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Changes in salivary estradiol predict changes in women's preferences for vocal masculinity

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ABSTRACT

Although many studies have reported that women's preferences for masculine physical characteristics in men change systematically during the menstrual cycle, the hormonal mechanisms underpinning these changes are currently poorly understood. Previous studies investigating the relationships between measured hormone levels and women's masculinity preferences tested only judgments of men's *facial* attractiveness. Results of these studies suggested that preferences for masculine characteristics in men's faces were related to either women's estradiol or testosterone levels. To investigate the hormonal correlates of within-woman variation in masculinity preferences further, here we measured 62 women's salivary estradiol, progesterone, and testosterone levels and their preferences for masculine characteristics in men's *voices* in five weekly test sessions. Multilevel modeling of these data showed that changes in salivary estradiol were the best predictor of changes in women's preferences for vocal masculinity. These results complement other recent research implicating estradiol in women's mate preferences, attention to courtship signals, sexual motivation, and sexual strategies, and are the first to link women's voice preferences directly to measured hormone levels.

Introduction

Recent meta-analyses suggest that women's preferences for masculine men are stronger during the late follicular (i.e., high-fertility) phase of the menstrual cycle than during the early follicular or luteal (i.e., low-fertility) phases (Gildersleeve et al., in press; but see Wood et al., 2014). For example, this pattern of results has been reported in studies of women's preferences for men's faces (Johnston et al., 2001; Penton-Voak et al., 1999), bodies (Little et al., 2007), voices (Feinberg et al., 2006; Puts, 2005), body odors (Havlicek et al., 2005), and behavioral displays (Gangestad et al., 2004). Researchers have suggested that increased preferences for masculine men during the fertile phase of the menstrual cycle may function to increase offspring health (Gangestad and Thornhill, 2008) and/or dominance (Scott et al., 2013).

The majority of studies investigating changes in women's masculinity preferences during the menstrual cycle have simply compared preferences between high-fertility and low-fertility phases (Gildersleeve et al., in press). Far fewer studies have addressed the hormonal mechanisms that may underpin these cyclic shifts in women's mate preferences. Initial research on this topic examined women's estimated hormone levels by converting information about each participant's position in the menstrual cycle at test to estimated hormone levels using actuarial tables. These studies reported negative correlations between estimated progesterone levels and women's facial (Jones et al., 2005) and vocal (Puts, 2006) masculinity preferences. More recent work has extended this early research by measuring estradiol, testosterone, and progesterone levels from saliva (Bobst et al., 2014; Roney and Simmons, 2008; Roney et al., 2011; Welling et al., 2007). These studies found that women's preferences for sexually dimorphic and/or androgen-dependent characteristics in men's faces were positively correlated with *either* their salivary estradiol (Roney and Simmons, 2008; Roney et al., 2011) or testosterone (Bobst et al., 2014; Welling et al., 2007) levels, both of which can show mid-cycle peaks (Dabbs and de La Rue, 1991; Sherman and Korenman, 1975). These inconsistent results indicate that further research is required to elucidate the hormonal mechanisms that might contribute to within-woman variation in masculinity preferences.

Previous studies investigating the possible relationships between measured salivary hormone levels and women's masculinity preferences have focused exclusively on women's judgments of men's *facial* attractiveness. However, masculine characteristics are also known to be important factors for women's perceptions of men's *voices*, with women perceiving men with masculine voices as both attractive and physically dominant (reviewed in Feinberg, 2008; Puts, 2010).

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Although previous studies have shown that women's preferences for masculinized versus feminized versions of men's voices are stronger during the fertile phase of their menstrual cycle (Feinberg et al., 2006; Puts, 2005), no previous studies have used direct measures of women's hormone levels to investigate the hormonal correlates of within-woman changes in preferences for men's vocal masculinity[1]. Additionally, previous studies investigating the hormonal correlates of preferences for experimentally-manipulated vocal masculinity (Feinberg et al., 2006; Puts, 2005) assessed women's preferences for vocal masculinity by simultaneously altering two anatomically and acoustically distinct sexually dimorphic characteristics in recordings of men's voices: voice pitch (i.e., the perception of fundamental frequency and/or corresponding harmonics, Titze, 1994) and formants (i.e., the resonant frequencies of the supralaryngeal vocal-tract and an index of body size, Fant, 1960; Titze, 1994). This is potentially noteworthy, because pitch and formants are known to have independent effects on women's judgments of men's vocal attractiveness (Feinberg et al., 2005; Pisanski and Rendall, 2011) and both masculine pitch and masculine formants are correlated with circulating testosterone levels in men (Bruckert et al., 2006; Dabbs and Mallinger, 1999). Other studies investigating the hormonal correlates of women's preferences for vocal masculinity did not use experimental methods to assess preferences, but calculated the correlation coefficient between naturally occurring variation in voice pitch and each woman's attractiveness ratings of these voices (Puts, 2006). Consequently, the relative contribution of voice pitch and formant frequencies to hormone-linked variation in vocal masculinity preferences is unclear.

In light of the above, we investigated the hormonal correlates of within-woman variation in preferences for masculine versus feminine pitch and masculine versus feminine formants in recordings of men's voices. Women (none of whom were using any form of hormonal supplement, such as hormonal contraceptives) were each tested once a week for five weeks (i.e., each woman completed five weekly test sessions). In each of these test sessions, women's preferences for vocal masculinity were assessed and a saliva sample was collected. Saliva samples were then analyzed for estradiol, progesterone, and testosterone levels. Previous studies that linked variation in women's preferences for facial masculinity to estradiol (Roney and Simmons, 2008; Roney et al., 2011) suggest that within-woman changes in preferences for vocal masculinity are likely to be best predicted by changes in salivary estradiol. However, other studies of variation in women's preferences for facial masculinity (Bobst et al., 2014; Welling et al., 2007) suggest that within-woman changes in preferences for vocal masculinity are likely to be best predicted by changes in salivary testosterone. Note that our study design directly examines the relationship between variation in hormone levels and preferences, avoiding the method of allocating certain days of the menstrual cycle to high-fertility and low-fertility phases using diary data (see Gildersleeve et al., 2013 and Wood et al., 2014 for recent discussions of potential problems with this method).

Methods

Participants

Sixty-two women (mean age = 21.17 years, SD = 2.51 years), all of whom reported that they preferred to have romantic relationships with men, participated in the main study. All participants were students at the University of Glasgow (Scotland, UK) and provided informed consent. None of these women were currently pregnant, breastfeeding, or taking any form of hormonal supplement and all indicated that they had not taken any form of hormonal supplement in the previous 90 days.

Voice stimuli

Recordings of 6 men between the ages of 18 and 25 speaking the English monophthong vowels, "ah"/ /, "ee"/i/, "e"/ɛ/, "oh"/o/, and "oo"/u/, were made in an anechoic sound-controlled booth. Recordings were made using a Sennheiser MKH 800 condenser microphone with a cardioid pick-up pattern and at an approximate distance of 5–10 cm. Audio was digitally encoded with an M-Audio Fast Track Ultra interface at a sampling rate of 96 kHz and 32-bit amplitude quantization, and stored onto a computer as PCM WAV files using Adobe Soundbooth CS5 version 3.0. The number of voices used in our study is similar to the numbers used in previous studies examining voice preferences (e.g., Feinberg et al., 2008a; Pisanski and Rendall, 2011; Riding et al., 2006), the results of which generalize well to studies using larger samples of voices (e.g., Feinberg et al., 2008b; Puts, 2005).

We created two masculinized and two feminized versions of each original voice recording by independently manipulating pitch or formants using the Pitch-Synchronous Overlap Add (PSOLA) algorithm in Praat version 5.2.15 (Boersma and Weenink, 2013; Moulines and Charpentier, 1990). The PSOLA method allows one voice feature (e.g., pitch or formants) to be manipulated while leaving other voice features unaltered, and has been used successfully in many past studies of voice perception in humans (Feinberg et al., 2005, 2008b; Jones et al., 2010) and other mammals (Ghazanfar et al., 2007; Reby et al., 2005). Following results of psychophysical experiments identifying the optimal level of manipulation for studies of the attractiveness of acoustic properties of human speech (e.g., Re et al., 2012), we raised or lowered pitch by 10% from baseline while holding formants constant (*pitch masculinity manipulation*) and raised or lowered formants by 10% from baseline while holding pitch constant (*formant masculinity manipulation*). This process created 6 pairs of male voices that differed in pitch and 6 pairs of male voices that differed in formants. Work by Pisanski and Rendall (2011) suggests that percent-based manipulations of pitch and formants are perceptually equivalent.

The mean fundamental frequencies and formant frequencies of masculinized and feminized voices, given in Table 1, span the natural ranges of frequencies for large samples of English vowel sounds spoken by adult males (Bruckert et al., 2006; Feinberg et al., 2008b; Puts et al., 2012; Rendall et al., 2005). Following masculinity manipulation, we amplitude normalized the sound pressure level of all voices to 70 dB using the root mean squared method.

Masculinity manipulation check

We conducted a manipulation check to verify that masculinized voice stimuli influenced women's perceptions of men's masculinity

Table 1
Mean voice pitch and formant measures taken from feminized and masculinized male voice stimuli (given in Hz).

Manipulation	*F0*	*F1*	*F2*	*F3*	*F4*	*Fn*
Masculinized pitch	111	457	1525	2567	3440	1997
Feminized pitch	135	460	1525	2571	3437	1998
Masculinized formants	123	421	1375	2351	3145	1823
Feminized formants	123	513	1682	2817	3756	2192

Acronyms: *F0* = fundamental frequency (pitch); *F1*–*F4* = first to fourth formant; *Fn* = mean formant frequency (an average of *F1*–*F4*). Mean *F0* was measured using Praat's autocorrelation algorithm with a search range set to 65–300 Hz. Formants *F1*–*F4* were measured using the Burg Linear Predictive Coding algorithm. Formants were first overlaid on a spectrogram and manually adjusted until the best visual fit of predicted onto observed formants was obtained. All acoustic measurements were taken from the central, steady-state portion of each vowel, averaged across vowels for each voice, and then averaged across voices. This was done separately for each type of masculinity manipulation.

[1] Feinberg et al. (2006) did not investigate the hormonal correlates of cyclic shifts in women's masculinity preferences, but did find that women with higher average (i.e., trait) estradiol tended to show smaller cyclic shifts between fertile and non-fertile phases in their masculinity preferences.