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EFFECTS OF FOUR VOICE QUALITIES AND FORMANT DISPERSION ON PERCEPTION OF A FEMALE VOICE

Stimuli produced by a female speaker with four different voice qualities - modal, girlish, breathy and creaky - were manipulated to have more or less formant dispersion and were rated on four scales (dominance, attractiveness, sexiness and youthfulness) by men and women. Stimuli with less formant dispersion were rated more dominant and those with more dispersed formants were rated as less dominant. Breathy voice and girlish voice were rated more attractive and sexy. Stimuli with a creaky voice were rated less attractive and sexy, as were stimuli with less formant dispersion. Girlish voices and those with greater formant dispersion were rated as more youthful; creaky voices and those with less formant dispersion were rated as less youthful. There were also gender differences in ratings of attractiveness and youthfulness. Our results suggest that women's voice qualities can affect perceptions of their attractiveness, sexiness and youthfulness. We discuss the implications of these findings in the context of social signaling.

Key words: vocal judgments; female voice; voice qualities; formant dispersion

Introduction

The resonant frequencies of the supralaryngeal vocal tract are called formants, and they vary in speakers in part as a function of vocal tract length. Male speakers typically have longer vocal tract lengths and so produce less dispersed and lower formants than do female speakers, whose formants tend to be higher and more dispersed. Pitch is the perceptual correlate of the fundamental frequency (F0) of a speech signal, and again male speakers, who typically have longer and thicker vocal cords, tend to produce utterances at

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a lower F0 than do female speakers. Thus, these features of the human voice are sexually dimorphic. These differences suggest that the human voice conveys the sex and aspects of the physical characteristics of the speaker that can be relevant in mate choice and determination of status (see Puts, Doll, & Hill, 2014 for a review). Children's formants tend to be even more dispersed than those of women and their F0 is higher as well, so these features also provide information about the age of the speaker.

Although many studies have identified the formant and pitch characteristics that lead listeners to identify qualities such as dominance, attractiveness or sexiness in men's voices, less is known about how women's vocal characteristics affect listeners' judgments for similar qualities. Men's judgments of the sexiness and attractiveness of female voices are often based on features that are associated with youthfulness, such as greater formant dispersion (Puts, Barndt, Welling, Dawood, & Burriss, 2011) or higher pitch (Feinberg, DeBruine, Jones, & Perrett, 2008; Puts, et al., 2011), both of which are associated with young female voices. Whether there are vocal features that distinguish between voices that are considered sexy or attractive and those that are considered merely youthful has been little studied.

Other voice qualities such as creakiness, also known as vocal fry, and breathiness have been little examined. The perception of creaky voice occurs when the vocal folds "open and close abruptly, and remain closed for most of each cycle" (Kreiman & Sidtis, 2011, p. 63), and the perception of breathy voice occurs when the vocal folds close more gradually and "may not close completely at the end of each cycle, so that the voice may also be mixed with unmodulated airflow through the glottis, producing the sound of noise of turbulence" (Kreiman & Sidtis, 2011, p. 64). Some attention has been paid to how listeners interpret breathiness, a voice quality associated with women (Van Borsel, Janssens, & De Bodt, 2009), with respect to voice judgments of sexiness (Batstone & Tuomi, 1981). But the effect of creakiness - a voice quality on the rise in young American women (Mendoza-Denton, 2007; Yuasa, 2010) - on judgments about the dominance, attractiveness, sexiness or youthfulness of the female voice has been largely unexplored. Our goal in this paper is to investigate the effects of these relatively unstudied voice qualities on the perception of a woman's voice in conjunction with one of the more widely explored dimensions that affect those perceptions: formant spacing.

Formant dispersion and pitch

Judgments of the function of formant dispersion and pitch on the perception of dominance have been extensively studied, but primarily in men's voices. In general, researchers have found that judgments of dominance are associated with low pitch (Apicella, Feinberg, & Marlowe, 2007; Feinberg, Jones, Law Smith, Moore, DeBruine, Cornwell, Hillier, & Perretta, 2006; Fraccaro, O'Connor, Re, Jones, DeBruine ,& Feinberg, 2013; Jones, Feinberg,

DeBruine, Little, & Vukovic, 2010) and with closely spaced formants; as noted above, the latter correlates with longer supralaryngeal vocal tract length and greater physical size. Although Feinberg, Jones, Little, Burt, & Perrett (2005) found F0 to have a greater effect on judgments of the attractiveness of male voices than formant dispersion, in contrast, other researchers have found that closer formant spacing contributes more to listeners' attractiveness, size, and masculinity judgments (Pisanski & Rendall, 2011) or to dominance judgments (Puts, Hodges, Cárdenas, & Gaulin, 2007) than the F0 of the male voice. Feinberg et al.'s failure to find an effect of formant dispersion is likely due to the fact that the changes made to the formants in that study were below just noticeable differences (Pisanski & Rendall, 2011). Although less studied in women than in men, research on listeners' perception of dominance in women's voices shows that, as in the case of men's voices, vocal dominance is associated with lower pitch (Borkowska & Pawlowski, 2011; Fraccaro, et al., 2013; Jones, et al., 2010) and generally masculinized voices, manipulated to have both lower pitch and less formant dispersion (Feinberg, et al., 2006).

In terms of attractiveness, as with judgments of dominance, listeners perceived men's voices to be attractive or pleasant when they had a low F0 (Bruckert, Liénard, Lacroix, Kreutzer, & Leboucher, 2006; Collins, 2000; Feinberg, Jones, Little, Burt, & Perrett, 2005), although some researchers found that both normal pitched and lower pitched men's voices were attractive (Fraccaro, Jones, Vukovic, Smith, Watkins, Feinberg, Little, & Debruine, 2011; Riding, Lonsdale, & Brown, 2006). Again, voices with less dispersed formants were also judged to be more attractive (Collins, 2000). Furthermore, some researchers have noted that male vocal attractiveness is associated with perceived male dominance (Berry, 1992) and greater reproductive success (Apicella, et al., 2007; Hughes, Dispenza, & Gallup, 2004; Puts, 2005).

Judgments of the sexiness of men's voices are also generally associated with voices with lower fundamental frequencies (Daniel & McCabe, 1992). Men who were attempting to sound sexy (Tuomi & Fisher, 1979) or who were judged to be successful seducers (Anolli & Cicero, 2002) spoke with more pitch excursion and lowered their pitch over time, although Daniel and McCabe (1992) found that mid-pitched male voices were rated the sexiest. In contrast, women rated men's voices with high F0 and greater formant spacing as less attractive than those with low pitch and less formant spacing, possibly because these voices are associated with youthfulness in male voices (Feinberg, et al., 2005).

As is the case with men's voices, judgments of female vocal attractiveness were more influenced by formant spacing than by F0 (Pisanski & Rendall, 2011; Puts, et al., 2011), in this case with greater formant dispersion, which correlates with their smaller physical size. Wider formant spacing in women is also correlated with youthfulness. The findings on the relationship between

attractiveness and pitch in women's voices are mixed. In several studies, male listeners' perception of vocal attractiveness in women is associated with higher-pitched voices (Borkowska & Pawlowski, 2011; Collins & Missing, 2003; Fraccaro, et al., 2013), but other work has found that female listeners' judgments of vocal attractiveness in women are associated with voices with normal rather than high or low pitch (Fraccaro, et al., 2013).

The findings on sexiness and pitch in women's voices are also mixed. Some studies indicate that both men and women think that low pitch is sexy, because both lower the F0 of their voices when asked to sound seductive (Tuomi & Fisher, 1979) and speak in a lower pitch to attractive opposite-sex listeners (Hughes, Farley, & Rhodes, 2010), although Fracarro, et al., (2011) found that women raised their pitch instead. Farley, Hughes, & LaFayette (2013) found that women lowered voice pitch when speaking to their current romantic partners, and such voices were also judged to be sexier than those used when talking to friends. But men in that study actually raised their pitch when speaking to partners. This gender difference might have been due to vocal accommodation to one's interaction partner, possibly to signal affection and connection. Daniel & McCabe (1992) found that men and women label mid-pitched voices as most sexy, and men but not women found high-pitched women's voices to be sexy as well. Low-pitched women's voices were rated as least sexy. However, their values for women's F0 in the low range (175.2-183.5 Hz) were considerably lower than the low values for Farley et al. (2013) (approximately 225 Hz). The latter were, in fact, closer to Daniel and McCabe's high values (226.6 to 229.2 Hz), so the difference in the results may be due how specific pitch ranges are labeled by researchers.

In general, women's voices are more attractive to men when they are perceived to be younger, i.e., when they have a higher pitch and greater formant spacing (Puts, et al., 2011). As noted above, however, women tend to prefer female voices with a normal pitch, so youthful voice characteristics like high pitch are not uniformly associated with attractiveness judgments across genders. Also, youthfulness in the female voice is associated less with dominance than is youthfulness in the male voice (Berry, 1992).

As this review indicates, most of the literature looking at perceptions of vocal characteristics of men's and women's voices has focused mainly on the effects of F0 and formant spacing. But other vocal characteristics can also contribute to perceptions of dominance, attractiveness, sexiness or youthfulness.

Other voice qualities: creakiness, breathiness and girlishness

The voice quality normally used by a speaker is known as modal voice, but speakers can modify their voice quality in several ways to change how listeners perceive them (see Pisanski, Cartei, McGettigan, Raine, & Reby, 2011 for a summary of studies on voice modulation). For example, speakers can make

adjustments to their vocal folds during phonation to make their voices sound breathy or creaky (Crystal & Quirk, 1964). Also, women can make their voices sound more girlish and men can make theirs sound more boyish by raising their second formants through the use of tongue fronting (Ladefoged & Harshman, 1979). Such effects are enhanced when speakers raise their pitch as well. Although changes in voice quality can be used to signal linguistic differences such as differences in meaning (e.g., Gordon & Ladefoged, 2001), voice qualities such as creaky, breathy, and girlish or boyish voice may also serve to signal social or physical characteristics, such as dominance, attractiveness, sexiness or youthfulness.

The use of creaky voice, also known as glottal fry, in young American women has received a great deal of attention recently in the popular press, with articles appearing in the New York Times (Quenqua, 2012) and the Chicago Tribune (Hageman, 2013), among others. Wolk, Abdelli-Beruh, and Slavin (2012) found it to be a common voice quality in young English-speaking women, and Yuasa (2010) found that the use of creaky voice in young Californian women was greater than that found in the speech of young Japanese women or young Californian men. Abdelli-Beruh, Wolk, and Slavin (2014) found that it was also less common in American males.

The recent increase in the use of creaky voice by young women may be due to its social signaling functions. Researchers have attributed several different social functions to the use of creaky voice. In early studies, investigators noticed that it was used by upper-class men in the United Kingdom to indicate their superior social status (Esling, 1978; Hendon & Bladon, 1988). Pittam (1987) also found it to be characteristic of Australian males rather than females. These early studies of the use of creaky voice generally interpreted it as indicating masculinity or authority. The more recent use by young women of creaky voice has been described by Yuasa as "hesitant, nonaggressive and informal, but also educated, urban-oriented and upwardly mobile" (2010, p.315). Other studies have suggested that its use in women is linked to toughness (Mendoza-Denton, 2007). To the extent that it is heard as masculine or tough, creaky voice is likely to lower the ratings of the attractiveness of women's voices. On the other hand, it may also contribute to judgments of dominance in women's voices, given its association with authority. Whether the presence of creaky voice among young women is widespread enough to have become associated with youthfulness in the female voice is another open question.

Breathy voice can communicate intimacy (Laver, 1980) or sexiness (Crystal, 1975). Indeed, Henton and Blandon (1985) suggest that breathiness signals intimacy because it is associated with the sound of sexual arousal. Kreiman and Sidtis (2013) argue that breathiness is one of several features that contribute to a stereotypically sexy voice, which include, in addition, extreme intonation contours and slow speaking rate. They note that sexy women's voices can either be high pitched, a characteristic associated with youthfulness, or low

pitched, associated with maturity. Not many studies have directly examined the effects of breathiness on judgments of women's voices, however. Although breathy women's voices have been rated as more feminine (Van Borsel, et al., 2009), at least one study did not find that breathiness in women's voices was associated with judgments of sexiness (Batstone & Tuomi, 1981), although Hughes, Mogilski, and Harrison (2014) did find that women lowered the pitch of their voices and made them hoarser sounding when trying to sound sexy or attractive.

The current study

Our study was designed to explore the effect of these less studied voice qualities, in conjunction with one of the components that has received more attention in the literature on vocal judgments, that of formant dispersion or spacing. We sought to develop a set of stimuli from a single speaker that would show the full range of voice qualities, but would allow us to keep the formant pattern relatively stable, so as to avoid differences in judgment based on different vocal tract sizes. Our only manipulation of these natural utterances was to modify the formants acoustically so as to increase their dispersion and make the voice sound as though it came from a smaller person, or to decrease their dispersion and make the voice sound as if it came from a larger person. We then elicited judgments from female and male listeners of the dominance, attractiveness, sexiness and youthfulness of the various voice types of the selected female speaker.

We expected to replicate generally the effects of formant spacing on judgments of dominance, attractiveness, sexiness and youthfulness: Stimuli with more dispersed formants should be judged as more sexy, attractive and youthful than those with the original formants, and those with less dispersed formants should be judged less sexy, attractive and youthful. In contrast, those stimuli with less dispersed formants should be judged more dominant and those with more dispersed stimuli should be judged less dominant.

In terms of voice qualities, we predicted that girlish voices as compared to modal voices would be rated as more youthful and attractive, but as less dominant. Whether girlish voices would be perceived as sexy compared to modal voice was less certain, since they can also be perceived as more childlike. We predicted that stimuli with creaky voice would be rated more dominant and less attractive or sexy than those with modal voice. Whether creaky voice has begun to be associated with youthfulness was not clear. Finally, we predicted that stimuli with breathy voice would be judged sexier and perhaps also more attractive than modal voice, since breathy voice has been found to make voices sound more feminine.

We predicted that the pattern of relationships between the voice qualities and the dominance scale would be very different from that observed with the other three scales. In women's voices, whatever voice qualities elicit

higher ratings for dominance should be judged to be *lower* in attractiveness, sexiness, and youthfulness. We were also interested in exploring whether judgments of youthfulness paralleled those of sexiness and attractiveness, i.e., whether attractive and sexy voices are just those that sound young. Finally, although we did not have specific predictions about gender differences, we were interested in exploring these differences in our data. Although there are few investigations or reports of gender differences in voice ratings in the literature, we wanted to see if there were any indications that women are more or less sensitive than men to cues for the voice attributes we were studying.

Methods

Participants

Participants were recruited from an announcement on the Mechanical Turk service from Amazon.com. Only participants from the United States who successfully completed 95% or better of their previous tasks were included in the pool. One hundred and one participants completed the study. Since it is not clear that those with a non-heterosexual orientation would respond in the same way to male and female voices as those with a heterosexual orientation, only heterosexual subjects were included, which eliminated 6 participants (four women and two men). Data were analyzed from the remaining 95 participants (Males = 56), who were paid for their participation. Twenty-four percent of the subjects were between 18 and 25 years of age, 46% were between 26 and 35, 16% were between 36 and 45, 7% were between 46 and 55 and 8% were over 56 years old. Participants were 84% Caucasian, 10% African-American and 6% Asian. The protocol for this study was approved by the institutional review board.

Stimuli

In order to develop our natural stimuli from a single speaker, we began by recruiting four college-age women to record a series of vowels (/a/, /i/ and /u/), words, sentences, and a short passage. They were paid $20 for their participation. They produced each utterance multiple times in one of four voice types that were described to them as "your normal voice" (modal) and "breathy," "creaky" or "girlish." Audio clips of a breathy, creaky and girlish female /a/ were produced by one of the authors, a trained phonetician. The clips were provided as models the first time the participants were asked to record the vowels with those types of phonation. (See supplemental materials for examples.) The participants' utterances were recorded directly into PRAAT (Boersma & Weenink, 2013) at 44.1 KHz using a Logitech USB Desktop Microphone. Only tokens of the vowel /a/ were used in this experiment.

The recordings of one woman were discarded because she failed to consistently pronounce the vowel sounds correctly. From each of the other three women,

we selected one /a/ vowel from each of the four voice categories (modal, breathy, creaky and girlish), such that the vowel pronunciation was consistent and each of the categories was easy to identify perceptually. We then did acoustic analyses and pilot testing of the stimuli.[1] Each vowel was analyzed for duration, mean amplitude, mean F0, the frequency of the first three formants, and the amplitude of the first harmonic minus the amplitude of the first formant peak (H1-A1). The latter measure can be used as a marker of breathiness (positive values) and creakiness (negative values), with modal (normal) phonation values in between the other two (Gordon & Ladefoged, 2001). Our pilot testing indicated that the utterances from one of the three women received significantly different ratings than the other two speaker's voices from both men and women for each of the four dimensions we were investigating, so we excluded her utterances from further consideration. For the utterances of the remaining two speakers, the acoustic measurements indicating differences in breathiness and creakiness were more consistent in one set than in the other, so we chose to use that speaker's /a/ syllables for this study. Her breathy /a/ had a positive H1-A1 value of 11.9 and the creaky voice /a/ gave the lowest value, -10.6. The values for girlish voice and modal voice were between -1.5 and -7.2, as expected. This study is thus an investigation of the voice qualities of a single woman. As our pilot results and other research indicate, the voices of other women may express these qualities differently and may be perceived differently by listeners.

Pilot testing also indicated that participants responded strongly to differences in the intensity of the syllables, so we normalized all the syllables for mean intensity in PRAAT. We also determined that the utterances produced when our speakers were asked to speak in a girlish voice did have a higher second formant than their normal voices, but since we also wanted to examine the effect of formant spacing in general on participants' judgments of all types of voices, we made two adjustments to each of the four /a/ syllables using the formant shift ratio function in PRAAT. In one case the formants were more dispersed, using a ratio of 1.1 to produce a voice that sounded as though it came from a smaller person. In the other their dispersion was reduced, using a ratio of .9, in order to make the speaker sound larger. None of the formant manipulations created voices that sounded masculine as opposed to feminine, since research has shown that both the F0 and the formant spacing need to be adjusted in order to make voices sound as though they had changed gender (Hillenbrand & Clark 2009). See Table 1 for the mean F0, formant values for F1, F2 and F3, and H1-A1 values for the four original syllables.

[1] We originally recorded our participants' productions of vowels in the upper and lower ranges of their normal pitches, but the variability of the F0 in these natural productions led us to eliminate them from our study.

Table 1. Acoustic Measures for the Twelve Original Syllables

Voice Type	F0 Mean	F1	F2	F3	H1-A1
Modal	221	748	1253	3280	-7.2
Girlish	217	888	1476	3371	-1.5
Breathy	216	871	1404	3227	11.9
Creaky	179	756	1367	3081	-10.6

Procedure

After completing the consent form, participants were asked to answer a series of demographic questions, including their gender, age, and relationship status. They were also asked to indicate whether they were using headphones to listen to the stimuli. Approximately 90% of the participants used headphones. In the main part of the study, for each trial, they were instructed to click on the play button to listen to the sound clip and then to answer the question for that trial. For each trial, they heard one of the 12 /a/s and were asked to rate it on a scale of 1-to-9 for dominance, attractiveness, sexiness or youthfulness. The 1 represented an absence of the quality (e.g., not dominant) and the 9 represented an unconditional degree of that quality (e.g., dominant). Participants were instructed to pay close attention to the voice and to use the whole range of the scale in their responses. The order of presentation of the questions was randomized. At four points in the session, participants were asked to identify the scale that had been used in the question before last. These attention questions were inserted in order to make sure participants were not just clicking through the questions without thinking about them. Subjects had to get 3 out of 4 attention questions correct in order to be included in the sample.

Results

We first conducted a MANOVA on the data from our 95 participants, with two between subject variables, gender and relationship status (single or in a relationship), and four within subject variables: scale (dominance, attractiveness, sexiness, youthfulness) voice quality (modal, girlish, breathy, creaky), and formant spacing (original, young, old). Since scale was a significant effect, $F(3,89) = 7.48$, $p < .0001$, we analyzed the data for each scale separately. Relationship status was not a significant main effect, nor did it enter into any significant interactions in the MANOVA, so it was eliminated as a factor in the separate ANOVAs. Only main effects and interactions that were significant in the MANOVA are reported in the individual ANOVAs for each scale.

For each ANOVA there was thus one between subject variable, gender, and two within subject variables: four levels of voice quality (modal, girlish, breathy and creaky) and three levels of formant spacing (more dispersed, original and less dispersed).

Mauchly's test indicated that the assumption of sphericity was violated in nearly all the univariate tests. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity.

Dominance

For the dominance ratings, there was a significant main effect of formant spacing, $F(1.84, 170.77) = 19.13$, $p < .0001$, partial $\eta^2 = .17$. Tests of the two a priori hypotheses comparing stimuli with more and less dispersed formants to the originals were conducted with Bonferroni-adjusted alpha levels of .025 (.05/2). Results indicated that the ratings for the /a/s with less dispersed formants ($M = 4.02$, $SE = .15$) gave the highest dominance scores and were significantly different from the ratings of the /a/s with the original formants ($M = 3.68$, $SE = .13$), $F(1,93) = 10.95$, $p = .001$, partial $\eta^2 = .11$. Ratings of /a/s with the original formants were also significantly different from those with more dispersed formants ($M = 3.36$, $SE = .10$), $F(1,93) = 11.30$, $p = .001$, partial $\eta^2 = .11$. See Table 2.

Table 2. Mean Ratings by Scale for More Dispersed, Original and Less Dispersed Formants

Scale	Formants		
	More Dispersed	**Original**	**Less Dispersed**
Dominance	3.36*	3.68	4.02*
Attractiveness	4.39	4.44	3.56*
Sexiness	4.35	4.31	3.32*
Youthfulness	5.57*	4.78	3.95*

Note: * ratings were significantly different from those for the original formants, p<.001 or better.

There was no main effect of voice quality.

There were three significant two-way interactions, two of which included gender as a factor, formant spacing by gender, $F(1.84, p = .007, 170.77) = 5.35$, $\eta^2 = .05$, and voice quality by gender: $F(2.31, 214.60) = 3.45$, $p = .027$, partial $\eta^2 = .04$. For formant spacing by gender, post-hoc t-tests using the Bonferroni adjustment for multiple comparisons showed a marginal effect ($p = .08$) for women rating less dispersed formants as more dominant ($M = 4.28$) than did men ($M = 3.77$). For voice quality by gender, post-hoc t-tests using the Bonferroni adjustment for multiple comparisons showed a marginal effect ($p = .07$) for women rating creaky voices ($M = 4.11$) as more dominant than men did ($M = 3.46$).

The remaining two-way interaction was voice quality by formant spacing, $F(5.06, 470.17) = 4.31$, $p = .001$, partial $\eta^2 = .04$. Since we did not have predictions for how these two factors would interact and this interaction is incidental to the primary concerns of our study, we included a table with the means in the supplementary materials.

Attractiveness

For the attractiveness ratings, formant spacing was a significant main effect, $F(1.79, 166.04) = 33.09$, $p < .0001$, partial $\eta^2 = .27$. Tests of the two a priori hypotheses comparing stimuli with more and less dispersed formants to the originals were conducted with Bonferroni adjusted alpha levels of .025 (.05/2). The /a/s with the original formants were rated most attractive ($M = 4.44$, $SE = .10$), and planned comparisons indicated that those ratings were significantly different from those with the less dispersed formants ($M = 3.56$, $SE = .11$), $F(1,93) = 59.16$, $p < .0001$, partial $\eta^2 = .40$. There was no significant difference between the ratings of the /a/s with the original formants ($M = 4.44$, $SE = .10$) and those to the more dispersed formants ($M = 4.39$, $SE = .13$). See Table 2.

Voice quality was also a significant main effect, $F(2.45,228.13) = 230.17$, $p < .0001$, partial $\eta^2 = .71$ Breathy voices were rated the highest ($M = 5.70$, $SE = .16$), followed by girlish ($M = 5.27$, $SE = .15$) and then creaky ($M = 1.93$, $SE = .12$) voice. Tests of the three a priori hypotheses comparing stimuli with girlish, breathy and creaky voice to those with modal voice were conducted with Bonferroni adjusted alpha levels of .017 (.05/3). The planned comparisons indicated that ratings of breathier voices were significantly different than those for modal voice ($M = 3.63$, $SE = .12$), $F(1,93) = 175.84$, $p < .0001$, partial $\eta^2 = .65$. Ratings of girlish /a/s were significantly different from those for modal voice, $F(1,93) = 198.24$, $p < .0001$, partial $\eta^2 = .68$, and ratings of /a/s with creaky voice were also significantly different from ratings of /a/s with modal voice: $F(193) = 121.84$, $p < .001$, partial $\eta^2 = .57$. See Table 3.

Table 3. Mean Ratings by Scale for Voice Quality

Scale	Voice Quality			
	Modal	**Girlish**	**Breathy**	**Creaky**
Dominance	3.77	3.63	3.56	3.78
Attractiveness	3.63	5.27*	5.70*	1.93*
Sexiness	3.20	4.53*	6.04*	2.20*
Youthfulness	5.18	5.84*	5.00	3.05*

Note: * * ratings were significantly different from those for modal voice, p<.0001.

There were two significant two-way interactions, one of which involved gender, i.e., voice quality by gender, $F(2.45, 208.13) = 6.80$, $p = .001$, partial

$\eta^2 = .07$. Post-hoc t-tests using the Bonferroni adjustment for multiple comparisons revealed that women rated girlish voices as more attractive ($M = 5.69$) than the men did ($M = 4.84$), $p = .005$. See Figure 1.

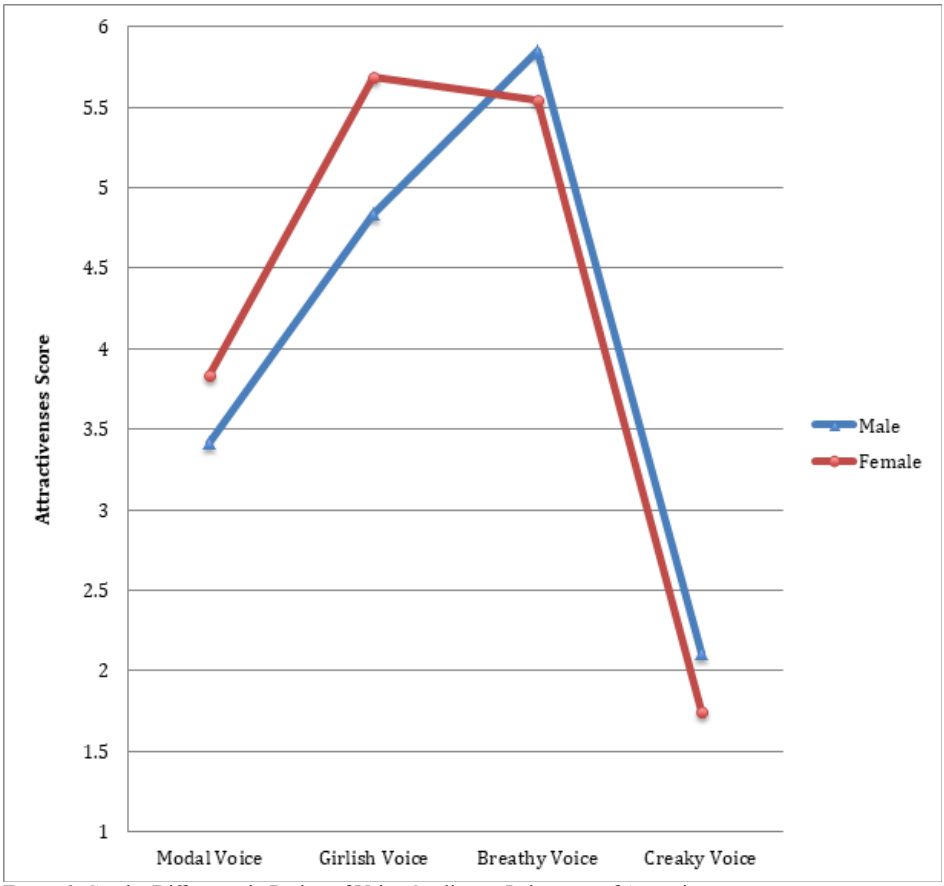

Figure 1. Gender Difference in Rating of Voice Quality on Judgments of Attractiveness.

The remaining two-way interaction was voice quality by formant spacing, $F(5.23, 486.28) = 30.06$, $p < .0001$, partial $\eta^2 = .24$. Since we did not have predictions for how these two factors would interact and this interaction is incidental to the primary concerns of our study, we included a table with the means in the supplementary materials.

Sexiness

For sexiness ratings, formant spacing was a significant main effect, $F(1.53, 142.56) = 37.64$, $p < .0001$, partial $\eta^2 = .29$. Tests of the two a priori hypotheses comparing stimuli with more and less dispersed formants to the originals were conducted with Bonferroni adjusted alpha levels of .025 (.05/2). The stimuli with more dispersed formants were rated the most sexy ($M = 4.35$, $SE = .15$). Planned comparisons indicated that those ratings were

not significantly different from ratings of the /a/s with the original formants (M = 4.31, SE = .11). The least sexy were /a/s with the less dispersed formants (M = 3.32, SE = .12). These ratings and those for /a/s with the original formants were significantly different, $F(1,93) = 86.38$, $p < .0001$, partial $\eta^2 = .48$. See Table 2.

Voice quality was also a significant main effect for the sexiness scale, $F(2.65,254.60) = 196.91$, $p < .0001$, partial $\eta^2 = .68$. Tests of the three a priori hypotheses comparing stimuli with girlish, breathy and creaky voice to those with modal voice were conducted with Bonferroni adjusted alpha levels of .017 (.05/3). Breathy voices were rated the highest (M = 6.04, SE = .17), and planned comparisons indicated that those ratings were significantly different to those for modal voice (M = 3.20, SE = .13), $F(1,93) = 288.93$, $p < .0001$, partial $\eta^2 = .76$. Girlish voices were rated next highest for sexiness (M = 4.53, SE = .15). Those ratings were significantly different to those for modal voice (M = 3.20, SE = .13), $F(1,93) = 96.75$, $p < .0001$, partial $\eta^2 = .51$. Finally, creaky voice was rated least sexy (M = 2.20, SE = .13). Those ratings were also significantly different to those for modal voice (M = 3.20, SE = .13), $F(1,93) = 121.84$, $p < .0001$ partial $\eta^2 = .32$. See Table 3.

There was one significant two-way interaction for sexiness, voice quality by formant spacing, $F(5.17, 480.57) = 10.41$, $p < .0001$, partial $\eta^2 = .10$. Since we did not have predictions for how these two factors would interact and this interaction is incidental to the primary concerns of our study, we included a table with the means in the supplementary materials.

Youthfulness

For the youthfulness ratings, formant spacing was a significant main effect, $F(1.59, 148.17) = 104.05$, $p < .0001$, partial $\eta^2 = .53$. Tests of the two a priori hypotheses comparing stimuli with more and less dispersed formants to the originals were conducted with Bonferroni adjusted alpha levels of .025 (.05/2). The stimuli with more dispersed formants were rated more youthful (M = 5.57, SE = .11), and planned comparisons indicated that those ratings were significantly different from ratings of /a/s with the original formants (M = 4.78, SE = .10), $F(1,93) = 68.31$, $p < .0001$, partial $\eta^2 = .42$. Ratings of /a/s with less dispersed formants were rated the least youthful (M = 3.95, SE = .13), and those ratings were significantly different from ratings of /a/s with the original formants (M = 4.78, SE = .10), $F(1,93) =$ = 70.85, $p < .0001$, partial $\eta^2 = .43$. See Table 2.

Voice quality was also a significant main effect, $F(2.56, 237.54) = 100.10$, $p < .0001$, partial $\eta^2 = .52$. Tests of the three a priori hypotheses comparing stimuli with girlish, breathy and creaky voice to those with modal voice were conducted with Bonferroni adjusted alpha levels of .017 (.05/3). Ratings of girlish voices were rated the highest for youthfulness (M = 5.84, SE = .12), and planned comparisons indicated that those ratings were significantly different

from ratings of /a/s with modal voice (M = 5.18, SE = .14), $F(1,93) = 21.82$, $p < .0001$, partial $\eta^2 = .19$. Planned comparisons indicated that there was no significant difference between ratings of breathy /a/s (M = 5.00, SE = .13) and modal /a/s (M = 5.18, SE = .14). The ratings of /a/s with creaky voice indicated that they were rated the lowest for youthfulness (M = 3.05, SE = .17), and planned comparisons indicated that those ratings were significantly different from ratings of /a/s with modal voice (M = 5.18, SE = .14), $F(1,93) = 142.27$, $p < .0001$, partial $\eta^2 = .61$. See Table 3.

There were two significant two-way interactions for youthfulness. The first was voice quality by gender, $F(2.55, 237.54) = 3.32$, $p = .027$, partial $\eta^2 = .03$. Post-hoc t-tests using the Bonferroni adjustment for multiple comparisons revealed that women rated modal voice (M = 5.44) as more youthful then men (M = 4.91), $p = .05$. See Figure 2.

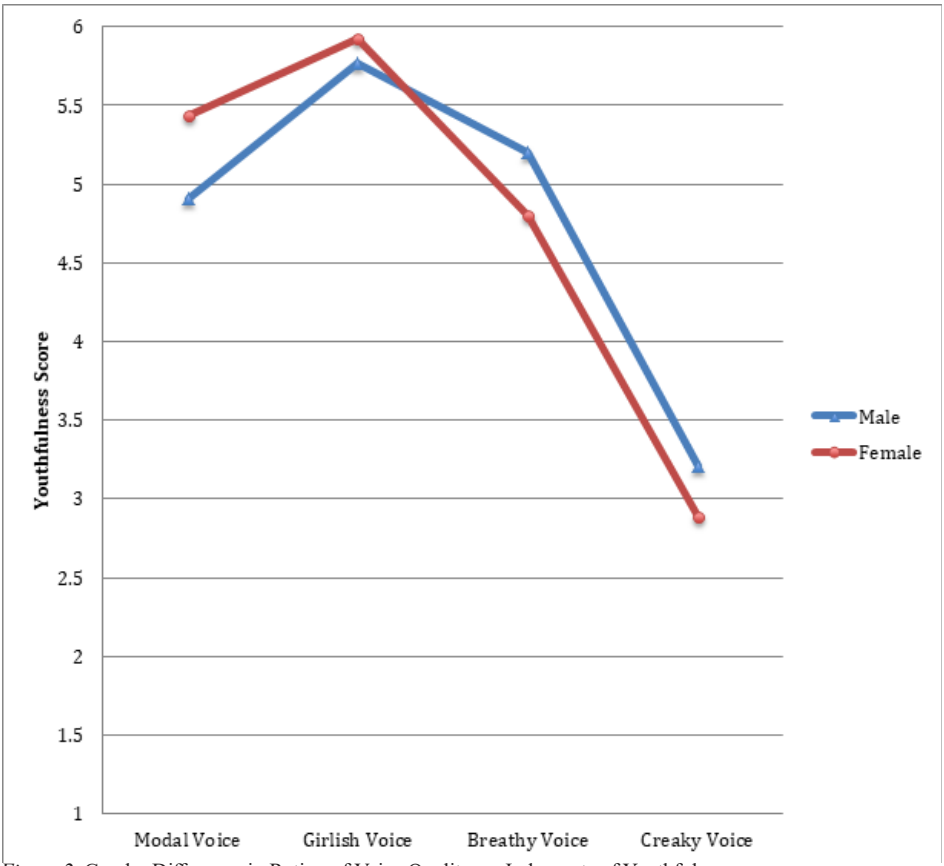

Figure 2. Gender Difference in Rating of Voice Quality on Judgments of Youthfulness.

The other significant two-way interaction was voice quality by formant spacing, $F(5.46, 507.58) = 7.85$, $p < .0001$, partial $\eta^2 = .08$. Since we did not have predictions for how these two factors would interact and this interaction

is incidental to the primary concerns of our study, we included a table with the means in the supplementary materials.

Discussion

The effects of formant spacing on judgments of dominance were largely as predicted: /a/s with less dispersed formants were rated more dominant than those with the original formants, and those with more dispersed formants were rated less dominant than those with the original formants. In addition, female listeners showed a tendency to rate voices with less dispersed formants as more dominant than male listeners did. Although we predicted that creaky voice would contribute to higher ratings of dominance, only women showed a tendency to rate creaky voice higher for dominance than men did. Since the use of creaky voice appears to be more on the rise among young American women as compared to young men (Abdelli-Beruh, et al., 2014; Yuasa, 2010), using it to signal authority and the ability to recognize that signal may be gender linked, a possibility that future studies could explore.

Like the dominance ratings, the attractiveness ratings showed a significant effect of the formant dispersion manipulation, although only more masculinized voices (those with less dispersed formants) were judged significantly less attractive than the /a/s with the original formants. There was no difference in ratings of the /a/s with the more dispersed and the original formants, as we had predicted, even though greater formant dispersion as is found with youthful voices has also been associated with higher attractiveness ratings (Puts, et al., 2011), and our manipulation of the formants exceeded the threshold for perceptual detection (Pisanski & Rendall, 2011). Since the stimuli with more dispersed formants were, in fact, rated more youthful than those with the original formants (see below), it may be that there is a limit to the contribution that perceived youthfulness can make to judgments of attractiveness. As we predicted, creaky voice significantly decreased ratings of attractiveness as compared to modal voice. Also as predicted, breathiness and girlishness were rated as more attractive than modal voice. We also found that women rated girlish voices significantly higher for attractiveness than did men. Since there was no gender difference in women's and men's ratings of girlish voice with respect to sexiness, it may be the case that women and men have slightly different interpretations of attractiveness as compared to sexiness, a possibility that future research could explore.

The results for sexiness were quite similar to those we found for attractiveness. Again, unlike the dominance rating results but like the attractiveness ratings results, stimuli with less dispersed formants were rated as significantly less sexy than those with the original formants, but there was no difference in the ratings between /a/s with the original or more dispersed formants, unlike our prediction. Also similar to the attractiveness ratings, creaky voice, as

predicted, significantly decreased ratings of attractiveness as compared to modal voice. Breathy and girlish voices were rated sexier, as predicted, when compared to modal voice. Since breathiness has been associated with feminine voices (Van Borsel, et al., 2009) and with intimacy (Laver, 1980), it makes sense that listeners would find that voice quality sexier and more attractive. Some actresses are known for their husky, breathy, low voices, such as Scarlett Johansson and Kathleen Turner. Indeed, this type of voice is considered stereotypically sexy in our society (Karpf, 2006).

Finally, the pattern of results for youthfulness was somewhat different than that for attractiveness and sexiness. As predicted, both formant spacing manipulations were significantly different from the original. Stimuli with less dispersed formants were rated as less youthful than those with the original formants, and stimuli with more dispersed formants were rated as more youthful. In terms of other voice qualities, girlish voices were, as predicted, rated significantly higher for youthfulness when compared to modal voice. Although we did not predict it, ratings for creaky voices were significantly lower than those to modal voices. Ratings of modal voice and breathy voice did not differ; however, women rated modal voice as significantly more youthful than did men, suggesting that there may be a gender difference in the way that age is assessed by voice. Given the differences in which the formant dispersion clues and the voice quality clues were interpreted for judgments of youthfulness as compared to those for attractiveness and sexiness, our data suggest that youthful voice characteristics do not necessarily improve ratings of attractiveness or sexiness.

Our prediction that dominance ratings would be lower for vocal traits that gave higher ratings for attractiveness, sexiness, and youthfulness was only partly supported. There were no main effects of voice quality for dominance, so our predictions that creakiness would increase dominance ratings and girlishness reduce them were not supported in our data. Only one of the formant dispersion manipulations was significant and in the opposite direction from dominance in the attractiveness and sexiness scales. Both formant manipulations were effective in changing the ratings on the dominance and youthfulness scales, although in opposing ways, which suggests that judgments of dominance and youthfulness are more closely tied to cues for speaker size than attractiveness and sexiness. Formant spacing in vocalizations is a cue that animals use to assess the size of potential rivals (e.g., Charlton, Whisson, & Reby, 2008). This cue is very old in evolutionary terms, and it appears to be a generally reliable source of information, even though there is evidence that it can be volitionally manipulated by male and female speakers in ways that affect listeners' perception of body size (Pisanski, Mora, Pisanski, Reby, Sorokowski, Frackowiak, & Feinberg, 2106).

Voice quality cues, however, appear to be learned associations for the most part, used for either social signaling or linguistic purposes. When voice qualities

are used primarily for social signaling rather than for linguistic distinctions, the ways in which they influence listener judgments of how dominant, attractive, sexy or youthful a voice sounds would presumably be quite different for listeners who have been exposed to their use as opposed to those who have not. It would be interesting to see, for example, how participants from a country like Japan, where the use of vocal fry may be less prevalent among women (Yuasa, 2010), assess the kind of stimuli used in this study. A voice quality such as breathiness can also be used for indicating a linguistic distinction in a language such as Gujarati (Esposito & Khan, 2012). But even linguistic use of such a cue, if differences in its exploitation are associated with class differences, might contribute to mate selection, since researchers have shown that linguistic dialect features of men's speech, such as accent differences, can, along with F0, influence women's assessment of the speaker's socioeconomic status and appeal as a mate (O'Connor, Fraccaro, Pisanski, Tigue, O'Donnell, & Feinberg, 2014). O'Connor et al. (2014) found that whereas both voice pitch and dialect affected perception of socioeconomic status, a high status accent enhanced the socioeconomic perception of low pitch, but low pitch did not change the status perceptions of the dialects. As there was a significant interaction of voice quality and formant dispersion for each of our scales (see supplemental information), further exploration of how voice qualities can affect judgments of dominance, attractiveness, sexiness and youthfulness in the context of older evolutionary cues such as formant dispersion is clearly warranted.

In summary, our results provide some new insights as to how female voices are judged and how voice qualities such as breathiness, creakiness, and girlishness affect listeners' judgments of women's, attractiveness, sexiness and youthfulness. They also suggest that changes to formant dispersion may have more consistent effects on ratings of dominance and youthfulness than on those of attractiveness and sexiness. The patterns of ratings for judgments of sexiness and attractiveness tended to be similar, indicating that perceptions of attractiveness are influenced by the same voice qualities that contribute to perceptions of sexiness. Both scales differed somewhat from judgments of youthfulness, indicating that what is perceived to be attractive and sexy in a female voice is not due simply to perceptions of youthfulness.

The current study has a number of limitations that could be eliminated in future research. Our study used stimuli from a single female speaker. It would be important to replicate these findings with stimuli from multiple female speakers, because there are individual differences in how voices are produced and listeners may perceive these differences in ways that could reveal somewhat different patterns for the qualities we explored. In addition, it would be useful to develop similar stimuli from male speakers to see to how these voice quality differences are interpreted as signs of dominance, youthfulness, attractiveness or sexiness. Finally, future experiments with larger groups of

male and female listeners may provide clearer evidence for some of the patterns of gender differences that we found in our study.

Variations in voice qualities such as creakiness or breathiness can signal social status (Hendon & Bladon, 1988; Esling, 1978; Yuasa, 2010) or make speakers sound masculine (Pittam, 1987) or feminine (Henton & Blandon, 1985; Van Borsel, et al., 2009). These variations can serve purposes related to social influence or mate attraction. The current study investigated voice qualities that have been little studied and indicated how changes in these qualities affect others' perceptions of one's attractiveness, sexiness, and youthfulness. This information could be useful to women seeking to effect certain desired social or mating outcomes by indicating how their voices are actually perceived, as opposed to how they might (erroneously) believe their voices are perceived. For example, women who might use creaky voice to sound "tough" or dominant should be aware that this voice quality does not necessarily have the effect they are seeking. Women who are looking to attract a mate by sounding more attractive or sexy might want to know that this effect cannot be achieved by merely sounding youthful. They might also benefit from knowing that perceptions of attractiveness are tied closely to perceptions of sexiness. Future research into these voice qualities could provide further information that would help both women and men use voice to influence their social world.

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Supplementary materials

Supplemental Table 1. Dominance scale ratings for formant adjust and voice quality.

	Formants		
Voice Quality	**More dispersed**	**Original**	**Less dispersed**
Modal	3.20	4.13	3.99
Girlish	3.43	3.60	3.86
Breathy	3.26	3.21	4.21
Creaky	3.56	3.76	4.03

Supplemental Table 2. Attractiveness scale ratings for formant adjust and voice quality.

	Formants		
Voice Quality	**More dispersed**	**Original**	**Less dispersed**
Modal	4.21	4.03	2.64
Girlish	4.62	5.66	5.52
Breathy	6.59	6.13	4.37
Creaky	2.13	1.94	1.73

Supplemental Table 3. Sexiness scale ratings for formant adjust and voice quality.

	Formants		
Voice Quality	**More dispersed**	**Original**	**Less dispersed**
Modal	3.85	3.32	2.44
Girlish	4.33	5.11	4.09
Breathy	6.74	6.55	4.84
Creaky	2.45	2.25	1.89

Supplemental Table 4. Youthfulness scale ratings for formant adjust and voice quality.

	Formants		
Voice Quality	**More dispersed**	**Original**	**Less dispersed**
Modal	6.02	5.42	4.10
Girlish	6.88	5.52	5.11
Breathy	6.07	5.07	3.86
Creaky	3.32	3.10	2.74