Evolution and Human Behavior 28 (2007) 340–344

Men's voices as dominance signals: vocal fundamental and formant frequencies influence dominance attributions among men

David Andrew Puts[a,*], Carolyn R. Hodges[b], Rodrigo A. Cárdenas[c], Steven J.C. Gaulin[b]

[a]Neuroscience Program, Michigan State University, East Lansing, MI 48824, USA
[b]Department of Anthropology, Center for Evolutionary Psychology, University of California, Santa Barbara, Santa Barbara, CA 93117, USA
[c]Department of Psychology, Michigan State University, East Lansing, MI 48824, USA

Initial receipt 15 November 2006; final revision received 4 May 2007

Abstract

Men's vocal folds and vocal tracts are longer than those of women, resulting in lower fundamental frequency (F_0) and closer spacing of formant frequencies (formant dispersion, D_f) in men than in women. The evolutionary reasons for these sex differences are uncertain, but some evidence implicates male dominance competition. Previous manipulations of F_0 and D_f affected perceptions of dominance among men. However, because these acoustic dimensions were manipulated simultaneously, their relative contributions are unclear. In unscripted recordings of men speaking to a competitor, we manipulated F_0 and D_f independently and by similar perceptual amounts to examine effects on social and physical dominance ratings. Recordings lowered in either F_0 or D_f were perceived as being produced by more dominant men than were the respective raised recordings. D_f had a greater effect than did F_0, and both D_f and F_0 tended to affect physical dominance more than social dominance, although this difference was significant only for D_f.

Keywords: Formant frequency; Fundamental frequency; Dominance; Intrasexual competition; Sexual selection; Voice pitch

1. Introduction

Large sex differences characterize the human voice and its anatomical substrates. Men's fundamental frequency (F_0), the primary acoustic correlate of pitch, is approximately half as high as women's (Titze, 2000). F_0 is inversely related to vocal fold length, which is 60% longer in men (Titze, 2000), far greater than the roughly 7% difference in height (Gaulin & Boster, 1985). Formant frequencies, which affect perceptions of voice timbre (Cleveland, 1977), are more closely spaced in men (Rendall, Kollias, Ney, & Lloyd, 2005). This spacing, called formant dispersion (D_f), is inversely related to vocal tract length (Fitch & Hauser, 1995), which is greater in men, both absolutely and relative to height (Fitch & Giedd, 1999).

Vocal sex differences emerge at puberty when high testosterone levels cause males' vocal folds and tracts to grow faster than overall body growth (Fitch & Giedd, 1999; Lee, Potamianos, & Narayanan, 1999). No comparable changes occur in females. The evolutionary reasons for these sex differences are unclear, but several lines of evidence indicate that sexual selection specifically shaped men's voices (Collins, 2000; Feinberg et al., 2006; Feinberg, Jones, Little, Burt, & Perrett, 2005; Puts, 2005; Puts, Gaulin, & Verdolini, 2006).

Sexual selection can operate through mate choice. Women prefer deeper male voices (Collins, 2000; Feinberg et al., 2005; Puts, 2005), especially near ovulation (Feinberg et al., 2006; Puts, 2005) and when evaluating short-term mates (Puts, 2005). Male–male dominance competition may also have played a role (Puts, Gaulin, & Verdolini, 2006). Manipulations of both F_0 and D_f independently affect women's ratings of speakers' age, masculinity, and size (Feinberg et al., 2005), and these parameters might also affect perceptions of dominance among men. Indeed, men rate male voices lowered in both F_0 and D_f as more dominant than the same voices with these acoustic parameters raised (Puts, Gaulin, & Verdolini, 2006). These manipulations affect ratings of physical dominance (fighting ability) more than ratings of social dominance (respect among peers, leadership, etc.). However, because both F_0 and D_f were manipulated simultaneously by Puts, Gaulin,

* Corresponding author. 108 Giltner Hall, Michigan State University, East Lansing, MI 48824, USA.
E-mail address: puts@msu.edu (D.A. Puts).

1090-5138/$ – see front matter
doi:10.1016/j.evolhumbehav.2007.05.002

Verdolini, & Hodges, (2006), it is impossible to determine whether F_0, D_f, or both, affected perceptions of dominance among men—an issue central to understanding how sexual selection shaped men's voices. Thus, we examine the relative contributions of F_0 and D_f to ratings of physical and social dominance by manipulating F_0 and D_f independently and by similar perceptual amounts.

2. Methods

2.1. Subjects

Fifty male and 20 female (ages 18–24) English-speaking, normally hearing undergraduates at UC Santa Barbara participated in one of three IRB-approved studies. Two were preliminary just-noticeable-difference (JND) studies; the third was the focal study.

2.2. Studies 1 and 2: JND studies

Experiments were computerized (E-Prime), and voice parameters were manipulated using Praat 4.4.06.

A common measure of perceptual magnitude was required to compare the relative effects of F_0 and D_f on dominance ratings. Using Fechnerian and Weberian psychophysical principles (Marks & Gescheider, 2002), we chose the JND. Although previous studies have examined the JND for various acoustic parameters (e.g., Smith, Patterson, Turner, Kawahara, & Irino, 2005), results vary due to methodological differences. The JND will depend on stimulus magnitude as well as details of instrumentation. Thus, we obtained our own JNDs—tailored to our equipment, methods, and the magnitude of the stimuli used in Study 3—for both F_0 and D_f.

Twenty-eight subjects (8 men, 20 women) participated in a JND study of either F_0 or D_f. For both F_0 and D_f studies, 30 pairs of voice stimuli were created, comprising an equal mix of 10 specific manipulations, including a null manipulation. F_0 manipulations ranged from 0.6 to 2.2 semitones in nine increments of 0.2 semitones, plus unmanipulated recordings. D_f manipulations ranged from 2.5% to 6.5% changes in apparent vocal tract length in nine increments of 0.5%, plus unmanipulated recordings. For F_0 manipulation, voices were raised and lowered from baseline levels without affecting tempo. For D_f manipulation, formant structure was shifted up and down (increasing or decreasing D_f) without affecting tempo. Where F_0 was affected by this procedure, it was manipulated back, using the procedures described above, to within 0.2 semitones (<0.17 JND) of its original, unmanipulated values. For both F_0 and D_f manipulation, parameters were set to a time step of 0.01, a minimum pitch of 75 Hz, a maximum pitch of 300 Hz, and otherwise to default.

Participants were directed through an experimental session where paired voice stimuli were presented in random order. Each stimulus pair consisted of (A) a 3- to 5-s voice clip of an 18- to 24-year-old man introducing himself, followed by (B) the same clip at the same or different F_0 or D_f. AB pairs were presented three times before a response was permitted. Participants were instructed to determine if Clip B was the same as or different from Clip A. We defined the JND as the smallest increment in F_0 or D_f for which 50% of subjects perceived a difference. For F_0, this was 1.2 semitones; for D_f, it was a 4% change.

2.3. Study 3: voice effects on dominance

Information on JNDs was used to manipulate 30 voice recordings selected randomly from 111 produced in a previous "dating-game" experiment (Puts, Gaulin, & Verdolini, 2006) where men (ages 18–24) were recorded as they spoke to a male competitor.

In Study 3, F_0 and D_f were both raised and lowered independently using the procedures described above. An experimental manipulation of 1.5 JND was chosen because, from our data, 100% of subjects should perceive differences between voices raised and lowered by this amount in either F_0 or D_f. At the same time, this manipulation remains close to the JND, where small increments are maximally likely to have comparable effects on perception (Marks & Gescheider, 2002). For F_0 manipulation, voices were raised and lowered by 1.8 semitones (1.5 JND) from baseline levels, and for D_f manipulation, formant structure was shifted up and down by 6% (1.5 JND), without affecting tempo.

Thus, from each of the 30 original voices, five versions were produced: unmanipulated, raised F_0, lowered F_0, raised D_f, and lowered D_f, for a total of 150 voice recordings. These recordings were distributed into five stimulus sets of 30 recordings, each set comprising 6 raised F_0, 6 lowered F_0, 6 raised D_f, 6 lowered D_f, and 6 unmanipulated recordings and only one version of each of the 30 voices. Thus, no subject heard two versions of the same voice.

2.3.1. Procedure

Each male subject (n=42) was seated at a computer station, where a program instructed him on the tasks to be performed, played through headphones the audio stimuli to be rated, and recorded his choices. Subjects rated 30 voices (one stimulus set) on whether each speaker was likely to be able to win physical fights (physical dominance) and whether he was likely to be a respected leader (social dominance). Physical dominance was assessed by selecting from a 10-point scale with endpoints labeled *strongly agree* and *strongly disagree* below the statement: "If this man got in a fistfight with an average male undergraduate student, this man would probably win" (Puts, Gaulin, & Verdolini, 2006). Subjects assessed social dominance by selecting from a 10-point scale with endpoints labeled *extremely dominant* and *extremely submissive* underneath Mueller and Mazur's (1997) description: "a 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."

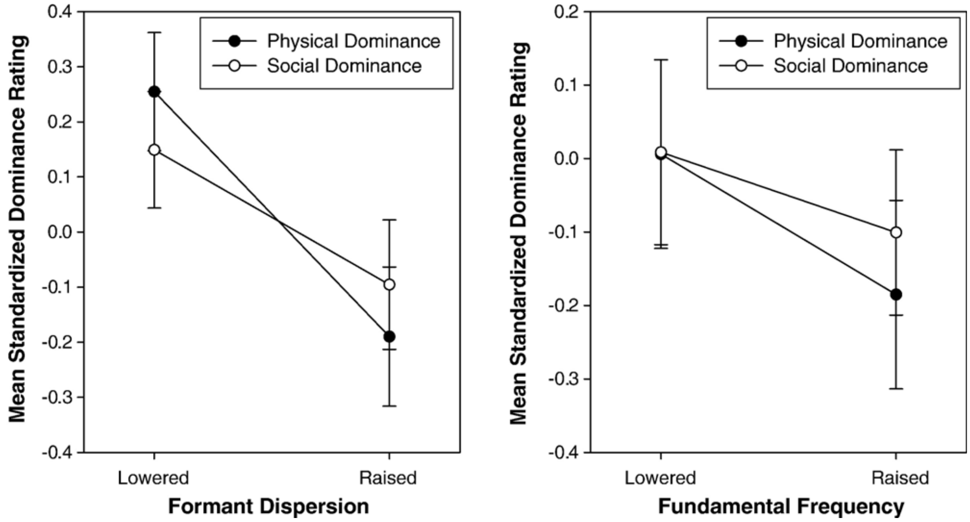

Fig. 1. Formant dispersion (D_f) and fundamental frequency (F_0) negatively affected perceptions of dominance (p<.05). D_f and F_0 tended to affect physical dominance more than social dominance, but this interaction was significant only for formant dispersion.

To eliminate the influence of any order effects on relationships between voice manipulations and dominance ratings, we presented the 30 stimuli in a different random order for each subject, and whether a given subject always rated social or physical dominance first was determined randomly.

2.3.2. Data treatment

Eight or nine subjects rated each stimulus set, and their ratings were averaged to produce mean physical and social dominance ratings for each recording. Thus, each original voice received 10 mean dominance ratings (5 acoustic variations×2 dominance types). Interrater reliability was high (Cronbach's α=.81±.08). Nevertheless, to control for any global differences in subjects' rating tendencies, we first standardized each subject's ratings (converted to z scores) before they were averaged with other subjects' ratings. Standardization did not affect the results.

Effects of F_0 and D_f on dominance ratings were analyzed using repeated measures ANOVA. All p values are two tailed; α = .05.

3. Results

Three factors, each with two levels, were analyzed: *manipulation* (raised vs. lowered), *acoustic measure* (F_0 vs. D_f), and *dominance type* (physical vs. social). In separate Manipulation×Dominance Type repeated measures ANOVAs, both F_0 and D_f negatively affected dominance ratings [main effects of manipulations: F_0: $F(1, 29)$=6.06, p=.020; D_f: $F(1, 29)$=37.40, p<.001]. The effect of D_f manipulation (partial η^2=.56) was greater than the effect of F_0 manipulation [partial η^2=.17; three-way repeated measures ANOVA: Manipulation×Acoustic Measure interaction: $F(1, 29)$=4.32, p=.047].

D_f affected both physical and social dominance [$F(1, 29)$=45.82, partial η^2=.61, p<.001 and $F(1, 29)$=13.12, partial η^2=.31, p=.001, respectively] and affected physical dominance ratings more than it affected social dominance ratings [Manipulation×Dominance Type interaction: $F(1, 29)$=7.92, p=.009; Fig. 1, Table 1]. Similarly, F_0 manipulation tended to affect physical dominance ratings [$F(1, 29)$=7.66, partial η^2=.21, p=.010] more than it affected social dominance ratings [$F(1, 29)$=1.89, partial η^2=.06, p=.180], but this interaction was not statistically significant [$F(1, 29)$=0.92, p=.345; Fig. 1, Table 1].

Table 1
Standardized dominance rating means (S.E.) for D_f and F_0 manipulations

		D_f		F_0	
	n	Increased	Decreased	Increased	Decreased
Physical dominance	30	−.25 (.11)	.19 (.13)	−.01 (.13)	.19 (.13)
Social dominance	30	−.15 (.11)	.10 (.12)	−.01 (.13)	.10 (.11)

4. Discussion

In addition to replicating the finding that vocal masculinity affects dominance perceptions among men (Puts, Gaulin, & Verdolini, 2006), we report three novel results here. First, both D_f and F_0 independently affected attributions of dominance among men. Second, to the degree that our ±1.5 JND manipulations of D_f and F_0 were perceptually similar, D_f appears to have a greater effect than F_0 on dominance ratings. Finally, both acoustic measures tended to more strongly affect attributions of physical dominance than attributions of social dominance, although this difference was significant only for D_f.

These results are likely to have ecological validity. To the extent that men have evolved to assess dominance during verbal interactions, the stimuli used in this study are realistic (men of the raters' age speaking spontaneously to a male competitor), and the within-speaker/between-rater design did not draw attention to the acoustic manipulations. Moreover, the effects of within-subject D_f and F_0 manipulations were observed in the presence of naturally occurring between-subject variation in speech content and extralinguistic features, such as amplitude and aspiration rate. Thus, D_f and F_0 probably affect perceptions of dominance among men in real interactions. This suggests a function for a deep male voice and its anatomical substrates: men's voices evolved to signal physical dominance.

A potential shortcoming of the present study concerns the distinction between physical and social dominance. Henrich and Gil-White (2001) argue persuasively that social influence can be achieved through force or force threat (what we call here physical dominance). Alternatively, deference may be freely given to individuals who possess valued qualities and who would thus be said to enjoy *prestige*. Although our variable "social dominance" in some ways approximates prestige ("is respected, influential, and often a leader"), in other respects, it connotes coercion ("tells other people what to do … assertive"). Thus, depending upon how subjects understood this variable, social dominance may conflate physical dominance (or simply "dominance") and prestige. It is possible that D_f affected ratings of respect, influence, and leadership only because this social status variable suggested the threat of force. On the other hand, subjects were also asked to rate physical fighting ability; hence, they may have understood the leadership variable to differ from this. If so, D_f may have affected this variable because physical competitive ability was a prestigious quality to our subjects. Future research should more clearly distinguish between dominance and prestige.

4.1. What does a masculine voice advertise?

Several lines of evidence suggest a relationship between these acoustic parameters and physical competitive ability. First, both D_f and F_0 may correlate with body size. Some studies have found statistically significant relationships between F_0 and men's height (Graddol & Swann, 1983) and weight (Evans, Neave, & Wakelin, 2006), although most have not (e.g., Collins, 2000; Kunzel, 1989; Lass & Brown, 1978; Rendall et al., 2005; van Dommelen & Moxness, 1995). Similarly, some studies have found relationships between D_f and men's height (Evans et al., 2006; Rendall et al., 2005) and weight (Evans et al., 2006; Gonzalez, 2004), although others have not [Collins, 2000 (neither height nor weight); Gonzalez, 2004 (weight but not height); Rendall et al., 2005 (height but not weight)]. Relatively small sample sizes may account for some of these discrepancies. However, if D_f is developmentally constrained to more closely reflect height than is F_0 (Fitch & Hauser, 1995), this could explain our observation that D_f more strongly affects dominance attributions.

F_0 also appears to correlate negatively with circulating androgens (Dabbs & Mallinger, 1999), which have been positively related to physical aggressiveness (Harris, 1999) and physical prowess (Clark & Henderson, 2003). More generally, it has been suggested that masculine traits such as low D_f and F_0, whose development or maintenance depends on high androgen levels, may be honest signals of health and vigor (Folstad & Karter, 1992). Finally, some aspects of men's voices may reflect self-perceived dominance (Gregory, 1994; Puts, Gaulin, & Verdolini, 2006). For example, men who rate themselves as physically dominant tend to lower their F_0 from baseline when competing, whereas men who rate themselves as nondominant tend to raise it (Puts, Gaulin, & Verdolini, 2006).

4.2. Selection for low male voices versus high female voices

D_f and F_0 may have evolved to exaggerate the appearance of size in men (Fitch & Giedd, 1999; Morton, 1977). This could occur if there were a strong enough correlation between voice and physical prowess for selection to favor deference to masculine voices. However, current utility is insufficient evidence that a trait is an adaptation; there must also be evidence that the trait was modified for this function (West-Eberhard, 1992). Unfortunately, most vocal structures are soft tissue and would not fossilize, and scant data exist on sex differences in primate vocal anatomy. Thus, evolutionary trends in vocal anatomy cannot easily be established by paleontological or comparative means at present.

On the other hand, ontogeny offers clues. Precipitous pubertal changes suggest that men's voices have been modified to sound deeper, with developmental events added to elongate the vocal tract and lengthen and thicken the vocal folds relative to overall body size. Of course, it is also possible that such pubertal changes occurred in both sexes ancestrally and that females subsequently lost these developmental events. This could occur, for example, due to selection for neotenic features in women (e.g., Jones, 1995), which might increase their apparent residual reproductive value. Indeed, men may prefer higher female voices (Collins & Missing, 2003). However, sexual selection tends to be stronger among males in mammals generally and in humans in particular (Daly & Wilson, 1988).

4.3. Male contests versus female choice

Men's voices may have been modified over human evolution to sound deeper, but if so, was the function to increase physical dominance among men or attractiveness to women? In fact, F_0 and D_f seem to signal dominance more effectively than they increase attractiveness. Based on a comparison of effect sizes, simultaneous manipulation of D_f and F_0 affected men's judgments of physical dominance nearly 15 times more than they affected fertile–menstrual phase women's judgments of sexual attractiveness (Puts, Gaulin, & Verdolini, 2006). This does not necessarily imply that men's voices affect mating success primarily through dominance. Voice attractiveness could have a larger effect than voice dominance on men's mating success. However, with age and sociosexuality (attitudes toward uncommitted sex) statistically controlled, physical dominance ratings of a man's spontaneous speech significantly predicted his number of sex partners over the last year, but sexual attractiveness ratings did not (Puts, Gaulin, Verdolini, & Hodges, 2006).

Although more work is needed, these data suggest that men's voices may have evolved as dominance signals, and women secondarily evolved preferences for aspects of men's voices that conveyed information about mate quality. It has been suggested, for example, that men's voices signal genetic quality (Feinberg et al., 2006; Hughes, Harrison, & Gallup, 2002; Puts, 2005), including perhaps, heritable physical competitive ability. Once evolved, female preferences might then have become complementary selection pressures on men's voices.

Acknowledgments

We would like to thank Daniel Fessler and two anonymous reviewers for their helpful comments on the manuscript and Drew Rendall for advice on acoustic manipulations.

References

Clark, A. S., & Henderson, L. P. (2003). Behavioral and physiological responses to anabolic–androgenic steroids. *Neuroscience and Biobehavioral Reviews, 27*(5), 413–436.

Cleveland, T. F. (1977). Acoustic properties of voice timbre types and their influence on voice classification. *Journal of the Acoustical Society of America, 61*(6), 1622–1629.

Collins, S. A. (2000). Men's voices and women's choices. *Animal Behaviour, 60*, 773–780.

Collins, S. A., & Missing, C. (2003). Vocal and visual attractiveness are related in women. *Animal Behaviour, 6*, 997–1004.

Dabbs, J. M., & Mallinger, A. (1999). High testosterone levels predict low voice pitch among men. *Personality and Individual Differences, 27*, 801–804.

Daly, M., & Wilson, M. (1988). *Homicide*. New York: Aldine de Gruyter.

Evans, S., Neave, N., & Wakelin, D. (2006). Relationships between vocal characteristics and body size and shape in human males: An evolutionary explanation for a deep male voice. *Biological Psychology, 72*(2), 160–163.

Feinberg, D. R., Jones, B. C., Law Smith, M. J., Moore, F. R., DeBruine, L. M., Cornwell, R. E., et al. (2006). Menstrual cycle, trait estrogen level, and masculinity preferences in the human voice. *Hormones and Behavior, 49*, 215–222.

Feinberg, D. R., Jones, B. C., Little, A. C., Burt, D. M., & Perrett, D. I. (2005). Manipulations of fundamental and formant frequencies affect the attractiveness of human male voices. *Animal Behaviour, 69*, 561–568.

Fitch, W. T., & Giedd, J. (1999). Morphology and development of the human vocal tract: A study using magnetic resonance imaging. *Journal of the Acoustical Society of America, 106*(3 Pt 1), 1511–1522.

Fitch, W. T., & Hauser, M. D. (1995). Vocal production in nonhuman primates: Acoustics, physiology and functional constraints on 'honest' advertising. *American Journal of Primatology, 37*, 191–219.

Folstad, I., & Karter, A. J. (1992). Parasites, bright males and the immunocompetence handicap. *American Naturalist, 139*, 603–622.

Gaulin, S. J. C., & Boster, J. S. (1985). Cross cultural differences in sexual dimorphism: Is there any variance to be explained. *Ethology and Sociobiology, 6*, 193–199.

Gonzalez, J. (2004). Formant frequencies and body size of speaker: A weak relationship in adult humans. *Journal of Voice, 32*, 277–287.

Graddol, D., & Swann, J. (1983). Speaking fundamental frequency: Some physical and social correlates. *Language and Speech, 26*(Pt 4), 351–366.

Gregory, S. (1994). Sounds of power and deference: Acoustic analysis of macro social constraints on micro interaction. *Sociological Perspective, 37*, 497–526.

Harris, J. A. (1999). Review and methodological considerations in research on testosterone and aggression. *Aggression and Violent Behavior, 4*, 272–291.

Henrich, J., & Gil-White, F. J. (2001). The evolution of prestige: Freely conferred deference as a mechanism for enhancing the benefits of cultural transmission. *Evolution and Human Behavior, 21*(3), 165–196.

Hughes, S. M., Harrison, M. A., & Gallup, G. G. (2002). The sound of symmetry: Voice as a marker of developmental instability. *Evolution and Human Behavior 23*, 173–180.

Jones, D. (1995). Sexual selection, physical attractiveness, and facial neoteny: Cross-cultural evidence and implications. *Current Anthropology, 36*, 723–748.

Kunzel, H. J. (1989). How well does average fundamental frequency correlate with speaker height and weight? *Phonetica, 46*(1–3), 117–125.

Lass, N. J., & Brown, W. S. (1978). Correlational study of speakers' heights, weights, body surface areas, and speaking fundamental frequencies. *Journal of the Acoustical Society of America, 63*, 1218–1220.

Lee, S., Potamianos, A., & Narayanan, S. (1999). Acoustics of children's speech: Developmental changes of temporal and spectral parameters. *Journal of the Acoustical Society of America, 105*(3), 1455–1468.

Marks, L. E., & Gescheider, G. A. (2002). Psychophysical scaling. In H. Pashler, J. Wixted, (Eds.), *Stevens' handbook of experimental psychology* (3rd ed., Vol. 4: Methodology in experimental psychology, pp. 91–138). Hoboken, NJ: John Wiley & Sons.

Morton, E. S. (1977). One the occurrence and significance of motivation—Structural rules in some bird and mammal species. *American Naturalist, 111*, 855–869.

Mueller, U., & Mazur, A. (1997). Facial dominance in *Homo sapiens* as honest signaling of male quality. *Behavioral Ecology, 8*, 569–579.

Puts, D. A. (2005). Mating context and menstrual phase affect women's preferences for male voice pitch. *Evolution and Human Behavior, 26*, 388–397.

Puts, D. A., Gaulin, S. J., Verdolini, K., & Hodges, C. (2006, June 7–11). Is low voice pitch a male dominance display? Paper presented at the 18th Annual Meeting of the Human Behavior and Evolution Society, Philadelphia, PA.

Puts, D. A., Gaulin, S. J. C., & Verdolini, K. (2006). Dominance and the evolution of sexual dimorphism in human voice pitch. *Evolution and Human Behavior, 27*, 283–296.

Rendall, D., Kollias, S., Ney, C., & Lloyd, P. (2005). Pitch (F0) and formant profiles of human vowels and vowel-like baboon grunts: The role of vocalizer body size and voice-acoustic allometry. *Journal of the Acoustical Society of America, 117*(2), 944–955.

Smith, D. R., Patterson, R. D., Turner, R., Kawahara, H., & Irino, T. (2005). The processing and perception of size information in speech sounds. *Journal of the Acoustical Society of America*, *117*(1), 305–318.

Titze, I. R. (2000). *Principles of voice production*. Iowa City, IA: National Center for Voice and Speech.

van Dommelen, W. A., & Moxness, B. H. (1995). Acoustic parameters in speaker height and weight identification: Sex-specific behaviour. *Language and Speech, 38*(Pt 3), 267–287.

West-Eberhard, M. J. (1992). Adaptation. In E. F. Keller, & E. A. Lloyd, (Eds.), *Keywords in evolutionary biology* (pp. 13–18). Cambridge: Harvard University Press.