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The influence of voice pitch on perceptions of trustworthiness across social contexts

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ABSTRACT

Perceptions of trustworthiness are an important predictor of social outcomes, such as monetary exchanges, criminal sentencing, and the attainment of leadership roles. Higher testosterone levels predict both lower voice pitch and untrustworthy behavior, across economic and mating contexts. Here, we tested the influence of voice pitch on perceptions of trustworthiness across general, economic, and mating-related (mate poaching, infidelity) contexts. We found that the context of trust and the sex of the speaker both changed how voice pitch affected perceived trustworthiness. Listeners were more trusting of higher-pitched female voices in economic and mate poaching contexts, but trusted lower-pitched female voices more in general. Listeners were more trusting of higher-pitched male voices in economic and mating-related contexts, and also tended to perceive higher-pitched male voices as more trustworthy in general. Listeners' attributions of trustworthiness were generally unrelated to perceptions of attractiveness from similarly-pitched voices, indicating that trust-related attributions were independent of preferences for higher- or lower-pitched voices. Furthermore, perceptions of general trustworthiness were associated with perceptions of economic trust, but were not consistently associated with perceptions of mating-related trust. These findings provide evidence that voice pitch alone is sufficient to influence trust-related perceptions, and demonstrates that listeners use voice pitch as a cue to trustworthy behavior.

1. Introduction

Trust is a fundamental component of human sociality (Bateson, 1988), and has broad implications for exchanges between individuals across social contexts. Individuals who are perceived as trustworthy are preferred in leadership roles (Chen, Jing, & Lee, 2014; Little, Roberts, Jones, & DeBruine, 2012), are entrusted with more money in economic games (Ewing, Caulfield, Read, & Rhodes, 2015; van't Wout & Sanfey, 2008), and receive less severe sentences for criminal offenses (Wilson & Rule, 2015). The same hormones associated with individual differences in trustworthy behavior are also implicated in the development of adult vocal characteristics (see section 1.1). In the present study, we examine whether listeners' attributions of trustworthiness are influenced by voice pitch across different social contexts.

1.1. The relationship among voice pitch, hormones, and behavior

Voice pitch is the perceptual correlate of fundamental frequency (f0) and/or the corresponding harmonics, which is equivalent to the rate of vocal fold vibration (Titze, 1994). Assuming equal tension, larger vocal folds vibrate more slowly than do smaller vocal folds, and are therefore capable of producing lower frequencies than are smaller vocal folds (Titze, 1994). At puberty, testosterone causes the vocal folds to increase in mass, thus lowering voice pitch (Harries, Hawkins, Hacking, & Hughes, 1998). Due to relatively higher levels of pubertal testosterone among males than females, this change results in an adult male voice pitch (120 Hz) that is on average half that of the mean adult female voice pitch (220 Hz) (Childers & Wu, 1991). Voice pitch continues to be negatively related to men's testosterone levels through adolescence (Hodges-Simeon, Gruven, & Gaulin, 2015) and into adulthood (Cartei, Bond, & Reby, 2014; Dabbs & Mallinger, 1999; Evans, Neave, Wakelin, & Hamilton, 2008; Hodges-Simeon et al., 2015; Puts, Apicella, & Cárdenas, 2012).

If voice pitch influences perceptions of trustworthiness, it may do so owing to associations between hormone levels and behavior. Men with relatively high testosterone levels act more punitively with other players in economic games (Burnham, 2007), and return less money to senders in the trust game (Takagishi, Takahashi, & Yamagishi, 2011). Men who possess facial cues of relatively higher levels of testosterone are more likely to exploit their partner's trust in economic games (Stirrat & Perrett, 2010). Men with relatively higher testosterone levels are also more likely to report a higher number of extra-pair sex partners (Booth & Dabbs, 1993; Fisher et al., 2009, 2012). Therefore, men with higher levels of testosterone, and hence, lower-pitched voices, may be less trustworthy in both economic and in mating-related contexts.

Similarly to men, women with relatively higher levels of testosterone return less money to senders in the trust game (Takagishi et al.,

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2011), suggesting that women with higher levels of testosterone may be less trustworthy in economic contexts. However, women's trait levels of estrogen, rather than testosterone, appears to be associated with lower trustworthiness in the context of mating. For instance, women with higher levels of estrogen report a greater future likelihood of adulterous behaviors (Durante & Li, 2009). Women who possess cues to relatively higher estrogen levels, such as feminine waist-to-hip ratios (Jasienska, Ziomkiewicz, Ellison, Lipson, & Thune, 2004), also report a higher number of extra-pair partners than do other women (Hughes & Gallup, 2003). Therefore, whereas women with relatively higher testosterone levels and lower-pitched voices may be less trustworthy in economic contexts, women with higher estrogen levels and higher-pitched voices may be less trustworthy in mating contexts.

1.2. Perceptions of general trustworthiness

There are mixed results on how voice pitch influences perceptions of general trustworthiness. Some research finds that relatively higher-pitched, feminine-sounding male voices are perceived as more trustworthy than are lower-pitched, masculine-sounding voices (McAleer, Todorov, & Belin, 2014). Yet, other research finds that lower-pitched voices are perceived as more trustworthy than are higher-pitched voices, among both male (Tigue, Borak, O'Connor, Schandl, & Feinberg, 2012) and female speakers (Klofstad, Anderson, & Peters, 2012). Furthermore, other studies have failed to detect a significant effect of male voice pitch on perceptions of trustworthiness (Klofstad et al., 2012; Vukovic et al., 2011). Therefore, the influence of male voice pitch on perceptions of trustworthiness in general is equivocal.

One potential explanation for these conflicting findings may be that perceptions of trustworthiness are tied to listener's voice pitch preferences. Generally, voices which are perceived as attractive are also perceived as trustworthy (Rezlescu et al., 2015). Lower-pitched male voices are rated as both more attractive and as more trustworthy than are higher-pitched male voices (Tigue et al., 2012). Vukovic et al. (2011) found that women who preferred lower-pitched male voices more as a long-term than as a short-term mates also perceived lower-pitched male voices as relatively trustworthy. Therefore, perceptions of lower-pitched voices as trustworthy could potentially be due to a halo effect (Feingold, 1998), where attractive voices are perceived positively on other personality attributes (Zuckerman & Driver, 1989).

1.3. Perceptions of mating-related trustworthiness

The influence of voice pitch on perceptions of trustworthiness may also be clarified by examining the specific social contexts of trustworthiness judgements. When perceptions of trustworthiness are examined within a mating-related context, highly sex-typical voices (i.e., higher-pitched voices among women, lower-pitched voices among men) tend to be perceived as less trustworthy than less sexually dimorphic voices. Specifically, lower-pitched male voices and higher-pitched female voices are perceived as more likely to commit infidelity than are other voices (O'Connor, Pisanski, Tigue, Fraccaro, & Feinberg, 2014; O'Connor, Re, & Feinberg, 2011). When asked to select who they would prefer to accompany their romantic partner on a weekend trip, men chose higher-pitched male voices and women chose lower-pitched female voices (O'Connor & Feinberg, 2012). Therefore, lower-pitched male voices and higher-pitched female voices are perceived as less trustworthy in mating contexts by both potential mates and same-sex rivals.

Although the above suggests that highly sex-typical voices are perceived as less trustworthy in mating contexts, it is unclear whether perceptions of same-sex voices as intrasexual rivals reflect trust-related perceptions or reflect perceptions of the attractiveness of such individuals. A more specific measure of mating-related trust for same-sex individuals would be perceptions of mate poaching, a sexual strategy which could be attempted regardless of one's desirability to the opposite-sex. Here, it may be that both men and women with lower-pitched voices are perceived as more likely to mate poach. This is because relatively higher levels of testosterone are associated with both lower voice pitch (Cartei et al., 2014; Dabbs & Mallinger, 1999; Evans et al., 2008; Hodges-Simeon et al., 2015; Puts et al., 2012) and increased mating effort (for review see Roney & Gettler, 2015). For example, women in polyamorous relationships have relatively higher levels of testosterone in comparison to women who are single or in monogamous relationships (van Anders, Hamilton, & Watson, 2007). Men with higher levels of testosterone report a higher number of sex partners than do other men (Peters, Simmons, & Rhodes, 2008; Pollet, van der Meij, Cobey, & Buunk, 2011). Therefore, if individuals with relatively higher levels of testosterone are more likely to mate poach as a result of increased mating effort, then listeners may be less trusting of lower-pitched same-sex voices in mating contexts.

1.4. The social context of trustworthiness

Ratings of general trustworthiness are formed spontaneously, with high inter-rater agreement (for review see Todorov, 2008), but it is unclear whether perceptions of general trustworthiness are readily applied to specific social contexts. Trust-based exchanges have an underlying framework that is applicable across different social contexts:

> "Trust" is inherently a matter of the beliefs that one agent has about the behavior of another. An action that is trusting of another is one that creates the possibility of mutual benefit, if the other person is cooperative, and the risk of loss to oneself if the other person defects. [(p.263, Cox, 2004)]

This definition of trust reflects some economic exchanges, such as the trust game (Berg, Dickhaut, & McCabe, 1995), but also exchanges in other social contexts, such as romantic scenarios. For instance, if *A* believes that *B* is romantically faithful, but *B* is unfaithful (i.e., defects), then *A* may incur fitness costs resulting from infidelity, such as the loss of protection and provisioning (Geary & Byrd-Craven, 2004). This scenario may also be applied to the context of mate poaching. Romantic relationships are very often public information, and mate poaching can be perceived as a violation of social norms where coupled individuals are "off the market." If *A* believes *C* will not attempt to poach his/her mate, but *C* does attempt to mate poach (i.e., defects), then *A* may lose his/her current mate or experience increased paternity uncertainty (Geary & Byrd-Craven, 2004). In the present study, we use these two scenarios of infidelity and mate poaching to examine perceptions of mating-related trustworthiness.

Examining perceptions across different social contexts of trust, such as economic exchanges or mate selection, could clarify the influence of voice pitch on trust-related perceptions. In economic contexts, individuals who are rated as highly trustworthy in general also sent more money in economic games in which the return of any money is not guaranteed (van't Wout & Sanfey, 2008). In the context of mate selection, Rhodes, Morley, and Simmons (2013) did not find evidence for a relationship between perceptions of trustworthiness and attributions of infidelity to faces. Therefore, perceptions of general trustworthiness appear to be associated with economic trust, but may be distinct from perceptions of mating-related trust. In the present study, we examine whether this pattern is also observed when examining trust-related perceptions of voices varying in pitch.

1.5. The present study

We examined whether voice pitch influences perceptions of trustworthiness in an economic context, in a mating context, and in an unspecified context (general trustworthiness). In order to test whether voice pitch influences economic trust, participants took part in a modified version of the trust game (Berg et al., 1995) wherein listeners

selected who they trusted to equitably divide a sum of money. If voice pitch is used as a cue to trustworthy behavior, then listeners will be more likely to trust higher-pitched than lower-pitched voices to divide money in the economic context.

To examine the influence of voice pitch on mating-related trust, we tested perceptions of infidelity when voices were the opposite-sex of the listener, and perceptions of mate poaching when voices were the same-sex as the listener. We predicted that, consistent with previous research (O'Connor et al., 2011, 2014), women will perceive men with lower-pitched voices as more likely to commit infidelity, whereas men will perceive women with higher-pitched voices as more likely to commit infidelity. If individual differences in testosterone levels are associated with increased mating effort, then lower-pitched same-sex voices will be perceived as more likely to mate poach than will higher-pitched same-sex voices.

In addition, we also examined whether perceptions of context-specific trustworthiness are associated with perceptions of trustworthiness in general. Finally, we test whether perceptions of trust across contexts are due to a halo effect whereby listeners who prefer lower-pitched voices also tend to rate lower-pitched voices more positively on other attributes, such as trustworthiness. If perceptions of trustworthiness are dependent upon voice preferences, then listener's preferences for voice pitch will predict the selection of voices as trustworthy across general, economic, and mating contexts.

2. Methods

2.1. Participants

Protocols for this study were approved by the University of Guelph Research Ethics Board. Heterosexual men ($n = 88$; mean age = 18.49 years, $SD = 1.12$) and women ($n = 89$; mean age = 18.34 years, $SD = 1.01$) were recruited from the University of Guelph and compensated with partial course credit for participation. Participants were recruited until estimated sample size requirements ($n = 84$ per sex) were met to detect a medium effect size ($r = 0.3$) with 80% power using a correlation with $\alpha = 0.05$ (G*Power, Faul, Erdfelder, Lang, & Buchner, 2007).

2.2. Stimuli

Voice stimuli were collected at McMaster University, Hamilton, Ontario. Speakers were 48 undergraduate men ($n = 24$, mean age = 18.42, $SD = 0.58$) and women ($n = 24$, mean age = 18.83, $SD = 1.20$). Voice recordings included the Canadian English monophthong vowels /ɑ/ "ah," /i/ "ee," /ɛ/ "eh," /o/ "oh," /u/ "oo" and the word "hello." We created two versions of each recording, a feminized version with raised pitch, and a masculinized version with lowered pitch. Feminized and masculinized voice pairs were created using Praat software (version) by adding or subtracting (respectively) 0.5 equivalent rectangular bandwidths (ERBs) of the baseline frequency. See supplementary material (S1) for recording procedures and descriptive statistics of voice stimuli.

2.3. Procedure

Participants listened to 12 stimulus pairs in each of four different contexts: 1) a trust game; 2) mating-related trustworthiness; 3) general trustworthiness; and 4) attractiveness. Participants completed a block of voices in one context (e.g., trust game) before starting the next context (e.g., attractiveness), with the order of contexts randomized. All participants listened to voices of both sexes: 6 male and then 6 female, or vice versa, within each context. Voice stimuli in the trust game spoke the word "hello" and voice stimuli in the attractiveness, mating-related trustworthiness, and general trustworthiness rating contexts spoke the English vowel sounds. Participants always chose between a feminized and masculinized voice of the same speaker. Twelve different speakers were used across rating contexts. Within each rating context, all listeners heard the same 12 pairs of voices. Following previous research (O'Connor et al., 2011), speaker identity and speech content differed across rating contexts in order to prevent participants from engaging in identity matching across tasks.

In order to avoid deception (Hertwig & Ortmann, 2001; Jamison, Karlan, & Schechter, 2008), the economic trust game was hypothetical. Participants were instructed:

> In this experiment, you will play a series of economic games for theoretical money. No real money is involved. Imagine you have been given $10, which will be divided by one of the other players. The other player can either (1) divide the money equally so that you each receive $5 OR (2) divide the money unequally so that you receive $3 and player 2 keeps $7. You must select which person you trust to divide the money. You will hear 2 female/male voices. Pick the voice of the person that you trust to divide the money.

Participants did not receive feedback regarding their partner selection decisions in the hypothetical trust game. Participants rated voices in 3 additional contexts. In the attractiveness context, participants were instructed: "You will hear 2 female/male voices. Pick the voice that you think sounds more attractive." In the general trustworthiness context, participants were instructed: You will hear 2 female/male voices. Pick the voice that you think sounds more trustworthy." The mating-related trustworthiness context was comprised of two different ratings depending upon whether voices were the same-sex or opposite-sex of the listener. For opposite-sex voices, participants were instructed "You will hear 2 female/male voices. Choose the voice that you think is more likely to cheat on you if you were their romantic partner." For same-sex voices, participants were given the following instructions:

> Someone who is mate poaching is trying to seduce, lure, or "steal" someone else's romantic partner. You will hear two female/male voices. Select which voice, in your opinion, would be more likely to mate poach your romantic partner. If you are not currently in a romantic relationship, please imagine that you are.

Rating contexts were fully randomized for order of presentation. Voice pairs were displayed simultaneously, and fully randomized for order and side of screen presentation. Files were played by the participant selecting the "play" button for each individual voice in a pair. Participant responses automatically loaded the next voice pair. Participation lasted approximately 30 min.

2.4. Statistical analyses

For each context (e.g., economic, attractiveness), we calculated the proportion of trials in which participants selected the lower-pitched version of a voice from each voice pair. We analyzed listener's selection of lower-pitched voices with a repeated measures ANOVA [within-subject factors: rating context (trust game, general trustworthiness, attractiveness), voice sex (female, male), between-subject factor: listener sex (female, male)]. We did not include the mating-related trustworthiness contexts in this analysis because participants selected voices in response to different questions depending upon whether voices were the same-sex (i.e., perceptions of mate poaching) or opposite-sex (i.e., perceptions of infidelity) of the listener. In section 3.2, we analyzed listener's selection of lower-pitched voices in the mating contexts with a repeated measures ANOVA [within-subject factors: rating context (same-sex mate poaching, opposite-sex infidelity), between-subject factor: listener sex (female, male)]. All analyses used two-tailed probability estimates ($\alpha = 0.05$). Post hoc t-tests were corrected for multiple comparisons with the Holm method (Holm, 1979), and we report both original and Holm-corrected p-values. See supplementary material for additional analyses (S2, S3) and raw data (S4).

3. Results

3.1. The influence of trust context, speaker sex, and listener sex on the selection of lower-pitched voices

Mauchly's test indicated that the assumption of sphericity had been violated for the interaction between context and listener sex ($\chi^2 = 6.70$, $p = 0.035$), therefore degrees of freedom for that variable were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.964$; Girden, 1992). The results were not qualitatively influenced by using other methods of correcting for sphericity assumption violations, nor were they altered by using uncorrected degrees of freedom.

We found a significant effect of rating context ($F_{2,\ 350} = 85.89$, $p < 0.001$, $\eta_p^2 = 0.329$) and a significant effect of voice sex ($F_{1,\ 175} = 21.80$, $p < 0.001$, $\eta_p^2 = 0.111$) on participants' selection of lower-pitched voices (Fig. 1). However, the effect of voice sex was qualified by a significant interaction with rating context ($F_{1.93,\ 337.26} = 70.58$, $p < 0.001$, $\eta_p^2 = 0.287$), so we analyzed the rating contexts separately. When choosing the more attractive voice, listeners chose lower-pitched male voices significantly more often than predicted by chance ($M = 0.72$, $SE = 0.02$, one-sample $t_{176} = 13.24$, $p < 0.001$), but did not choose lower-pitched female voices at rates significantly different from chance ($M = 0.47$, $SE = 0.02$, one-sample $t_{176} = -1.36$, $p = 0.175$); the difference between male and female voices is significant (paired $t_{176} = -9.77$, $p < 0.001$, *Holm* $p = 0.003$). Results were nearly the opposite when choosing the more generally trustworthy voice: listeners chose lower-pitched male voices marginally less often than chance ($M = 0.47$, $SE = 0.02$, one-sample $t_{176} = -1.81$, $p = 0.093$) and lower-pitched female voices significantly more often than predicted by chance ($M = 0.60$, $SE = 0.02$, one-sample $t_{176} = 4.84$, $p < 0.001$); this difference between male and female voices is also significant (paired $t_{176} = 5.79$, $p < 0.001$, *Holm* $p = 0.002$). In the trust game, listeners chose lower-pitched male voices ($M = 0.39$, $SE = 0.02$, $t_{176} = -6.64$, $p < 0.001$) and lower-pitched female voices to divide the money significantly less often than chance ($M = 0.31$, $SE = 0.02$, $t_{176} = -9.24$, $p < 0.001$), and this effect was significantly stronger for female voices than for male voices (paired $t_{176} = -3.53$, $p = 0.001$, *Holm* $p = 0.001$).

The ANOVA also revealed a significant interaction between voice sex and listener sex ($F_{1,\ 175} = 14.06$, $p < 0.001$, $\eta_p^2 = 0.0974$), so we analyzed the simple effects with paired sample *t*-tests on the proportion of trials listeners selected the lower-pitched voice, averaged across all contexts. Men chose more lower-pitched voices overall when speakers were male ($M = 0.56$, $SE = 0.03$) than when they were female ($M = 0.44$, $SE = 0.02$; paired $t_{87} = -5.46$, $p < 0.001$, *Holm* $p = 0.002$). By contrast, women were equally likely to choose lower-pitched male ($M = 0.49$, $SE = 0.02$) and female voices ($M = 0.48$, $SE = 0.02$; paired $t_{88} = -0.72$, $p = 0.474$). When collapsing across rating contexts, men's selection of lower-pitched male voices (one-sample $t_{87} = 3.12$, $p = 0.002$) and higher-pitched female voices (one-sample $t_{87} = -3.41$, $p = 0.001$) were significantly different from chance (0.5). Women's selection of lower-pitched voices was not significantly different from chance for either male (one-sample $t_{88} = -0.427$, $p = 0.670$) or female speakers (one-sample $t_{88} = -1.041$, $p = 0.301$).

The interaction between rating context and listener sex was significant ($F_{2,\ 350} = 5.61$, $p = 0.004$, $\eta_p^2 = 0.031$). An investigation of this interaction shows that women chose more lower-pitched voices than did men when judging attractiveness ($t_{175} = -2.42$, $p = 0.017$, Holm $p = 0.051$). There were no other significant differences (all $t < 1.62$, all $p > 0.108$). The ANOVA did not indicate any other significant effects or interactions (all $F < 1.55$, all $p > 0.215$).

3.2. The influence of voice pitch on mating-related trustworthiness

The effect of rating context ($F_{1,\ 175} = 3.86$, $p = 0.051$, $\eta_p^2 = 0.02$) was qualified by a significant interaction with listener sex ($F_{1,\ 175} = 19.36$, $p < 0.001$, $\eta_p^2 = 0.10$) on participants' selection of lower-pitched voices (Fig. 2). In the infidelity context, women perceived greater infidelity risk from the lower-pitched (opposite-sex) voices more often than predicted by chance ($M = 0.66$, $SE = 0.03$, one-sample $t_{88} = 5.75$, $p < 0.001$), but men did not ($M = 0.52$, $SE = 0.03$, one-sample $t_{87} = 0.60$, $p = 0.549$); this sex difference is significant (independent $t_{175} = -3.35$, $p = 0.001$, Holm $p = 0.002$). By contrast, in the mate poaching context, both women ($M = 0.59$, $SE = 0.03$, one-sample $t_{88} = 3.23$, $p = 0.002$) and men ($M = 0.70$, $SE = 0.03$, one-sample $t_{87} = 7.31$, $p < 0.001$) perceived a higher risk of mate poaching from lower-pitched (same-sex) voices than predicted by chance; this sex difference is significant (independent $t_{175} = 2.65$, $p = 0.009$, Holm $p = 0.002$). The effect of listeners sex did not reach significance ($F_{1,\ 175} = 0.39$, $p = 0.533$, $\eta_p^2 = 0.002$).

3.3. Pearson correlations among perceptions of voices across rating contexts

We used Pearson correlations to examine (a) whether listeners who perceived lower-pitched voices as attractive also perceived lower-

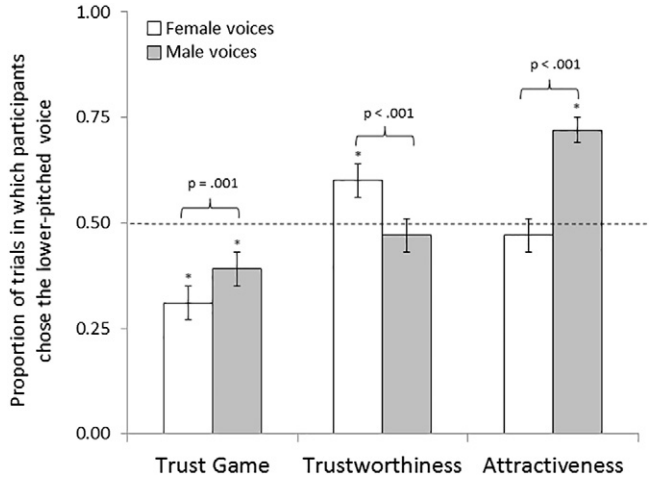

Fig. 1. Mean and 95% CI of the proportion of trials in which participants chose the lower-pitched version of a voice pair to divide money in the trust game, as trustworthy in general, and as attractive. CIs that do not overlap with the dotted line are significantly different from chance (0.50), indicated by *. Significant differences between female voices (light bars) and male voices (filled bars) are indicated by the associated *p* value.

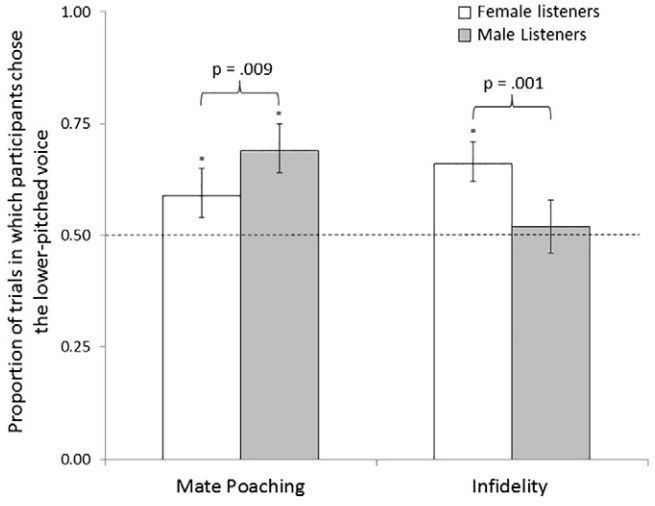

Fig. 2. Mean and 95% CI of the proportion of trials in which women (light bars) and men (filled bars) chose the lower-pitched version of a voice pair as more likely to commit infidelity (opposite-sex voices) and mate poach (same-sex voices). CIs that do not overlap with the dotted line are significantly different from chance (0.50), indicated by *. Significant differences between female listeners (light bars) and male listeners (filled bars) are indicated by the associated *p* value.

Table 1
Bivariate correlations (and *p*-values/Holm corrected *p*-values) across contexts for female participants (n = 89). Female voices are above the diagonal, male voices are below the diagonal. Bold indicates Holm corrected $p < 0.05$.

	Trust game	General trustworthiness	Trust regarding infidelity/mate poaching	Attractiveness
Trust game	–	0.22 (0.041/0.205)	−0.03 (0.796/0.796)	0.07 (0.547/1.00)
General trustworthiness	**0.32 (0.002/0.012)**	–	**−0.32 (0.002/0.012)**	0.07 (0.532/1.00)
Trust regarding infidelity/mate poaching	−0.21 (0.052/0.260)	−0.15 (0.147/0.441)	–	0.20 (0.057/0.228)
Attractiveness	−0.05 (0.650/1.00)	−0.02 (0.856/0.856)	0.16 (0.135/0.540)	–

pitched voices as trustworthy, and (b) whether listeners who trusted lower-pitched (or higher-pitched) voices in general also trusted lower-pitched (or higher-pitched) voices in other contexts. We corrected for multiple comparisons with the Holm method (Holm, 1979) to maintain familywise $\alpha = 0.05$ for each combination of listener sex and voice sex.

Women who trusted higher-pitched voices in general also tended to select higher-pitched male voices in the trust game (male voices $r = 0.32$, $p = 0.002$; female voices $r = 0.22$, $p = 0.041$). However, this relationship only survived correction for multiple comparisons among male voices (Holm $p = 0.012$) and not female voices (Holm $p = 0.205$).

Women who perceived lower-pitched female voices as generally trustworthy also perceived lower-pitched female voices as less likely to mate poach ($r = -0.323$, $p = 0.002$, Holm $p = 0.012$). No other significant relationships among women's perceptions of male or female voices survived correction (see Table 1).

Men who trusted lower-pitched voices in general also selected lower-pitched voices in the trust game (female voices: $r = 0.39$, $p < 0.001$, Holm corrected $p = 0.006$; male voices: $r = 0.28$, $p = 0.008$, Holm corrected $p = 0.048$). There were no other significant relationships among men's voice perceptions that survived correction (see Table 2).

4. Discussion

4.1. Trust-related perceptions of male voices

Based on the association between testosterone and trustworthiness (Booth & Dabbs, 1993; Fisher et al., 2009, 2012; Takagishi et al., 2011), we predicted and found that listeners were more likely to trust higher-pitched than lower-pitched male voices. Listeners perceived higher-pitched male voices as more likely to equitably divide a hypothetical sum of money, as less likely to commit infidelity, and as less likely to mate poach someone else's romantic partner. Listeners also tended to perceive higher-pitched male voices as more trustworthy *in general*, but this pattern did not reach significance ($p = 0.093$). Therefore, listeners appear to use higher male voice pitch as a cue to trustworthy behavior in both economic and mating-related contexts.

The results from the present study indicate that listeners are more likely to trust speakers with higher-pitched voices to equitably divide money in a hypothetical economic game. These results are consistent with other research finding that women are more likely to trust male speakers with higher-pitched voices in a hypothetical economic game (Montano et al., in press). That study, however, did not include male listeners or female voices. Here, we find evidence that perceptions of economic trustworthiness from higher-pitched voices are not limited to female listeners or male voices, but are also applicable to male listeners and female voices.

Our findings that lower-pitched male voices were perceived as relatively less trustworthy in mating contexts are consistent with prior research on perceptions of masculine men's voices and faces as presenting a greater risk of infidelity (Kruger, 2006; O'Connor et al., 2011, 2014) and as belonging to relatively threatening intrasexual rivals (Kruger, 2006; O'Connor & Feinberg, 2012). Thus, masculine men's voices and faces are perceived as less trustworthy in mating-related contexts, by both potential mates and by same-sex competitors. Individuals who attend to such cues may be better able to target their mate retention and/or mate selection strategies to avoid the potential fitness risks associated with relatively masculine male mates and rivals.

4.2. Trust-related perceptions of female voices

For female speakers, we predicted and found that lower-pitched women's voices were perceived as less trustworthy in both economic and mate-poaching contexts. Relatively higher levels of testosterone have been associated with less trustworthy behavior in an economic game (Takagishi et al., 2011) and with increased mating effort (see Roney & Gettler, 2015 for review). As lower-voice pitch is a testosterone-dependent trait, (Cartei et al., 2014; Dabbs & Mallinger, 1999; Evans et al., 2008; Hodges-Simeon et al., 2015; Puts et al., 2012), listeners may be using female voice pitch as a cue to both economic trustworthiness and to the proclivity to poach someone else's romantic partner.

Although higher-pitched female voices were trusted in the economic context, listeners trusted lower-pitched female voices *in general*. It is unclear why female voice pitch would have contrasting effects on perceptions of economic versus general trustworthiness. Potentially, perceptions of lower-pitched female voices as more trustworthy in general maybe driven by underlying perceptions of competence (Klofstad et al., 2012). In contrast, perceptions of higher-pitched female voices may be perceived as more economically trustworthy owing to perceptions of cooperativeness (Knowles & Little, 2016). Although we find evidence for a positive association between general and economic trust (see section 4.3), we cannot rule out the possibility that other conceptually related attributions underlie the contrasting influence of female voice pitch on economic and general trustworthiness.

In contrast to previous research (O'Connor et al., 2011), we did not find a significant effect of female voice pitch on men's perceptions of infidelity. In comparison to O'Connor et al. (2011), the present study uses a similar stimulus set and degree of pitch manipulation, suggesting that the failure to detect an effect of voice pitch on men's perceptions of female infidelity is unlikely to be due to methodological differences

Table 2
Bivariate correlations (and *p*-values/Holm corrected *p*-values) across contexts for male participants (n = 88). Female voices are above the diagonal, male voices are below the diagonal. Bold indicates Holm corrected $p < 0.05$.

	Trust game	General trustworthiness	Trust regarding infidelity/mate poaching	Attractiveness
Trust game	–	**0.39 (<0.001/0.006)**	−0.12 (0.270/1.00)	0.08 (0.414/1.00)
General trustworthiness	**0.28 (0.008/0.048)**	–	−0.24 (0.024/0.120)	0.08 (0.446/0.892)
Trust regarding infidelity/mate poaching	−0.17 (0.108/0.324)	−0.03 (0.767/1.00)	–	0.02 (0.890/0.890)
Attractiveness	0.01 (0.951/0.951)	0.23 (0.031/0.124)	0.25 (0.021/0.105)	–

between the two studies. As these are the only two studies examining men's perceptions of infidelity from female voices, additional attempts at replication are required in order to determine whether the failure to detect an effect of female voice pitch on perceptions of infidelity is a result of either a Type I or Type II error.

4.3. Are perceptions of general trustworthiness related to economic or mating-related trust?

Until now, it has been unclear whether perceptions of general trustworthiness from voices are associated with perceptions of trust in specific social contexts. We found that for opposite-sex voices, perceptions of general trustworthiness are associated with economic trustworthiness, but not with mating trustworthiness. Men and women who trusted higher-pitched opposite-sex voices in general also trusted higher-pitched opposite-sex voices in the trust game, but perceptions of general trustworthiness were unrelated to perceptions of infidelity. Other research has also found that perceptions of facial trustworthiness are associated with measures of economic trust (van't Wout & Sanfey, 2008), but not with perceptions of infidelity (Rhodes et al., 2013). Thus, individual differences in perceptions of general trustworthiness from opposite-sex voices are positively associated perceptions of economic trust, but appear to be functionally distinct from perceptions of infidelity. However, we found that women who chose lower-pitched female voices as more trustworthy in general also perceived lower-pitched female voices as less likely to mate poach, but this relationship was not observed among male listeners. Therefore, perceptions of general trustworthiness may be related to perceptions of mating-related trust when assessing potential romantic rivals.

4.4. Do perceptions of attractiveness predict trust-related perceptions?

The influence of voice pitch on trust-related perceptions in the current study are unlikely to be due to listeners' perceptions of attractiveness. If this were the case, then we would have found that listeners who perceived lower-pitched (or higher-pitched) voices as attractive also trusted lower-pitched (or higher-pitched) voices in general, in the economic context, and/or in the mating-related context. We found that men who perceived lower-pitched male voices as attractive also perceived lower-pitched male voices as more trustworthy in general, but this relationship was not significant after correcting for multiple comparisons ($p = 0.031$, Holm $p = 0.124$). We also found that women who perceived lower-pitched female voices as attractive also perceived women with lower-pitched voices as more likely to mate poach, but this trend did not reach significance ($p = 0.057$, Holm $p = 0.228$). Therefore, the overall results are not likely owing to a positive response bias where listeners who rate lower- or higher-pitched voices as attractive also rate similarly-pitched voices more positively in other contexts.

4.5. The influence of rating context on the selection of lower-pitched voices

In our analysis of the influence of trust context, speaker sex, and listener sex on the selection of lower-pitched voices (see section 3.2), we found a significant interaction between speaker sex and listener sex. When collapsing across rating contexts, men selected lower-pitched male voices and higher-pitched female voices more often than predicted by chance. However, women's selection of lower-pitched voices was not significantly different from chance for male or female speakers. Importantly, we also found that there was a significant effect of context on the selection of lower-pitched voices, as well as an interaction between rating context and voice sex. As we demonstrate, women selected lower-pitched men's voices as relatively attractive but as less economically trustworthy, at rates significantly different from chance. These findings contrast with research suggesting that the influence of lower voice pitch on the selection of male voices is irrespective of rating context (Tsantani, Belin, Paterson, & McAleer, 2016). Therefore, our findings do not support a general response bias toward lower-pitched male voices, but rather indicate the importance of social context in voice perception.

4.6. Limitations

The structure of the hypothetical game in the present study closely resembles the decision of player 1 in a binary version of the trust game (Berg et al., 1995). The difference being that in the present study, participants selected *who* rather than *if* they trusted to divide a hypothetical sum of money. The version of the trust game used in the present study has the advantage of avoiding deception (Hertwig & Ortmann, 2001; Jamison et al., 2008), but does have limitations. The present study cannot address the degree to which higher-pitched voices are trusted more than lower-pitched voices, as quantified by the amount of money listeners would transfer to the other player. Additionally, the trust game used in the present study involved decisions regarding hypothetical money. It is unclear whether using real money would impact the influence of voice pitch on partner selection in the trust game.

4.7. Conclusions

Our findings that higher-pitched male and female voices are more likely to be trusted in economic contexts have practical implications for financial exchanges, such as sales and lottery gaming. Financial risk taking may also be more likely when lottery gaming involves vocal communication with a higher- versus lower-pitched agent. Consumers may be more likely to purchase goods and services from telemarketers with higher- versus lower-pitched voices. Indeed, Oksenberg, Coleman, and Cannell (1986) found higher participation rates in a telephone survey when the interviewer had a higher- versus lower-pitched voice. In contrast, listeners perceive male-voiced advertisements more positively when the speaker was faster-paced with average versus higher voice pitch (120 Hz versus 142 Hz: Chattopadhyay, Dahl, Ritchie, & Shahin, 2002). Whether these perceptions result in differences in consumer purchasing behavior is a direction for future research.

From a functional perspective, those who can preferentially select trustworthy individuals for social exchanges could potentially gain fitness benefits stemming from increases in material resources, beneficial reputational effects, or sexual fidelity in the case of potential mates. Our research demonstrates that voice pitch may be one such cue which aids in selecting trustworthy social partners and/or avoiding untrustworthy individuals. As voice pitch is tied to trust-related behaviors via underlying hormone levels, voice pitch may influence perceptions of trustworthiness because it is a reliable cue to trustworthy behavior.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.evolhumbehav.2017.03.001.

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