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Dominance and the evolution of sexual dimorphism in human voice pitch

David Andrew Puts[a,*,1], Steven J.C. Gaulin[b], Katherine Verdolini[c]

[a]*Department of Anthropology, University of Pittsburgh, Pittsburgh, PA 15260, USA*
[b]*Department of Anthropology, University of California, Santa Barbara, CA 93106, USA*
[c]*Department of Communication Science and Disorders, School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, PA 15260, USA*

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Abstract

The developmental and anatomical causes of human voice sexual dimorphisms are known, but the evolutionary causes are not. Some evidence suggests a role of intersexual selection via female mate choice, but other evidence implicates male dominance competition. In this study, we examine the relationships among voice pitch, dominance, and male mating success. Males were audio recorded while participating in an unscripted dating-game scenario. Recordings were subsequently manipulated in voice pitch using computer software and then rated by groups of males for dominance. Results indicate that (1) a masculine, low-pitch voice increases ratings of men's physical and social dominance, augmenting the former more than the latter; and (2) men who believe they are physically dominant to their competitor lower their voice pitch when addressing him, whereas men who believe they are less dominant raise it. We also found a nonsignificant trend for men who speak at a lower pitch to report more sexual partners in the past year. These results are consistent with the hypothesis that male intrasexual competition was a salient selection pressure on the voices of ancestral males and contributed to human voice sexual dimorphism.

Keywords: Dominance; Male contests; Mating success; Sexual selection; Vocal fundamental frequency; Vocal masculinity; Voice pitch

* Corresponding author. Tel.: +1 517 896 9017; fax: +1 517 432 2744.
E-mail address: puts@msu.edu (D.A. Puts).
[1] Current address: Neuroscience Program, Michigan State University, East Lansing, MI 48824, USA.

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1. Introduction

The human voice is highly sexually dimorphic. Pitch, the most perceptually salient feature of human voice (Banse & Scherer, 1996), is about half as high in men as it is in women (Titze, 2000). This dimorphism is due not merely to sex differences in body size; relative to both height and body volume, voice pitch is lower in men than it is in women and prepubescent children of both sexes (Titze, 2000). Sexual selection (Darwin, 1871) is the primary evolutionary cause of sex differences, and Collins (2000) suggested that sex differences in the human voice evolved though sexual selection via female mate choice. Some studies have shown correlations between female mate preferences and male voice pitch (Collins, 2000; Oguchi & Kikuchi, 1997), whereas others have examined the effects of experimental pitch manipulation on female preferences (Feinberg, Jones, Law Smith, et al., in press, Feinberg, Jones, Little, Burt, & Perret, 2005; Puts, 2005). Puts (2005) and Feinberg, Jones, Law Smith, et al., (in press) demonstrated menstrual cycle variation in women's preferences for masculine voices. Normally-cycling women's preferences for low, masculine voices increased with conception risk (Feinberg, Jones, Law Smith, et al., in press; Puts, 2005), and women preferred lower male voices mainly for short-term, sexual relationships (Puts, 2005). Taken together, these findings suggest that female mate choice may have influenced the evolution of male voice.

However, another type of sexual selection, intrasexual selection via male dominance competition, may also have been an important selection pressure on the voices of ancestral males. Dominance entails access to mates and resources that is relatively unchallenged by competitors. In most animals, dominance is achieved through aggression or threats of aggression, here termed *physical dominance*. In humans, dominance may also be achieved through skillful leadership and persuasion (Henrich & Gil-White, 2001), hereafter called *social dominance*. Among nonhuman animals, low voice pitch is associated with physical dominance (Morton, 1977; Morton & Page, 1992), and in humans, voice pitch is associated with interpersonal power and deference relations (Benjamin, 1981, 1992; Gregory, 1994; Gregory, Webster, & Huang, 1993).

The reasons that the acoustic features of voice may have evolved as dominance signals can be clarified by examining their proximate causes. The frequency of vocal fold vibration during phonation is called the fundamental frequency, or F_0, and closely determines what is perceived as pitch. The determinants of F_0 are apparent from the equation

$$F_0 = \frac{1}{2L}\sqrt{\frac{\sigma}{\rho}} \tag{1}$$

where L is the vocal fold length, σ is the longitudinal stress on the vocal folds, and ρ is the vocal fold tissue density (Titze, 2000). Thus, voice pitch is inversely proportional to vocal fold length and directly proportional to the square root of tension on the vocal folds. Longer vocal folds with less tension on them lead to lower voice pitch. The perception of pitch is also affected by formant frequencies (Higashikawa, Nakai, Sakakura, & Takahashi, 1996; Wolfe & Ratusnik, 1988). The term *pitch* will thus be used hereafter to refer to the perception of voice "highness" or "lowness," which is influenced by both fundamental and formant frequencies. Formant frequencies, and, in particular, the spacing between them (formant dispersion), are largely determined by the length of the supralaryngeal vocal tract (Fant, 1960; Fitch & Hauser, 1995).

Vocal fold length and tension and vocal tract length have direct relationships to traits associated with dominance. Vocal tract length is related to body size (Fitch & Giedd, 1999), and both fundamental and formant frequencies influence perceptions of speaker size (Collins, 2000; Smith, Patterson, Turner, Kawahara, & Irino, 2005). In addition, substantial evidence supports an association between vocal anatomy and androgens. Under the influence of pubertal androgens, the vocal folds (Hollien, Green, & Massey, 1994) and supralaryngeal vocal tracts (Fitch & Giedd, 1999) of human males lengthen faster than the overall rate of body growth, resulting in drops in F_0, formant position, and formant dispersion. Fundamental frequency continues to correlate negatively with endogenous androgen levels in young adult men (Dabbs & Mallinger, 1999) and decreases with exogenous androgen treatment (Need, Durbridge, & Nordin, 1993). In addition to its association with low voice pitch, androgen is positively related to physical aggressiveness (Archer, 1991; Harris, 1999; Ramirez, 2003) and physical prowess (e.g., Clark & Henderson, 2003). More generally, it has been suggested that masculine traits such as low voice pitch, whose development or maintenance depends on high androgen levels, may be honest signals of a competitor's health and vigor (Folstad & Karter, 1992; see also Zahavi & Zahavi, 1997).

Habitual voice pitch varies across individuals, but pitch is also modulated between and within interactions. If low voice pitch is generally a reliable signal of physical dominance, then the relationship between voice pitch and dominance should be reciprocal. That is, not only should pitch affect perceptions of dominance, but dominance relationships should influence how pitch is modulated during competitive interactions. Indeed, pitch modulation is related to dominance and submissiveness across nonhuman animal species (Morton, 1977; Morton & Page, 1992). Morton (1977) suggested that lowering pitch may be analogous to piloerection in that it increases the apparent size of an animal and thus the threat it poses.

In humans, voice pitch varies with emotional state (Williams & Stevens, 1972) and actors' portrayals of emotional states (Banse & Scherer, 1996), and considerable agreement about speakers' emotional states exists among listeners (Johnson, Emde, Scherer, & Klinnert, 1986), whose judgments depend partly on voice pitch (Sobin & Alpert, 1999). In particular, pitch modulation appears to convey information about the relative emotional engagement, or activation, of a speaker (Russell, Bachorowski, & Fernandez-Dols, 2003). Emotional activation raises F_0 by increasing tension on the vocal fold mucosa (σ, in Eq. (1)), mainly via contraction of the cricothyroid muscles and consequent lengthening of the vocal folds (Titze, 2000). Thus, raised F_0 is associated with disparate high-activation emotions such as hot anger, elation, and panic fear, whereas lowered F_0 is associated with sadness, boredom, and contempt (low-activation emotions) (Banse & Scherer, 1996; Ekman, Friesen, & Scherer, 1976; Sobin & Alpert, 1999; Williams & Stevens, 1969; Wittels, Johannes, Enne, Kirsch, & Gunga, 2002).

The positive relationship between emotional stress and voice pitch in humans may reflect homology with nonhuman animals (Ohala, 1983; 1984). Across animal species, interaction with relatively dominant conspecifics may increase activation (nervousness), inhibiting displays of dominance and raising vocalization pitch, whereas interaction with submissive associates may induce less activation, disinhibiting dominance displays and lowering pitch.

Surprisingly, no study has examined whether perceived dominance affects speakers' voice pitch during competitive human interactions. Several studies have explored whether voice pitch affects dominance ratings made by listeners, but these studies have obtained mixed results. Aronovich (1976) found no correlation between speakers' average F_0 and dominance ratings made by listeners, whereas Tusing & Dillard (2000) found a significant positive correlation between F_0 and dominance ratings (i.e., lower F_0 voices were rated as less dominant). However, these results are difficult to interpret because neither study was experimental, so neither can address whether any acoustic sexual dimorphism, by itself, affects perceptions of dominance. Other features of vocalizations, such as speech content, intonation, speed, and inflection, may have covaried with pitch and substantially influenced ratings.

A recent experimental study investigated the effects of voice manipulation on dominance ratings. Feinberg, Jones, Little, et al. (2005) manipulated voice pitch/masculinity by shifting both fundamental and formant frequencies. Female participants rated masculinized male and female voices as more dominant than feminized voices. However, because this experiment examined the effects of voice on females' perceptions of male dominance, it could not address whether voice pitch mediates dominance competition among males.

1.1. The present research

In the present study, we experimentally test the hypothesis that intrasexual selection influenced the evolution of human voice pitch sexual dimorphism through its role in male dominance competition. Specifically, we test three predictions of this hypothesis: voice pitch (1) signals dominance to other males, (2) is modulated in response to circumstantial dominance, and (3) increases mating success.

In testing Prediction 1 (voice pitch signals dominance to other males), we examine the effects of experimental voice manipulation on dominance ratings made by male listeners. If our hypothesis is correct, more masculine voices should lead to higher dominance ratings. Because voice pitch may generally advertise health, strength, vigor, or other traits that contribute to physical competitive ability, pitch manipulation is predicted to affect ratings of physical dominance more than ratings of social dominance.

We test Prediction 2 (voice pitch is modulated in response to relative dominance) by examining whether males who rate their dominance as high tend to lower their pitch more during competition than males who rate themselves as less dominant. We predict that pitch modulation will be more closely related to physical dominance than to social dominance.

Finally, we test Prediction 3 (voice pitch increases mating success) by examining whether men who spontaneously speak at a lower pitch report more sexual partners in the past year.

2. Methods

2.1. Subjects

One hundred ninety-seven self-identified heterosexual male undergraduates from the University of Pittsburgh took part as "participants" or "raters" in this human subjects board-approved study. The mean age of participants (n=111) was 18.9 years (range=18-24, S.D.=1.2). The mean age of raters (n=86) was 20.0 years (range=18-28, S.D.=2.1). Participants were native English-speaking nonsmoking males who reported being uninvolved in committed relationships.

2.2. Procedures

2.2.1. Participants: voice pitch in competition for mates

Upon arrival at the voice laboratory and following informed consent, each participant was seated at a computer monitor in a soundproof recording room (approximately 2.5×3 m). The participant was given a combination headphone/headset microphone and a short written passage excerpted from the "Rainbow Passage" (Fairbanks, 1960). The experimenter's recorded voice instructed the participant to read the passage aloud. The participant was then told that he would be competing with a man in another room for a lunch date with a woman in a third room, following a protocol similar to one used by Simpson, Gangestad, Christensen, and Leck (1999). In actuality, the male competitor was audio recorded, the female was video recorded, and both sets of recordings were spliced into a single digital recording, which could be played and paused by the experimenter. The participant's voice was recorded as he (1) read the Rainbow Passage aloud (baseline recording) and (2) responded to his competitor by discussing why he (the participant) might be respected or admired by other men (competitive recording).

In producing the competitive recordings, we explicitly chose to let subjects compose their own utterances. The confounding effects of between-subject variation in content can be removed experimentally (see hereinafter), and we believe that an unscripted format produced more ecologically valid vocal stimuli for male raters than the stimuli used in previous studies (Aronovich, 1976; Feinberg, Jones, Law Smith, et al., in press; Feinberg, Jones, Little, et al., 2005; Ohala, 1984; Tusing & Dillard, 2000). Furthermore, this protocol enabled us to compare the presumably more neutral baseline recordings made before the subjects engaged in the dating competition with actual competitive vocalizations.

Following this dating-game scenario, each participant was given a questionnaire targeting dominance, mating success, and interest in the female. Social and physical dominance was assessed via self-ratings. Following procedures described by Mazur, Halpern, and Udry (1994), participants were instructed that "a [socially] dominant person tells other people what to do, is respected, influential, and often a leader; whereas submissive people are not influential or assertive and are usually directed by others." Participants were asked to rate their own social dominance on a six-point scale. To measure physical dominance, we asked the participants their level of agreement (six-point scale) with the statement, "If you got in a fistfight with an average undergraduate male, you would probably win." Using the same scales and criteria, participants also rated the social and physical dominance of their competitor. Because all participants faced the same competitor, participants' ratings of this standard could be used to calibrate self-ratings across participants. For each of the two types of dominance, the difference between a participant's self-rated dominance and his rating of his competitor's dominance thus ranges from −5 to +5 and is here referred to as relative (social and physical) dominance. Mating success was assessed by asking participants their number of female sex partners over the past year (Faurie, Pontier, & Raymond, 2004; Pérusse, 1993). Eight participants did not answer this item. Interest in the female was assessed by asking participants, "How much would you like to go on a date with the woman who just interviewed you?" Participants chose along a six-point scale from "very strongly want to go" to "very strongly do not want to go."

2.2.2. Raters: assessing vocal dominance

Average F_0, an acoustic correlate of pitch, was later measured for each (unmodified) baseline and competitive recording using Praat voice analysis software, which uses an acoustic periodicity detection algorithm based on an autocorrelation method described by Boersma (1993). Parameters were set to a pitch floor of 75 Hz and a pitch ceiling of 300 Hz, with all other values set to default. Each competitive recording (mean length=17.9 s, mean F_0=113.2 Hz, F_0 range=85.6-154.6 Hz) was then both raised one semitone and lowered one semitone, without affecting sample speed, using the sound-editing program, CoolEdit 2000, and saved as separate sound files (F_0 range=80.8-163.8 Hz). F_0 manipulations were validated using Praat pitch analysis.

A question relevant to the experimental hypotheses concerns the effects of pitch manipulations on samples' spectral compositions. CoolEdit's algorithms in this regard were not transparent, but post hoc examination using Pratt showed that pitch manipulations affected spectral output. Steady-state spectra of vowels /a/, /i/, and /u/ extracted from 11 (10% of total) pairs of randomly selected lowered and raised speech samples revealed the following formant frequency changes with pitch manipulations: (1) First through fourth formants ($F1$-$F4$) were shifted in the same direction as F_0 [repeated-measures analysis of variance (ANOVA), main effect of pitch manipulation on formants, $F(1,11)=22.1$, $p=.001$]. (2) Frequency changes were greater for higher formants; mean differences between raised- and lowered-pitch formants for $F1$-$F4$, averaged across the three vowels, were 54.7, 92.7, 199.9, and 283.0 Hz, respectively. These differential formant shifts were significant, as indicated by the interaction between pitch manipulation and formant [repeated-measures ANOVA, $F(3,11)=6.42$, $p=.002$]. (3) Differential shifting of formants led to an increase in formant dispersion (calculated as in Fitch, 1997) from lowered-pitch to raised-pitch recordings [mean difference, 76.1 Hz; $F(1,11)=16.9$, $p=.002$].

Generally, formant positions and dispersion were shifted in the same direction as F_0, producing either lower-pitch/more masculine voices or higher-pitch/more feminine voices. A one-semitone pitch change corresponded to slightly more than twice the just noticeable difference (JND) (Puts and Gaulin, unpublished data). However, all recordings sounded "natural," and no rater reported any suspicion of recordings having been altered.

In sum, for each participant, three competitive recordings differing only in voice pitch/masculinity were available for use as stimuli in the rating phase of the study. The resulting 333 total competitive recordings were divided into 11 stimulus sets of approximately 30 recordings each. Recordings were divided among stimulus sets so that each set included (1) no more than one version of a single participant's recordings and (2) nearly equal numbers of raised, lowered, and unmodified recordings (from different participants).

Raters attended 1 of 11 experimental sessions held in classrooms equipped with audio systems on which voice recordings could be played. Raters received rating sheets for judging participants' physical and social dominance. The experimenter explained the importance of obtaining independent ratings and directed raters not to react visibly or audibly to recordings or pay attention to others. The experimenter then played a compact disc of the following: (1) a description of the stimulus set, approximately 30 recordings of men describing themselves to a man with whom they were competing for a date with an attractive woman; (2) directions to rate each man for both social and physical dominance and definitions of these terms; (3) five sample recordings illustrating the range of variation in samples; (4) 30 or 31 competitive recordings of participants, each separated by 10 s of silence for rating; and (5) directions to fill out a questionnaire at the end of the rating packet (not used in this study). All recorded instructions were spoken by a 25-year-old female in a pleasant, professional tone.

Raters assessed social dominance by placing a mark anywhere on a line from "extremely dominant" to "extremely submissive" underneath a description of social dominance identical to the one given to participants (see Section 2.2.1). Raters assessed physical dominance by placing a mark anywhere on a line from "strongly disagree" to "strongly agree" underneath the statement, "If this man got in a fistfight with an average male undergraduate student, this man would probably win." One hundred unlabelled tick marks on each line enabled the experimenter to assign values from 0 to 100 for dominance ratings according to the placement of the rater's mark.

2.3. Data treatment: dominance ratings

The three versions of each male participant's competitive recording (raised, lowered, and unmodified pitch) received both social and physical dominance scores. These scores were obtained by averaging the ratings given to each version by all the raters who listened to it. To increase comparability between recordings judged by different groups of raters, we normalized each rater's ratings to a mean of 0 before being used to calculate dominance scores. That is, each rater's mean rating was subtracted from all of his individual ratings. Thus, dominance scores were positive if the raters who listened to a particular recording rated it above their average ratings and negative if it was rated below average. Normalization did not alter the results.

2.4. Statistical analyses

Statistical tests are two-tailed and considered significant if $p<.05$. Self-rated (social and physical) dominance differences between participants and the standard competitor ranged from

+5 to −5. In analyses involving this truncated scale, we used a conservative nonparametric technique (Spearman's ρ). Number of sexual partners was positively skewed; hence, this variable was log transformed to produce a distribution that did not differ significantly from normality. For all other variables, the assumptions of parametric techniques were satisfied.

3. Results

3.1. Dominance ratings of unmodified competitive recordings

For comparison with prior research (Aronovich, 1976; Tusing & Dillard, 2000), we initially examined the correlations between dominance (physical and social) and voice pitch (measured by F_0) for the unmodified competitive recordings. Although both relationships were in the predicted direction (lower voices rated as more dominant), neither correlation attained statistical significance (Pearson correlations: $r=-.176$, $n=111$, $p=.064$ for physical dominance; $r=-.150$, $n=111$, $p=.106$ for social dominance). Controlling for speaker's age did not affect these results (partial $r=-.176$, $df=108$, $p=.066$ for physical dominance; partial $r=-.156$, $df=108$, $p=.104$ for social dominance). Because these relationships may confound the effects of F_0 with those of content, volume, intonation, and the like, we proceeded to analyze the ratings of the experimentally manipulated voices.

3.2. Effects of experimental pitch manipulation on dominance ratings

Multifactor repeated-measures ANOVA revealed a significant main effect of pitch manipulation on dominance ratings [ANOVA, $F(1,110)=128.53$, $p<.0001$, Fig. 1]. Lowered

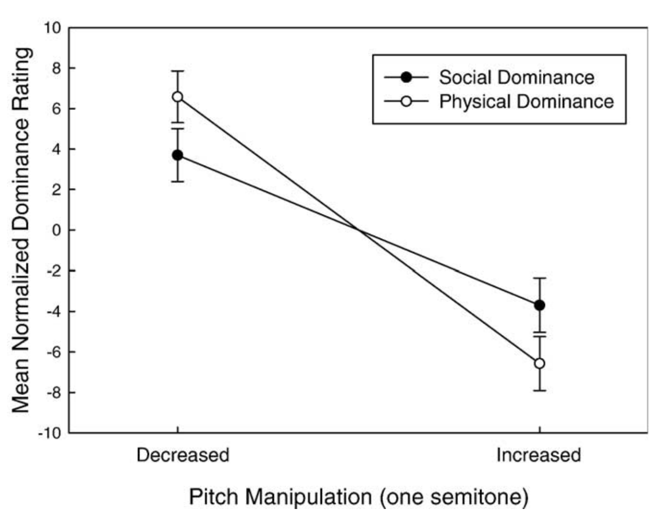

Fig. 1. Two-way interaction between pitch manipulation and dominance type (means±S.E.). Pitch manipulation significantly affected dominance ratings overall [$F(1,110)=128.53$, $p<.0001$] and had a larger effect on physical dominance ratings than on social dominance ratings [$F(1,110)=30.85$, $p<.0001$].

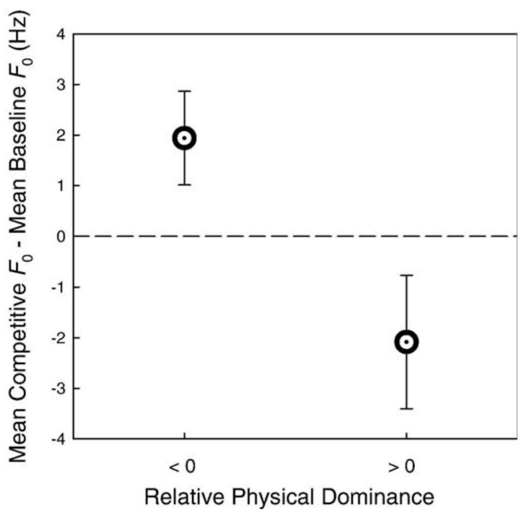

Fig. 2. Change in F_0 from baseline to competitive recordings as a function of self-rated relative physical dominance (means±S.E.). On average, males who rated their competitor as more dominant raised their F_0, and those who rated themselves as more dominant lowered their F_0 [$t(77)=2.55$, $p=.006$].

pitch recordings received significantly higher physical and social dominance scores than did the same recordings raised in pitch and rated by a different group of raters [paired t test, $t(110)=12.40$ and 7.20, respectively, both $p<.0001$]. As predicted, a significant two-way interaction was also found between pitch manipulation and dominance type [ANOVA, $F(1,110)=30.85$, $p<.0001$, Fig. 1]. Pitch manipulation had a greater effect on ratings of physical dominance than on ratings of social dominance.

3.3. Pitch change in response to competition

The competition condition produced no significant overall change in voice pitch (measured by F_0) from baseline F_0 (112.7 Hz) to competitive F_0 (113.2 Hz) [paired t test, $t(110)=0.93$, $p=.352$]. However, individual F_0 changes varied significantly with participants' perceptions of their relative physical dominance (Spearman's rank correlation, $\rho=-.27$, $n=111$, $p=.004$), and this was not changed by controlling for reported interest in the female (partial $r=-.26$, $n=106$, $p=.002$). Participants who rated themselves as more physically dominant than their competitor tended to lower their F_0 when speaking to him (mean change=−2.08 Hz), whereas participants who rated themselves as less physically dominant on average raised their F_0 when speaking to their competitor (mean change=+1.94 Hz). This difference (approximately 4 Hz) was statistically significant [t test, $t(77)=2.55$, $p=.006$, Fig. 2] and exceeds the JND in the frequency range of normal men's voices (Ladefoged, 1996). A participant's perception of his relative social dominance had no significant effect on F_0 modulation (Spearman's rank correlation, $\rho=.07$, $n=111$, $p=.454$), even after controlling for interest in the female (partial $r=-.11$, $n=106$, $p=.134$).

3.4. Voice pitch and number of sexual partners

Participants with lower baseline and unmodified competitive F_0 tended to have more sexual partners in the past year, but these trends were not statistically significant (Pearson correlations, $r=-.16$, $n=103$, $p=.112$ for baseline F_0; $r=-.15$, $n=103$, $p=.140$ for competitive F_0). Results were similar after controlling for participant age (partial $r=-.15$, $n=103$, $p=.128$ for baseline F_0; partial $r=-.13$, $n=103$, $p=.186$ for competitive F_0).

4. Discussion

Preliminary analyses showed a marginally significant negative correlation between ratings of physical (but not social) dominance and the F_0 of subjects' unmodified competitive recordings. Experimental manipulation of these same recordings, however, produced strong negative relationships between voice pitch and both types of dominance, with pitch manipulation affecting perceptions of physical dominance more than it affected perceptions of social dominance. This paper is the second (after Feinberg, Jones, Little, et al., 2005) to show that manipulating the pitch of male utterances affects perceived dominance and the first to show this effect using male listeners.

One concern that can be raised regards the potential contributions of spectral influences on dominance ratings. Both the study by Feinberg, Jones, Little, et al. (2005) and the present study simultaneously manipulated fundamental and formant frequencies and examined the effects of these manipulations on dominance ratings. Thus, from these studies, the relative contributions of F_0 and formant structure cannot be teased apart. Marginally significant correlations between F_0 and dominance ratings of unmanipulated voices in the present study suggest an effect of F_0 on perceptions of physical dominance. However, the relationship between body size and formant structure also strongly indicates that formants affect dominance attributions, and thus, the relative contributions of F_0 and formant structure warrant further investigation.

In this study, perceptions of relative physical dominance predicted how men adjusted their F_0 when speaking to a competitor, suggesting that F_0 modulation signals circumstantial physical dominance. Participants who rated themselves as more physically dominant than the standard competitor tended to lower their F_0 when speaking to him, whereas men who rated themselves as less physically dominant tended to raise it. One plausible interpretation of this correlation is that the competitor intimidated some males more than others, and this differential intimidation affected whether males raised their F_0 or lowered it. The alternative explanation — that participants gauged their relative dominance retrospectively by monitoring their own pitch shifts — is logically possible but unsatisfying, because it fails to address why some men raised and others lowered their voices in the first place.

Finally, the relationship between spontaneous voice pitch and number of sexual partners was in the predicted direction but was nonsignificant. That is, men who spoke at a lower pitch reported (nonsignificantly) more mates in the past year.

These findings highlight the salience of voice in male intrasexual competition and generally support the hypothesis that intrasexual selection contributed to human vocal sexual dimorphisms. A potential limitation of this study is that it does not investigate voice pitch and dominance in women. As noted above, Feinberg, Jones, Little, et al. (2005) found that more masculine and lower-pitched female voices were rated as more dominant among females. However, the relationship between vocal acoustic parameters (such as F_0) and dominance among females need not differ from the relationship among males in order for intrasexual selection to have created vocal sex differences. It is sufficient for dominance to affect reproductive success differently in the two sexes (Andersson, 1994, p.146), a condition for which there is abundant evidence in humans (e.g., Daly & Wilson, 1988). Moreover, that fact that males, but not females, exhibit a dramatic pubertal pitch change suggests that vocal sexual dimorphism is a result of sexual selection on males rather than on females.

Although both intrasexual and intersexual selection may have affected the evolution of vocal sexual dimorphism, their relative contributions are unclear. Some evidence suggests that intrasexual selection may have been a relatively stronger influence on the evolution of male voices: A two-semitone experimental manipulation of vocal pitch significantly affects both males' ratings of a man's physical dominance and fertile-menstrual-phase females' ratings of his sexual attractiveness (Puts, 2005), but the effect size (η^2) of such a two-semitone pitch change is nearly 15 times greater on physical dominance ratings than on sexual attractiveness ratings (Puts, 2004). These results parallel research on other human sexual dimorphisms, such as facial masculinity, in which masculine traits have smaller or less consistent effects on attractiveness (e.g., Johnston, Hagel, Franklin, Fink, & Grammer, 2001; Penton-Voak et al., 1999; Penton-Voak & Perrett, 2001) compared to their effects on dominance ratings (e.g., McArthur & Berry, 1987; Mueller & Mazur, 1997; Perrett et al., 1998).

In summary, we suggest that low voice pitch evolved in men because it increased mating success via two (nonmutually exclusive) routes. First, voice pitch increased the appearance of physical dominance, enabling some men to exclude others from resources (including mates), thus, augmenting mating success. Second, a low voice, through its association with heritable, fitness-related traits such as health and physical prowess, made men more sexually attractive to women near peak fertility in their cycles.

These results should be replicated, particularly in other (non-Western) cultures. However, given the widespread association between dominance and pitch across animal species, including nonhuman primates (Morton, 1977; Morton & Page, 1992), and the cross-cultural universality of voice pitch sexual dimorphism, masculine vocal traits such as low pitch are expected to increase perceived physical dominance among men generally, with cultural variables influencing the degree, but not the direction, of this effect.

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