* (2007) suggest that this could also be related to social dominance or prestige. This generalised association between low D_f and cooperativeness may be linked to the social benefits of height. Taller individuals have greater social status (Cavelaars *et al.*, 2000; Power, Manor, & Li, 2002), higher levels of education (Power *et al.*, 2002; Silventoinen, Lahelma, & Rahkonen, 1999) and greater earnings than shorter individuals (Judge & Cable, 2004; Loh, 1993), which may make them more favourable as potential cooperators. It could be that listeners are attuned to cues of social status, while male listeners are more attuned to specific cues of physical dominance. Indeed, while both male and female listeners seem to be influenced by D_f , male listeners alone seem to be influenced by P_f . Although this relationship was not confirmed in

our mixed model results, the relationship is nonetheless an intriguing one. P_f is associated with masculinity and dominance (Puts *et al.*, 2012), and was sexually dimorphic in our data. It is also negatively related to height, weight, arm strength, and physical aggression, suggesting that this trait may be generally indicative of threat potential (Puts *et al.*, 2012). Why a trait thus linked to threat potential would be positively associated with cooperativeness is unclear, though it may be that male listeners also associate this trait with social dominance, while female listeners may not respond to the trait in purely social terms.

Further research may give more attention to the inter-relationships between dominance, prestige, and pro-sociality. The median split used in Study 1 to divide our stimuli into groups based on high and low measures of vocal traits does unfortunately contribute to some loss in variation amongst these traits, and is dependent upon the voices in our particular stimulus set. The nature of the data required that differing median splits be made for each of the four measured vocal traits, such that different vocal stimuli fell on either side of this split dependent upon the trait under analysis. This calls attention to the variability and complexity of vocal characteristics, and serves as testament to their respective importance when examining perceptions based on these traits.

Individual Differences

While we found no effects of listener age or self-measures of dominance to be associated with sensitivity to dominant vocal cues in Study 2, we did observe generalised effects of age and dominance on mean ratings of cooperativeness given across both studies. Women's age was positively correlated with cooperativeness ratings of male voices in both Study 1 and Study 2, and our mixed models in Study 1 confirm that older women tended to give higher cooperativeness ratings to men's voices than younger women. We also found that women's age was associated with their sensitivity to F_0 as a cue to cooperativeness in male voices, such that older women found low-pitched voices cooperative, while younger women

tended to favour higher-pitched male voices. Age can be judged by listening to vocal stimuli with reasonable accuracy (Mulac & Giles, 1996; Ramig, Scherer, & Titze, 1984), and older women generally prefer older men as potential mates (Buss & Schmitt, 1993; Buss, 1989; Mathes, Brennan, Haugen, & Rice, 1985). With age, women may become more confident and socially able, and thus, may find young men less intimidating (the mean ages of stimuli in Study 1 and Study 2 were 20.4 years and 21.0 years, respectively, while the age range of female listeners was 18-35 years and 16-40 years respectively). Women's ratings of young female voices did not produce the same pattern of results, which seem to be unaffected by the age of the listener. There was no effect of age amongst male listeners in either Study 1 or Study 2.

Self-rated dominance appeared to play a role in how male listeners attribute vocal cooperativeness. Low-dominance men gave higher mean cooperativeness ratings to male and female voices than high-dominance men in Study 1. The dominance of the listener also interacted with men's sensitivity to F_0 as a cue to cooperativeness. Low-dominance men found low-pitched male and female voices more cooperative, and high-dominance men tended to favour high-pitched male and female voices. It may be that dominant men feel more socially favourable toward voices which exhibit signs of a small physical stature and low masculinity, as these voices may not pose any threats to the listener's own perceived dominance status.

While this result was not replicated in Study 2, we found a similar effect of dominance on women's cooperativeness ratings of female voices (which we did not find in Study 1). Like men rating other men in Study 1, high dominance in women was associated with lower overall cooperativeness ratings given to the voices of other women. Watkins, Jones, & DeBruine (2010) demonstrated that dominance (measured as a personality characteristic) influences the way men perceived dominance in other men, and it may also affect the way listeners perceive other social traits, such as cooperativeness. Dominant personality traits may "interfere" with the way both men and women perceive

cooperativeness, such that those who are dominant may tend to view same-sex individuals as uncooperative, and favour low masculinity in a cooperative partner, possibly due to an enhanced sense of intra-sexual competition among high-dominance individuals. Additionally, low-dominance individuals may have a generally more positive view of others, as they are less likely to engage in aggressive and antisocial behaviour (Ehrenkranz, Bliss, & Sheard, 1974; Rowe *et al.*, 2004).

Conclusion

While we expected vocal qualities indicating smaller, shorter, feminine individuals to be found more cooperative than those indicating larger, taller, more masculine individuals, our results here were mixed. Feminine F_0 and F_0 -SD positively influenced cooperativeness ratings. F_0 's link to perceptions of speaker masculinity is reflected here – high pitched and dynamic voices sounded more cooperative than low-pitched and monotone voices. Formants also appeared to play a role in cooperativeness judgments, with more masculine formant measures (D_f and P_f) being found more cooperative than feminine formants in male voices. These seemingly dichotomous results further illustrate the relative importance of F_0 and the formants on person perception and the perception of social traits.

Self-rated dominance had some effect on how male and female listeners perceived vocal cooperativeness. We also found that high-dominance men seemed to be more sensitive to F_0 , as they found high-pitched voices of male and female speakers as cooperative, while low-dominance men found low-pitched voices to be more cooperative. However, our results

regarding the negative link between dominance and the attribution of prosociality in others which we found in Study 1 were not replicated in Study 2. We also found that older women tended to rate low-pitched male voices as cooperative, while younger women favoured higher-pitched male voices, perhaps because masculine voices may sound intimidating to younger women. Further experiments may usefully examine the individual differences of listeners and how these affect their perceptions of social traits.

In summary, our results demonstrated that different vocal traits can work in synchrony to create complex interpersonal judgments. While we found that pitch alone was a consistent factor influencing listeners' cooperativeness ratings of both male and female voices, we also found that pitch variation and formants also play an important role in the perception of cooperativeness.

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Table 1

Sexual dimorphism of male and female voice measurements in Study 1. Means, standard deviations, and *t*-values (independent-samples *t*-tests) are reported.

Measure	Male Voices		Female Voices		<i>t</i> (30)	95% CI	
	Mean	<i>SD</i>	Mean	<i>SD</i>		LL	UL
F ₀	115.87Hz	18.24Hz	194.44Hz	35.83Hz	-7.82***	-99.11	-58.05
F _{0-SD}	15.58Hz	7.11Hz	37.10Hz	14.80Hz	-5.24***	-30.04	-12.99
F ₁	495.46Hz	27.42Hz	526.67Hz	59.03Hz	-1.92	-65.04	2.60
F ₂	1618.65Hz	54.61Hz	1782.13Hz	90.69Hz	-6.18***	-218.03	-108.93
F ₃	2567.47Hz	80.98Hz	2766.90Hz	107.58Hz	-5.92***	-268.17	-130.67
F ₄	3547.47Hz	88.23Hz	3806.84Hz	97.93Hz	-7.87***	-326.67	-192.08
D _f	763.00Hz	22.18Hz	820.04Hz	27.01Hz	-6.53***	-74.88	-39.20
P _f	-0.648	0.401	0.648	0.674	-6.61***	-1.70	-0.90

Note. Degrees of freedom for *t* = 30 in all cases barring F_{0-SD} (*df* = 21.577), F₁ (*df* = 21.184), and F₂ (*df* = 24.613). These cases did not pass Levene's test for equality of variance, and thus, we report corrected confidence intervals.

*** *p* < .001

Table 2

Correlated vocal measurements and cooperativeness ratings in Study 1 (Pearson r).

Measure	Male Voices		Female Voices	
	Rated by Men	Rated by Women	Rated by Men	Rated by Women
	r	r	r	r
F_0	.48	.39	.28	.33
F_0 - SD	.33	.24	-.14	.05
D_f	.04	.02	.23	.20
P_f	-.27	-.21	-.37	-.48

Table 3

Categorical measurements and mean ratings (Study 1). Voices were categorised by high or low F_0 , F_0 - SD , D_f and P_f for ANOVA analyses.

Category	Range	Mean	SD	Female Listeners		Male Listeners	
				Mean Coop. Rating	SD	Mean Coop. Rating	SD
High F_0 (Male Voices)	112.9 – 150.7 Hz	130.1	13.8	4.23	0.68	4.15	0.65
Low F_0 (Male Voices)	90.8 – 110.0 Hz	101.6	7.51	3.84	0.73	4.06	0.62
High F_0 (Female Voices)	203.1 – 239.7 Hz	219.8	12.4	4.38	0.66	4.38	0.68
Low F_0 (Female Voices)	110.5 – 202.6 Hz	169.1	33.6	3.67	0.72	3.89	0.97
High F_0 - SD (Male Voices)	16.1 – 30.3 Hz	21.1	5.6	4.37	0.70	4.33	0.69
Low F_0 - SD (Male Voices)	6.9 – 14.6 Hz	10.1	2.9	3.69	0.85	3.87	0.71
High F_0 - SD (Female Voices)	36.2 – 60.6 Hz	49.8	9.1	4.14	0.79	4.30	0.91
Low F_0 - SD (Female Voices)	17.6 – 30.9 Hz	24.4	4.4	3.73	0.71	3.93	0.80
High D_f (Male Voices)	772 – 791 Hz	780	7.8	3.73	0.78	3.87	0.71
Low D_f (Male Voices)	712 – 761 Hz	746	17.2	4.33	0.70	4.33	0.72
High D_f (Female Voices)	828 – 855 Hz	841	11.8	3.78	0.70	4.01	0.89
Low D_f (Female Voices)	775 – 825 Hz	799	20.1	4.09	0.65	4.22	0.67
High P_f (Male Voices)	-0.74 – 0.18	-0.33	0.30	3.98	0.70	3.92	0.70
Low P_f (Male Voices)	-1.18 – -0.74	-0.97	0.15	4.08	0.54	4.28	0.70
High P_f (Female Voices)	0.66 – 1.96	1.18	0.49	3.96	0.67	4.29	0.84
Low P_f (Female Voices)	-0.30 – 0.58	0.12	0.29	3.91	0.66	3.94	0.85

Figure 1

Scatterplots of cooperativeness ratings and measurements of voice F_0 (a, e), F_0 - SD (b, f), D_f (c, g), and P_f (d, h). Male voices (left panel) and female voices (right panel) are represented separately. Separate fit lines are provided for male listeners (solid line) and female listeners (dotted line).

Figure 2

Cooperativeness ratings (Study 1) by high/low F_0 (a), F_0 - SD (b), D_f (c), and P_f (d). Error bars represent the standard error of the mean.

Figure 3

Cooperativeness ratings by pitch condition (Study 2). Error bars represent the standard error of the mean.