SINGING VOICE ATTRACTIVENESS

The Attractiveness of the Singing Voice in Women

By

Sari G. E. Isenstein, B.A. (Hons)

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AUTHOR: Sari G. E. Isenstein, B.A. (Hons)

SUPERVISOR: Dr. David R. Feinberg

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Abstract

Previous experiments have shown that voice pitch (the perception of fundamental frequency and/or corresponding harmonics) is positively associated with women's voice attractiveness, however all of this research is on women's speaking voices. Singing is important for the mating success of non-human animals, is cross-culturally universal in humans, and is highly sexualized in many cultures. Thus, singing could contribute to mating success and attraction in humans. First, we investigated whether previous findings, that high voice pitch when speaking predicts women's voice attractiveness, extend to when women sing. We also examined whether pitch- and rhythm accuracy contribute to women's singing voice attractiveness. Voice pitch was positively related to women's singing voice attractiveness as judged by men more than when judged by women, and speaking voice attractiveness was positively related to singing voice attractiveness. Thus, men and women may be reacting to the same indicator of women's underlying quality (i.e. voice pitch) in both women's speaking and singing voices, differently. Men may be attracted to high pitch, whereas women may show a weaker relationship, as they tend to be more romantically jealous of women with high pitched voices. Pitch- and rhythm accuracy did not predict women's singing voice attractiveness. This result can be interpreted in different ways. It could mean that women's voice pitch may be more important in determining men's perceptions of their singing voice attractiveness than is their singing ability, or our measures were ill suited to the task. Collectively, these

results are the first to show that singing voices are more attractive than speaking voices, people with attractive speaking voices tend to have attractive singing voices, and that singing and speaking voices relate to the same underlying qualities. Thus, singing may be an indicator of mate value and could have played a role in the evolution of sex differences in the voice if our ancestors had similar preferences.

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Montano, K. J.: Data collection, edited paper
Jones, B. C.: Edited paper
Feinberg, D. R.: Experimental design, theoretical advisor, data analysis, edited paper

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Chapter 1: General Introduction

We judge several traits such as attractiveness, trust, and dominance almost instantly based on a person's voice (McAleer, Todorov, & Belin, 2014). Not only does the human voice indicate a person's gender (Belin, Bestelmeyer, Latinus, Watson, & 2011), and age range (Stathopoulos, Huber, Sussman, & Schlauch, 2011), but we can also form impressions of an individual's attractiveness based on their voice (Feinberg, 2008; Feinberg, DeBruine, Jones, & Perrett, 2008; Hughes, Dispenza, & Gallup, 2004; Hughes, Harrison, & Gallup, 2002; Hughes, Pastizzo, & Gallup, 2008; McAleer et al., 2014; O'Connor, Fraccaro, Pisanski, Tigue, & Feinberg, 2013; O'Connor, Re, & Feinberg, 2011; Pipitone & Gallup, 2008; Pisanski et al., 2016; Puts, Barndt, Welling, Dawood, & Burriss, 2011; Puts, Jones, & DeBruine, 2012; Re, O'Connor, Bennett, & Feinberg, 2012; Vukovic, Feinberg, DeBruine, Smith, & Jones, 2010). The ability for us to form perceptions of these traits quickly is adaptive because it helps us identify the best quality potential mates and compete for them (Buss, 1989; Feinberg et al., 2005; see Miller, 1998 for a review). In addition to the human speaking voice, the human singing voice may be important for sexual selection. There is an abundance of research showing how singing is important for animal mating success (Baptista & Morton, 1982; Botero et al., 2009; Burk & Webb, 1983; Croll et al., 2002; Eriksson & Wallin, 1986; Etges et al., 2007; Nowicki, Peters, & Podos, 1998; Nowicki, Searcy, & Peteres, 2002; Searcy & Andersson, 1986; Smith, Goldizen, Dunlop, & Noad, 2008; Tregenza, Simmons, Wedell, &

Zuk, 2006). While it is theorized that singing is important for human sexual selection (Darwin, 1871; Miller, 2000), this concept is largely absent from research.

1.1 Human Voice Attractiveness Studies

Speaking attractiveness.

Voice pitch (the perception of fundamental frequency and/or corresponding harmonics) has been identified as one of the primary predictors of women's attractiveness (Collins & Missing, 2003; Feinberg et al., 2008; O'Connor et al., 2013; Pisanski & Rendall, 2011; Puts et al., 2011). In general, men rate relatively higher-pitched women's voices as more attractive than they rate lower-pitched voices (Collins & Missing, 2003; Feinberg et al., 2008; Jones, Feinberg, DeBruine, Little, & Vukovic, 2008; O'Connor et al., 2011; O'Connor et al., 2013; Pisanski & Rendall, 2011; Puts et al., 2011; Re et al., 2012). This holds true both for when women's voices are manipulated (Feinberg et al., 2008; Jones, Feinberg, DeBruine, Little, & Vukovic, 2008; O'Connor et al., 2011; Puts et al., 2011; Re et al., 2012), and when they are rated in their natural state (Collins & Missing, 2003; Feinberg et al., 2008; Pisanski & Rendall, 2011). Women's voice attractiveness is associated with other attractive features, such as feminine faces (Collins & Missing, 2003), low waist-to-hip ratio (WHR; Hughes et al., 2004), and bilateral symmetry (Hughes et al., 2002). Women's voice attractiveness also tends to vary across the menstrual cycle, with women's voices being most

attractive when their risk of conception is highest (Pipitone & Gallup, 2008). However, when trying to replicate this finding using measurements of sexual hormones rather than calculations of conception risk, Puts et al. (2013) found that voice attractiveness varied across women's menstrual cycle within-subjects only. Voice attractiveness is also indicative of women's age and peaks in early adulthood (Röder, Fink, & Jones, 2013; Wheatley et al., 2014). Since women's fecundity peaks in the mid-twenties (Anderson, Wohlfahrt, Christens, Olsen, & Melbye, 2000), this suggests that women's voice attractiveness may indicate women's reproductive potential. Furthermore, women's voice attractiveness also predicts their sexual behaviour, such that women's voice attractiveness is positively associated with their number of sexual partners and number of extra-pair copulation partners (Hughes et al., 2004). Thus, women's voice attractiveness may indicate their sexual interest and/or availability. Collectively, this research provides us with evidence that women's voice attractiveness is associated with many other attractive and desirable traits. While there is a large amount of research on voice attractiveness, the majority of this research focuses on speaking voices (see, e.g. Collins & Missing, 2003; Feinberg et al., 2008; Hughes et al., 2002; Hughes et al., 2004; Jones et al., 2010; Pipitone & Gallup, 2008; Puts et al., 2011; Puts et al., 2013).

Singing attractiveness.

We are unaware of any studies to date on perceptions of women's singing voice attractiveness. We did note one study which tested for a relationship between ratings of physical attractiveness and ratings of vocal performance (Wapnick, Darrow, Kovacs, & Dalrymple, 1997), where male singers' vocal performance ratings were positively related to how physically attractive they were. However, this study did not include raters' assessments of singing voice attractiveness itself, nor did it test for whether objective measures of vocal characteristics could predict singing voice attractiveness. Rather, some participants rated the physical attractiveness of the singers in a visual-only condition, and other participants assessed singers' vocal performance in both an audio-only and audio-visual condition, based on a vocal evaluation form developed by Ekholm (1994), as cited by Wapnick et al. (1997). The study also assessed female singers, however results were equivocal. Additionally, there are studies that investigate the effects of vocal training on singing ability (e.g. LeBorgne & Weinrich, 2002; Mendes, Rothman, Sapienza, & Brown Jr., 2003; Sulter, Schutte, & Miller, 1995). However, these studies also do not include subjective assessments of singing voice attractiveness. There are no known studies that are designed to investigate subjective perceptions of singing voice attractiveness, nor are there studies that test whether objective measures of the voice predict these perceptions. This thesis seeks to fill the gap where there is no research on judgements of women's singing voice attractiveness.

1.2 Aims of Thesis

The first aim of this thesis is to investigate whether voice pitch, pitch accuracy, and rhythm accuracy predict singing voice attractiveness. The second aim of this thesis is to determine whether speaking and singing attractiveness correlate.

1.3 Structure of Thesis

This thesis examines speaking and singing voice attractiveness and some of the acoustic properties that predict women's voice attractiveness. In the study presented below, we will begin with a brief summary of the process of vocal production. We will then discuss the relationship between voice pitch and women's underlying quality. We will cover what we know so far regarding men's and women's judgements of women's voices. We will then discuss the importance of conducting research on the human singing voice. From there, we will explain what we did to investigate what predicts speaking and singing attractiveness, and whether speaking and singing attractiveness are related. We will finish with a general discussion on how we can relate our findings to what is already known about vocal attractiveness, and how our findings fit within the bigger picture.

Chapter 2: The Attractiveness of the Singing Voice in Women

2.1 Abstract

Despite music being a human cultural universal, most research on voice attractiveness focuses on speaking voices. Prior work on speaking voices shows that men perceive women with relatively higher-pitched voices as more attractive. To test if these results extend to women singing, we recorded the voices of female students singing and speaking "Happy Birthday.'' Both men and women rated the voices based on attractiveness. We measured fundamental frequency (voice pitch) and created pitch accuracy and rhythm accuracy scores for each voice. We found a positive linear relationship between speaking and singing attractiveness. In addition, we found an effect of voice pitch on singing attractiveness as judged by men, but not as judged by women. Pitch accuracy and rhythm accuracy scores did not predict voice attractiveness. There are several ways to interpret our results. One of which is that women's voice pitch, as perceived by men, is more important in determining the attractiveness of female singers than is their actual ability to sing well.

Keywords: singing attractiveness, voice pitch, pitch accuracy, rhythm accuracy

2.2. The Attractiveness of the Singing Voice in Women

2.2.1. Voice Anatomy and Bioacoustics

The basic model of human vocal production, known as the source-filter model (Fant, 1960, as cited by Fitch, 2000), explains how vocalizations are produced via the larynx and altered through the vocal tract. In this model, the

larynx is considered the source and the vocal tract is considered the filter (Titze, 1994). The larynx is an organ within the neck that houses vocal folds which allow us to speak and sing (Titze, 1994). To oscillate, the vocal folds are drawn together so that air pressure builds beneath the larynx. They are then pushed apart by subglottal pressure. This, combined with the myoelastic vocal fold tissue, produces sustained oscillation (Van den Berg, 1958, as cited by Fitch & Hauser, 2003). Vocal fold oscillation produces a source sound with a fundamental frequency and corresponding harmonics. This is perceived as voice pitch (Titze, 1994).

2.2.2. Relationship between Voice Pitch and Indices of Femininity/Youth in Women

Research demonstrates that women's voice pitch is associated with indices of women's underlying mate quality (Collins & Missing, 2003; Feinberg, 2008; Feinberg et al., 2008; Vukovic, Feinberg, DeBruine, Smith, & Jones, 2010). Women's voice pitch deepens at puberty as a result of increased levels of testosterone. However, it remains relatively higher than men's voice pitch due to the presence of estradiol, which is derived from testosterone, and progesterone. Estrogens and progesterone act to mask the masculinizing effect of testosterone on the voice in women (Abitbol, Abitbol, & Abitbol, 1999). Women's voice pitch also gradually decreases with age (Stathopoulos et al., 2011). The most noticeable changes occur both at the age of puberty, after which women are most fertile, and menopause, after which women are no longer able to reproduce

(Abitbol et al., 1999). During menopause, when the production of progesterone and estrogens slows and androgen levels increase, this often leads to a deepening of women's voice pitch (Abitbol et al., 1999). Thus, we may use women's voice pitch to track their reproductive potential. Voice pitch is also positively related to other indices of women's underlying quality, such as long-term health (Vukovic et al., 2010), and facial femininity (Feinberg et al., 2005).

Literature also demonstrates a positive relationship between women's voice pitch and their reproductive success (Atkinson et al., 2012). Moreover, voice pitch is highest at the most fertile ovulatory cycle phase (Bryant & Haselton, 2009). However, research on the relationship between women's voice pitch and menstrual cycle (Bryant & Haselton, 2009; Puts et al., 2013) and the relationship between voice attractiveness and menstrual cycle (Pipitone & Gallup, 2008; Puts et al., 2013) is equivocal (Gangestad et al. 2015).

Men's judgements of women's voices.

Since voice pitch is tied to indices of women's underlying quality (Collins & Missing, 2003; Feinberg, 2008; Feinberg et al., 2008; Hughes et al., 2002; Wheatley et al., 2014), it may be an important component of men's mate selection (Feinberg, 2008). Most studies of men's preferences for women's voices show that exaggerated sex typical features, such as high voice pitch, are perceived as attractive (Collins & Missing, 2003; Feinberg et al., 2008; Jones et

al., 2010). Men also perceive women with relatively higher-pitched voices to be younger and more feminine (Collins & Missing, 2003; Feinberg et al., 2008).

On some level, women may be aware that high voice pitch is attractive to men. Indeed, research has shown that women raise their voice pitch when speaking to men they find attractive (Fraccaro et al., 2011). Thus, men may also prefer exaggerated sex typical features in women's voices because they may reflect women's intent in mating contexts. Overall, these aforementioned findings demonstrate a notable relationship between voice pitch and a number of desirable female features, which provides us with evidence that men may use women's voices to assess them as potential mates.

Women's judgements of women's voices.

Studies on women's preferences for other women's voices show that women do not always prefer women with relatively higher-pitched voices (Feinberg et al., 2008).

If vocal femininity is perceived by men as attractive, and is an indicator of sexual interest, voice pitch may be used in female-female competition. Indeed, Puts et al. (2011) found that women perceive feminized women's voices as more attractive to men and more flirtatious. Therefore, women may use other women's vocal characteristics to track whether they may be a potential threat to their romantic relationships (Puts et al., 2011). Additionally, O'Connor and Feinberg (2012) found that women reported increased jealousy in response to higher-

pitched women's voices than to lower-pitched women's voices when they were asked to indicate which woman they would rather accompany their partner on a weekend getaway (O'Connor & Feinberg, 2012).

Some studies indicate that women perceive relatively higher-pitched women's voices as more attractive (Collins & Missing, 2003; Feinberg et al., 2008), although women appear to have a limit to how high women's voice pitch can be and still remain attractive, when assessing other women's voices (Feinberg et al., 2008).

Overall, men show stronger preferences for high-pitched women's voices than do women (Feinberg et al., 2008; Jones, Feinberg, DeBruine, Little, & Vukovic, 2008; Jones et al., 2010). The importance of voice attractiveness in determining mate quality, and in assessments of potential competition, is shown through an abundance of voice-related research (see, e.g. Collins & Missing, 2003; Feinberg et al., 2008; Hughes et al., 2002; Hughes et al., 2004; Jones et al., 2010; O'Connor & Feinberg, 2012; Pipitone & Gallup, 2008; Puts et al., 2011; Puts et al., 2013), however, such research is limited to the human speaking voice.

2.2.3. Importance of Human Singing Research

Although all of the aforementioned research is on speaking, researching the role of voice pitch in singing attractiveness may also be important. First, research demonstrates that song/calls indicate a notable amount of information

about animals (Ballentine, 2009; Barelli, Mundry, Heistermann, & Hammerschmidt, 2013; Botero et al., 2009; de Kort et al., 2009; Voigt, & Leitner, 2013), and the importance of song in animal mating success (Bapista & Morton, 1982; Botero et al., 2009; Burk & Webb, 1983; Croll et al., 2002; Eriksson & Wallin, 1986; Etges et al., 2007; Nowicki et al., 1998; Nowicki et al., 2002; Searcy & Andersson, 1986; Smith et al., 2008; Tregenza et al., 2006). There are also many similarities between the function of animal and human vocalizations (Bolhuis, Okanoya, & Scharff, 2010; Doupe & Kuhl, 1999). Although non-human and human animal song vary in a number of different ways, we can hypothesize that given the similarities, human singing voices may be important for both detecting information and sexual selection in humans.

Second, singing is a cross-cultural universal. Nearly all human beings are exposed to music on a daily basis (Rideout, Roberts, & Foehr, 2005). A large proportion of music is created from the human voice, in what we refer to as singing (Durrant & Himonides, 1998). Singing is prominent in many aspects of our daily lives. Examples of cross-cultural singing include maternal singing (Trehub, Unyk, & Trainor, 1993), religious singing (Durrant & Himonides, 1998), celebratory singing, such as at weddings (Hagen & Bryant, 2003; McDermott & Hauser, 2005), and group singing to increase interpersonal cohesiveness (Brown, 2000; Freeman, 1998), and cooperation and trust (Anshel & Kipper, 1988). In North America, it is estimated that adolescents and young adults listen to music three to four hours per day on average (Agbo-Quaye & Robertson,

2010). Furthermore, the total revenue reported by the Recording Industry Association of America alone was 7 billion dollars in 2013 (Lewis, 2014). The success of the music industry, and its cross-cultural prevalence, clearly illustrates how much music influences our lives.

Third, singing is highly sexualized in western cultures. Dating back to the 1960s, sexuality has been a main theme in popular music (Christenson & Roberts, 1998; Martino et al., 2006). Indeed, content analyses show that between 70% to 90% of popular songs contain sexual themes (Arnett, 2002). Sexuality is also salient in music videos, with an estimated 40% to 75% of music videos displaying sexual imagery (Tapper, Thorson, and Black, 1994; Turner, 2011; Zhang, Miller, & Harrison, 2008). Furthermore, music interests usually emerge in adolescence (Rideout et al., 2005) at the time of sexual maturation (Forbes & Dahl, 2010). This evidence suggests that singing can play a role in human mate attraction.

Research on singing attractiveness is important because there are both similarities and differences between human speaking and singing. Thus, we are largely unaware of how people may react to singing voices. We use the same basic vocal anatomy (lungs, vocal folds of the larynx, and vocal tract) and vocal production process to produce both speech and song (Titze, 1994). Furthermore, there is significant overlap in brain regions involved in speech and music processing (Hickok, Buchsbaum, Humphries, & Muftuler 2003; Koelsch, 2005). We use the same reward circuitry for perceptions of speaking and singing. For

instance, there is increased activity in brain regions involved in emotion and reward, such as the orbitofrontal cortex, anterior insula, nucleus accumbens, and midbrain, during aural perception of music (Blood & Zatorre, 2001; Brown, Martinez, & Parsons, 2004). The anterior insula is also involved in processing speaking voices (Belin, Bestelmeyer, Latinus, & Watson, 2011) and the orbitofrontal cortex is involved in processing vocal emotion (Ethofer et al., 2006). Thus, people may react to the same indicators of underlying quality (i.e. voice pitch) in singing than in speaking, and perceptions of speaking and singing attractiveness may be correlated.

There are some differences between speaking and singing. Speech and song production differ in the extent to which pitch is controlled, in size of pitch range, and in phoneme length (Natke, Donath, & Kalveram, 2003; Ohishi, Goto, Itou, & Takeda, 2005; Saitou, Goto, Unoki, & Akagi, 2007). There are also differences in singing and speaking perception. For example, brain imaging shows that speech and language perception is processed more in the left hemisphere (Burton, Small, & Blumstein, 2000; Caplan, Gow, & Makris 1995; Peterson, Fox, Posner, Mintun, & Raichle, 1988). Whereas, some processing of musical stimuli is more closely associated with the right hemisphere (Hugdahl et al., 1999; Zatorre & Belin, 2001; Zatorre, Evans, & Meyer, 1994), and some musical processing is closely associated with the left hemisphere (Zatorre & Belin, 2001), indicating that music processing may take on more of a

bihemispheric network pattern than speech processing (Ozdemir, Norton, & Schlaugh, 2006).

Moreover, as discussed above, voice pitch is controlled to a greater extent in singing than in speaking voices (Natke et al., 2003). It has been proposed that since a nervous affect may interfere with vocal motor control, greater control of pitch may indicate self-confidence (Miller, 2000). Therefore, accurate vocal control may be perceived as attractive. Moreover, other indicators of underlying quality such as fluctuating asymmetry, a measure of developmental stability (Van Valen, 1962), are tied to measures of motor control in athletics (Trivers et al., 2014). Fluctuating asymmetry is also tied to voice attractiveness, although the exact acoustic features which convey this information are unknown (Hughes et al., 2002; 2008). Given that the ability to sing accurately could reflect vocal motor control, we calculated voice pitch accuracy scores for each voice to test whether these scores predict ratings of singing voice attractiveness. Furthermore, singing requires one to maintain a rhythm more than does speaking (Hauser & McDermott, 2003). Indeed, literature proposes that the majority of music has a "pulse" (Bispham, 2006). It is suggested that we can perceive musical rhythmic behaviour as an indicator of timing ability, pulse perception and error correction mechanisms (Bispham, 2003). It is also related to the adaptive function of motor-coordination (Bispham, 2003). Thus, we calculated voice rhythm accuracy scores for each voice to test whether these scores predict ratings of singing voice attractiveness.

Given the above, people might react differently to indicators of underlying quality (i.e. voice pitch) in singing than in speaking. Thus, it is important to assess whether previous research on the relationship between speaking voice pitch and ratings of speaking attractiveness extends to singing. Moreover, these differences lead us to investigate whether vocal characteristics that are more necessary for singing production than for speech production might predict singing voice attractiveness. There is a larger emphasis on rhythm, such as timing of notes, in music than in language (Hauser & McDermott, 2003). Furthermore, the nature of rhythm is fundamentally different in music than in language (Bispham, 2006), such that in music, pulses are more regularly timed. Singing is also characterized by strong intentional pitch changes and as such, pitch control is more necessary for singing than for speaking (Natke et al., 2003). This evidence suggests that pitch accuracy and rhythm accuracy are two characteristics that are important to investigate.

2.2.4. Our Study

In our study we investigated whether voice pitch predicted singing and speaking voice attractiveness, and whether pitch- and rhythm accuracy predicted singing voice attractiveness. We predicted that since women's voice pitch is positively related to voice attractiveness in speaking (Collins & Missing, 2003; Feinberg et al., 2008; O'Connor et al., 2011; Pisanski & Rendall, 2011; Puts et al., 2011; Re et al., 2012), voice pitch would also be positively related to voice attractiveness in singing. Since rhythm and pitch are fundamental to proper

singing, we predicted that pitch- and rhythm accuracy would also positively predict singing voice attractiveness.

Finally, since speaking and singing voices reflect the same basic process of vocal production, we predicted that there would be a positive correlation between ratings of speaking attractiveness and ratings of singing attractiveness.

2.2.5 Methods

Participants.

Protocols for this study were approved by the McMaster University Research Ethics Board. Both men (N = 38; mean age = 18.63 ± 1.46 years) and women (N = 37; mean age = 18.38 ± 1.53 years) were recruited from the McMaster University on-line participant pool and were compensated with course credit for participation.

Stimuli collection.

Voice stimuli were collected at McMaster University. We obtained voice recordings of undergraduate women (N = 48; mean age = 19.96 ± 2.12 years) both speaking and singing the song "Happy Birthday" (see Jacobs & Lincoln, 1911 for the first publication of the lyrics to "Happy Birthday" with an indication of the song being set to a tune) in separate sound clips. Voices were recorded in a sound-controlled booth with a Sennheiser MKH 800 condenser microphone at an approximate distance of 20-25 cm. Audio recordings were encoded using M-

Audio Fast Track Ultra interface at a 96 kHz sampling rate and 32-bit amplitude quantization, and were stored as WAV files using Adobe Soundbooth CS5 version 3.0. Each voice stimulus was normalized in amplitude to 70 dB RMS SPL using Praat (Boersma & Weenink, 2015). We then sectioned off each recording using Praat Software (Boersma & Weenink, 2015) so that only the first line, "Happy birthday to you," of the recordings were saved. This shortened the experiment duration to prevent participant fatigue and maintain participant concentration.

Procedure.

Participants were presented with 48 speaking and 48 singing voice recordings (i.e. each listener heard the same 48 people speaking and singing the first line of "Happy Birthday") within the same block, totalling 96 recordings. Speaking and singing recordings were presented in a random order and this order was randomized between raters. Participants selected the 'play' button to play each sound file, and listened to the recordings using Sennheiser HD 280 Pro headphones. After listening to each voice, participants provided their rating of the voice's attractiveness on a scale from 1 (very unattractive) to 7 (very attractive). Participants reported their age and sex.

Data preparation.

We calculated average attractiveness ratings for each voice collapsed across sex of rater. We then calculated average attractiveness ratings for each voice as judged by male and female raters separately.

Analysis.

Voice pitch measurement.

Voice pitch for each syllable in the song line "Happy birthday to you" was analyzed separately using Praat Software (Boersma & Weenink, 2015) and averaged together for each voice recording. Syllables were used as each one corresponds to a beat in the music. Voice pitch was measured using Praat's autocorrelation algorithm. Voice pitch measurement was identical to pitch measurement by Feinberg et al. (2008).

Voice pitch- and rhythm accuracy measurement.

Accuracy scores were determined by calculating how far participants digressed, on average, from the key (for voice pitch accuracy) and tempo (for voice rhythm accuracy) indicated on the "Happy Birthday" piano sheet music (Hill & Hill, 1935). To calculate voice pitch accuracy scores, we used the equation $12\log_2\frac{X}{Y}$ (Lloyd & Boyle, 1979), where X is the first note and Y is every subsequent note sang, to determine the average unsigned distance between predicted notes and actual observed notes in an equal temperament scale. Equal

temperament divides an octave (the space between frequency doublings) into 12 semitones (see Lloyd & Boyle, 1963; 1979, for details on equal temperament scale). The notes in the first line of "Happy Birthday" are D, D, E, D, G, F# (see Figure 1; Hill & Hill 1935). Thus, using the major scale pattern (Ionian mode) as denoted in the sheet music for "Happy Birthday" (Hill & Hill, 1935), the intervals between each note on the sheet music are 0, 2, 0, 5, & 4 semitones. In other words, the second note would be 0 semi-tones away from the first note, the third note would be 2 semi-tones away from the first note, the third note would be 0 semi-tones away from the first note, etc. By using an equal temperament scale, the exact same pattern emerges regardless of which note is used as the point of origin. This also yields the same results independent of the key sang, so our calculations are accurate regardless of what key people sang in, or what notes we start measuring from. To create an overall pitch accuracy score, we calculated the average unsigned distance between each actual note and that predicted by the sheet music.

Figure 1: First Line of "Happy Birthday" Sheet Music

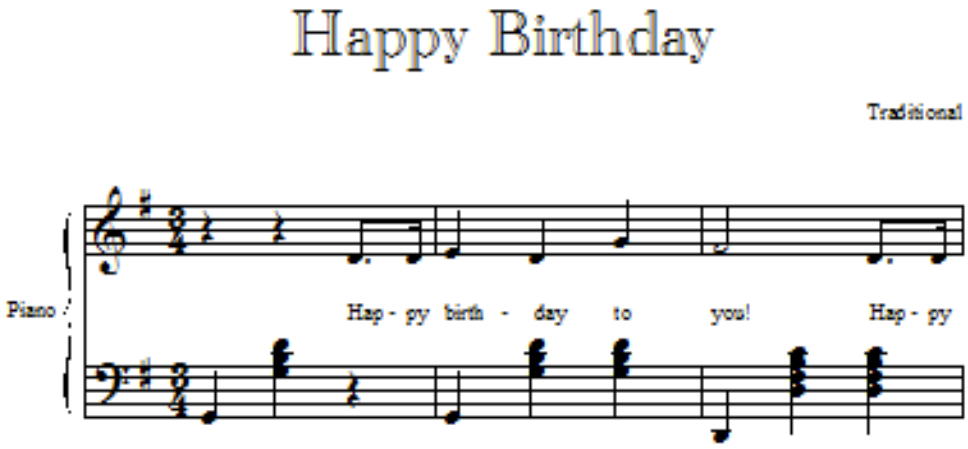

Figure 1: The first line of the piano sheet music for the song "Happy Birthday." Participants were asked to sing and speak the words "Happy birthday to you." Adapted from *Music for Music Teachers*, Retrieved July 20, 2016, from http://www.music-for-music-teachers.com/happy-birthday.html. Copyright 2011 by Music-forMusic-Teachers.com.

To calculate voice rhythm accuracy scores, we used the total duration and note length as denoted by the sheet music to predict the onset of each note. To create an overall rhythm accuracy score, we calculated the average unsigned distance between each actual note onset and that predicted by the sheet music.

Statistics.

First, we conducted analyses to test for relationships between voice pitch and ratings of voice attractiveness for both singing and speaking voices as judged by both sexes, and then each sex separately. Then, we conducted analyses to test for relationships between voice accuracy (voice pitch accuracy and voice rhythm accuracy) and ratings of voice attractiveness in singing voices as judged by men, women, and both men and women overall. Finally, we conducted analyses to test for the relationship between speaking attractiveness ratings and singing attractiveness ratings as judged by both sexes, and then each sex separately. We used SPSS Statistics 23 with α = .05 and two-tailed probability estimates.

2.2.6 Results

Initial analyses.

As our experimental design presented singing and speaking voices in a single block, we conducted an initial ANCOVA [dependent variable: overall voice attractiveness ratings; between-subjects factor: voice stimuli type (singing or speaking); covariate: voice pitch] to test whether there was an effect of voice stimuli type on attractiveness ratings while controlling for voice pitch. There was a significant main effect of whether participants sang or spoke ($F_{1,93}$ = 7.06, p = .009, η_p^2 = .071), and a significant main effect of voice pitch ($F_{1,93}$ = 4.85, p = .030, η_p^2 = .050) on voice attractiveness ratings. Repeating these analyses with

linear regression and generalized linear models revealed no change in significance levels.

We performed paired-samples *t*-tests to test for differences in participants' preferences for singing and speaking. Significant results of paired-samples *t*-tests survived Bonferroni corrections. Attractiveness ratings of singing voices were significantly higher than attractiveness ratings of speaking voices as judged by women (t_{47} = 6.54, p < .0001, d = 0.94), men (t_{47} = 6.77, p < .0001, d = 0.98) and when male and female ratings were pooled (t_{47} = 7.14, p < .0001, d = 1.03; see Table 1 for means and standard error of attractiveness ratings).

Table 1

Means and Standard Error of Singing and Speaking Voice Attractiveness Ratings

	Singing		Speaking	
Rater Group	*M*	*SEM*	*M*	*SEM*
Women	4.02	.124	3.39	.090
Men	4.13	.122	3.53	.108
Pooled	4.08	.120	3.47	.100

The aforementioned effects could be in part due to differences in average pitch between speaking and singing voices. To test if this is possible, we performed a paired-samples *t*-test that showed that indeed, singing pitch (*M* =

262.65, *SEM* = 3.95) was significantly higher than speaking pitch (*M* = 236.39, *SEM* = 3.80), t_{48} = 9.00, $p < .001$, d = 1.30. A Pearson correlation showed that the pitches of singing and speaking voices were highly positively correlated (r_{48} = .72, $p < .001$).

Influence of voice pitch on voice attractiveness ratings.

We conducted Pearson correlations to test for relationships between men's, women's and overall ratings of singing voice attractiveness and singing voice pitch, and for relationships between men's, women's and overall ratings of speaking voice attractiveness and speaking voice pitch. There was a significant positive relationship between voice pitch and singing attractiveness as judged by men (r_{48} = .33, p = .021). However, there was no significant relationship between voice pitch and singing attractiveness as judged by women (r_{48} = .18, p = .225), or as judged by both men and women combined (r_{48} = .27, p = .065). To test whether the relationship between voice pitch and ratings of singing attractiveness differed significantly between men's and women's ratings, we performed Steiger's *Z*-test for comparing related correlation coefficients (Steiger, 1980). We found that the strength of the relationship between voice pitch and singing attractiveness as judged by men was stronger than the same relationship when judged by women (Z = 2.47, p = .013).

There were no significant relationships between voice pitch and speaking attractiveness as judged by men, women, or by both men and women combined

(all $r_{48} < .17$, $p > .254$). We tested whether the strength of the relationship between singing voice pitch and ratings of singing voice attractiveness differed significantly from the strength of the relationship between speaking voice pitch and ratings of speaking voice attractiveness using Fisher's r-to-z correlation comparison for independent data. The strength of the non-significant correlation between pitch and attractiveness in speaking voices was not significantly different than the strength of the significant correlation between pitch and attractiveness in singing voices (male raters: $Z = .89$, $p = .37$; female raters: $Z = .05$, $p = .96$; pooled sample: $Z = .51$, $p = .61$). Despite the difference in significance levels in the relationship between pitch and attractiveness in the two conditions, there is no statistical difference in the strength of the relationship between pitch and speaking and pitch and singing. We conducted a Pearson correlation on a pooled sample of speaking and singing voice pitch and a pooled sample of speaking and singing voice attractiveness ratings and found a significant positive relationship between voice pitch and voice attractiveness ratings as judged by men ($r_{96} = .37$, $p < .0001$), women ($r_{96} = .32$, $p = .002$), and by both men and women combined ($r_{96} = .35$, $p < .0001$).

Influence of pitch and rhythm accuracy on voice attractiveness ratings.

For practicality, here we only analyzed singing voices. We used linear regressions to test whether singing voice pitch accuracy and singing voice rhythm accuracy predict singing voice attractiveness ratings. There were no significant

relationships between either accuracy score and attractiveness ratings as judged by men, women, or by both men and women combined (all $F_{1,46} < .45$, $p > .92$). We then performed Pearson correlations to test for relationships between ratings of singing attractiveness and singing voice pitch accuracy and for relationships between ratings of singing attractiveness and singing voice rhythm accuracy separately. There were no significant relationships (all $|r_{48}| < .134$, $p > .366$).

Speaking and singing attractiveness.

A Pearson correlation tested the relationship between ratings of speaking and singing attractiveness. As shown in Figure 2, we found significant positive relationships between ratings of speaking attractiveness and ratings of singing attractiveness (male raters: $r_{48} = .712$, $p < .0001$; female raters: $r_{48} = .636$, $p < .0001$; pooled sample: $r_{48} = .707$, $p < .0001$). To determine whether the aforementioned effects were independent of voice pitch, we conducted partial correlations. The relationship between ratings of speaking attractiveness and ratings of singing attractiveness remained significant when controlling for speaking voice pitch (male raters: $r_{45} = .707$, $p < .0001$; female raters: $r_{45} = .634$, $p < .0001$; pooled sample: $r_{45} = .704$, $p < .0001$), singing voice pitch (male raters: $r_{45} = .690$, $p < .0001$; female raters: $r_{45} = .621$, $p < .0001$; pooled sample: $r_{45} = .685$, $p < .0001$), and both singing and speaking voice pitch together (male raters: $r_{44} = .697$, $p < .0001$; female raters: $r_{44} = .621$, $p < .0001$; pooled sample: $r_{44} = .688$, $p < .0001$). The relationship between speaking attractiveness ratings and singing attractiveness ratings also remained significant when controlling for the

average of speaking and singing voice pitch (male raters: r_{45} = .697, p < .0001; female raters: r_{45} = .627, p < .0001; pooled sample: r_{45} = .693, p < .0001).

Figure 2: The Relationship between Singing and Speaking Attractiveness Ratings

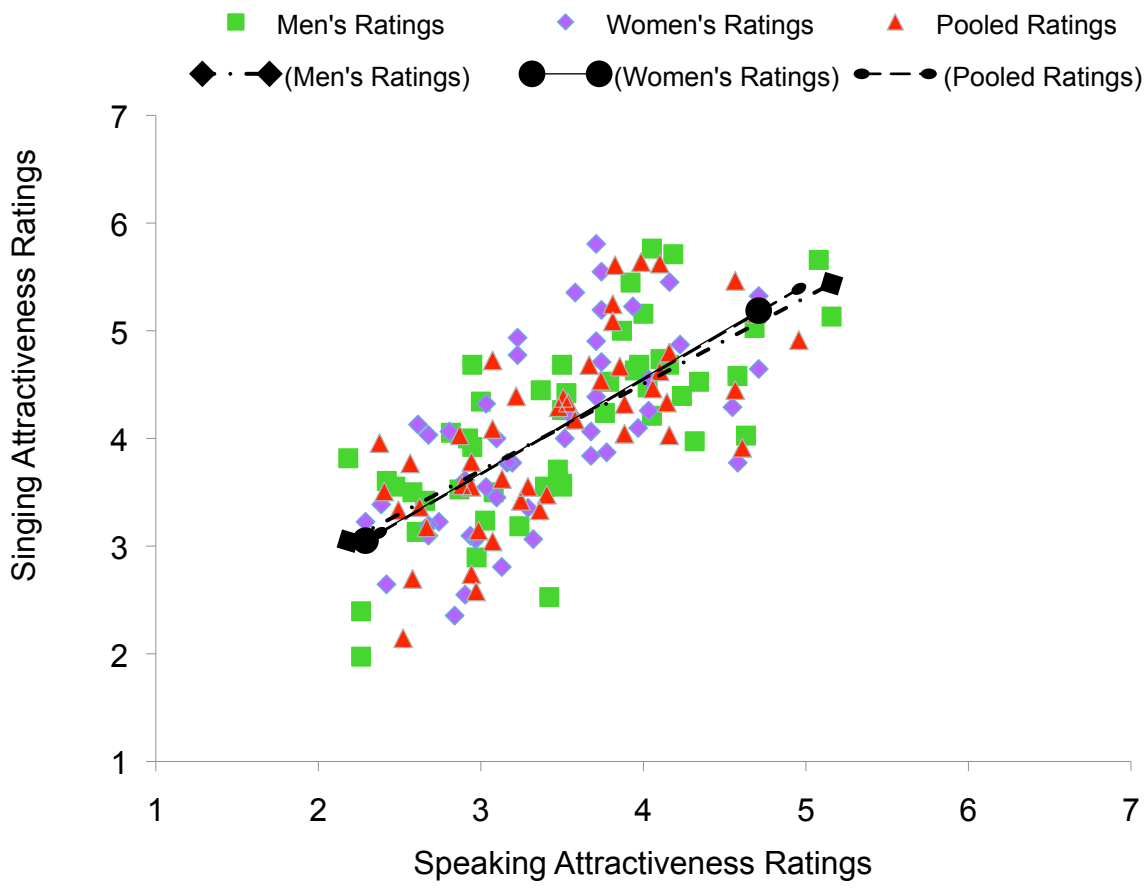

Figure 2: The positive linear relationship between singing and speaking attractiveness ratings as judged by men, women, and both men and women overall.

2.2.7 Discussion

Influence of voice pitch on singing voice preferences.

We found that men preferred high voice pitch in our pooled sample. Although we did not find a significant relationship between pitch and attractiveness in the speaking condition, it was in the same direction as the significant result in the singing condition and the strength of these relationships were not different from each other. Thus, in general, higher-pitched women's voices were associated with higher ratings of voice attractiveness when judged by men. This finding is consistent with our prediction and previous research on the relationship between women's voice pitch and speaking voice attractiveness (see, e.g. Collins & Missing, 2003; Feinberg et al., 2008; O'Connor et al., 2011; Puts et al., 2011; Re, et al., 2012). These preferences may be adaptive since women's voice pitch is an indicator of underlying qualities such as long-term health (Vukovic et al., 2010), youthfulness (Collins & Missing, 2003; Feinberg et al., 2008), facial femininity (Feinberg et al., 2005; Röder, Fink, Feinberg, & Neave, 2013; Collins & Missing, 2003), and possibly menstrual cycle phase (Bryant & Haselton, 2009; c.f. Puts et al., 2013).

We did not find a significant relationship between relatively higher-pitched women's singing voices and ratings of singing voice attractiveness as judged by other women. We found that the relationship between singing voice pitch and ratings of singing voice attractiveness was significantly stronger for male raters

than for female raters. Women perceive relatively higher-pitched women's voices as more attractive to men, and more flirtatious (O'Connor & Feinberg, 2012; Puts et al., 2011). Therefore, it could be that women did not rate relatively higher-pitched women's singing voices as more attractive because of their underlying competitive threat potential (Schmitt & Buss, 1996; Cox & Fisher, 2008).

Influence of voice pitch on speaking voice preferences.

We did not find a significant relationship between relatively higher-pitched women's speaking voices and ratings of speaking voice attractiveness. This could, on the surface, appear to be in contrast with prior work (Collins & Missing, 2003; Feinberg et al., 2008; Jones et al., 2008; O'Connor et al., 2011; O'Connor et al., 2013; Pisanski & Rendall, 2011; Puts et al., 2011; Re et al., 2012). However, several factors could explain this, such as presenting singing and speaking voices in the same experimental block. We found that singing voices were consistently rated as more attractive than were speaking voices, and were also higher-pitched than were speaking voices. However, the significant relationship between voice pitch and attractiveness ratings of singing voices was not significantly stronger than the same relationship in speaking voices, and the pooled sample of speaking and singing voices showed a significant positive relationship between voice pitch and voice attractiveness. Thus, the lack of significance is not strong evidence against the idea that voice pitch positively predicts women's voice attractiveness.

Accuracy of pitch and rhythm and singing attractiveness.

We found that neither our voice pitch accuracy nor our voice rhythm accuracy scores predicted ratings of singing voice attractiveness. There are several potential explanations for this. First, although all of the singers in our study were familiar with "Happy Birthday" and were able to sing it from memory, some degree of voice training and training in reading music would be required to sing the song as it appears on sheet music. Even then, while better singers can sing in key better than worse singers, better singers are likely to sing the song differently than written on sheet music, adding their own inflections. Thus, mathematical accuracy in singing may be more of a target in training than performance. We did not measure musical ability of our singers. However, the distribution of singing voice attractiveness was not significantly different from normal, according to the Shapiro-Wilk test of normality (male raters: $W_{48} = .978$, $p = .48$; female raters: $W_{48} = .967$, $p = .185$; pooled sample: $W_{48} = .968$, $p = .211$), suggesting that there is no bias from higher performing musicians.

Singing and speaking voice attractiveness.

We found that women's speaking voice attractiveness and singing voice attractiveness were highly positively correlated and there was a strong effect size. Since speaking voice attractiveness indicates underlying quality (Atkinson et al., 2012; Bryant & Haselton, 2009; Collins & Missing, 2003; Feinberg et al., 2005; Feinberg et al., 2008; Vukovic et al., 2010), and speaking voice

attractiveness was positively correlated with singing voice attractiveness, this might mean that both types of vocalization (speaking/singing) are indicators of underlying quality.

Another possible explanation is that participants were matching the identities of speaking and singing voices, and recalling their previous ratings. After controlling for voice pitch, the correlations between singing attractiveness and speaking attractiveness remained. Thus, this explanation cannot be ruled out.

Finally, since speaking voice pitch and singing voice pitch were highly correlated, the high correlation between singing and speaking attractiveness could have been due to a general response bias to prefer high frequency voices. However, as discussed previously, the correlations between singing attractiveness and speaking attractiveness as judged by men, women, and by both men and women overall, remained after controlling for voice pitch. Therefore, this is unlikely to be the explanation of why speaking and singing attractiveness were positively related.

In summary, our results suggest that singing voice pitch is more important in determining men's perceptions of the attractiveness of female singers than is their ability to sing in tune and stay on rhythm. Our results indicate that men and women may react to the same indicators of underlying quality (i.e. voice pitch) in both women's speaking and singing voices. Finally, our results help to determine

how women's singing voices, in addition to women's speaking voices, could serve as helpful aids in men's assessments of women's attractiveness.

General Discussion

Previous research on the human singing voice has mainly looked at differences in objective measurements of vocal characteristics, like voice frequency range, in participants with and without vocal training (see, e.g. LeBorgne & Weinrich, 2002; Mendes et al., 2003; Sulter et al., 1995). Our research is the first to examine what makes singing voices sound attractive. Research demonstrating that non-human animal song is important for their mating success (Bapista & Morton, 1982; Botero et al., 2009; Croll et al., 2002; Eriksson & Wallin, 1986; Nowicki et al., 1998; Nowicki et al., 2002; Searcy & Andersson, 1986; Smith et al., 2008), highlighting the similarities between non-human animal song and human vocalization (Bolhuis et al., 2010; Doupe & Kuhl, 1999), and asserting that singing is highly sexualized in our culture (Arnett, 2002; Christenson & Roberts, 1998; Martino et al., 2006; Tapper et al., 1994; Turner, 2011; Zhang et al., 2008), suggests that human singing may be important for sexual selection. Thus, our understanding of what makes human singing attractive is important because it allows us to explore a possible contributor to human sexual selection that has been largely ignored in the past. In our study, men found higher-pitched women's singing voices more attractive than lower-pitched women's singing voices. Since higher voice pitch is an indicator of women's underlying quality (Atkinson et al., 2012; Bryant & Haselton, 2009; Collins & Missing, 2003; Feinberg et al., 2005; Feinberg et al., 2008; Vukovic et al., 2010), and we now know that high voice pitch predicts men's ratings of

women's singing voice attractiveness, we can approximate how human singing may be just as important for human mating success as non-human animal song is to non-human animal mating success. This finding may also help explain why sexualized music is so popular. If women's singing voices help men assess women's underlying quality, men may be highly sensitive to women singing. This could lead men to buy into media portrayals of female singers and increase the amount they listen to certain female artists' music. Furthermore, women may recognize particular female artists as being attractive to men through listening to their voices, which may lead them to purchase more of their music or other merchandise in an effort to be like them.

We extend previous findings on the relationship between women's voice pitch and men's ratings of women's voice attractiveness in speaking voices to singing voices. We now know that high voice pitch is perceived as attractive for both women's speaking (Collins & Missing, 2003; Feinberg et al., 2008; Jones et al., 2008; O'Connor et al., 2011; O'Connor et al., 2013; Pisanski & Rendall, 2011; Puts et al., 2011; Re et al., 2012) and singing voices. As far as we are aware, this finding is the first indication of subjective perceptions of women's singing voice attractiveness. Importantly, this research involved a random sample of participants, meaning some participants could have had previous singing experience whereas others may not have. Thus, our findings demonstrate what makes women's singing voices attractive generally, rather than focusing on voice attractiveness of trained and/or famous female singers. Women without previous

vocal training who want to become better singers may be encouraged by this research. Our findings are also important because they suggest that singing voice pitch, in itself, could be an indicator of women's underlying quality. This means that men may be able to assess women's mate quality solely by hearing a woman's song recording, without seeing them in person or hearing them speak. Since voice pitch is shown to be an indicator of women's underlying quality, and voice pitch is an important indicator of women's singing voice attractiveness for men, and is used to derogate competition by women, it is likely that the attractiveness of singing voices may have played an important role in human evolution.

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