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Original Article

Women's voice attractiveness varies across the menstrual cycle

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Abstract

We investigated ratings of female voice attractiveness as a function of menstrual cycle phase. Women had their voices recorded at four different times during their menstrual cycle. Voice samples were categorized from low to high conception risk based on menstrual cycle phase and empirical pregnancy data. Results showed a significant increase in voice attractiveness ratings as the risk of conception increased across the menstrual cycle in naturally cycling women. There was no effect for women using hormonal contraceptives. Previous research shows that the sound of a person's voice appears to serve as an honest signal of fitness, and our results show perceptual shifts in women's voices that match the predicted output of an independent and well-designed fertility monitoring system. More work is needed to identify the biological mechanisms that underlie these perceptual differences, but growing evidence points to the impact of hormones on the larynx as being the source of these changes.

Keywords: Voice attractiveness; Conception risk; Hormonal contraceptives; Menstrual cycle; Ovulation

1. Introduction

Research on the human voice has been subject to increased attention in recent years. Variation in dominance (Feinberg et al., 2006; Puts, Gaulin, & Verdonili, 2006), personality attributes (Zuckerman & Driver, 1989), fluctuating asymmetry (Hughes, Harrison, & Gallup, 2002), attractive body features (Hughes, Dispenza, & Gallup, 2004) and a host of other behavioral characteristics have been shown to correlate with variation in the sound of a person's voice. In other words, independent of the content of speech, voice appears to be a medium for the transmission of important biological information.

The human larynx is a hormonal steroid target organ (Caruso et al., 2000). During puberty, estrogen and progesterone affect the morphology of the larynx and shape the mature female voice, while testosterone modifies and deepens the male voice (Abitbol, Abitbol, & Abitbol, 1999). The same sex hormones that affect the voice at puberty also influence the development of sex-specific body configurations (Kasperk et al., 1997; Singh, 1993).

Just as physical characteristics like facial features may be involved in mate choice (Thornhill & Gangestad, 1999), vocal cues may also be important, especially since they can provide information about potential mates when visual cues are ambiguous or not available, such as at night (Hughes et al., 2002). Recent evidence shows that the sound of a person's voice not only provides information about body morphology, but also about features of their sexual behavior as well (Hughes et al., 2004).

Cyclic hormones affect the physical properties of a woman's voice across the menstrual cycle (Abitbol et al., 1999). Variations in female vocal production that occur during menstruation, pregnancy and menopause (Caruso et al., 2000) all coincide with marked hormonal changes. Epithelial smears from the larynx and vagina show similar cytology for steroid hormones (Caruso et al., 2000), particularly estrogen (Fegusson, Hudson, & McCarthy, 1987). Histologic laryngeal changes during the menstrual cycle mirror those of the endometrium (Abitbol et al., 1999). The use of hormonal contraceptives also has an effect on female vocal production. Investigating these changes

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through spectrogram analysis, Amir, Kishon-Rabin and Muchnik (2002) found that females using hormonal contraceptives had significantly lower jitter and shimmer in their voices than naturally cycling females. Chae, Choi, Kang, Choi and Jin (2001) showed that females experiencing premenstrual syndrome (PMS), which corresponds to hormonal aberrations, were also more prone to vocal changes (e.g., more jitter, lower frequency) compared to other times during the menstrual cycle. G. Bryant and M. Haselton (unpublished data) have also recently reported preliminary evidence for an increase in voice pitch at ovulation compared to other times during the menstrual cycle.

Progesterone increases the viscosity and acidity levels of glandular laryngeal cells, which leads to a decrease in volume, causing vocal cord edema. Estrogen has a hypertrophic effect on laryngeal mucus and increases glandular cell secretion (Abitbol et al., 1999; Amir et al., 2002). Abitbol (1989) and Abitbol et al. (1999) have identified vocal characteristics such as hoarseness, fatigue and decreases in range as being clinical signs of vocal PMS. In summary, the larynx and genitals clearly seem to be targets for the same sex hormones, and both seem to be affected by hormonal fluctuations across the menstrual cycle.

A number of adaptive behaviors vary across the menstrual cycle that correspond to changes in conception risk. Sexual risk-taking behaviors (Chavenne & Gallup, 1998), reactions to the scent of more symmetrical males (Gangestad & Thornhill, 1998) and preference for more masculine facial features (Penton-Voak & Perrett, 2000) have all been shown to vary as a function of cycle phase. It is reasonable to suppose that the cyclic hormones driving these behaviors could also affect women's voices as well.

In the present study, we investigated attractiveness ratings of female voices collected at different points during the menstrual cycle.

2. Methods

2.1. Voice participants

A total of 51 female undergraduates from the State University of New York at Albany were recruited to provide voice samples. Students were recruited through the research subject pool and by advertisements posted around campus. Participants recruited through the research pool were given course credit; those recruited by posters were paid US$2.50 for each voice session they participated in. The study was approved by the university Institutional Review Board.

Using a coded anonymous survey, participants were asked about their age, number of committed partners and number of lifetime sexual partners. There were no significant differences between females using hormonal contraceptives and naturally cycling females for number of committed partners (t_{35}=.24, p=.81), or number of sexual partners (t_{36}=−.86, p=.39). Naturally cycling females were between 17 and 30 years of age (mean=21.12, S.D.=3.16), and their cycle length ranged from 19 to 48 days (mean=29.59, S.D.=7.12). All females were asked to report whether their menstrual cycle was regular, somewhat regular, somewhat irregular or very irregular (regularity was defined as the number of days between periods being the same from cycle to cycle, e.g., every 28 days). The majority of females reported having either somewhat regular or regular cycles. All females except three met the criterion of reporting somewhat regular or regular cycles and were included in the analyses. Two females had atypical cycle lengths but reported having regular cycles. Upon returning for follow-up voice samples, we were able to verify that menstruation did happen on the days predicted for these females; therefore, they were included in analyses. One naturally cycling female had used a form of hormonal contraceptive 3 months prior to the study. All other naturally cycling females indicated not having used hormonal contraceptives for more than 3 months prior to this study.

Females taking hormonal contraceptives ranged from 18 to 26 years of age (mean=20.19, S.D.=2.09), and their cycle length ranged from 24 to 34 days (mean=27.86, S.D.=1.8). One participant started using hormonal contraceptives 2 months prior to the study. All others had been using hormonal contraceptive for longer periods of time. Participants were not included in the analysis if they were not fluent in English, had speech impediments, were chronic smokers (more than a pack a week), had a cold or illness on the day of voice recording, had very irregular menstrual cycles, were pregnant or used any form of morning-after pill within the last 3 months. Thirteen women were excluded for these reasons, leaving 17 naturally cycling females and 21 females using hormonal contraceptives.

2.2. Voice raters

An additional 34 males and 32 females were recruited through the university research subject pool to rate the voice recordings. Raters ranged from 17 to 25 years of age. All raters reported being heterosexual. Raters all reported having normal hearing. Six raters handed in incomplete rating forms and were not included in the analysis, leaving 30 male and 30 female raters.

2.3. Procedures — female voice recordings

The initial session consisted of two parts: completion of a background survey (menstrual cycle length and regularity, use of hormonal contraceptives, etc.), and a voice sample. To preclude the possibility that the content of what participants said could influence the perception of their voices, subject's voices were only recorded while they counted from 1 to 10. This procedure has been used previously to hold the content of recordings constant and to obtain speech samples that are cognitively and affectively neutral (Hughes et al., 2002, 2004). Voice recordings were taken using an Altec Lansing

AHS515 headset, with the microphone placed approximately 8 cm from the subject's mouth. Voices were recorded onto computer software at 48 kHz, 16 bit, mono (Microsoft Sound Recorder 5.0). After the initial voice recording, participants were scheduled to return for three follow-up voice recording sessions depending on their menstrual cycle length. For example, if a female indicated having a cycle length of 28 days, she would be instructed to return every 7 days, but if she indicated having a 35-day cycle, she would be asked to return every 9 days. Thus we attempted to obtain a total of four equally spaced voice recordings across every female's menstrual cycle. Other studies investigating behavior across the menstrual cycle have often dichotomized females into high and low conception groups (i.e., Feinberg et al., 2006; Haselton & Gangestad, 2006; Penton-Voak & Perrett, 2000). With the average menstrual cycle length being around 28 days, we chose four, weekly spaced follow-up voice sessions that would enable us to map effects within groups, but would not burden the participants with excessive requirements for return visits.

All participants provided information about the first day of their last menstruation and their average cycle length. Since our subjects returned to give follow-up voice samples, we were able to verify whether they did begin menstruation on the day calculated from the initial voice recording session. As evidence that our estimates were accurate, menstruation began within 1 or 2 days of our calculations for the majority (87%) of females. If subjects had a shortened or delayed onset of their next menstrual flow (meaning shorter or longer cycle length), we adjusted the projected length of the subject's cycle in order to provide a more accurate estimate of where they were in their menstrual cycle when voice samples were obtained.

2.4. Procedures — voice ratings

The entire stimulus set was too large to have each rater listen to all 152 voice samples from the 38 females. Raters were divided into two groups: one group (14 males, 14 females) listened to each of four different voice recordings from 20 females (10 naturally cycling and 10 taking hormonal contraceptives), the other group (16 males, 16 females) listened to the four different voice recordings from the remaining 18 females (7 naturally cycling and 11 taking hormonal contraceptives). Raters were asked to rate the level of voice attractiveness on a 100-point unlabelled scale, with 1 being the least attractive and 100 being the most attractive. The presentation of voice recordings was randomized and each voice was presented only once unless a rater asked to hear the voice again. Subjects were instructed not to rate any voices they thought they recognized. After the completion of the study, raters were informed that they heard four different versions of each female's voice. Only two raters indicated being aware of this, suggesting that for the most part raters were oblivious to hearing repeated versions of the same voice.

2.5. Conception risk calculations

Since each voice sample coincided with a particular day in the subject's menstrual cycle, we calculated conception risks for each of the four voice samples obtained from each female using empirical pregnancy rates derived from Wilcox, Dunson, Weinberg, Trussell and Baird (2001). Conception risk is the probability of conceiving from a single act of unprotected sexual intercourse. The closer a female is to ovulation, the greater the risk of conception (obviously females who were taking hormonal contraceptives would not be subject to changes in conception risk, but for purposes of comparison their data were organized according to their cycle phase as though they were normally cycling). For instance, according to Wilcox et al., a regularly cycling female has a 9.3% chance of conceiving from having unprotected sexual intercourse on Day 13 of her menstrual cycle and a 0.5% chance on Day 28. With the Puts (2006) methodology, females who had cycle lengths other than 28 days were standardized into a 28-day cycle and conception risks were calculated according to the variation that occurred during the follicular phase of the menstrual cycle.

2.6. Data organization and analysis

After all of the voices had been rated, the dataset was organized for planned comparison contrasts. Female's voice samples were arranged in order from lowest to highest risk of conception. Phase 1 represents voices that were recorded at the lowest risk of conception, and Phase 4 represents those obtained at the highest risk of conception, with Phases 2 and 3 corresponding to intermediate levels of conception risk. In the initial analysis, we collapsed across voices, yielding four composite scores for all of the voices that each rater heard at each of the four different phases. This was done separately for the naturally cycling females and those using hormonal contraceptives. In a subsequent analysis, we collapsed across raters rather than voices in order to conduct additional analyses on voice attractiveness, yielding average ratings across raters for each female voice. The average risk of conception for all females across the four phases was 0.25% (S.D.=.25%), 0.97% (S.D.=.68%), 3.04% (S.D.=1.37%) and 7.84 % (S.D.=1.83%), respectively.

A 2×4 repeated measures MANOVA was used to analyze the data. The first factor was hormonal contraceptive use: naturally cycling or hormonal contraceptives. The second factor was phase: the four different voice samples from females collected at different times across the menstrual cycle.

3. Results

Initial data screening revealed no univariate Z score outliers among the voice samples. With a critical chi-square value of 24.32 (df=7, p<.001) for Mahalanobis distance

(Tabachnick & Fidell, 2007), no multivariate outliers were found. For Cook's distance (Tabachnick & Fidell, 2007), all cases fell within the acceptable range of 0 and 1. Before collapsing across voices, there were several missing data points in both groups for five raters. In order to include their ratings in subsequent analyses, the mean attractiveness rating that other raters gave the same voice was substituted for the missing data.

The Contraceptive Use by Phase interaction was significant (Wilks' $F_{3,56}$=12.14, p<.001). As shown in Fig. 1, ratings of voice attractiveness for naturally cycling females increased as the risk of conception increased. However, there was no effect of voice attractiveness and menstrual cycle phase for females taking hormonal contraceptives. No other omnibus tests were considered since planned comparisons were the focus of interest (Tabachnick, & Fidell, 2007).

A priori trend analysis contrasts were conducted to identify trends in vocal attractiveness ratings in each of the simple main effects of phase, moving from lowest to highest conception risk. Trend analysis was used because of the quantitative nature of conception risk as an independent variable. Since conception risk for females was not the same when moving from low to high conception risk across the groups, the polynomial coefficient weights matched the varying, monotonic increases in conception risk. The voice attractiveness rating trend as a function of conception risk among naturally cycling females was significant ($F_{1,58}$=41.95, p<.001). The partial eta^2 (η^2), which is a measure of effect size in MANOVA, showed that 42% of the variance in the ratings of vocal attractiveness could be explained in an increasing fashion moving from low to high conception risk in females who were naturally cycling. The trend among females who were using hormonal contraceptives was not significant ($F_{1,58}$=1.48, p=.229, partialη^2=.02) (see Fig. 1). Since we predicted a priori the best-fitting weights for the trend derived from calculated conception risks, the higher order polynomial contrasts such as quadratic and cubic functions were not of interest (Myers & Well, 2003, p. 280). There were no significant sex differences between male and female raters ($F_{1,58}$=1.15, p=.289). Naturally cycling females had higher voice attractiveness ratings than those using hormonal contraceptives when collapsed across phases, but the difference was not significant ($F_{1,58}$=.69, p=.409).

We also conducted stepwise post hoc comparisons on each of the mean voice attractiveness ratings using Hochberg's step-up method, which organizes mean comparison p values from largest to smallest, then adjusts error rates sequentially to keep the familywise error rate constant, in this instance .05 (see Myers & Well, 2003, p. 247). The results are presented in Table 1 and show that none of the phase comparisons for women using hormonal contraceptives was significant, while five out of the six phase comparisons for naturally cycling females were significantly different.

As further evidence that the perceptual features of female voices vary as a function of cycle phase, the correlation between conception risk and the average rank-ordered voice attractiveness ratings from each rater was significant for naturally cycling females (r=.41, p<.01), but not for those taking hormonal contraceptives.

In a subsequent analysis, we collapsed attractiveness ratings across raters and ran trend analyses among females who were naturally cycling and those using hormonal contraceptives, focusing on individual female voices as the level of analysis, not raters. Comparable effects were found

Table 1
Hochberg's step-up post hoc comparisons in naturally cycling females and those taking hormonal contraceptives

Phase comparisons	Mean difference	Adjusted error rate	*P* value	Cohen's *d*
Natural cycling				
1–2	−1.645	.05	.076	−.23
3–4	−2.265	.025	.016 *	−.32
2–3	−2.031	.0167	.007 *	−.36
1–3	−3.676	.0125	.001 *	−.43
2–4	−4.296	.01	<.001 *	−.66
1–4	−5.94	.008	<.001 *	−.79
Hormone contraceptives				
1–4	−.012	.05	.987	<−.01
2–3	.26	.025	.756	.04
3–4	1.487	.0167	.064	.24
1–3	−1.499	.0125	.057	−.25
1–2	−1.759	.01	.021	−.31
2–4	1.747	.008	.011	.34

* Indicates significant effect compared to adjusted error rate.

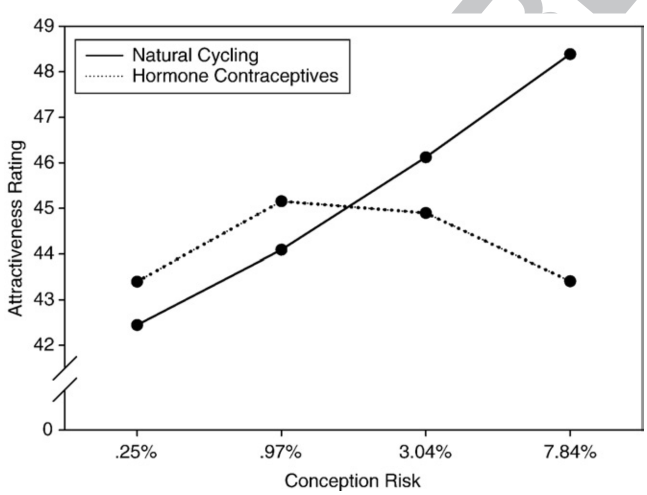

Fig. 1. Mean voice attractiveness ratings as a function of conception risk in naturally cycling women and those taking hormonal contraceptives (females taking hormonal contraceptives are not at risk of conception, but for purposes of comparison their voices were analyzed according to comparable points in the menstrual cycle). Means and standard errors for naturally cycling women (from lowest to highest likelihood to conceive) were 42.45±1.56, 44.1±1.18, 46.12±1.2 and 48.39±1.38; for women who were taking hormonal contraceptives, they were 43.4±1.2, 45.15±1.13, 44.89±1.42 and 43.41±1.2.

whether collapsing on voices or raters. The Contraceptive Use by Phase interaction was significant [Wilks' $F_{3,14}$=4.72, p<.05 (since there were more females using hormonal contraceptives, in order to compute the interaction with equal n's we randomly excluded four females in the hormonal contraceptive group)]. The trend was also significant for naturally cycling females ($F_{1,16}$=9.18, p<.01, partial η^2=.36), but not for females using hormonal contraceptives ($F_{1,16}$=.82, p=.38, partial η^2=.05).

4. Discussion

Students listening to women count from 1 to 10 at different times during the menstrual cycle rated the voices as being more attractive as the speaker's risk of conception increased. This increase in vocal attractiveness was only found for females who were naturally cycling. There were no menstrual cycle effects on voice attractiveness ratings for those taking hormonal contraceptives.

Consistent with the findings of Hughes et al. (2002) concerning voice and fluctuating asymmetry where there were no sex differences in ratings of voice attractiveness, we also found no differences in how males and females rated voices as a function of where the speakers were in their menstrual cycle. Had more targeted questions been asked such as, "rate this voice for *sexual* attractiveness," or "how likely would you be to date or have sex with this person," it is possible that sex differences might have emerged. For example, the correlations between voice attractiveness ratings by members of the opposite sex and different aspects of the speaker's sexual behavior are higher than same sex ratings (Hughes et al., 2004). Females also rate feminized voices of other females as more attractive than masculinized voices (Feinberg et al., 2006). When rating male voices, females prefer those lower in pitch (Collins, 2000), especially when they are near ovulation (Feinberg et al., 2006; Puts, 2005). Males, on the other hand, judge male voices that are lower in pitch as being more dominant (Puts et al., 2006; Puts, Hodges, Cárdenas, & Gaulin, 2007). However, both sexes rate male and female voices as more attractive if they are collected from speakers who have pronounced sex-specific body configurations (Hughes et al., 2004). Clearly under certain circumstances both sexes are discerning of same/opposite sex vocal cues, albeit for different reasons. Puts et al. (2006) argue that males can distinguish vocal dominance cues from other males because of male–male intrasexual competition.

Although raters preferred voice samples taken from females who were closer to ovulation, the physical properties of voice that mediate these effects remain unclear. Abitbol et al. have identified physical features of women's voices that change with the PMS (Abitbol et al., 1989; Abitbol et al., 1999). Collins and Missing (2003) found that female voices higher in frequency were rated as more attractive and younger, whereas lower frequency voices were rated as being less attractive and older. Chae et al. (2001) found that vocal parameters in most of the women in their study who experienced PMS showed an increase in jitter and slightly lower frequency compared to other times during the menstrual cycle. Vocal cord edema produces a decrease in vocal frequency, causes antiproliferative effects on mucosa and increases the viscosity and acidity of cellular secretions which frequently occur around menstruation and are thought to be driven by higher progesterone and lower estrogen levels (Abitbol et al., 1999; Amir et al., 2002). Consistent with this, recent evidence suggests that fundamental frequency in female voices may be higher at ovulation compared to other times during the menstrual cycle (Bryant, G., & Haselton, M., unpublished data), suggesting that fundamental frequency may be one component of attractiveness.

Puberty (Abitbol et al., 1999) and menopause (Caruso et al., 2000) affect vocal production. The evidence suggests that the impact of hormones across the menstrual cycle might drive vocal changes and perceptual features of voice, but more research is needed. Premenstrual syndrome and the more psychologically detrimental premenstrual dysphoric disorder occur during the luteal phase just before menstruation, when progesterone is highest. These disorders are thought to be dependent on the menstrual cycle and are disabling both behaviorally and emotionally (Indusekhar, Usman & O'Brien, 2007). Because of potential hormonal influences on mood, female voices recorded close to ovulation might actually seem more prosocial or interactive compared to voice recordings that were closer to menstruation, which in turn could be driving the perceptual differences obtained in our study.

Our data interpretation is limited to perceptual effects. We did not perform acoustic analyses (i.e., spectrogram analysis) on our voice data. From the perspective of evolutionary theory, we were principally interested in whether people could detect differences. In trying to pinpoint the physical parameters of voice attractiveness using spectrogram analysis, Hughes, Pastizzo and Gallup (in press) have recently failed to find a substantial number of parametric differences between attractive and unattractive voices. Hughes et al. attribute the lack of acoustical correlates in their study as evidence for highly evolved modules in the human brain that conduct a more complicated and/or more efficient assessment of voice than what contemporary acoustic computer software provides.

A number of behaviors vary across the menstrual cycle in relationship to conception risk (e.g., Chavenne & Gallup, 1998; Gangestad & Thornhill, 1998; Penton-Voak & Perrett, 2000). Most studies focus on how females may be affected by their menstrual cycle (e.g., Feinberg et al., 2006; Puts, 2005, 2006), and less attention has focused on how people's judgments vary as a function of the target female's cycle phase. Recent evidence, however, suggests that men may adjust their mate guarding strategies depending on their partner's cycle (Haselton & Gangestad, 2006), and our data suggest that the sound of a woman's voice may also change as a function of her menstrual cycle phase.

Consistent with our findings, it has been shown that male macaque monkeys distinguish and prefer female vocal calls made in estrus, compared to nonfertile calls (Semple & McComb, 2000). The basic underlying anatomy, acoustics and central control over vocal tracts are similar between humans and other mammals (Fitch, 2000) implying that our findings may not be unique to humans.

Unlike visual cues, vocal communication is light independent (Gallup & Cameron, 1992). Patterns of nocturnal copulation are common among humans the world over (Ford & Beach, 1951). During daylight, vocal cues probably compliment other sensory domains when it comes to mate selection and the timing of copulation relative to changes in the probability of conception. Collins and Missing (2003) and Johnstone (1995) refer to this as "back up signaling" or "multiple messages" of overall fitness. How important vocal cues are compared to other sensory domains remains unclear, but in the absence of other cues the evidence suggests that the human vocal tract is a medium that provides cues about many biologically/reproductively relevant features. Not only are fluctuating asymmetry and body configuration conveyed through voice, but significant differences in sexual behavior can also be accounted for by the sound of someone's voice (see Hughes et al., 2002, 2004).

In support of the hypothesis that voice is a medium for conveying important fitness and mate assessment cues, our data show that voice varies as a function of fertility in females and ratings of voice attractiveness peak during the ovulatory phase. These results showing that ratings of female voices vary as a function of menstrual cycle-induced changes in fertility may, along with other changes, help explain recent findings showing that lap dancers make significantly more tip revenue when they are in midcycle (Miller, Tybur, & Jordan, 2007).

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