MEN'S EVALUATIONS OF WOMEN'S SPEECH IN A SIMULATED DATING CONTEXT

by

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Abstract

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The study adopted an evolutionary approach to advance and test directional hypotheses on changes in women's vocal attractiveness and vocal pitch as a function of the varying fertility levels. A pre-recorded male speech sample that was selected as sexually attractive among a few others by an independent group of ten female raters was used to simulate a dating context. A separate group of thirty six normally cycling women responded to the masculinized and feminized versions of the male speech sample during the high and low fertility phases of the menstrual cycle. The cycle phases were determined by the menstrual cycle details provided by the women on a screening questionnaire, and the phases were confirmed by self-administered commercially available ovulation tests. Every woman's speech sample included a pre-decided made up phone number given as a response to the male's request for the same. This number was extracted from each of the women's responses, and was evaluated by men for attractiveness. The phone numbers were analyzed acoustically to obtain the average fundamental frequencies. The results revealed that consistent with one of the hypotheses, the male listeners gave higher attractiveness ratings to the females' speech samples collected in the high fertility phase than the ones from the low fertility phase. Overall, the average speaking fundamental frequency was relatively low for the samples from the high-fertility phase, which was partly contrary to another hypothesis in terms of the hypothesized direction of the pitch difference between the fertility

phases. Also contrary to expectation was the finding that the masculinity of the male voice failed to affect the women's speech; the explanation offered mainly pertains to a study design issue. The results have been discussed by integrating evidence for situation-dependent vocal adjustments involving pitch, ethological explanations on the use of high and low pitch as potential signals of submissiveness and dominance/maturity, and evolutionary arguments explaining the purported dual nature of female sexuality.

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I. INTRODUCTION

Research in linguistics and, in speech and language sciences has focused on the information conveyed by phonological, morphological, and lexical units, especially when they are carried by grammatically well-formed sentences. Speakers voluntarily provide this information to attentive listeners. In the related field of psychology, speech research has also involved examining listeners' ability to infer speaker-specific information, which includes age, sex, physical characteristics, emotionality, attitudes, and personality attributes. Evolutionary psychology relies on Neo-Darwinism (explained later) to formulate specific hypotheses about features of modern human behavior as either direct adaptive solutions to problems faced in ancestral environments that aided survival and reproduction or as indirect side effects maintained as a result of other adaptations (Confer, Easton, Fleischman, Goetz, Lewis, Perilloux, & Buss, 2010).

Any branch of the study of the human mind or behavior will benefit from taking into account the evolutionary function of the phenomenon in question. Consider, for instance, the act of speaking. It is a vocal and verbal behavior that follows a developmental pattern. Infants babble, children put words together to form meaningful short phrases, and adolescents engage in increasingly performative ways of speaking. In order to fully appreciate the occurrence of these phenomena in their natural settings, it is crucial to identify the putative pressures in the evolutionary history that may have led to the selection and maintenance of these aspects in each of these stages (Locke & Bogin, 2006; Locke, 2009).

The biological benefits--higher probability of survival, reproduction, and offspring fitness--conferred to successive generations by certain dispositions may have built in the human

mind "rules of thumb" (e.g., Dawkins, 1982) that even today influence our perceptual or aesthetic evaluations, psychological experiences, and behavior. To clarify the above point, the following analogy pointed out by the evolutionary biologist Richard Dawkins (2006) may be helpful. Whereas the biological benefit of copulation was genetic propagation via sexual reproduction, the rough rule of thumb this resulted in was "enjoy sex" and not "enjoy sex whenever sex can produce offspring". Sexual desire exists in spite of our active attempts to stop genetic transfer with contraception.

Along the same lines, in our evolutionary past some of the favored rules-of-thumb may have been something like the following: "attract attention", a strategy that served vulnerable human infants by eliciting care from adults (e.g., Locke & Bogin, 2006: Locke, 2006), "listen to and inform kin", another that helped mobile but dependent children in avoiding danger (e.g., Fitch, 2000; Locke & Bogin, 2006), "in situation X be dominant" for sub-adult males to attract mates, and so on (e.g., Locke & Bogin, 2006). When triggered by environmental cues we tend to spontaneously follow these built-in rules without having to consciously acknowledge them or link them with the adaptive benefits that may have led to their origin in the first place. The effects of these kinds of built-in rules or strategies may be examined in a conspicuous and flexible behavior like speaking by eliciting it in appropriate contexts.

Applying the Evolutionary Psychology rationale to speech and language expands the field of communication sciences by opening up new and exciting avenues of investigation. Some empirical work linking biological fitness and the speaking voice of adults has been carried out. The fitness variables include the reproductive potential of speakers, evaluated by listeners as short-term sexual attractiveness and attractiveness in a long-term relationship. The current study focuses on the variations in attractiveness of women's speaking voice as a function of the

varying fertility levels. The pilot study examined the potential changes in men's attractiveness-evaluations and in the average speaking pitch of women's read speech samples elicited in a relatively neutral context as a function of the menstrual cycle phases (two phases classified in terms of the probability of conception), and the larger study explored the same aspects on women's spontaneous speech samples elicited in a simulated dating context.

The study aimed to gain evolutionary insight into potential cycle-related vocal pitch changes in women and corresponding aesthetic judgments by men. Therefore, the review of literature will first briefly introduce the Neo-Darwinian theory of evolution by selection and will examine human mate-choice criteria from this perspective. These sections will serve as a foundation for understanding the pattern of attractiveness-evaluations of women's and men's speaking voices, mostly in relation to vocal pitch, the acoustic factor of interest. Hypotheses will be advanced by integrating the evolutionary interpretation of mate preferences, the role of women's and men's vocal pitch in influencing aesthetic judgments and signaling fitness, and the contextual and physiological effects on women's pitch. The Method chapter will detail the procedural aspects of the larger study followed by the results and discussion of the same as two separate chapters. The method and results of the pilot study will be included in the appendix to which sections in the Introduction will refer.

II. REVIEW OF LITERATURE

2.1 Evolution by selection

Darwin proposed the theory of evolution by natural selection (1859). He understood that variations existed between as well as within species in terms of their physical and behavioral characteristics. The variants that facilitated the survival of organisms were inherited by future generations, and in this way, were preserved by nature (natural selection). Ever since the discovery of genes as particulate units of information capable of self-replication (starting with Mendel's laws, of which Darwin was unaware), the notion of inheritance, as Darwin had envisaged it, underwent modifications (Cronin, 1991; Dawkins, 1976).

Neo-Darwinism focuses on gene-survival in addition to organism-survival. The gene-centered view clarifies and extends the core idea of traditional Darwinism; bodies of organisms die but genes find their way into future generations via sexual reproduction. Which genes succeed in replicating and thereby disproportionately populating the gene pool of a species depends on the adaptive capacity of the phenotypic effects--the physical or behavioral expression of the genes. That is, if certain genes, by virtue of their phenotypic effects, predispose their owners to behave and perceive in ways that help them to survive long enough to enter and appear popular in the mating market, there is a high likelihood that these genes get passed on, and that the characteristics they code for get expressed in future generations (Cronin, 1991; Dawkins, 1976, 1982).

2.2 Neo-Darwinian interpretation of mate-choice criteria

Before proceeding, it is important to indicate that the language used below may lead one to think of the perceptions and actions as consciously calculated processes, but it is crucial to

remember that they are not. For example, usages with the prefix "trying to" such as trying to: maximize fitness, sound attractive, manipulate, deceive, attract, signal, and the like are convenient ways to refer to unconscious strategies (rules of thumb as discussed in the beginning) that have been assumedly favored in evolutionary time among several other strategies, and that reveal themselves when triggered by specific environmental cues[1]. Also, the intention of the following evolutionary analyses is not to advocate any particular male-female interaction style or process of aesthetic evaluation.

From a Neo-Darwinian standpoint every individual is viewed as a living unit trying to maximize its genetic fitness. Everybody else from the individual's perspective is a competitor with whom, depending upon the degree of shared or conflicting interests, it has to cooperate or compete to move ahead. Manipulation and mindreading of others are of paramount importance in such a scenario. These activities involve costs in the form of spent time, energy, and risk involved. Benefits are in the form of survival, reproduction, and offspring (or kin) fitness. Hence cost-benefit trade-offs must be considered. These are the few basic assumptions made in order to formulate a parsimonious evolutionary hypothesis for any behavior, be it behaviors associated with kin (all genetic relatives—parents, offspring, siblings), mates, or altruistic acts towards strangers (Dawkins, 1976; 1979; 1982; Krebs & Dawkins, 1984).

[1] 'Strategy' is a concept derived from game theory. It was adopted by evolutionary biology. For example, John Maynard Smith, a pioneer in the use of this term in the theory of evolutionarily stable strategies, predicted and explained alternative strategies that could evolve and stabilize over evolutionary time in animal fighting (Dawkins, 1982). Aspects of evolved female sexuality have been treated in similar ways using game theoretical models (Rodriguez-Girones &Enquist, 2001).

2.2.1 Reproductive costs and vocal fitness indication

In sexual reproduction, only half of a parent's genes are transferred to the offspring, the other half come from the other parent. It follows from this fact that potential mates will be evaluated on their genetic fitness. Masculinity- and femininity-indicators are often referred to as honest or costly fitness-indicators or good-gene indicators in humans, which affect attractiveness-evaluations. The putative reason for this is that the generation of the primary reproductive hormones--testosterone in males and estrogen in females--which in turn influence the development of the fitness-indicators, depends on the genetic quality of the individual. For example, because of the potential handicapping effects of the hormones on the immune system less fit individuals may not be able to allocate energy to exaggerated mating efforts in addition to efforts on somatic repair (e.g., immunocompetence hypothesis by Folstad & Kartar; also reviewed in Thornhill & Gangestad, 2008).

The speaking voice may be an honest fitness-indicator as aspects of it have been associated with the reproductive hormones, and are indicative of masculinity/femininity. Heritability of vocal aspects has been reported as well (DeBruyne, Decoster, Gijsel, & Vercammen, 2002; Van Lierde, Vinck, De Ley, Clement, & Van Cauwenberge, 2005). A relatively low vocal pitch in men is considered masculine, dominant, and attractive (e.g., Feinberg, Jones, Little, Burt, & Perrett, 2005), and a relatively high pitch in women is considered feminine and attractive (e.g., Feinberg, DeBruine, Jones, & Perret, 2008). Men's vocal pitch is negatively correlated with the amount of circulating testosterone (Dabbs & Mallinger, 1999), the number of offspring (Apicella, Feinberg, & Marlowe, 2007), and other fitness indicators such as shoulder to hip ratio or SHR (Evans, Neave, & Wakelin, 2006). Even though the female

speaking voice has not been directly linked to estrogen, attractiveness-evaluations of women's speech-samples by men negatively correlated with waist-to-hip ratios or WHR, which is a putative estrogen-marker (Hughes, Dispenza, & Gallup, 2004; also Hughes, Harrison, & Gallup, 2009). Significant correlations were reported between attractiveness ratings of men's speech and SHR as well (Hughes et al. 2004; also see Hughes et al. 2009).

Moreover, vocal behavior or the act of speaking itself may be an honest or costly fitness-indicator (Locke, 2008). Even though males and females both agree about the speaking vocal pitch that is considered attractive in each of the sexes, individuals may still differ in their ability to effectively employ the strategy of pitch-lowering in situations in which spontaneous speech is elicited. For example, males and females evaluate a relatively low male vocal pitch as dominant-sounding (Jones, Feinberg, DeBruine, Little, & Vukovic, 2010). Yet in a simulated dating context in which male participants were asked to verbally compete with a male competitor to win a lunch date with an attractive woman, the participants lowered or raised their pitch based on the perception of relative dominance in the competitor male's speech. This indicates that one cannot pretend to be a dominant speaker just because one intuitively knows what may be considered dominant and attractive. In a competitive situation the male speaking behavior, in terms of his vocal pitch, appears to qualify as an honest fitness-indicator (Locke, 2008).

Apart from costs related to fitness-indication, reproductive costs must be taken into account. The fundamental difference between males and females lies in the size and the number of gametes or sex cells; this is the basic defining feature of the sexes. Whereas sperm, the male gametes are small in size and are continuously produced in prodigious quantities for a relatively large proportion of a man's life, the rate of production of ova, the relatively large female gametes, is much lower, and the cyclically interrupted supply pattern lasts for a relatively limited

period of time in a woman's life. Moreover, whereas nutrition availability and energy flux/balance significantly affect ovarian (organ producing ova) functioning, only severe malnutrition affects sperm production (Ellison, 2001). Hence, the reproductive costs for females involve energetic requirements in gamete production, in addition to costs related to child bearing (gestation for 9 months) and lactation (the average age of weaning is 3.5 years, Locke & Bogin, 2006)—costs that males do not share. Being the bigger obligate investor in reproduction it is logical to expect females to exercise greater caution than males in mate-selection (Trivers, 1972). The only cost incurred by males in reproduction is some waste of time and energy during copulation, which is negligible.

It could be expected that the mate-choice criteria of women would reveal a strategy that attempts to offset the extra costs. David Buss's (1989) cross-cultural study on mate-preferences demonstrated that across 37 cultures on five continents, the same pattern of sex-difference emerged. Overall, men focused on features indicative of women's reproductive capacity and women valued cues related to financial prospects or resource acquisition capacity in men. In social monogamy with bi-parental care, this trend seems reasonable—women with the greater obligatory reproductive investment seek material resources from men, and men seek to channel their investment towards healthy and fertile women. Aspects of these sex-specific mate-choice criteria may be reflected even in the aesthetic evaluations of the speaking voices of men and women.

2.2.2 Sex-specific aesthetic and personality evaluations based on the speaking voice

What is considered attractive in each sex seems to be different. Consider the differences in the aesthetic judgments of similar voice characteristics in male and female speakers. An earlier study by Addington (1963) found sex-differences in personality attributions based on

males' and females' speech that simulated similar speaking attributes (i.e. by manipulating voice quality, rate, and pitch variety). Female listeners did not differ from male listeners in the direction or strength of perception. However, similar voice qualities such as tenseness and throatiness in male and female speakers led to different personality perceptions; while throatiness in males was evaluated as realistic, mature, and sophisticated, females with the same voice quality were judged as masculine, unemotional, lazy, ugly, uninteresting, careless and neurotic. In another study although both men's and women's voices with lowered rather than raised pitch were rated as dominant-sounding by male- and female-listeners, the dominance-quality affected attractiveness-evaluations in sex-specific ways; lowered pitch was significantly more attractive than raised pitch in males, and vice versa in females (Jones, Feinberg, DeBruine, Little, & Vukovic, 2010). This is in line with the mate-preference literature. In women, vocal pitch reduces with age (Russell, Penny, & Pemberton, 1995; Collins & Missing, 2003), and so does female fecundity and future reproductive capacity (Ellison, 2001); social dominance in men positively correlates with testosterone levels (e.g., Mazur & Booth, 1998), and dominant men may also have high status and access to resources (e.g., Cashdan, 1995).

Additionally, male-stimuli that received high scores on masculinity and dominance received low scores on trustworthiness, kindness, and reliability as long-term partners (e.g., Kruger, 2006). In the same vein, studies that specifically asked female subjects to evaluate attractiveness of male stimuli presented via different modalities (face, voice, body, smell) for both short- and long-term mating contexts, consistently demonstrated that masculinity preference was enhanced or revealed in the short-term mating contexts (one-night stands) (e.g., Little, Connely, Feinberg, Jones, & Roberts, 2011) and during peak fertility (see references in Little et al. 2011). Men who are masculine and dominant may be in demand in the mating market and

may tend to seek multiple mating opportunities (e.g., Booth & Dabbs, 1993), and men who are less masculine may be more faithful and committed to invest in relationships. Draper and Harpending (1982) labeled the two categories of men as cads and dads, respectively. In reality, these may only be two extremes of a continuum, but the many possibilities in between will be ignored for now for theoretical simplicity and clarity (Dawkins, 1982).

Women appear to be intuitive about the trade-offs in choosing a cad versus a dad (e.g. Kruger, Fisher, & Jobling, 2003). Even though, as noted earlier, a negative correlation has been found in men between vocal pitch and number of offspring (Apicella et al. 2007), it is interesting to note that breastfeeding mothers in a hunter-gatherer tribe preferred the high-pitched versions to the low-pitched versions of male voices, which may be part of an evolved psychological adaptation that once functioned to seek and secure long-term investment from males at a crucial time (Apicella & Feinberg, 2009; also explained later). Also, note that self-perceived attractiveness (e.g., Vukovic, Feinberg, Jones, DeBruine, Welling, Little, Smith, 2008; Penton-Voak, Little, Jones, Burt, Tiddeman, & Perrett, 2003), individual woman's average estrogen levels (Feinberg, Jones, Law Smith, Moore, DeBruine, Cornwell, et al. 2006), and ecological features (Little, Cohen, Jones, & Belsky, 2007; Penton-Voak, Jacobson, & Trivers, 2004) may mediate the degree of preference-shifts for masculinity in terms of the temporality of the mating contexts and women's current fertility levels.

The information on mate-preferences presented above will serve as a background to understand the motivation to elicit women's speech in a specific dating context, which will be a matter discussed later as well. Women's speech being the focus of the current study, the following sections will review 1) studies that have linked women's vocal pitch to reproductive variables in order to understand the possible role of pitch in signaling reproductive fitness, 2)

studies that have used within-subject in addition to between-subject designs in order to demonstrate that attractiveness-ratings appear to increase with increase in vocal pitch in either condition, and 3) studies that have shown that women's vocal pitch changes with environmental and physiological contexts in order to justify the use of a specific context for speech elicitation. Together, these sections will provide valid reasons to expect women to use vocal pitch as one of the tools or as part of a strategy to influence men's perceptions of attractiveness.

2.3 The speaking voice of women

2.3.1 The acoustic parameter that co-varies with fitness variables

Several studies have linked women's fundament frequency (f_0) with fitness variables, where fitness refers to the genetic propensity to live longer and reproduce better than other individuals in the population (Dawkins, 1982; also see at least five variations of the definition). Fundamental frequency or the base rate of vibration of the vocal folds is the physical correlate of pitch dependent on the length, mass, elasticity and tension of the vocal folds (e.g., Titze, 1989). F_0 values estimated from more than hundred connected speech samples of women negatively correlated with their health risk indices, derived from several health indicators such as weight, body mass index (BMI), hip circumference, waist circumference, and waist-to-hip-ratio. Moreover, negative correlations were found between fundamental frequency and each of the three physical factors---weight, BMI and hip circumference (Vukovic, Feinberg, DeBruine, Smith, & Jones, 2010a). These results are in agreement with a similar study by Collins and Missing (2003). A follow-up study by Vukovic et al. (2010a) employed a forced-choice test constructed by pairing up within-subject, f_0-manipulated vowel-samples of females; males selected, at above chance levels, the higher-pitched version as the healthier sounding voice. The findings suggest that vocal pitch may signal women's health status.

Females' f_0 values positively co-varied with their facial femininity as calculated by the index of facial-metric femininity (a measure of the degree of facial sexual dimorphism based on the main differences between averages of male and female faces). In a subsequent study by the same team, men preferred the facial prototype derived from averaging faces of women with high-pitched voices to the facial prototype that comprised faces of women with low-pitched voices. Similar results were obtained when real faces were used in place of the composite images; men preferred faces of women with high-pitched voices (Feinberg, Jones, DeBruine, Moore, Smith, Cornwell, et al. 2005). Note that facial feminity, like WHR, is a putative estrogen marker; ratings of facial femininity and attractiveness positively correlated with estrogen levels in females (Law Smith, Perrett, Jones, Cornwell, Moore, Feinberg, et al. 2006). The results of the studies so far support the claim that women's pitch may signal both health and reproductive potential.

2.3.2 Association between f_0 and attractiveness-evaluations in studies with between-subject and within-subject designs

In a large study with speech samples obtained from 17 to 27 year-old females, the f_0 values (range of 170.20 to 273.21; mean of 207.82 Hz) were linearly related to voice attractiveness ratings by males (Feinberg, DeBruine, Jones, & Perret, 2008). Collins & Missing (2003) found similar results in a smaller sample. Females who sounded relatively young received relatively high attractiveness-scores as well (Collins & Missing, 2003).

The studies mentioned above (Feinberg et al. 2008; Collins & Missing, 2003) employed a Likert scale. The results obtained by these studies were further corroborated by successive studies employing within-subject designs with two-alternative forced-choice tests. In these studies, evaluations were based on intra-individual f_0-manipulated pairs of female speech

samples. Feinberg et al. (2008) developed a forced-choice task using vowel-samples produced by females having high, low, and average, original pitch levels. The samples were experimentally raised and lowered by 20Hz to form the stimulus-pairs. Male-evaluations of attractiveness demonstrated increased preference for the high-pitched versions in all the three categories. The high-pitched versions in each of the three categories were selected as relatively feminine- and young-sounding. The starting pitch levels significantly influenced the *degree* to which the high-pitched voices were chosen as the more attractive- and the more feminine-sounding voice. That is, the proportion of voices with the raised pitch chosen, increased in the following order of starting pitch levels: low>average>high.

In a similar forced-choice task, when asked to choose the better marriage partner, a significant preference for the high-pitched female voice was demonstrated by males belonging to the Hadza tribe (a hunter-gatherer tribe in Tanzania); the female speech samples consisted of both Hadza and UK voices (Apicella & Feinberg, 2009). In yet another forced-choice study, when the stimulus-pairs contained socially relevant content ("I really like you" vs. "I don't really like you"), the raised pitch versions were chosen more frequently than the lowered pitch versions. It is to be noted that despite the difference in the "interest" expressed in the two conditions, males exhibited greater preference for the raised pitch than the lowered pitch in each of the two conditions, with stronger preferences in the positive interest condition (Jones, Feinberg, Debruine, Little, & Vukovic, 2008).

The studies thus far consistently demonstrate that men are attracted to relatively high-pitched voices in women (up to 270 Hz, see Feinberg et al. 2008; but see Leaderbrand, Dekam, Morey, & Tuma, 2008; Oguchi & Kikuchi, 1997; Van Bezooijen, 1995). Given that the fundamental frequency manipulations of individual women's speech samples affect their

attractiveness, it is reasonable to ask if a woman's f_0 varies naturally so as to affect perceptions of listeners.

2.3.3 Intra-individual changes in f_0

F_0 adjustments are possible by means of the pitch raising and lowering mechanisms of the larynx. Elongating and tensing the vocal folds helps to raise the f_0. Similarly, raising the larynx has similar effects on f_0. The major muscle responsible for the raising of pitch is the cricothyroid, and others involved may be thryoarytenoid and suprahyoid muscles. Pitch lowering may be facilitated by the infrahyoid muscles and the strap muscles of the neck. Also note that changes in the average f_0 may be a consequence of intensity (due to the increased Bernoulli effect and/or reflexive tensing of the folds) and prosodic variations (changes in intonation, stress, and durational aspects) (Raphael, Borden, & Harris, 2011).

Context- and task-related variations in female f_0 have been demonstrated. Despite providing instructions to speak with normal pitch, loudness, and speed, female participants spoke with significantly different fundamental frequencies while pretending to speak to a superior and a subordinate, and also between each of these conditions and several other contexts (Zraick, Gentry, Smith-Olinde, & Gregg, 2006). The female speaking fundamental frequency significantly differed across tasks such as number counting, vowel production, reading, and spontaneous speech whereas task-effects were not found in males' and children's speech samples (Zraick, Skaggs, & Montague, 2000). As shown in two recent studies, appropriate context- and task-dependence may be the reason for women alternating between relatively high and low pitch while interacting with attractive male stimuli as shown recently, in two different studies (Fraccaro, Jones, Vukovic, Smith, Watkins, Feinberg, Little, & DeBruine, 2011; Hughes, Farley, & Rhodes, 2010).

While these studies inform us that the female f_0 may be manipulated across situations, we do not know if these changes are perceivable (but see Hughes et al. 2010). In addition to behavioral modifications, possible hormonally mediated variations in vocal fold physiology may also influence f_0 (explained later). The menstrual cycle can be divided into two phases based on the particular hormones that are released and the fertility status (a feature of evolutionary relevance).

2.4 Menstrual cycle

2.4.1 Phases of the menstrual cycle

The two major cycle phases are the follicular phase and the luteal phase. The end of menstruation (approx. 1-4 days) marks the onset of the follicular phase (triggered by the release of the follicular stimulating hormone) during which the estrogen level increases until it peaks on the day of ovulation (approx. day 14 in a 28-day cycle). The luteal phase that follows (triggered by the release of the luteinizing hormone) is characterized by increasing progesterone levels, and the phase lasts until the beginning of the next onset of menstruation (Abitbol, Abitbol, & Abitbol, 1999). Closely following the consistent changes in estrogen and progesterone, are the changes in the conception probability across the menstrual cycle. Conception probability or conception risk is the likelihood of conception with a single act of unprotected sexual intercourse. The risk is higher during the brief follicular phase compared to the luteal phase. In the follicular phase, the probability of conception increases as women get closer to the day of ovulation after which it markedly decreases (Wilcox, Weinberg, & Baird, 1995).

2.4.2 The cycle-phases and acoustic effects

The larynx has receptors for estrogen and progesterone (Abitbol et al. 1999). Cytological smears of laryngeal and cervical tissues show menstrual cycle phase-specific changes. Estrogen

and progesterone have antagonistic effects on the laryngeal and cervical mucosa. Estrogen has a proliferative effect on the laryngeal mucosa that facilitates cell-differentiation and triggers the secretion of the glandular cells, which hydrate the mucosa. Progesterone leads to increase in the viscosity and acidity of the glandular secretions, decrease in the total volume of the secretions, and also decrease in capillary permeability leading to tissue congestion. This host of progesterone-led changes contributes to dryness and edema of the vocal folds (Abitbol et al. 1999). Earlier studies speculated that the potential increase in mass of the edematous vocal folds in the pre-menstrual phase may lower the fundamental frequency or f_0, but failed to find supporting results (e.g. Brown & Hollien, 1981; Hirson & Roe, 1993; also pilot study, see appendix I, p. 58). In contrast, Bryant & Haselton (2009) found that women's mean speaking f_0 as measured from connected speech samples (and not vowel stimuli) increased in the follicular phase, with proximity to ovulation. A hormonal assay was used to confirm ovulation, and a relatively large group of normally cycling women was sampled (n=69). The difference in f_0 between the two menstrual cycle phases was moderated by the number of days to ovulation, but not the number of days to menstruation. The magnitude of the increase in f_0 was the highest two days before the day of ovulation with a mean difference of 15.6 Hz between the ovulatory and luteal phase speech samples. Thus, Bryant & Haselton (2009) speculated that the pitch-change tends to track the varying conception probability. Indeed, the weighted averages of conception risks from five published medical reports indicate that the probability of conception is highest one to two days prior to the day of ovulation (Putz, 2004).

Fischer, Semple, Fickenscher, Jürgens, Kruse, Heistermann, & Amir (2011), who used direct hormonal measurements for an entire cycle of each of the participants, obtained a slightly different result—mean f_0 was higher in the preovulatory phase than around ovulation for free

speech (and not for vowel stimuli), but no difference emerged between the pre-ovulatory or ovulatory (high-fertility) and premenstrual (low-fertility) phases. The pilot study obtained no difference in mean f_0 between the high- and low-fertility phases for vowels or connected speech samples (see appendix I, p. 58). Unlike Bryant & Haselton (2009), and Fischer et al. (2011), hormonal confirmation tests were not done for the pilot study, the group tested was small (N=10), and the connected speech samples consisted of read speech as opposed to spontaneous speech. Cosmides (1983) reported that silent reading of emotionally salient material influenced the prosodic contour and the f_0 of the read-aloud speech that followed, resulting in uniform melodic patterns across participants. In order to avoid any reading errors and repetitions due to unfamiliarity with the material, the participants in the pilot study were instructed to silently read the dialogue before reading it aloud. This suggests that subtle, within-subject physiological variations may be obscured by task demands.

Also, all of the studies have not investigated the impact of acoustic changes on perception, except Bryant & Haselton (2009), Fischer (2011), and the pilot study (explained later). It is unclear if the hormone-induced changes in the acoustic characteristics are large enough to be sufficiently noticeable by listeners that they could affect attractiveness- judgments.

2.5 Signaling the fluctuating conception probability: an adaptive strategy in evolution[2]?

Examining a related developmental aspect may give some clues. We must first see when in development the sexes acquire the sexually mature pitch and whether it closely matches the timing of attainment of adult-like fertility. If it does match, we could reasonably ask if pitch

[2] In evolutionary studies, a signal may refer to an evolved cue (olfactory, acoustic, visual, or tactile) that demonstrates a communicative function such that the signaler biologically benefits from emitting it; the cue evolved over time as receivers happened to operate on it in a way that was reproductively advantageous to signalers. (e.g., Thornhill & Gangestad, 2008).

reliably signals fluctuations in fertility. If it does not match, it would suggest that pitch does not serve the function of signaling current fertility status.

2.5.1 Sex-difference in the age of acquisition of the sexually mature pitch

The fundamental frequencies of 12 year-old girls and women (18 to 50 years) were not significantly different from each other (Lee, Potamianos, & Narayanan, 1999). As the age-range was broad and the descriptive statistics of age were not provided for the adult group, the distribution of young and older women in this group is unknown. This is important because Whiteside, Hodgson, and Tapster (2002) reported a difference of approximately 30Hz in f_0 between two age-groups of women--- the young group of 18- to 25-year olds and the middle-aged group with an age range of 36 to 50 years. However, in the same study, somewhat consistent with Lee et al.'s (1999) findings, girls of over 9.5 years of age and young women did not significantly differ in their fundamental frequency values (Whiteside et al. 2002). In contrast to the developmental trend in girls, both Lee et al. (1999) and Whiteside et al. (2002) reported that the drop in boys' fundamental frequencies continued beyond 13 years of age.

Therefore, the female vocal pitch gradually lowers from the beginning of juvenility until the beginning of adolescence at which point it is similar to that of a young woman's vocal pitch. Males, by contrast, acquire the adult pitch later in adolescence, and the change in pitch is characterized by abrupt downward shifts. These trends coincide with the sex-differences in the development of secondary sexual characteristics such as body shape and breast development in females, and muscularity and body hair in males. Relative to males, females attain the sexually mature, adult-like body shape early in development. On average, females acquire the low waist to hip ratios by 15 or 16 years of age (Thornhill & Gangestad, 2008) and complete the development of breasts by approximately 13 years (Bogin, 1999) before they attain adult-like

ovulatory patterns and birth canal size at 18 years (Bogin, 1999; Locke & Bogin, 2006). By contrast, males are fertile (sperm production starts by 13.5 years) before they acquire the outwardly appearance of men i.e. body hair and muscularity by 17 and 18 years of age, respectively (Bogin, 1999; Locke & Bogin, 2006).

Given the developmental patterns in girls and boys, the secondary sexual characteristics including the vocal pitch do not appear to be reliable indicators of current fertility levels per se. The development of these characteristics does not exactly coincide with the attainment of adult-like fertility patterns. It has been proposed that the secondary sexual characteristics in females are estrogen-facilitated traits that signal their future reproductive potential, and in males, the secondary sexual characteristics are markers of testosterone, the variable that has been consistently associated with dominance (e.g., Thornhill & Gangestad, 2008; Ellison, 2001). The sex-specific developmental pattern also fits the sex-specific mate-preferences discussed earlier.

2.5.2 Signaling future reproductive potential and not current fertility

Advertisement of future reproductive value (and not current fertility) through evolved secondary sexual characteristics or 'permanent ornaments' (e.g., breasts and narrow waist to hip ratios) seems to have been advantageous to women. The advantage may have been in terms of long-term extraction of material benefits from males by signaling that they were attractive and safe investment opportunities, and not by signaling that conception probability at a given moment was high (Thornhill & Gangestad, 2008)[3]. Along the same line, the early development of the estrogen-facilitated ornaments relative to the development of adult-like fertility patterns has been speculated to be beneficial to females in terms of learning the social and sexual

[3] (no intent implied by the words 'advertisement' or 'signaling'; these are strictly used in the sense described earlier in footnote 2 on p. 17)

practices, without the risk of pregnancy (Locke & Bogin, 2006; also see Thornhill & Gangestad, 2008).

Given the reproductive costs that females have to bear it would not have been biologically adaptive for ancestral females to advertise the varying fertility levels, and thereby for ancestral males to be able to consistently and perfectly distinguish the high- from the low-fertility state. In the evolutionary history of women, concealment--and not loss--of estrus (sexuality specific to the follicular phase characterized by enhanced preference for male fitness-indicators) in conjunction with extended sexuality (sexual activity extending beyond the follicular phase) may have been selected. It has been argued that concealment of estrus and extension of sexuality in women served dual purposes—the former allowed females to seek out high quality sire for offspring during the high conception risk phase and the latter allowed them to extract material resources from males in exchange for sex mostly outside of the fertile phase. Similar explanations on dual sexual strategies have been presented for pair-bonding bird species (e.g., collared flycatchers) and non-human primates (e.g., chimpanzees) (reviewed in Thornhill & Gangestad, 2008). In sum, in the high fertility phase, women may be expected to be maximally discriminating while choosing a mate, and also may be expected to be maximally wary of possibilities of sexual coercion or maladaptive sex (inbreeding).

Consistent with these explanations, Lieberman, Pillsworth, & Haselton (2011) reported that women avoided interactions with fathers during peak fertility compared to low fertility, as inferred from the low frequency of phone calls made to them. Chavanne and Gallup (1998) found that there was a significant decrease in the frequency with which women engaged in "risky" activities in the ovulatory phase; an independent group determined the level of riskiness for each of the activities. A replication study that tested a much bigger group on an extended list

of activities found the same effect (Bröder & Hohmann, 2003). Petralia and Gallup (2002) reported that women's handgrip strength, as measured by a dynamometer, increased exclusively in the ovulatory phase after reading a passage on sexual assault. Conversely, in the low-fertility phases, the grip strength reduced compared to the measurement obtained in the pre-reading trial. Women's walking patterns (presented by point-light displays that were obtained by attaching reflective markers on several points on the body, so that the subjects' motion, excluding all other morphological details, may be recorded and played back) recorded during the low-fertility phase were rated as more attractive by men than those recorded during the high-fertility phase (Provost, Quinsey, & Troje, 2008). Furthermore, the instances of rape were not greater in the ovulatory (high-fertility) phase than in the pre-menstrual phase (Morgan, 1981; Rogel, 1976), a finding contrary to the expected trend if the signaling of the varying fertility levels had been selected in the evolutionary history. These studies suggest that females have evolved strategies that conceal their high-fertility status.

As for males, it must be expected that in evolutionary time they would have developed counter-strategies to identify the high-fertility phase (antagonistic co-evolutionary arms race between the sexes). This is mainly because a man cannot be certain of his paternity (paternity uncertainty) whereas a woman can be confident about her maternity. The evolutionary pressure for an ancestral male would have involved the need to constantly ensure that he reaped benefits from his investment in the pair-bond and did not waste it on another man's offspring or on the woman bearing the offspring. If ancestral males had been continuously deceived into providing hard-earned resources to rearing and protecting offspring who were not their own, these types of providers would have eventually vanished; genes that predisposed ancestral males to offer material help without ascertaining paternity could not be passed on. The argument follows that

males may have evolved counter-strategies that aided in discerning the potential "byproduct" cues that "leaked" (and not signaled by females) as a result of the normal cyclic physiological changes. Complete concealment of ovulation may not have been favored in evolution because total suppression of cues could have hindered normal physiology and as a result overall fertility. Selection would have favored an optimum level of concealment without compromising normal physiology (Thornhill & Gangestad, 2008). Perhaps the subtle increase in pitch in spontaneous speech nearing ovulation is one such byproduct.

A few studies have demonstrated that female behavior appears more attractive in the high-fertility phase than in the low-fertility phase (e.g., Miller, Tyber, & Jordan, 2007), possibly because males have won the co-evolutionary arms race of strategies and counterstrategies, and are able to home in on byproduct cues of fertility phases, as explained earlier. The other possibility is that the testing environment cued the female participants to behave attractively. If concealed estrus is associated with females gaining control over mating decisions, it is reasonable to expect them to play an active role in signaling their attractiveness depending upon the presence of favorable environmental cues. Possible cues can be exposure to, interaction with, or even expectation of evaluation by potential mates (e.g., Grammar, Renninger, & Fischer, 2004).

2.6 Context-dependent cycle-effects on attractiveness of women's behavior

If one only considered research that obtained enhanced attractiveness in the high-fertility phase, one notes that female participants were either informed about the focus on "attractiveness and sexuality" putting them in the right frame of mind, or they were observed under natural situations that promoted the relevant male-female interactions. Petralia & Gallup (2002) pointed out that they had failed to find cycle-phase dependent variations in handgrip strengths when

testing was done out of context; the cycle-effects emerged exclusively as a response to the fear-inducing stimulus: reading the passage on sexual assault. Lap dancers' tip earnings increased during the high-fertility phase, which suggest that they were more attractive to clients in this phase than in the other cycle-phases (Miller et al. 2007). The dancers did not perform in a mate-choice context per se. Nonetheless, they were presumably motivated to behave attractively because the tips they earned (the dependent variable in the experiment) were directly affected by the quality of the short-term interactions with the clients, especially because of the presence of "rivals" or competitors (Miller et al., 2007). In more controlled laboratory situations, the female participants were made aware that the investigators were interested in attractiveness (Haselton & Miller, 2007; Pipitone & Gallup, 2008, Pipitone, personal communication) and sexuality (Haselton & Miller, 2007). Even though the subjects were unaware of the details of the judging panel, they were indirectly reminded to look or sound attractive.

2.7 Vocal attractiveness across the menstrual cycle

Findings on variations in vocal attractiveness as a function of the fertility status of women remain equivocal (Fischer et al., 2011, Pipitone & Gallup, 2008, Bryant & Haselton, 2008, Bryant, personal communication; pilot study, see appendix I, p. 58). For example, in the pilot study that employed a forced choice attractiveness evaluation test, males chose the female speech samples recorded in the low-fertility phase more frequently than those recorded in the high-fertility phase (57% of the time). Bryant & Haselton used a similar forced choice approach but failed to find cycle-dependent attractiveness-variations, even though the two speech samples differed in pitch. In contrast, Pipitone & Gallup (2008) found that the speech samples collected during the highest fertility phase received the highest attractiveness-ratings on finely graded likert scales with no change in pitch across the speech samples (Pipitone & Gallup, personal

communication). In a subsequent study, they found that speech recorded in the menstruation phase was identified as unattractive (Pipitone & Gallup, 2011). Fischer et al (2011) reported that listeners marginally preferred the pre-ovulatory speech samples to ovulatory but not to pre-menstrual samples. Interestingly, except in the study by Fischer et al. (2011), attractiveness-evaluations did not correspond with vocal pitch changes in three of the others.

An important difference between the pilot study and the study by Pipitone & Gallup (2008)—the only one that found a change in attractiveness scores with fertility levels-- was with regard to the frame of mind of the participants. Whereas the subjects in Pipitone & Gallup's (2008) study were informed that their speech would be evaluated for attractiveness (Pipitone, personal communication), the subjects in two other studies were not aware of the attractiveness-judgment phase (Bryant, personal communication; pilot study, see appendix I, p. 58). It is unknown if Fischer et al. (2011) included this information while instructing participants to speak. This seems to be an important aspect to be considered in studies investigating behaviors that exhibit situation-dependent flexibility. There is some evidence for context-related variation in non-verbal/vocal behaviors as well. In a study that investigated females' turning behavior, the quality of the movement showed significant positive correlations with estrogen levels exclusively in the group that had a male-onlooker. This effect was absent in the group that had the female-onlooker (Grammer, Filova, & Fieder, 1997).

According to the concealed estrus hypothesis, males may not always be able to consistently discern the high-fertility phase due to the subtlety of the leaked cues. Following this logic, equivocal results may be expected for men's attractiveness-evaluations of women's cycle-specific spontaneous speech samples elicited in neutral contexts. This, however, may not be a sufficient reason to preclude the possibility that with appropriate modifications in the testing

context, walking styles, speaking, or other flexible behaviors may become slightly more attractive in the fertile phase relative to the non-fertile phase, and therefore, may be more consistently perceived and rated as attractive during the high-fertility phase.

2.8 Experimental setting

If the experimental situation recreated a courtship scenario with masculinized and feminized versions of male voice, which elicited estrus-related preference-shifts in masculinity (e.g., Puts, 2005) it would be reasonable to expect the context and the female hormonal status to affect spontaneous vocal behavior in predictable ways. Recent evidence is suggestive of this possibility. In an interactive dating-initiation context, women raised their vocal pitch depending on the perceived degree of attractiveness of the male facial stimuli (Fraccaro et al. 2011). Also, Bryant (work in progress) observed that female subjects raised their pitch when instructed to sound attractive (Bryant, personal communication). A simulated dating context may elicit an attractive speaking strategy, which may involve raising of pitch. Also, as already pointed out, at least in two studies pitch of spontaneous utterances elicited in neutral contexts increased when the women were in the high estrogen phase (Bryant & Haselton, 2009; also see Fischer et al. 2011). Assuming that the potential behavioral adjustment of vocal pitch elicited by an appropriate context (a strategic raising of pitch) may be reinforced by the laryngeal physiology (a byproduct pitch rise) during the high fertility phase, the following hypotheses were advanced.

2.9 Hypotheses:

H1: Males will assign higher attractiveness ratings to the female speech samples collected during the high-fertility phase than to those collected during the low-fertility phase.

H2: Males will assign higher attractiveness ratings to the female speech samples directed to the masculinized male voice than to that directed to the feminized male voice.

H3: The difference between the ratings for the female speech samples elicited by the masculinized and feminized versions of the male voice will be larger in the high-fertility phase than in the low-fertility phase.

H4: The female speech samples recorded in the high-fertility phase will be characterized by higher mean f_0 than those recorded in the low-fertility phase.

H5: The female speech samples directed to the masculinized male voice will be characterized by higher mean f_0 than those directed to the feminized male voice.

H6: The difference in mean f_0 between the speech samples elicited by the masculinized male voice and those elicited by the feminized male voice will be larger in the high-fertility phase than in the low-fertility phase.

III. METHODS

The study was conducted in three parts:

3.1 Obtaining the male courtship sample

3.1.1 The courtship speech task

Four 18 to 35 year-old male students who pursued theatre studies and were native speakers of American English agreed to participate in this part of the study. The students were informed that the study aimed to examine courtship interactions. They were asked to imagine that they were interested in a young attractive woman for a short-term, purely sexual relationship (a one-night stand, e.g., Puts, 2005), and that their task was to seduce them (based on Anolli & Ciceri, 2002; Puts, 2005). Each of them was asked to "perform" the courtship speech in two parts, each ending with a question to the woman 1) introduce himself, talk about his hobbies, interests, future plans, and ask the woman about the same 2) comment on the woman's attractiveness, suggest that he would like to meet her again, and ask for her phone number at the end. The first part was aimed to prime the female participants to respond in a situation-appropriate manner (based on Rosenberg & Tunney, 2008). Since it was expected that the women's responses would vary in content, no plan was made to use these responses in the attractiveness-evaluations. Rather, the stimuli for the attractiveness-evaluation sessions (the last part of the study) comprised the women's responses to the second question—the same made-up phone number that consisted of all numbers from 0 to 9 (based on Cosmides, 1983; Pipitone & Gallup, 2008). The recording was done in a quiet room using the Marantz CD recorder.

3.1.2 Rating the courtship speech samples

The courtship samples by the male students were judged for attractiveness on a 7-point Likert scale for a short-term relationship by ten females who were native speakers of American English and within the age range of 18 to 35 years (M=21.27, SD=0.90). Short-term relationship was defined *as a purely sexual relationship such as a one-night stand* (e.g., Puts, 2005). The evaluation was done on a single day in an audio-equipped classroom. The speech sample that received the highest mean score of attractiveness (M=5.18, SD=1.08) was used as the target courtship stimulus.

3.1.3 Manipulating the courtship stimulus

The target stimulus (Mean f_0=145.54 Hz; SD=27.67) was raised and lowered in pitch by 20 Hz (following Feinberg et al. 2005) using Praat software (raised version M=163.69 Hz, SD=27.43; lowered version M=128.34Hz, SD=27.10). This difference in pitch (approx.40Hz) elicited a significant difference in female preference between the high- and low-fertility phases in previous work (reviewed in Chapter II). The lowered pitch version was the masculinized male voice and the raised pitch version was the feminized male voice. The naturalness of the f_0-manipulated stimuli was verified by the experimenter and two members of the doctoral committee.

3.2 Recording female responses to the courtship stimuli

3.2.1 Participant selection

Interested participants were recruited from various departments at Marywood University, Scranton, PA, through ads posted on the internet and through word of mouth. The advertisement invited potential subjects for a study that examined the relationship between hormonal aspects and dating interactions. Female volunteers completed the screening questionnaire that included

questions related to the inclusion and exclusion criteria and information on menstrual cycle (see appendix II, p. 63). The importance of providing precise answers to the questions was emphasized. The volunteers were informed that due to practical constraints and study criteria, everybody would not be selected to participate in the study.

The inclusion criteria were the following: age range of 18 to 35 years, native speaker of American English, heterosexual, and healthy and normally menstrual cycling (25 to 35 days) – all based on self-reports. The exclusion criteria were: any hormonal treatment, use of contraceptive pills, implants or patches, smoking, pregnancy, any neurological, hearing, speech, language, and voice problems, and absence of the Luteinizing hormone surge (explained in the following section, see below). 36 participants who satisfied the criteria were selected for the study (M=19.36 years, SD=1.36). An a priori power analysis for repeated measures ANOVA with an effect size of .25, and the conventional significance level of .05 and high power of 0.95 resulted in a sample size of 36 based on the assumption of no greater variance than has been observed in earlier work (e.g., Potvin & Schutz, 2000).

3.2.2 Determination and confirmation of the cycle phases

Based on the cycle-related information given on the questionnaire, the day of ovulation was estimated using the reverse count method (Gangestad & Thornhill, 2004). 6 days before the day of ovulation was considered as the high-fertility phase (e.g., Wilcox et al. 1995; M= 2.08, SD=1.98). The low-fertility session was assigned within the eleven day period before the onset of menstruation (M=4.47, SD=3.57). Following Bryant & Haselton (2009), ovulation kits (Clearblue) were used to confirm the surge of the Luteinizing hormone (LH), and hence, the high-fertility phase and the preceding/following low-fertility phase. Ovulation occurs two days following the LH surge (Lynch, Jackson, & Buck Louis, 2006). Prior to the high-fertility

recording sessions, each of the female participants was given six ovulation test sticks, instructions for self-administration (see appendix II, p. 65) and a numbered form (number refers to the participant) to mark the absence/presence of the surge (see appendix II, p. 64). After the completion of the recording session, the experimenter asked the participant to go through the screening questionnaire she had completed prior to the study. This was done to confirm the lack of use of contraception and to identify any recent change in health condition in either of the recording phases that could have warranted the exclusion of the data from further analysis. None of the participants indicated any change.

3.2.3 Audio-recording sessions

The order of the recording sessions was counterbalanced for the fertility phase. The female participant was led to a quiet room and seated in front of a computer. She was reminded that the study aimed to understand the interactions between dating interactions and hormonal changes. The participant was required to speak into a head-worn microphone connected to the computer. The experimenter provided instructions to the participant (the same as the ones the participants eventually read on the computer screen; given below). The recording was done using the Marantz CD recorder. A constant distance between the mouth and the microphone was maintained between the recording sessions. In order to assure privacy during the dating interactions, the experimenter left the room after clicking on the Record button on the recorder. The participant was asked to follow the instructions on the computer screen, and was advised not to change the position of the microphone or manipulate the recorder settings until the end of the session. At the end of the second interaction, the final slide indicated that the dating game was over, and asked the participant to inform the experimenter who waited in the adjacent room about the completion of the session.

The following instructions were provided on PowerPoint slides.

"Imagine that you are in a speed dating-like set-up. Two men are interested in you. You will interact with each of them separately. Each time, you will not see the face of the person; he will talk to you. He will introduce himself and will try to get to know you by asking you about your hobbies, interests, and so on. When he talks, a blank slide will appear. You will respond to him when prompted by a slide indicating: *your turn*. When you finish talking, click on the mouse to move to the next slide. The man talks to you again, and this time, he will express his interest in you and may ask you for your phone number. If he does ask for the number, the following made-up number will appear on the screen: 213-546-7890. When the slide indicates: *your turn*, all you need to do is read it off the screen in response to the man's request, after which you can click on the mouse to move to the next slide. After a brief break, the second man will talk to you, and you can respond to him. Click on the mouse to interact with the first man. Relax and be yourself. Take your time and respond to each of the men."

The order of presentation of the masculinized and feminized male voices was counterbalanced in each of the phases. Following the interaction with the first man, a slide indicated that the second man would talk with the female participant in two minutes.

3.3 Attractiveness-judgments by men

3.3.1 Stimuli-extraction

The recorded responses of each of the subjects were saved as separate sound files. Sound Forge software was used to splice the test-stimuli from the courtship responses. The stimuli comprised the 4 repetitions of the string of numbers (the phone number) by each of the 36 females. The repetitions included 1) talking to the masculinized male in the high fertility phase (HPMasc), 2) talking to the feminized male in the high-fertility phase (HPFem), 3) talking to the

masculinized male in the low-fertility phase (LPMasc), and 4) talking to the feminized male in the low-fertility phase (LPFem). This resulted in a total of 144 test stimuli.

3.3.2 Attractiveness-rating sessions

Males who were between 18 and 35 years of age, native speakers of American English, heterosexuals, and generally in good health were invited to participate. The participants were recruited from various departments in Marywood University. They were instructed to imagine that each of the women gave her phone number to the male-evaluator(s) upon his (their) request. They were asked to judge the attractiveness of the women's response on Likert scales. One group of 50 men used a 100-point scale (M = 19.74 years, SD = 1.52) and a second group of 40 men used a 7-point scale for the judgments (M=20.59 years, SD=1.61). The 7-point scale was a numbered scale, marked and labeled with all 7 numbers; the 100 point scale had 100 markings, with the markings 1, 50, and 100 labeled with the numbers (based on the scale used by Pipitone & Gallup, 2008). Participants were instructed that 1 was least attractive, and 7/100 (depending on the scale they received) was most attractive. Each of the raters was seated in front of a computer, and listened to the samples through headphones (Shure SM10). The samples were played only once. A few trial rating sessions were included (which were not analyzed) in order to accustom the listener to the available range of variations in the speech samples. In an attempt to prevent the scores from clustering around the center, the participants were specifically reminded to make use of the entire scale based on the variations of attractiveness, however subtle they may be. They were also informed that there were no correct or wrong answers. The Likert scales were presented to the raters on Power Point slides, with one scale per slide. The appearance of successive slides was triggered by the participants' response clicks; the numbers corresponding to the clicks were later retrieved from excel sheets with pairs of slide number and click number.

3.4 F_0 measurement

The average speaking fundamental frequency was measured from each of the female speech samples, using Multi-Speech software. The software uses the autocorrelation method to estimate the f_0. The parameters were set to pitch floor of 75 Hz and ceiling of 300 Hz.

IV. RESULTS

4.1 Variables of interest

The dependent variables were men's ratings of attractiveness of women's speech samples and women's speaking fundamental frequencies (f_0). The independent variables were the fertility status of women and the masculinity of the male voice with whom the women interacted in the dating game. There were two levels to each of the independent variables: high- and low-fertility phases (HP and LP); masculinized and feminized versions of the male voice (Masc and Fem).

4.2 Data organization and statistical measure

Being a within-subject design, the ratings of attractiveness received from the male listeners (50 raters for the 100-point scale and 40 raters for the 7-point scale) by each of the 36 female participants for each of the four conditions in which speech was elicited were averaged. Four average scores were obtained for every female separately for the two scales. These were averaged scores for women's responses to 1) the masculinized version in the high fertility phase (HPMasc), 2) the feminized version in the high fertility phase (HPFem), 3) the masculinized version in the low fertility phase (LPMasc), and 4) the feminized version in the low fertility phase (LPFem). Separate analyses were done for data obtained from the 100- and 7-point scales. Similarly, the average speaking fundamental frequencies were derived using Multi-Speech for the four speech samples of every female participant.

Three separate 2x2 repeated measures ANOVAs were done to analyze the data. Three additional analyses were done: two correlation analyses between the two dependent variables—ratings and pitch, and a correlation analysis between the scores from the 100-point and 7-point scales. Each of the four hypotheses will be presented first with the results of the ANOVA following each. All variables were normally distributed (Shapiro-Wilk test $p > 0.05$ for all variables).

4.3 Hypotheses testing

H1: Males will assign higher attractiveness ratings to the female speech samples collected during the high-fertility phase than to those collected during the low-fertility phase.

The average attractiveness ratings (M) and standard deviations (SD) for each of the four conditions on the 100-point and 7-point scales are provided in Table 1 (see p. 39). There was a main effect of fertility phase on men's ratings obtained from the 100-point scale ($F_{(1, 35)} = 7.84$, $p = .004$), i.e. ratings of the samples from the high-fertility phase were greater than the ratings for the samples from the low-fertility phase (see Figure. 1, p. 36). A significant effect was observed for the ratings from the 7 point scale as well ($F_{(1, 35)} = 3.57$, $p = .035$) (see Figure. 2, p. 37).

H2: Males will assign higher attractiveness ratings to the female speech samples directed to the masculinized male voice than to that directed to the feminized male voice.

There was no main effect of masculinity of the male voice on the ratings from the 100-point or the 7-point scales ($F_{(1, 35)} = 1.87$, $p = 0.09$; $F_{(1, 35)} = 0.71$, $p = .21$). Since manipulation of the male voice did not affect the ratings, the separate Masc and Fem ratings for each of the phases were averaged for every participant resulting in only two sets of ratings for each: HP and LP scores. An additional paired t-test between the averaged HP and LP scores from the 100-point and 7-point scales confirmed the phase effect, respectively ($t_{(35)} = 2.8$, $p = .004$; $t_{(35)} = 1.88$, $p = .035$).

H3: The difference between the ratings for the female speech samples elicited by the masculinized and feminized versions of the male voice will be larger in the high-fertility phase than in the low-fertility phase.

There was no interaction effect of fertility status and masculinity of the male voice on the ratings obtained from the 100-point or the 7-point scales. ($F_{(1, 35)} = 0.93$, $p = 0.17$; $F_{(1, 35)} = 0.41$,

p = 0.27). A paired t-test of the difference scores of the ratings (Masc-Fem) from the high and low fertility phases did not reveal a statistical significance ($t_{(35)} = 0.64$, $p = 0.53$).

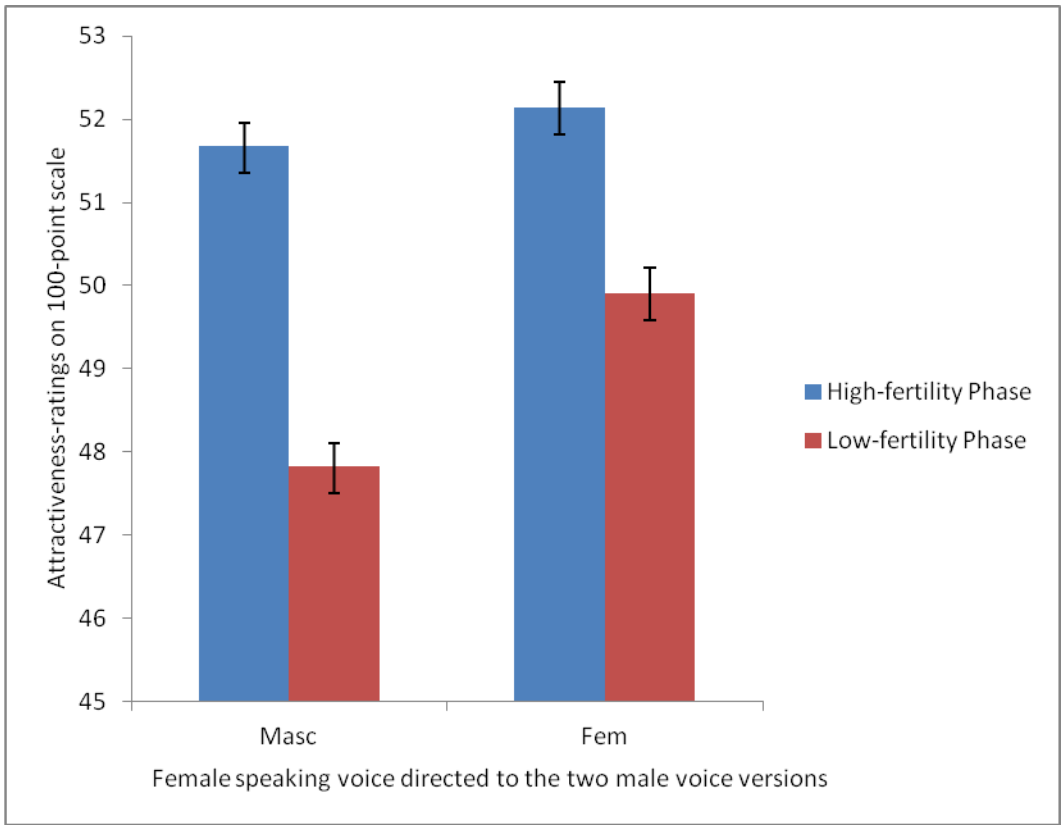

Figure. 1 Attractiveness ratings of women's speech samples from the 100-point scale collected during the high and low-fertility phases while responding to the masculinized and feminized versions of the male voice. The error bars show the relative standard deviations. Note that the range of scores on the y axis is narrow and does not represent the entire rating scale.

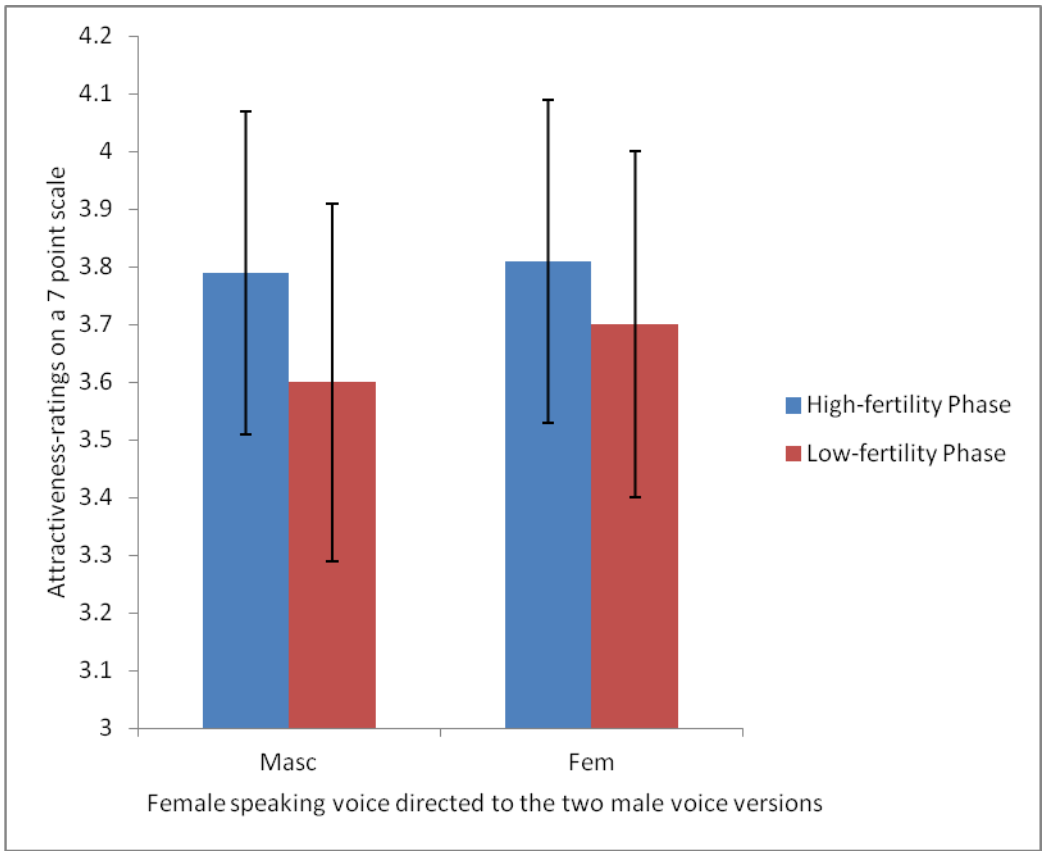

Figure. 2 Attractiveness ratings of women's speech samples from the 7-point scale collected during the high and low-fertility phases while responding to the masculinized and feminized versions of the male voice. The error bars show the relative standard deviations. Note that the range of scores on the y axis is narrow and does not represent the entire rating scale.

H4: The female speech samples recorded in the high-fertility phase will be characterized by higher mean f_0 than those recorded in the low-fertility phase.

The average speaking fundamental frequencies (M) and standard deviations (SD) for each of the four conditions are provided in Table 1. A main effect of fertility phase on the mean speaking fundamental frequencies was observed, but not in the predicted direction ($F_{(1, 35)} = 6.97$, two-tailed $p = 0.01$). Unlike what was predicted, the speech samples from the high-fertility phase had a lower mean f_0 than that of the low-fertility phase recordings (see Figure.3, p. 38).

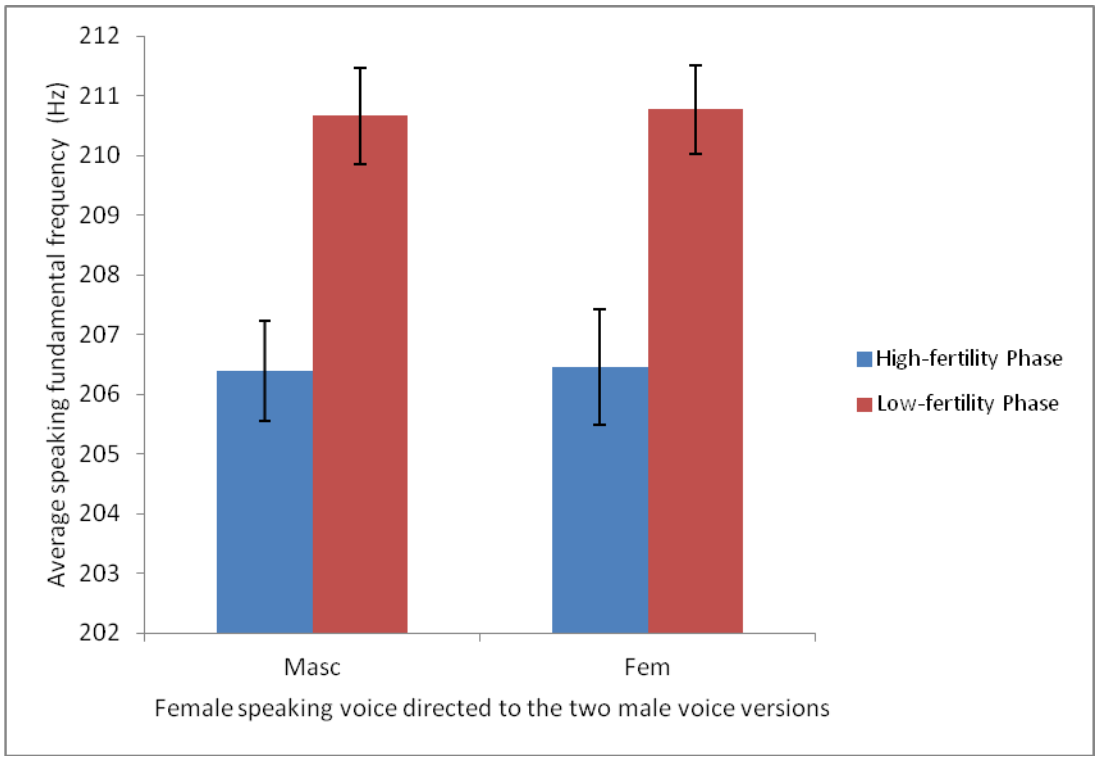

Figure. 3 Women's average speaking fundamental frequencies during the high- and low-fertility phases while responding to the masculinized (Masc) and feminized (Fem) versions of the male voice. The error bars depict relative standard deviations. Note that the range of f_0 values on the y axis is narrow and does not represent the full range observed.

H5: The female speech samples directed to the masculinized male voice will be characterized by higher mean f_0 than those directed to the feminized male voice.

There was no main effect of masculinity of the male voice on the mean f_0 values ($F_{(1, 35)} = 0.005$, $p = 0.47$). Since manipulation of the male voice did not affect the female mean f_0 values, the mean f_0s for Masc and Fem conditions for each of the phases were averaged for every participant resulting in two sets of values for each—HP and LP f_0s. A paired t-test between the averaged HP and LP f_0s was statistically significant ($t_{(35)} = -2.24$, two-tailed $p = 0.03$).

H6: The difference in mean f_0 between the speech samples elicited by the masculinized male voice and those elicited by the feminized male voice will be larger in the high-fertility phase than in the low-fertility phase.

There was no interaction effect of fertility status and masculinity on the f_0 values. ($F_{(1, 35)}$ = 0.00, p = 0.49). As a confirmation, a paired t test of the difference scores of the f_0 values (Masc-Fem) from the high and low fertility phases did not reveal a statistical significance ($t_{(35)}$ = 0.02, p = 0.49)

.

Table 1: Means and SDs (within parenthesis) of the dependent variables

Dependent variables	HPMasc (SD)	HPFem (SD)	LPMasc (SD)	LPFem (SD)
Ratings from100-point scale	51.68 (14.62)	52.14 (15.38)	47.83 (15.66)	49.91 (16.10)
Ratings from7-point scale	3.79 (1.07)	3.81 (1.05)	3.60 (1.10)	3.70 (1.10)
F_0 in Hz	206.38 (17.38)	206.45 (19.97)	210.66 (17.05)	210.77 (15.52)

Additional analyses

Additional analyses included correlation analyses between the two dependent variables i.e. between the ratings and the f_0s, between the HP-LP difference scores for ratings and the corresponding difference scores for f_0s, and between the ratings from the 100-point and 7-point scales.

In order to see if there was a direct correlation between females' speaking f_0 and males' ratings, the f_0s were collapsed across all four categories and the same was done with the ratings.

A Pearson Correlation between the ratings and the corresponding f_0s did not show any correlation, (for 100 point scale, r = 0.07, p = 0.41; for 7 point scale, r = 0.02, p = 0.78). The collapsed scores from 7-point and 100-point scales showed a significant positive correlation (r = 0.95, p = 0.000). Also, the difference between the f_0s of HP and LP did not correlate with the corresponding difference between the averaged Masc and Fem ratings obtained in HP and LP (for the 100 point scale, r=0.032, p=0.855; for the 7 point scale, r=-0.024, p=0.891).

V. DISCUSSION

Women's speech samples from the high-fertility phase were expected to receive higher ratings of attractiveness, and to be marked by higher speaking f_0 than the samples from the low-fertility phase. In the high-fertility phase, it was hypothesized that women's responses to the masculinized and the feminized versions of the male voice would be characterized by a larger difference in pitch as well as in attractiveness scores.

The statistical analyses revealed that the speaking f_0 and ratings of attractiveness varied between the two fertility phases. There was a high correlation between the ratings from the two scales (100 point and 7 point). Note that the effect on the f_0 was not in the predicted direction. Although the speech samples from the high-fertility phase were relatively low in pitch, these samples received higher ratings of attractiveness. Neither the women's f_0s and ratings nor the difference in f_0s and the corresponding difference in ratings between the two phases were correlated. Moreover, there was no effect of masculinity of the male voice on the women's f_0s or on the ratings.

5.1 Rejected hypothesis

First the rejected hypotheses will be examined in relation to the results. Several studies using various modalities (face, body, voice) for the presentation of masculinity-manipulated stimuli have shown that the probability of conception regulated the extent to which women evaluated masculinity as attractive –the higher the risk, the higher the attractiveness scores. This pattern mostly emerged in short-term mating scenarios (reviewed in Little et al. 2011). The expectation was that reconstructing the context that allowed the expression of cycle-related shifts in preferences for masculinity may also facilitate capturing any subtle cycle-dependent change in women's speaking behavior towards a masculine voice.

5.1.1 Possible explanations

The difference in average f_0 between the manipulated versions of the male voice, even though large (approx.40Hz), failed to affect the women's response pitch. This result could suggest that although women may prefer a masculinized voice to a greater extent than a feminized voice, the shift in the degree of preference may not be significant enough to affect behavior. During the course of the experiment, two separate studies revealed that women's speaking pitch exhibited variations as a function of the attractiveness of the male face photographs they interacted with (Hughes et al. 2011; Fracarro et al. 2011). Similar to the protocol of the current study, one of these studies used masculinized and feminized versions of the same male's face photograph to elicit women's speech (Fraccaro et al. 2011). Consider also that in other work, preference-ratings for masculinity for both facial and vocal stimuli were positively correlated (Feinberg, DeBruine, Jones, & Little, 2008a). Therefore when masculinity variations in one modality elicited predictable changes in women's speaking behavior, similar changes could be expected in response to masculinity variations in another modality—vocal in this study. Variations in vocal masculinity may be more effective with changes in formant frequencies as well, as formants may be a cue to body size (Puts, Hodges, Cardenas, & Gaulin, 2007).

The alternative explanation for the absence of masculinity effect on the dependent variables may be that the similarity between the two male voice versions was extremely high because of the unchanged content and other acoustic aspects (excluding f_0), and women interacted with both versions one after the other almost immediately (the gap between the two sessions was only two minutes). Even though Puts's study (2005) on which the dating simulation was based had women subjects rate many similar pitch-altered utterances in one sitting the

stimuli were separated into different test sets, each of which had only one manipulated version of the original utterance and was rated by a different group. Had the current study adopted a between-subject design like Puts's in which different women spoke to the masculinized and feminized versions, results may have been different. Responding to the same content twice would have seemed like a repetitive task to the participants of the present study.

5.2 Accepted hypotheses

Moving on to the accepted hypotheses, even though the speaking f_0 did not correlate with the ratings, the female speaking voice during the high fertility phase was judged attractive in spite of being marked by a relatively low pitch.

5.2.1 Low vocal pitch may be attractive

While it is true that several studies have demonstrated that a low vocal pitch in women is considered unattractive or less attractive, keep in mind that natural manipulations of pitch may not involve large differences (unlike the 40Hz difference in the within-subject pitch-altered studies); the magnitude of manipulation may be small, and/or it may be a significant part of a constellation of features that may all be adjusted within their respective ranges relative to one another. That is, natural adjustments of f_0 can influence other acoustic parameters as well (e.g., Fitzsimons, Sheahan, & Staunton, 2001) as opposed to carefully controlled f_0 adjustments using an acoustic software. This idea is somewhat in agreement with Pipitone and Gallup's (2011) observation that women's speech samples collected from various points in the menstrual cycle, including menstruation, did not differ in perceived pitch or rate, but only differed in perceived voice quality and mood. More recently, Re, O'Connor, Bennet, & Feinberg (2012) observed that vocal pitch may not be the primary or only acoustic factor affecting vocal attractiveness and that the combination of several acoustic parameters needs to be considered in studies of vocal

attractiveness. Note that this particular experiment examined the just-noticeable-differences (JND) in pitch discrimination, femininity judgments, and in attractiveness evaluations via several bi-alternative forced choice tests that presented pitch-manipulated vowel samples. The study found that even though the JNDs for pitch discrimination and vocal femininity did not differ, the JNDs for vocal attractiveness differed from that of vocal femininity and pitch discrimination. This indicates that vocal femininity judgments, *and not vocal attractiveness judgments*, may be closely related to vocal pitch perception.

There are reasons to expect that pitch-lowering in natural speech (and not computer-manipulations) may be considered attractive in certain contexts. At this point it may be helpful to review two recent studies, which adopted a male-female interaction method similar to the one in the current study. Fraccaro et al. (2011) and Hughes et al. (2010) used male photographs with which female participants interacted. The former study found that women's pitch rose with increase in perceived attractiveness of the men for whom they left a voice message, and the latter found that women spoke with a lower pitch to the attractive man than to the unattractive man. Fraccaro et al. (2011) attributed the inconsistency in the results to the difference in the tasks. Indeed, asking the man to participate in a phone survey conducted by the Psychology Department (Hughes et al. 2010) versus asking the man out (Fraccaro et al. 2011) may be expected to differentially affect the f_0 used with the attractive male. Fraccaro et al. (2011) discussed their result from an evolutionary perspective; females effectively signal their femininity and attractiveness to the attractive male by raising their pitch. Hughes et al. (2010) adopted a sociocultural explanation for the use of low pitch with the attractive person--women may be trying to fit in traditionally male dominated arenas by increasingly using a masculine demeanor or they may be trying to sound sexy.

This sort of explanation may be reasonable; in fact, as Hughes et al. (2010) pointed out, the average speaking pitch of women in America has lowered in the last 50 years (Pemberton et al. 1998, given in Hughes et al. 2010). It has also been shown that in a shadowing task of repeating words, female shadowers accommodated more to male speakers than to female speakers (Namy, Nygaard, & Sauerteig, 2002). In another study low-pitched versions of the pitch-manipulated samples of women were considered mature (and attractive) in a psychology text reading task (no information was provided on the difference in the masculinized and feminized versions of the women's voices) (Leaderbrand et al. 2008). Voters preferred a low pitched voice in a leader (Klofstad, Anderson, & Peters, 2011). This explains why Margaret Thatcher was trained to lower her voice to suit the prime ministerial role (Leathers, 1988).

An interesting point to be noted is that the use of a high vocal pitch by women has an easy and well-reasoned evolutionary explanation with the ultimate cause connected to femininity, youth, and reproductive fitness, whereas the use of a lower pitch is offered an immediate sociocultural explanation. It is as though women's use of high pitch alone qualifies for an evolutionary explanation, and a relatively low vocal pitch in women is treated like an evolutionary anomaly—a learned stereotype. This is understandable because several reproductive variables are *positively correlated* with the average speaking f_0, as reviewed in the second chapter. On the other hand, despite its negative correlation with age and fecundity, females use a low vocal pitch in conjunction with breathiness and slow pace to simulate sexiness (Tuomi & Fisher, 1979). Hughes et al. (2010) pointed out that participants in their study may have tried to sound sexy with the attractive person. Females in that study exhibited greater physiological changes, as measured by Galvanic Skin Response, during their interaction with the

attractive male. Clearly women were "trying" to sound more attractive with the attractive man compared to the unattractive man.

In an earlier study, sexiness and femininеness of female voice were associated with different perceptual characteristics--active, lively and colorful with the former, whereas soft, gentle, and sweet with the latter; evaluations of low pitch or breathiness did not correlate with sexiness in this study (Batstone & Tuomi, 1981). It appears that there may be two distinct ways of evaluating female voice—sexy and feminine, and that there may be more than one way of conveying sexiness; breathiness and lowering of pitch may be an exaggerated display of the same. If low pitch conveys sexiness, it still begs the questions: why does low and not high pitch convey sexiness? Does a low pitch signal that women may be slightly older and therefore more sexually experienced? If so, could ancestral females have benefited by using this as a tactic to attract males?

5.2.2 Possible evolutionary explanation of the direction of the pitch-difference

In terms of the normal vocal fold physiology, as described in the literature review, progesterone in the low-fertility phase or luteal phase leads to excessive water intake, and therefore, edematous vocal folds that could potentially result in a slightly lowered pitch because of the added mass. In the current study, speech was relatively high-pitched (and not low-pitched) in the low-fertility or luteal phase, a phase in which progesterone levels increase. This is the opposite of what we would expect according to the afore-mentioned logic on estrogen/progesterone effects on the vocal folds.

If we start thinking about pitch-lowering and -raising (along with other potential vocal changes at which we have not looked) as evolutionarily favored behavioral rules or strategies, as opposed to non-flexible byproducts of other evolutionarily favored physiological processes, then

again, we could expect a favorable context like the one used in this study to elicit a behavioral strategy that reinforces the normal vocal fold physiology i.e. something like "in situation X, be ultra-feminine in the high-fertility phase, and be less feminine or just don't bother in the low fertility phase". As we already know, the use of a high f_0 in the high-fertility phase would accurately signal high conception probability. This strategy, as we have seen from the explanation in the literature review, could not have been favored as a general rule by selection. Additionally, as we understand from the current study, even in a relatively appropriate pro-mating context, women did not make use of a higher pitch in the high fertility phase, but did tend to use it in the low fertility phase. This means that there could not have been a selection pressure for women to capitalize on the normal vocal fold physiology in order to behaviorally signal their high-fertility status to attractive men. What else could have been the pressure? Considering that the availability of conception opportunities is limited and very brief in duration, quick and tactful strategies may have been favored, especially in the case of women who were "less attractive" (explained later).

5.2.3 Considering reproductive costs and benefits from an evolutionary perspective

It has been shown that women's average f_0, as measured from running speech that was somewhat spontaneously elicited in a neutral context, tended to be high in the high-fertility phase (Bryant & Haselton, 2009; also Fischer et al. 2011). By contrast, the low f_0 displayed in the high-fertility phase in the simulated dating situation may be attributed to either of two evolutionary factors: 1) during the high-risk phase, women have evolved to guard themselves by manipulating their pitch in a way that sounds less attractive or 2) they have evolved to manipulate their pitch to signal something other than femininity and reproductive capacity.

As for the first explanation, women do avoid risky circumstances during the fertile phase compared to the non-fertile phase (e.g., Leiberman et al. 2011). Perhaps women have evolved to deceive men into thinking that they are not fertile (similar discussion in Provost et al. 2008). The results of the current study then indicate that men may be "winners" in the antagonistic co-evolutionary arms race, because despite the self-guarding attempts by women during high fertility they were able to see through the deception, albeit imperfectly. It is important to remember that in the evolutionary race between the sexes, we must not expect one sex to win, unless "losing" does not pose a significant risk to the other sex.

As discussed in the literature review, partnered males may be expected to discern the subtle byproduct cues of ovulation; natural selection would have favored male tendencies to excessively mate-guard during females' peak fertility days (e.g., Haselton & Gangestad, 2006). Men may, however, need to get accustomed to the partners' general cue profile before they can discriminate cycle-related cues. Male chacma baboons are able to discriminate conceptive and non-conceptive estrus cycles only after a couple of months of cohabitation with the females (Weingrill, Lycett, Barrett, Hill, & Henzi, 2003). On the other hand, for non-partnered males with absent investment pressure, the cost of copulating with (willing) females without confirming current fertility levels would have been too little. The question then is why females would be willing to copulate immediately without signaling an interest in gauging males' investment plans.

It is fitting to mention here that the evolutionary anthropologist, Sarah Hrdy (2006), expressed her dismay at the interpretation of the results of a study that examined the plausible reason for flycatcher females (a pair-bonding bird species) mating with already mated males without waiting to discern if the males would invest in them. The authors concluded that mated

flycatcher males succeeded in *deceiving* the females into quick copulations (Alatalo, Lundberg, & Stahlbrandt, 1982, given in Hrdy, 2006). It could have been the other way around; females *chose to* mate with mated males without any delay (Hrdy, 2006).

A reexamination of the evolutionary argument for concealment of estrus in women may be necessary. It has been argued that concealment of estrus (and not loss of estrus) has been favored in women's evolutionary history in order for women to gain control over the paternity of offspring. According to this evolutionary perspective, in a situation that is seemingly not associated with fear of sexual imposition or incest, excessive self-guarding behaviors need not be expected. Instead, in a situation that presents itself as a brief opportunity to secure genetic benefits, behaviors indicating sexual proceptivity (explained by Beach, 1976, as female behavior associated with initiation, maintenance or escalation of sexual interaction) may be expected; to quickly and tactfully seek the benefits may have been a reasonable "winning" strategy that could have been favored in the evolutionary past. There is some suggestive evidence for this as well. Women in the high fertility phase, relative to the low-fertility phase, tended to accept invitations for dinner from physically attractive males in two different situations with high ecological validity (nightclub and the streets) (Gueguen, 2009 a, b). With increasing estrogen levels, women increasingly tried to look provocative at a disco, only when unaccompanied by partners (Grammer et al. 2004). Ancestral women could have been opportunistic by being sexually proceptive to genetically superior males in the brief window of opportunity; they may have benefitted from being "fast" as opposed to "coy".

Fastness and coyness may be considered as two different sexual strategies that relate to the amount of time spent in courtship before mating. It has been argued that female coyness evolved to secure male investment (e.g., McNamara, Fromhage, Barta, & Houston, 2009). The

opposite strategy, fastness, may be characterized as a propensity to engage in sexual activity without spending time on courtship. Because of the higher reproductive costs, fastness may not be expected to be the majority strategy in women; nor is it completely out of the question. Mathematical models based on game theory have demonstrated that when cads and dads (males who tend to philander or be faithful) exist in a certain proportion, equivalent tactics could exist in females, even though in different proportions from that of the males (Dawkins, 1976; but see Schuster & Sigmund, 1981).

From ancestral males' standpoint, since there was nothing in principle to stop "fast" females from being equally sexually assertive with other males, a long-term partnership with them might have involved high costs. Female coyness, on the other hand, may have been favorable to ancestral males because a relatively long courtship would have helped to ascertain that the woman was not bearing anybody else's child, and that the possibility of him being cuckolded in the future might be low as well. Perhaps when considering long-term mates, males tend to focus on signals that are associated with coyness in addition to reproductive potential and health (similar discussion in Puts, Barndt, Welling, Dawood, & Burriss, 2011). Nevertheless, in theory, nothing should have restrained ancestral men from copulating with "fast" women who had willingly simulated short-term mating scenarios.

5.2.4 Vocal pitch: a multi-attribute signal

It may be helpful and necessary to think of the use of vocal pitch as part of a context-dependent strategy that has been selected in evolutionary time not necessarily because it drew attention to factors related to current fertility or future reproductive value but because it may have conveyed other reproductively relevant information, roughly related to coyness and fastness, as discussed earlier. An ethological explanation has been provided for the potential use

of a high vocal pitch to signal submissiveness, subordination, cooperation, appeasement and the like (Ohala, 1984), qualities that may convey a need for dependence. A relatively high pitch (a computer manipulated f_0 with low standard deviation of f_0) may also signal flirtatiousness (Puts et al. 2011). A relatively low pitch, on the other hand, may signal the opposite—qualities associated with independence (e.g., Van Bezooijen, 1995, as in normal speech) and low possibility of cuckoldry (e.g., a low f_0 derived through computer manipulation, Puts et al. 2011). Overt flirtatiousness may not be desirable in long-term partners; Puts et al. (2011) found that men did not prefer the female flirtatious vocal signal (the computer-adjusted raised f_0) when considering a long-term partner, and it was considered attractive only in short-term mating contexts[4].

5.2.5 Cycle-related signals are subtle and not obvious

David Buss's (1988) work on tactics of attraction revealed that, unlike what was predicted, signaling provocativeness as opposed to coyness was judged by both males and females as an effective tactic to attract males (similar finding by Boothroyd, Cross, Gray, Coombes, & Gregson-Curtis, 2011). Interestingly, females did not perform this tactic as frequently as would be expected from its perceived effectiveness (Buss, 1988). Following this line of reasoning, cycle-related signaling of fastness may be subtle because it is to the female's advantage to attract as well as retain an attractive mate. The subtlety of the cycle-related signals can be attributed to the risks involved—threats from rivals or competitors (e.g. derogation by competitors, Buss & Dedden, 1990), which tend to increase during ovulation (Fischer, 2004),

[4] Along the same lines, there is scope for prosodic, linguistic, and articulatory variations (and not only pitch variations in isolation) to be associated with different personality attributes, of which several may have been of evolutionary significance.

reduced possibility of retaining the cad, and loss of investment from primary partner for partnered females (Thornhill & Gangestad, 2008). Moreover, when senders and receivers share a common interest, signals issued may be weak in strength to start with—"conspiratorial whispers" (Krebs & Dawkins, 1984). It may be speculated that during the fertile phase, a signal that conveys an impression of sexual availability may be coupled with or superimposed on another that conveys confidence, maturity, self-sufficiency, or buoyancy. This may imply a lack of expectation or requirement of investment, and may serve as a lure to attract cads. Perhaps a reduction in vocal pitch during peak fertility in a dating context serves a similar function; signaling "no-strings-attached" may be sexy or attractive in a short-term mating context.

In chimpanzees, our closest relatives, males prefer mating with older females to younger ones (Muller, Thompson, & Wrangham, 2006). One of the reasons to which the authors attribute this trend is a promiscuous mating arrangement with less expectation of paternal investment, and the related reason that older females may be more experienced in successfully rearing offspring. Although the human mating system is mostly socially or serially monogamous involving bi-parental care, extra-pair copulations are not ruled out (EPC is the standard terminology in evolutionary psychology to refer to sexual relationships with individuals other than one's primary partner). It is also relevant to note here that the number of reported EPCs was positively correlated with men's and women's voice attractiveness ratings (Hughes et al. 2004).

5.2.6 Proximate factors

While the study shows an effect of the fertility-phase on the female speaking f_0, the proximate hormonal and neural mechanisms by which these changes are brought about remain unclear and are topics of interest. Informed speculations may be made by examining the few studies on cyclic shifts in masculinity preferences that explored hormonal effects. Two studies

that adopted within-subject designs and that used hormonal assays demonstrated that the change in estrogen or estradiol levels across the cycle did not contribute to the observed preference–shifts between masculinized and feminized male vocal (Feinberg et al. 2006) and facial stimuli (Welling, Jones, DeBruine, Law Smith, & Little et al. 2007). In line with these results, two other studies showed that estimated progesterone levels (and prolactin levels), and not estimated estrogen levels, predicted the masculinity preference in male vocal (Puts, 2006) and face stimuli (Jones et al. 2005). Welling et al (2007) found that salivary testosterone variation across the cycle were associated with variations in masculinity preferences. Welling et al. (2007) also suggest that the so-called effects of progesterone reported by earlier studies on cyclic-shifts in masculinity-preferences may have been caused or influenced by the untested but co-varying testosterone levels. Several studies including Welling et al. (2007) have shown that testosterone increases with approaching ovulation. Testosterone has been associated with indices of sociosexuality in women (see references in Edelstein, Chopik, & Kean, 2011).

Also recall that whereas females' estrogen-gradation across the cycle did not correlate with their masculinity-preference scores the between-subject average estrogen levels affected the magnitude of the preference-shift across the cycle (Feinberg et al. 2006). In other words, women with low average estrogen levels showed larger cyclic-shifts in attractiveness towards masculinity and vice versa. In light of these findings it may be speculated that similar hormonal mechanisms may be involved in cyclic behavioral changes. Especially in the current study, where the experimental situation somewhat resembled the setting of the above-mentioned studies on cyclic preference-changes, behavioral changes may be expected to be primarily driven by preference-shifts. Fraccaro et al. (2011) demonstrated that vocal pitch changed with ratings of self-reported attraction towards the male face stimuli.

While fertility phase may have an overall effect on vocal and possibly verbal and other modes of behavior, one could reasonably speculate that the degree of behavioral shift between the fertility phases may be significantly influenced by individual estrogen levels and changes in testosterone levels across the cycle. Less attractive women (where attractiveness is estimated in terms of individual estrogen concentrations or measurements of estrogen markers) may show greater behavioral shifts in accordance with preference-shifts than more attractive women.

In summary, it may be premature to conclusively refer to cycle-related cues as leaked byproducts of concealed estrus to which men have evolved to attend. The possibility of subtle signaling by women cannot be ruled out. Cycle-dependent and context-dependent facultative flexibility of female (vocal) behaviors seems to have been favored.

Before concluding, in order to prevent the common confusion caused by the conflation of genetic-selectionism and genetic-determinism, it seems appropriate to remark that the process of evolution driven by particulate gene-selectionism is not independent of environmental influences. Firstly, environmental factors that sustain for a long period of time in the evolutionary time scale constitute the selection pressures that shape morphological and psychological traits. Secondly, environmental factors (both in utero and postnatal) influence the development of traits. And, thirdly, expression of traits may be contingent upon appropriate environmental input (Confer et al. 2011), as the current study tried to demonstrate.

Variations in environmental input include cultural variations. Attempts have been made to understand differences in culture in terms of differences in ecological features. For example, it has been found that pathogen or parasite prevalence in a region modulates the degree of female preference for masculinity. This has been explained as a possible adaptation to elevate attention to genetic fitness indicators in potential mates during adverse conditions (Little, Cohen, Jones, &

Belsky, 2007; Penton-Voak, Jacobson, & Trivers, 2004). Additionally, social learning and imitation may be important processes that have been favored by natural selection by means of which biological organisms calibrate their preferences and behaviors according to local patterns of mate-choice (e.g., White & Galef, 2000) and –availability (e.g., Stone, Shackelford, & Buss, 2007) and self-evaluations of mate-value (e.g., Little, Burt, Penton-Voak, and Perrett, 2001); those alleles (alternative forms of a gene in the gene pool of a population) that allowed nervous systems to be flexible in biologically appropriate ways in ancestral environments were selected (Dawkins, 1982).

5.3 Limitations and Future Directions

The present study has advanced our understanding of cycle-related changes in attractiveness-perceptions and in one of the physical parameters (the average speaking f_0) of women's speaking behavior in a dating situation. Additionally, it has shed light on the potential importance of setting up the right kind of context to investigate cycle-related behavioral changes. For an evolutionary analysis of fertility-related changes in flexible behaviors, it may be necessary to appropriately prime the participants to elicit the behavior in question. Given below are a few limitations of the study, and following that is an attempt to point out the various ways in which future research on this topic may be carried out.

One of the limitations is that the current study did not collect pre-priming speech samples such as those produced in a neutral context, which would have been useful for a meaningful comparison with the pilot study and the findings of the larger study. This would have helped to confirm the context-dependence of cycle-related behaviors. The other limitation is that in order to conclusively attribute the observed effects to the cyclic hormonal changes, the study should have tested a control group with individuals using contraceptives. Several studies in the past

have reported differences in the findings between contraceptive users and normally cycling females in cycle-related preference and behavioral changes (e.g., Pipitone & Gallup, 2008). It is reasonable to assume that had a control group been included, the results would have been in line with the findings from previous research. Also, as reported earlier in the Discussion section, examination of proximate hormonal mechanisms would have been enlightening.

While it may be informative to redo the study by addressing the limitations, the data that have been collected already may be analyzed further in various ways. Firstly, as we have seen, the average speaking f_0 and vocal attractiveness scores did not correlate, as opposed to what could have been expected based on the several recent studies on positive associations between f_0 and attractiveness. The next step would be to look into other acoustic aspects that may have changed between the two cycle phases. These would include vocal intensity, durational and articulatory aspects. The f_0 could be affected by changes in rate of speech, prosodic factors, and vocal intensity (e.g., Zemlin, 1981). Conversely, variation of spectral parameters can affect temporal parameters (Fitzsimons et al. 2001). Additionally, several measures related to frequency itself could be examined—variability measures such as the f_0 range and the standard deviation of f_0. As described in the literature review, cycle-related changes for a few spectral and temporal parameters have been reported. However, the findings are equivocal, perhaps because they have been elicited out of context.

Another valuable series of follow-up studies would involve asking listeners to judge the samples for perceived pitch, loudness, speed, clarity of articulation, melody, and also short- and long-term attractiveness. Findings from this series together with the extra acoustic analyses (as mentioned above) would furnish detailed information on the nature of the attractiveness-

evaluations and the particular vocal aspects (if any) that drove the attractiveness-judgments in the current study.

An interesting point to consider in future research would be to examine how ratings of vocal attractiveness may be influenced by perceptions of the other attributes that are tested along with attractiveness. For example, a study that asks individuals to rate a female voice first on dominance and then on attractiveness may obtain different results from a study that instructs individuals to rate the same female voice first on maturity and later on attractiveness. As described in the literature review chapter, low-pitched female voices were not rated as attractive when the attractiveness-ratings were provided immediately after the dominance-ratings, and the speech samples consisted of multiple f_0-manipulated series of vowels (Jones et al. 2010). On the other hand, the results were different in another study when the attractiveness scale followed a scale to rate maturity, and the speech samples comprised f_0-manipulated read psychology text material (Leaderbrand et al. 2008). While designing future experiments, it may be important to look into the plausible reasons for these inconsistent results as female voice attractiveness may be influenced by several personality characteristics that may be inferred from the speaking voice; these characteristics may be reproductively relevant attributes as well, and can inform the evolutionary analysis of female vocal and verbal behavior.

Appendix 1

Pilot study

The pilot study aimed to determine potential changes in the attractiveness of the female speaking voice between the high and low-fertility phases as rated by males in a bi-alternative forced choice test.

Method

The study followed a within-subject design. Speech samples were obtained from ten female participants (mean age: 21.5, SD: 3.98) who satisfied the inclusion and exclusion criteria (same as the larger study; also see screening questionnaire, p.61). Each of the participants was recorded on the high- and low-fertility phases of the menstrual cycle. Three participants were recorded first during the low-fertility phase and seven of them were recorded first in the high-fertility phase. The backward counting method (same as the proposal) was used to determine the cycle phases. The participants were asked to read the schwa vowel ("uh" as in cup) and a dramatic dialogue (see p.62), which were presented on flash cards along with a few other items. This was done to prevent them from knowing the actual stimuli of interest. The stimuli occurred twice on separate cards, but not consecutively. The same order was followed on both the fertility phases. Hence, two samples (two readings) were obtained for each of the stimuli on each of the two phases. Recording was done using the Marantz CD recorder in a quiet room.

Sound forge software was used for splicing/editing the recorded samples and introducing the appropriate inter-stimulus interval (ISI=250 msec) between pairs of the same samples i.e. pairings of the vowels/sentences from the high- and low-fertility phases. The stimuli were counterbalanced for the order of the phases generating four stimulus-pairs each for the schwa

vowel and the sentence for playback (HP-LP pairs and LP-HP pairs). This produced a total of forty stimulus-pairs (from ten women) for the male participants to evaluate. Because inter-stimulus intervals in forced-choice tasks have been used for phoneme discrimination and short-term memory studies and rarely for attractiveness judgment tasks in the auditory modality, the investigators sampled three different ISIs (250msec, 500msec, 1 sec) and decided to use 250msec ISI.

Thirty males who satisfied the selection criteria (same as the larger study) volunteered to participate in the study (mean age: 24; SD: 3.9). A forced-choice attractiveness-evaluation task was designed: one with the vowel as the stimulus item and the other with the phrase as the stimulus item. Participants were given several practice trails in the beginning. The presentation of the stimulus items was randomized for every participant. Every stimulus-pair was presented on a separate PowerPoint slide. Participants listened to the stimuli only once via speakers. They responded by mouse-clicking on the number (1 or 2 of the stimulus-pair) of choice. With every mouse click, the response was tabulated in Excel. The response also triggered the next stimulus presentation after a fixed inter-trial interval of 1 sec. The responses were not timed. The PowerPoint slides were run in the Kiosk mode, which disabled all the keys of the computer (except the mouse), thus preventing any participant interference with the stimulus presentations.

Results

The four speech samples from each female speaker were judged by thirty male evaluators; hence, each female was evaluated 120 times. The number of times each of the female participants' high- (HP) and low- (LP) fertility phase speech samples was selected by the thirty male participants was tabulated. HP percentage scores were calculated, for vowel- and phrase-evaluations separately. Contrary to the directional hypothesis, in the forced-choice attractiveness-

evaluation tasks, males chose the vowels and phrases recorded in the high-fertility phase at below-chance levels i.e. 47% and 43% of the time, respectively, with the HP phrases being less frequently chosen than the HP vowels.

Acoustic analysis

The mean f_0 values of the HP and LP vowels and phrases were obtained using MultiSpeech software. The parameters were set to a pitch floor of 75Hz and ceiling of 350 Hz, with all other parameters set to default. Paired t-tests revealed no significant difference between the HP and LP f_0 values for vowels (M=-6.6, SD=19.4; $t_{(9)} = -1.08$, $p = 0.31$) and phrases (M=-3.5, SD=13.06, $t_{(9)} = -0.85$, $p = 0.41$).

Screening questionnaire[1]

Please answer all questions as precisely as possible.
What languages do you speak?

Where are you originally from?

What is your profession?

Do you follow any exercise routine?

Do you have regular menstrual cycles? If yes, please provide details on the length of the menstrual cycle, start date of the period, start date of the last period and the expected start date of the next period, number of days of menstrual bleeding.

Are you currently pregnant? Have you been pregnant before? If yes, when was your last pregnancy?

Briefly mention your dietary habits.

Do you smoke? If yes, how frequently do you smoke?

Are you undergoing, or have you undergone any hormonal treatment?

Do you drink alcoholic beverages? If yes, how frequently do you drink?

Do you use contraceptive pills, implant or patches? Have you used them in the past six months?

Sexual orientation -heterosexual/homosexual/bisexual

Do you have any persistent medical problems?

Have you been trained in music? Are you a vocal performer?

Do you experience any premenstrual complaints?

[1]*The questions were interspersed with irrelevant questions in order for the participants to be unaware of the aim of the study*

The dialogue (the target sentence is in italics)

Ann: "He loves me."

Jim: "The guy's never around to tell you that."

Ann: "He slogs away in some office so we can live a life of comfort in the future."

Jim: "Well….I thought I would give him a piece of my mind when he got home tonight..."

Ann: "***Paul's coming home tonight***?"

Jim: "Not if some cargo truck does us all a huge favor."

Ann: "You horrible brute! He is a nice guy."

Jim: "You wanted to kill him anyway for saying all those nasty things last week."

Ann: "You know I was not serious when I said that...Paul was just too drunk that day."

APPENDIX ll

Screening questionnaire

Instruction: Please answer all questions as precisely as possible.

How old are you?

Are you a native speaker of American English?

Do you smoke? If yes, how frequently do you smoke?

Do you have any persistent medical problems? If yes, what are they?

What is your sexual orientation?

Are you currently pregnant? Have you been pregnant before? If yes, when was your last pregnancy?

Have you undergone any hormonal treatment?

Do you use contraceptive pills, implant or patches? Have you used them in the past six months?

Do you have regular menstrual cycles?

How many days do the menstrual bleeding last?

Please circle the length of your typical menstrual cycle:

<22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 >38

Please circle the beginning dates of your last two menstrual bleeding and the expected beginning date of the next menstrual bleeding (Please circle the three dates in the calendar).

Example:

	Sun	Mon	Tue	Wed	Thurs	Fri	Sat
			1	2	3	4	5
June	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30			
					1	2	3
	4	5	6	7	8	9	10
July	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	31
	1	2	3	4	5	6	7
August	8	9	10	11	12	13	14
	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31				
September	…						

Instructions to use the ovulation test sticks

This test helps to determine the changes in certain hormones. We would like to monitor your hormonal levels. In order to do this, you will need to use six test sticks, each a day. All you need to do is to bring the liquid absorbent end of the stick in contact with your urine stream in the morning, after you wake up preferably (see the section on "How do I use the sticks"). You need to start testing on the first date that is indicated in the table below. Information on how to fill the table is also given in the section: "How do I use the sticks?"

Date	15 June	16 June	17 June	18 June	19 June	20 June
Blank/Smiley						

How do I use the sticks?[1]

1. The Clearblue Digital Ovulation Test is very easy to use. When you're ready to test remove a Test Stick from its foil wrapper. Before applying urine to the Test Stick it must be inserted into the Test Holder.
2. The Test Stick and Test Holder are marked with pink arrows that must be aligned to ensure correct insertion. The Test Stick clicks into place and a 'Test Ready' symbol appears on the Test Holder display.
3. When the 'Test Ready' symbol appears, you simply hold the Absorbent Sampler pointing downwards in your urine stream for 5 to 7 seconds. Alternatively, you can collect a sample of urine in a clean dry container and immerse just the Absorbent Sampler in the collected sample for 15 seconds.
4. Keep the Absorbent Sampler pointing downwards or lay the Test flat. After 20 to 40 seconds, the 'Test Ready' symbol will flash to show that the test is working. Do not eject the Test Stick. Replace the cap and then wipe off any excess urine.
5. Within 3 minutes, the display will show your result.
6. If you see a blank circle on the display, write "Blank" under the test date. If you see a smiley, write "smiley" under the test date. Repeat the test the next day at around the same time for the next six days.

[1]*The instructions (1 to 5) have been taken from the Clearblue Digital Ovulation test instruction manual available online.*

REFERENCES

Abitbol, J., Abitbol, P., & Abitbol, B. (1999). Sex hormones and the female voice. *Journal of Voice, 13,* 424-446.

Addington, D. W. (1968). The relationship of selected vocal characteristics to personality perception. *Speech monographs, 35,* 492-503.

Amir, O., Biron-Shental, T., & Shabtai, E. (2006). Birth control pills and nonprofessional voice: acoustic analyses. *Journal of Speech, Language, and Hearing Research, 49,* 1114-1126

Anolli, L., & Ciceri, R. (2002). Analysis of the vocal profiles of male seduction: from exhibition to self-disclosure. *Journal of General Psychology, 129,* 149-169.

Apicella, C. L., & Feinberg DR. (2009). Voice pitch alters mate-choice relevant perception in hunter-gatherers. *Proceedings of the Biological Sciences, 276,* 1077-1082.

Apicella, C. L., Feinberg, D. R., & Marlowe, F. W. (2007). Voice pitch predicts reproductive success in male hunter-gatherers. *Biology letters, 3,* 682-684.

Batstone, S., & Tuomi, S, K. (1981). Perceptual characteristics of female voices. *Language and Speech, 24,* 111-123.

Beach, F.A. (1976). Sexual attractivity, proceptivity, and receptivity in female mammals. *Hormones and Behavior, 7,* 105-138.

Bogin, B. (1999). *Patterns of human growth,* 2nd edition. Cambridge University Press.

Booth, A. G., & Dabbs, J. M. (1993). Testosterone and men's marriages. *Social Forces, 72,* 463–477.

Boothroyd, L.G., Cross, C.P., Gray, A.W., Coombes, C., & Gregson-Curtis, K. (2011). Perceiving the facial correlates of sociosexuality: further evidence. *Personality and Individual Differences 50,* 422–425.

Broder, A., & Hohmann, N. (2003). Variations in risk taking behavior over the menstrual cycle: an improved replication. *Evolution and Human Behavior, 24,* 391-398.

Brown, W. S., & Hollien, H (1981). Effects of menstruation on fundamental frequency of female voice. *Transcripts of the Tenth Symposium Care of the Professional Voice,* 94-101.

Brown, W. S., & Rothman, H. B. (1985). The menstrual cycle and its relationship to the highly stressed female voice. In Van L. Lawrence (Ed.), *Transcripts of the 14th Symposium, Care of the Professional Voice*, p. 114-123. New York: The Voice Foundation.

Bryant, G. A., & Haselton, M. G. (2009). Vocal cues of ovulation in human females. *Biology Letters, 5,* 12-15.

Buss, D. M. (1989). Sex differences in human mate preferences: evolutionary hypotheses tested in 37 cultures. *Behavioral and Brain Sciences, 12,* 1-49.

Buss, D. M., & Dedden, L. A. (1990). Derogation of competitors. *Journal of Personal and Social Relationships, 7,* 395-422.

Cashdan, E. (1996). Women's Mating Strategies. *Evolutionary Anthropology, 5,* 134–143.

Chae, S. W., Choi, G., Kang, H. J., Choi, J. O., & Jin, S. M. (2001). Clinical analysis of voice change as a parameter of premenstrual syndrome. *Journal of Voice, 15,* 278-283.

Chavanne, T. J., & Gallup Jr., G. G. (1997). Variation in risk taking behavior among female college students as a function of the menstrual cycle. *Evolution and Human Behavior, 19,* 1-6.

Collins, S. A., & Missing, C. (2003). Vocal and visual attractiveness are related in women. *Animal Behavior, 65,* 997-1004.

Confer, J. C., Easton, A. J., Fleischman, D. S., Goetz, C. D., Lewis, D. M. G., Perilloux, C., & Buss, D. (2010). Evolutionary psychology*:* controversies, questions, prospects and limitations. *American Psychologist, 65,* 110-126.

Cosmides, L. (1983). Invariances in the acoustic expression of emotion during speech. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 864-881.

Cronin, H. (1991). *The ant and the peacock: altruism and sexual selection from Darwin to today.* Cambridge: Cambridge University Press.

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

Dawkins, R. (1976). *The Selfish Gene.* Oxford: Oxford University Press.

Dawkins, R. (1979). Twelve misunderstandings of kin selection. *Zeitschrift für Tierpsychologie, 51,* 184-200.

Dawkins, R. (1982). *The extended phenotype*. Oxford: Oxford University Press.

Dawkins, R. (2006). *The God Delusion*. New York: Bantam Books.

De Bruyne, F., Decoster, W., Gijsel, A. V., & Vercammen, J. (2002). Speaking fundamental frequency in monozygotic and dizygotic twins. *Journal of Voice, 16,* 466-471.

Draper, P., & Harpending, H. (1982). Father absence and reproductive strategy: an evolutionary perspective. *Journal of Anthropological Research, 38,* 255–273.

Edelstein, R. S., Chopik, W. J., & Kean, E. L. (2011). Sociosexuality moderates the association between testosterone and relationship status in men and women. *Hormones and Behavior, 60,* 248-255.

Ellison, P.T. (2001). *On fertile ground: a natural history of reproduction.* Cambridge MA: Harvard University Press.

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

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

Feinberg, D. R., Jones, B. C., DeBruine, L. M., Moore, F. R., Smith, M. J. L., Cornwell, E. R., et al. (2005). The voice and face of woman: one ornament that signals quality? *Evolution and Human Behavior, 26,* 398-408.

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

Feinberg, D. R., DeBruine, L. M., Jones, B. C., Little, A. C. (2008a). Correlated preferences for men's facial and vocal masculinity. *Evolution and Human Behavior, 29,* 233-241.

Feinberg, D. R., DeBruine, L. M., Jones, B. C., & Perret, D. I. (2008b). The role of femininity and averageness of voice pitch in aesthetic judgments of women's voices. *Perception, 37,* 615-623.

Fischer, J., Semple, S., Fickenscher, G., Jürgens, R., Kruse, E., Heistermann, M., Amir, O. (2011). Do Women's Voices Provide Cues of the Likelihood of Ovulation? The Importance of Sampling Regime. *PLoS ONE, 6,* p. e24490.

Fisher, M. (2004). Female intrasexual competition decreases female facial attractiveness. *Proceedings of the Royal Society of London, Series B (Supplemental), 271,* S283-285.

Fitch, W. T. (2004). Kin selection and "mother tongues": a neglected component in language evolution. In Oller, D. K., & Griebel, U. (Eds.), The *evolution of communication systems: a comparative approach*. Cambridge, MA: MIT Press.

Fitzsimons, M., Sheahan, N., & Staunton, H. (2001). Gender and the integration of acoustic dimensions of prosody: implications for clinical studies. *Brain and Language, 78,* 94-108.

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

Fraccaro, P. J., Jones, B. C., Vukovic, J., Smith, F. G.,Watkins, C. D., Feinberg, D. R., Little, A. C., & DeBruine, L. M. (2011). Experimental evidence that women speak in a higher voice pitch to men they find attractive. *Journal of Evolutionary Psychology. 9,* 57-968.

Grammer, K., Filova, V., & Fieder, M. (1997). The communication paradox and possible solutions: Towards a radical empiricism. In A. Schmitt, K. Atzwanger, K. Grammer, & K. Schaefer (Eds.), *New aspects of human ethology* (pp. 91–120). London: Plenum Press.

Grammer, K., Renninger, L., Fischer, B. (2004) Disco clothing, female sexual motivation, and relationship status: is she dressed to impress? *Journal of Sex Research, 41,* 66–74.

Gueguen, N. (2009a). Menstrual cycle phases and female receptivity to a courtship solicitation: an evaluation in a nightclub. *Evolution and Human Behavior, 30,* 351-355.

Gueguen, N. (2009b). The receptivity of women to courtship solicitation across the menstrual cycle: a field experiment. *Biological Psychology, 80,* 321-324.

Haselton, M. G., Mortezaie, M., Pillsworth, E. G., Bleske-Rechek, A., & Frederick, D. A. (2007). Ovulatory shifts in human female ornamentation: Near ovulation, women dress to impress. *Hormones and Behavior, 51,* 41–45.

Higgins, M. B., & Saxman, J. H. (1989). Variations in vocal frequency perturbation across the menstrual cycle. *Journal of Voice, 3*, 233-243.

Hirson, A., & Roe, S. (1993). Stability of voice and periodic fluctuations in voice quality through the menstrual cycle. *British Voice Association, 2,* 78-88.

Hrdy, S. B. (2006). Empathy, polyandry, and the myth of the coy female. Reprinted in Sober, E. (Eds.), *Conceptual Issues in Evolutionary Biology*. Cambridge: Bradford Books of MIT Press.

Hughes, S. M., Dispenza, F., & Gallup Jr, G. G. (2004). Ratings of voice attractiveness predict sexual behavior and body configuration. *Evolution and Human Behavior, 25,* 295-304.

Hughes, S. M., Harrison, M. A., & Gallup Jr, G. G. (2009). Sex-specific body configurations can be estimated from voice samples. *Journal of Social, Evolutionary, and Cultural Psychology, 3,* 343-355.

Hughes, S. M., Farley, S. D., & Rhodes, B. C. (2010). Vocal and Physiological Changes in Response to the Physical Attractiveness of Conversational Partners. *Journal of Nonverbal Behavior, 34,* 155-167.

Jones, B. C., Feinberg, D. R., Debruine, L. M., Little, A. C., & Vukovic, J. (2008). Integrating cues of social interest and voice pitch in men's preferences for women's voices. *Biology Letters, 4,* 192-194.

Jones, B. C., Feinberg, D. R., DeBruine, L. M., Little, A. C., & Vukovic, J. (2010). A domain-specific opposite-sex bias in human preferences for manipulated voice pitch. *Animal Behaviour, 79, 57-62.*

Klofstad, C. A., Anderson, R. C., & Peters, S. (2012). Sounds like a winner: voice pitch influences perception of leadership capacity in both men and women. *Proceedings of the Royal Society B, 279,* 2698-2704.

Krebs, J.R., & Dawkins, R. (1984). Animal signals: mind-reading and manipulation. In Krebs, J. R., & Davies, N.B. *Behavioural Ecology: An Evolutionary Approach*. Oxford: Blackwell Scientific Publications.

Kruger, D. J. (2006). Male facial masculinity influences attribution of personality and reproductive strategy. *Personal Relationships, 13,* 451-463.

Kruger, D. J., Fisher, M., & Jobling, I. (2003). Proper and dark heroes as dads and cads: alternative mating strategies in british romantic literature. *Human Nature, 14,* 305-317.

Namy, L. L., Nygaard, L.C., & Sauerteig, D. (2002). Perceptual and social determinants of sex differences in vocal accommodation. *Journal of Language and Social Psychology, 21,* 422-432.

Law Smith, M. J., Perrett, D. I., Jones, B. C., Cornwell, R. E., Moore, F. R., Feinberg, D.R., et al. (2006). Facial appearance is a cue to oestrogen levels in women. *Proceedings of the Biological Sciences, 273,* 135-140.

Leaderbrand, K., Dekam, J., Morey, A., & Tuma, L. (2008). The effects of voice pitch on perceptions of attractiveness: Do you sound hot or not. *Winona State University Psychology Student Journal.*

Leathers, D. G. (1988). Impression management training: conceptualization and application to personal selling. *Journal of Applied Communication Research, 16,* 126-145.

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

Lieberman, D., Pillsworth, E. G., & Haselton, M. G. (2011) Kin affiliation across the ovulatory cycle : females avoid fathers when fertile. *Psychological Science, 22,* 13-8.

Little, A. C., Burt, D. M., Penton-Voak, I. S., & Perrett, D. I. (2001). Self-perceived attractiveness influences human female preferences for sexual dimorphism and symmetry in male faces. *Proceedings of the Royal Society B, 268,* 39-44.

Little, A. C., Cohen, D. L., Jones, B. C., & Belsky, J. (2007). Human preferences for facial masculinity change with relationship type and environmental harshness. *Behavioral Ecology and Sociobiology, 61,* 967−973.

Little, A. C., Connely, J., Feinberg, D. R., Jones, B. C., & Roberts, S. C. (2011). Human preference for masculinity differs according to context in faces, bodies, voices, and smell. *Behavioural Ecology, 22,* 862-868.

Locke, J. L. (2006). Parental selection of vocal behavior: crying, cooing, babbling and the evolution of spoken language. *Human Nature, 17,* 155-168.

Locke, J. L., & Bogin, B. (2006). Language and life history: a new perspective on the evolution and development of linguistic communication. *Behavioral and Brain Science, 29,* 259-325.

Locke, J. L. (2008). Cost and complexity: selection for speech and language. *Journal of Theoretical Biology, 251,* 640-652.

Locke, J. L. (2009). Evolutionary developmental linguistics: naturalization of the faculty of language. *Language Science, 31,* 33-59.

Lynch, C. D., Jackson, L. W., & Buck Louis, G. M. (2006). Estimation of the day specific probabilities of conception: current state of the knowledge and the relevance for epidemiological research. *Paediatric Perinatal Epidemiology, 20,* 3-12.

Mazur, A., & Booth, A. (1998). Testosterone and dominance in men. *Behavioral and Brain Sciences, 21,* 353-397.

McNamara, J. M., Fromhage, L., Barta, Z., & Houston, A. I. (2009). The optimal coyness game. *Proceedings of the Royal Society B, 276,* 953-960.

Miller, G., Tyber, J. M., & Jordan, B. D. (2007). Ovulatory cycle effects on tip earnings by lap dancers: economic evidence for human estrus? *Evolution and Human Behavior, 28,* 375-381.

Morgan, J. B. (1981). *Relationship between rape and physical damage during rape and phase of sexual cycle during which rape occurred.* Unpublished doctoral dissertation, University of Texas at Austin.

Muller, M. N., Thompson, M. E., & Wrangham, R. W. (2006). Male chimpanzees prefer mating with older females. *Current Biology, 16,* 2234-2238.

Oguchi, T. and Kikuchi, H. (1997), Voice and interpersonal attraction. *Japanese Psychological Research, 39,* 56–61.

Ohala, J. J. (1984). An Ethological Perspective on Common Cross-Language Utilization of F_0 of Voice. *Phonetica, 41,* 1-16.

Penton-Voak, I. S., Little, A. C., Jones, B. C., Burt, D. M., Tiddeman, B. P., & Perrett, D. I. (2003). Female condition influences preferences for sexual dimorphism in faces of male humans. *Journal of Comparative Psychology, 117,* 264-271.

Penton-Voak, I. S., Jacobson, A., & Trivers, R. (2004). Populational differences in attractiveness judgements of male and female faces: Comparing British and Jamaican samples. *Evolution and Human Behavior, 25,* 355-370.

Petralia, S. M., & Gallup Jr, G. G., (2002). Effects of a sexual assault scenario on handgrip strength across the menstrual cycle. *Evolution and Human Behavior, 23,* 3-10.

Pipitone R. N., & Gallup Jr, G. G. (2008). Women's voice attractiveness varies across the menstrual cycle. *Evolution and Human Behavior, 29,* 268-274.

Potvin, P. J., & Schutz, R. W. (2000). Statistical power for the two-factor repeated measures ANOVA. *Behavior Research Methods, Instruments and Computers, 32*, 347-356.

Provost, M. P., Quinsey, V. L., & Troje, N. F. (2008). Differences in gait across the menstrual cycle and their attractiveness to men. *Archives of Sexual Behavior, 37,* 598-604.

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

Puts, D. A. (2006). Cyclic variation in women's preferences for masculine traits — potential hormonal causes. *Human Nature, 17,* 114–127.

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

Puts, D. A., Hodges, C. R., Cardenas, R. A., & Gaulin, S. J. C. (2007). Men's voice as dominant signals: vocal and fundamental and formant frequencies influence dominance attributions among men. *Evolution and Human Behavior, 28,* 340-344.

Puts,D. A., Barndt, J. L., Welling, L. L. M., Dawood, K., & Burriss, R. P. (2011). Intrasexual competition among women: Vocal femininity affects perceptions of attractiveness and flirtatiousness. *Personality and Individual differences, 50,* 111-115.

Putz, D. A. (2004). *Female choice, male dominance, and the evolution of low voice pitch in men.* Doctoral Dissertation, University of Pittsburg, Pennsylvania.

Raphael, L. J., Borden, G. J., & Harris, K. S. (2011). *Speech Science Primer*. Philadelphia, PA: Lippincott Williams & Wilkins.

Re, D. E., O'Connor, J. J. M., Bennet, P. J., & Feinberg, D. R. (2012). Preferences for very low and very high voice pitch in humans. *PLoS One. 7*(3): e32719

Rodriguez-Girones, M. A., & Enquist, M. (2001). The evolution of female sexuality. *Animal Behavior, 61,* 695-704.

Rogel, M. J. (1976). *Biosocial aspects of rape.* Unpublished doctoral dissertation, University of Chicago, Illinois.

Roney, J. R., Lukaszewski, A. W., Simmons, Z. L. (2007). Rapid endocrine responses of young men to social interactions with young women. *Hormones and Behavior, 52,* 326-333.

Rosenberg, J., & Tunney, R. J. (2008). Human vocabulary use as display. *Evolutionary Psychology, 6,* 538-549.

Russell, A., Penny, L., & Pemberton, C. (1995). Speaking fundamental frequency changes over time in women: a longitudinal study. *Journal of Speech and Hearing Research, 38,* 101-109.

Schuster, P., & Sigmund, K. (1981) Coyness, philandering and stable strategies. *Animal Behaviour, 29,* 186–192.

Silverman, E. M., & Zimmer, C. H. (1978). Effect of the menstrual cycle on voice quality. *Archives of Otolaryngology, 104,* 7-10.

Stone, E. A., Shackelford, T. K., & Buss, D. (2007). Sex-ratio and mate-preferences: a cross-cultural investigation. *European Journal of Social Psychology, 37,* 288-296.

Thornhill, R., & Gangestad, S. W. (2008). *The evolutionary biology of human female sexuality*. New York: Oxford University Press.

Titze, I. R. (1989). Physiologic and acoustic differences between male and female voices. *Journal of the Acoustical Society of America, 85,* 1699-1707.

Trivers, R.L. (1972). Parental investment and sexual selection. In B. Campbell (Ed.), *Sexual selection and the descent of man*, 1871-1971 (pp. 136–179). Chicago, IL: Aldine.

Tuomi, S. K., & Fisher, J. E. (1979). Characteristics of a simulated sexy voice. *Folia Phoniatrica, 31,* 242– 249.

Van Bezooijen, R. (1995). Sociocultural aspects of pitch differences between Japanese and Dutch women. *Language and Speech, 38,* 253-265.

Van Lierde, K. M., Vinck, B., De Ley, S., Clement, G., & Van Cauwenberge, P. (2005). Genetics of vocal quality characteristics in monozygotic twins: a multiparameter approach. *Journal of Voice, 19*, 511-518.

Vukovic, J., Feinberg, D. R., Jones, B. C., DeBruine, L. M., Welling, L. L. M., Little, A. C., & Smith, F. G. (2008). Self-rated attractiveness predicts individual differences in women's preferences for masculine men's voices. *Personality and Individual Differences, 45,* 451-456.

Vukovic, J., Feinberg, D. R., DeBruine, L., Smith, F. G., & Jones, B. C. (2010a). Women's voice pitch is negatively correlated with health risk factors and is an acoustic cue to apparent health. *Journal of Evolutionary Psychology. 8*, 217-225.

Vukovic, J., Jones, B. C., DeBruine, L. M., Feinberg, D. R., Smith, F. G., Little, A. C., Welling, L., Main, J. (2010b). Women's own voice pitch predicts their preferences for masculinity in men's voices. *Behavioral Ecology. 21,* 767-772.

Wadnerker, M. B., Cowell, P. E., & Whiteside, S. P. (2006). Speech across the menstrual cycle: a replication and extension study. *Neuroscience letters, 408,* 21-24.

Weingrill, T., Lycett, J. E., Barrett, L., Hill, R. A., & Henzi, S. P. (2003). Male consortship behavior in chacma baboons: The role of demographic factors and female conceptive probabilities. *Behaviour, 140,* 405-427.

Welling, L. L. M., Jones, B. C., DeBruine, L. M., Conway, C. A., Law Smith, M. J., & Little, A. C., et al. (2007). Raised salivary testosterone in women is associated with increased attraction to masculine faces. *Hormones and Behavior, 52,* 156–161.

White, D. J., & Galef Jr, B. G. (2000*). Animal Behaviour, 59,* 975-979.

Whiteside, S. P., Hodgson, C., & Tapster, C. (2002). Vocal characteristics in pre-adolescent and adolescent children: a longitudinal study. *Logopedics Phoniatrics Vocology, 27,* 12-20.

Whiteside, S.P., Hanson, A., & Cowell, P.E. (2004). Hormones and temporal components of speech: sex differences and effects of menstrual cyclicity on speech. *Neuroscience Letters, 367,* 44-47.

Wilcox, A. J., Weinberg, C. R., & Baird, D. D. (1995). Timing of sexual intercourse in relation to ovulation. *The New England Journal of Medicine, 333,* 1517-1521.

Zemlin, W. R. (1981). *Speech and Hearing Science: Anatomy and Physiology*, 2nd ed. Prentice-Hall, Englewood Cliffs, NJ.

Zraick, R. I., Gentry, M. A., Smith-Olinde, L., & Gregg, B. A. (2006). The effect of speaking context on elicitation of habitual pitch. *Journal of Voice, 20,* 545-554.

Zraick, R. I., Skaggs, S. D., & Montague, J. C. (2000). The effect of task on determination of habitual pitch. *Journal of Voice, 14,* 484-489.