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Human vocal behavior within competitive and courtship contexts and its relation to mating success

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A B S T R A C T

Beyond the linguistic content of their speech, speakers of both sexes convey diverse biological and psychosocial information through their voices, which are important when assessing potential mates and competitors. However, studies investigating the relationships between mating success and acoustic inter-individual differences are scarce. In this study, we investigated such relationships in both sexes in courtship and competitive interactions—as they correspond to the two different types of sexual selection—using an experimental design based on a simulated dating game. We assessed which type of sexual selection best predicted mating success, here defined as the self-reported number of sexual partners within the past year. Our results show that only acoustic inter-individual differences in the courtship context for both men and women predicted their mating success. Men displaying faster articulation rate and louder voices reported significantly more sexual partners; in contrast, men displaying higher intonation reported a greater negative effect of roughness and breathiness on their mating success. Women who displayed relatively less breathy voices and shorter speech duration reported significantly fewer sexual partners. These novel findings are discussed in light of the mate choice context and the relative contribution of both types of sexual selection shaping acoustic features of speech.

1. Introduction

Beyond the linguistic content it conveys, voice is one of the fundamental aspects of human communication, as it enables the expression of a wide range of emotional and affective states.

A large body of work has shown that voices convey an array of different biological and social information such as sex (Puts, Gaulin, & Verdolini, 2006), age (Linville & Fisher, 1985; Ptacek & Sander, 1966), sexual orientation (Lyons, Lynch, Brewer, & Bruno, 2014; Munson, McDonald, DeBoe, & White, 2006), hormone levels (Dabbs Jr & Mallinger, 1999), physical strength (Sell et al., 2010), body configuration (Hughes, Dispenza, & Gallup, 2004) and social status (Cheng, Tracy, Ho, & Henrich, 2016). Such information is crucial to assess potential mates and competitors, as it reflects indexical cues of attractiveness, dominance, masculinity and femininity or impressions of size-related features (Puts, Jones, & DeBruine, 2012). For instance, men exhibiting a relatively lower voice pitch are perceived as more attractive by members of the opposite sex and more dominant by same-sex individuals (Collins, 2000; Puts et al., 2006; Puts, Hodges, Cárdenas, & Gaulin, 2007). Some studies have found that women with a relatively higher voice pitch are perceived as more attractive by men while being judged as more promiscuous by other women (Collins & Missing, 2003; Puts, Barndt, Welling, Dawood, & Burriss, 2011), although other evidence suggests the opposite relationship (Hughes, Farley, & Rhodes, 2010; Hughes, Mogilski, & Harrison, 2014; Tuomi & Fisher, 1979).

In addition to attractiveness and dominance, several other auditory impressions can be conveyed through voice. For instance, one study from O'Connor, Re, and Feinberg (2011) showed that the perception of infidelity risk increases with more feminine voices in women (i.e., relatively higher voice pitch) and more masculine voices in men (i.e., relatively lower voice pitch). Voice can also play upon perceptions of cooperativeness, where a higher voice pitch is associated with increased perception of cooperation (Knowles & Little, 2016) and trustworthiness, and individuals with lower voice pitch are preferentially selected when judges are asked to pick a leader (Tigue, Borak, O'Connor, Schandl, & Feinberg, 2012). However, other evidence has shown the opposite relationship (Montano, Tigue, Isenstein, Barclay, & Feinberg, 2017; Oleszkiewicz, Pisanski, Lachowicz-Tabaczek, & Sorokowska, 2017). Concerning impressions of the size-related feature, listeners regularly associate deeper voice pitch to larger and taller individuals, and

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conversely, higher voice pitch to thinner and smaller individuals (Pisanski & Rendall, 2011; Rendall, Vokey, & Nemeth, 2007); despite this, vocal features explain little variation in body size (Pisanski et al., 2014). Although voice pitch and its resonant frequencies signal little information on the latter, it has been suggested that they could rather be a reliable signal of hormonal quality; e.g., lower voice pitch in men correlated to circulating testosterone levels (Evans, Neave, Wakelin, & Hamilton, 2008) or a signal of fertility in women (Feinberg et al., 2005; Pisanski, Bhardwaj, & Reby, 2018).

Morton (1977) first suggested that in many birds and mammal species, a common structural convergence of acoustic features exists where low-frequency sounds are used in "hostile" and "harsh" contexts; conversely, higher-frequency sounds are used when "frightened" or "approaching in a friendly manner". Later, Ohala (1983) built upon this idea by suggesting that cross-language patterns in the use of vocal height in natural languages and vocalizations in other species serve purposes of threatening (or not) conspecifics. Listeners associate higher acoustic frequencies with the impression of a "small vocalizer" perceived as subordinate, submissive, non-threatening and lower acoustic frequencies with a "large vocalizer" perceived as dominant, aggressive and threatening. This theoretical framework is supported from recent comparative approaches studying dimorphism in the vocalizations of mammals, which is of great importance in the context of conspecific encounters within intra-sexual competition (Bowling et al., 2017; Charlton & Reby, 2016; Puts et al., 2016). Indeed, many males of mammal species use their vocalizations to assess and repel competitors, with deeper frequencies associated with higher mating and reproductive success. For humans, it is commonly accepted that vocal sexual dimorphism, which is due to anatomical and physiological differences between men and women (Fitch & Giedd, 1999), has also been shaped by sexual selection and is argued to be, at least in men, mostly shaped by intra-sexual competition (Hill et al., 2013; Kordsmeyer, Hunt, Puts, Ostner, & Penke, 2018; Puts, 2010).

Among the multiple acoustic components of human speech, fundamental frequency is the most studied and has been linked to the aforementioned indexical cues (i.e., F0, rate of vocal fold vibration corresponding to the acoustic correlate of voice pitch) and the formants (i.e., the acoustic resonances of the vocal tract); these cues are perceived as the most salient features of the human voice. However, other vocal traits can also convey information on indexical cues of speakers. For instance, variations of F0 (i.e., its standard-deviation, hereafter F0-SD, the acoustic correlate of intonation) appears to be a dimorphic acoustic characteristic, where men's speech is more monotonous in comparison with women's, who tend to vary their intonation more. Therefore, a more dynamic speech is more likely to be perceived as a reliable cue of femininity in women, while rather monotonous intonation can be linked to self-confident, relaxed and more masculine men (Hodges-Simeon, Gaulin, & Puts, 2011; Leongómez et al., 2014). Another vocal feature of interest is breathiness, which correlates with a lower harmonics-to-noise ratio (hereafter HNR) and quantifies the relative amount of additive noise in the voice signal (De Krom, 1995; Hillenbrand & Houde, 1996). Additive noise arises from turbulent airflow generated at the glottis during phonation, and it is believed to result from an inadequate closure of the vocal folds. HNR reflects breathy voice quality, which is considered to be a signal of femininity (De Krom, 1995; Van Borsel, Janssens, & De Bodt, 2009), and has recently been found to be correlated to perceived attractiveness (Šebesta et al., 2017). In addition, vocal roughness (or hoarseness), which is related to irregular patterns of vocal folds vibration (Coleman & Wendahl, 1967), can be captured by the jitter, a measure of the cycle-to-cycle variation of the pitch period (with higher jitter values being associated with rougher voices; see Jones, Trabold, Plante, Cheetham, & Earis, 2001). Though small irregularities in the acoustic wave are considered normal variation associated with physiologic body function and voice production, it has also been shown that roughness may increase attractiveness, as higher jitter values result in a voice quality known as vocal fry and is associated with impressions of desirability, more authoritative, educated, urban-oriented and upwardly mobile women (Greer & Winters, 2015; Oliveira, Davidson, Holczer, Kaplan, & Paretzky, 2016; Yuasa, 2010). Lastly, some other prosodic features of continuous speech, such as the speaking or the articulation rate (i.e., number of syllables produced per seconds, including or excluding pauses, respectively) may also play a role within courtship and competitive interactions; these have been previously shown to play upon perception of the speaker's competence, benevolence, trustworthiness, persuasiveness and social attractiveness (Brown, Strong, & Rencher, 1973; Miller, Maruyama, Beaber, & Valone, 1976; Smith, Brown, Rencher, & Strong, 1975; Street Jr & Brady, 1982).

Studies investigating the relationships between acoustic inter-individual differences and mating/reproductive success are scare, and the results vary from one study to another. Apicella, Feinberg, and Marlowe (2007) showed that hunter-gatherers' voice pitch could reliably predict their reproductive success where a relatively low F0 is correlated to higher fitness, but it has been recently reported that this relationship does not hold when controlling for reputation (Smith, Olkhov, Puts, & Apicella, 2017). Through a simulated dating game, two studies from Puts (2005) and Puts et al. (2006) showed that lower F0 negatively correlated to men's mating success, although the latter study found that it was not significant. Using a similar approach, Hodges-Simeon et al. (2011) found that men who spoke in a more monotonic manner (i.e., lower F0-SD) when speaking to competitors declared more sexual partners over the past year. Moreover, Hughes et al. (2004) reported that female and male vocal attractiveness (when rated by members of the opposite sex) could predict their mating success, their declared number of extra-pair copulations and their age at first sexual intercourse. Lastly, Atkinson et al. (2012) found that F0 significantly predicted several measures of reproductive success in a group of Namibian females; higher voice pitch was associated with overall higher fitness.

However, methodologies varied concerning speech samples used in previous studies; some studies used the recordings of spoken vowels and read speech without any contextual background (Apicella et al., 2007; Atkinson et al., 2012; Hughes et al., 2004; Smith et al., 2017), which may not properly reflect how an individual vocally behaves in real ecological and social interactions (Hodges-Simeon et al., 2011; Puts, 2005; Puts et al., 2006; Puts et al., 2007). Using the former approach seems problematic, as it has been regularly shown that studies conducted on read/reciting vs. spontaneous speech produce quite different results (Blaauw, 1992; Daly & Zue, 1992; Howell & Kadi-Hanifi, 1991), and therefore, a focus on the latter approach is needed when one is interested in voice and its association to mating and reproductive success. In addition, particular attention has been given to F0 and its resonance frequencies, but other, understudied acoustic parameters are perceptible and are known to potentially affect the listeners' perceptions, such as the aforementioned breathiness, hoarseness and speech tempo. In addition, most of the work devoted to the study of voice and sexual selection has been conducted with native English speakers (in other cases in hunter-gatherer societies), but some evidence suggest that cultural variations may affect acoustic and prosodic features of speech and that preferences for a certain range of vocal features may vary socially, culturally and ecologically (Everett, Blasi, & Roberts, 2015; Šebesta et al., 2017; Van Bezooijen, 1995). Finally, it remains unclear which particular type of sexual selection has shaped acoustic features of speech; to our knowledge, only one study formally tested this hypothesis for acoustic features (Hodges-Simeon et al., 2011). The latter stated that intra-sexual competition was the main force driving the evolution of acoustic features. However, mate choice may also have led to the selection of different vocal qualities, i.e., a set of acoustic features that defines a particular individual's tone of voice (Laver, 1980) in men and women.

The purpose of this study is thus to determine the acoustic and prosodic features of speech that best predict men's and women's mating success, here defined as the self-reported number of sexual partners within the past year, by studying spontaneous speech in both competitive and seductive contexts while taking a closer look at a set of understudied vocal parameters. Finally, we wish to assess which context best predicts the relationship between mating success and acoustic features.

2. Methods

2.1. Participants

In all, 68 female (mean age = 22.9; standard deviation = 1) and 56 male (mean age = 23; standard deviation = 3.36) participants were recruited by social networks and advertising in the university campus and other public places in Montpellier, France. All participants were self-declared heterosexual and native French speakers. For each participant, the general purpose of the study was explained ('a study on attractive vocal behavior'), and a written consent was requested for a statistical use of data (private information and recordings). All participants received financial compensation for their participation. The French National Commission on Informatics and Liberty approved protocols for this study (CNIL number 2-17029).

2.2. Stimuli

E-mails were sent to professional comedians who graduated from the National School of Dramatic Art of Montpellier (France). From those who responded positively, we selected one male and one female actor, respectively aged 28 and 25 years old. Both were French native speakers with European ascendants and were chosen because they should be able to act naturally to depict an attractive and dominant person, as they are professional comedians. They were first video recorded presenting themselves in front view with a blank background and facing the camera, then audio recorded speaking in a competitive manner stating why they should be better at winning the dating game (see below). The video and audio recordings were scripted to depict a friendly and a competitive picture of the person, respectively. The female and male video recordings lasted 84 s and 115 s, respectively, and the audio recordings lasted 12.5 s and 14 s, respectively (see Supplementary Materials for additional information).

2.3. Procedure and measures

Upon arrival at the laboratory, participants were seated in a quiet, anechoic, soundproof room equipped with a Sennheiser™ BF 515 microphone connected to a PC located in another room. All recordings were encoded using the Adobe© Audition CS6 at a sampling rate of 44 kHz – 32 bit – mono then saved as .wav files.

All participants played a simulated dating game using the same protocol as in (Hodges-Simeon et al., 2011; Puts, 2005; Puts et al., 2006). The game consisted of winning a date with a person of the opposite sex while being in competition with another same-sex person. Participants were first recorded producing a given sentence in their natural voice by repeating it after the examiner. Then, participants were either asked to seduce the potential date after seeing the video (courtship recording) or to explain why they were better mates after hearing the competitor (competitive recording). The rationale for using a video and an audio recording for courtship and competitive context, respectively, is that participants should be more motivated and involved when seeing the lunch date and less intimidated if they had seen the competitor, which in both cases could affect their vocal behavior during the dating game segment. The order of recordings was randomized between participants, and the same actors' recordings were used in all trials. To control for intensity, participants were asked to speak at a constant distance of 15 cm from the microphone.

After the dating game segment, participants completed a questionnaire assessing personal information: date and place of birth, parents' and grandparents' origins, sexual orientation, relationship status (categorical variable stating whether the participants were in a relationship or not at the moment of the study) and the number of sexual partners they had over the past year (i.e., mating success). First, the number of past-year sexual partners was chosen because it represents an interval over which participants' recollections were expected to be accurate and the measured voice characteristics were likely to be stable (Hodges-Simeon et al., 2011). Second, it is, among other measures, a valid way of measuring mating success in humans, as it has been used in similar previous studies and was shown to be accurate (Faurie, Pontier, & Raymond, 2004; Hodges-Simeon et al., 2011; Puts, 2005; Puts et al., 2006; Puts et al., 2007). Moreover, human mating success should be an important component of expected fitness in past environments, as it represents their potential fertility (Perusse, 1993). In both sexes, potential fertility varies considerably with age, so reducing the time interval should give a more accurate proxy of their potential current fitness at the moment of the study.

2.4. Acoustic analyses

The courtship and competitive recordings were analyzed using Praat© voice analysis software (version 6.0.31, Boersma & Weenink, 2018). For each recording, six acoustic and two prosodic parameters were extracted: mean F0 (Hz), F0-SD (i.e., variation of voice pitch, Hz), local jitter (i.e., the average absolute difference between consecutive periods, divided by the average period, calculated in percentage), harmonics-to-noise ratio (dB), intensity (dB), duration (i.e., duration of the recording, in seconds), speaking rate (defined as the number of syllables produced per seconds, including pauses) and articulation rate (defined as the number of syllables produced per seconds, excluding pauses). Pitch was extracted using the autocorrelation method with pitch settings set to 85 to 400 Hz for women and 75 to 300 Hz for men. Although Praat's recommendation is a ceiling of 600 Hz for women, reducing it allows a more thorough extraction of vocal parameters and has been common in previous studies (e.g., Babel & McGuire, 2015; Escudero, Boersma, Rauber, & Bion, 2009; Lortie, Rivard, Thibeault, & Tremblay, 2017). All other settings were kept as default.

2.5. Data analysis

Men and women for each context were analyzed separately. Mating success was considered a dependent variable in a linear regression with the vocal variables as the explanatory variables. As the measure of mating success consists of a number of discrete events occurring in a fixed interval of time, a generalized linear regression was used with a quasi-Poisson error structure to increase the robustness of possible findings since slight over- and under-dispersion were present (i.e., scale factor slightly higher or lower than 1). Each acoustic (i.e., mean F0, F0-SD, jitter, HNR and intensity) and prosodic parameter (i.e., speaking and articulation rate and speech duration) was added as an explanatory variable. Additionally, four interactions were added between F0 and F0-SD with both jitter and HNR, as some evidence suggest that vocal breathiness and roughness could affect pitch and intonation (e.g., Orlikoff & Baken, 1990; Šebesta et al., 2017; Xu, Lee, Wu, Liu, & Birkholz, 2013). Finally, age and relationship status (categorical variable) were added as control variables, as they may have confounding effects on the response variable. All continuous variables were standardized. The significance of each term was assessed from the comparison of the model excluding the term with the model including all the other variables. Pseudo R^2 were computed for each model and adjusted for the number of parameters and observations. All statistical analyses were performed using R software (version 3.4.0).

3. Results

Descriptive statistics of all variables used in the models are given in

Table 1
Descriptive statistics for A) men and B) women of all acoustic and prosodic parameters for the courtship and competitive recordings as well as for age, number of past-year sexual partners and individuals involved in a relationship. Values given correspond to mean ± standard-deviations.

A.

Men (n = 56)	Courtship recording	Competitive recording
Mean F0 (Hz)	109.76 ± 10.65	111.05 ± 12.25
F0-SD (Hz)	13.14 ± 3.58	12.90 ± 4.10
Jitter (%)	2.58 ± 0.60	2.68 ± 0.64
HNR (dB)	12.34 ± 1.75	11.67 ± 1.83
Speaking rate (syl/s with pauses)	3.65 ± 0.61	3.69 ± 0.87
Articulation rate (syl/s without pauses)	5.33 ± 0.56	5.67 ± 0.80
Intensity (dB)	62.25 ± 3.50	63.11 ± 3.50
Speech duration (s)	127.59 ± 77.13	68.70 ± 75.97
Age (years)	23 ± 3.36 (range = 18–33)	
Number of past-year sexual partners	2.03 ± 1.78	
In a relationship	Yes: 11	No: 45

B.

Women (N = 68)	Courtship recording	Competitive recording
Mean F0 (Hz)	195.70 ± 17.38	196.93 ± 18.00
F0-SD (Hz)	30.18 ± 7.29	29.23 ± 8.46
Jitter (%)	1.97 ± 0.71	1.94 ± 0.45
HNR (dB)	15.43 ± 2.14	15.07 ± 2.33
Speaking rate (syl/s with pauses)	3.45 ± 0.61	3.56 ± 0.73
Articulation rate (syl/s without pauses)	4.79 ± 0.53	4.96 ± 0.74
Intensity (dB)	62.02 ± 4.61	62.36 ± 4.93
Speech duration (s)	129.27 ± 62.84	69.11 ± 43.25
Age (years)	22.9 ± 1 (range = 19–36)	
Number of past-year sexual partners	1.70 ± 1.58	
In a relationship	Yes: 25	No: 43

Table 1. A Mann-Whitney-Wilcoxon test was first conducted to ensure that no discrepancy was observed between men and women in the self-reported past-year mating success. As we expected, the test revealed no significant difference (W = 1722, p = 0.34).

3.1. Men

The results of the generalized linear models for men are reported in Table 2A. In the courtship context, articulation rate and intensity positively predicted mating success (respectively $\chi^2 = 5.19$, df = 1, $p < 0.05$; respectively $\chi^2 = 6.76$, df = 1, $p < 0.05$); i.e., men displaying relatively faster speech tempo and louder speech reported significantly more past-year sexual partners. In addition, the interactions F0-SD with jitter and F0-SD with HNR both negatively predicted their mating success (respectively $\chi^2 = 4.96$, df = 1, $p < 0.05$; $\chi^2 = 4.55$, df = 1, $p < 0.05$). A negative value for the effect of the interactions term implies that for individuals displaying higher F0-SD, the greater the negative effect of jitter and HNR is on mating success. The model yielded a R^2 of 0.14. None of the other explanatory and control variables were significant ($p > 0.05$). Moreover, no variables explained the number of self-reported sexual partners in the competitive context ($p > 0.05$).

3.2. Women

The results of the generalized linear models for women are reported

Table 2
Results of the generalized linear models predicting self-reported past-year mating success in A) men and B) women in the courtship and competitive contexts. For each factor, the estimate, standard error of the mean (SE), the χ^2 and the p values associated from the likelihood ratio test of the comparison between the full model and the model without the factor are given. For the categorical variable "relationship status", the estimates are given for one category compared to the reference category (underlined term; "yes" refer to individuals in a current relationship at the moment of the study). R^2 is the variance explained by the model. Significance code: '***' $p < 0.001$; '**' $p < 0.01$; '*' $p < 0.05$.

A.

Predicting past-year mating success (courtship recording)

R^2 = 0.14	Estimate	SE	χ^2	p-Value
Intercept	0.45	0.18	/	/
Mean F0	−0.41	0.18	3.02	0.08
F0-SD	0.20	0.19	1.04	0.30
Jitter	−0.44	0.22	2.75	0.09
HNR	−0.01	0.18	0.02	0.87
Speaking rate	−0.18	0.14	1.66	0.19
Articulation rate	0.34	0.15	5.19	**0.02***
Intensity	0.37	0.14	6.76	**0.009****
Speech duration	−0.26	0.17	2.46	0.11
Mean F0: jitter	0.04	0.19	0.04	0.82
Mean F0: HNR	0.23	0.13	3.26	0.07
F0-SD: jitter	−0.62	0.29	4.96	**0.02***
F0-SD: HNR	−0.42	0.20	4.55	**0.03***
Age	−0.008	0.04	0.03	0.84
Relationship status Yes/<u>No</u>	0.043	0.31	0.02	0.89

Predicting past-year mating success (competitive recording)

R^2 = −0.12	Estimate	SE	χ^2	p-Value
Intercept	0.64	0.18	/	/
Mean F0	−0.18	0.20	0.28	0.59
F0-SD	0.12	0.22	0.29	0.58
Jitter	−0.14	0.20	0.08	0.76
HNR	0.07	0.19	0.11	0.73
Speaking rate	−0.12	0.21	0.34	0.55
Articulation rate	0.10	0.18	0.37	0.54
Intensity	0.07	0.15	0.21	0.64
Speech duration	−0.38	0.25	2.99	0.08
Mean F0: jitter	−0.17	0.28	0.39	0.53
Mean F0: HNR	0.09	0.21	0.18	0.66
F0-SD: jitter	0.03	0.35	0.008	0.92
F0-SD: HNR	−0.04	0.22	0.03	0.85
Age	0.01	0.04	0.08	0.77
Relationship status Yes/<u>No</u>	−0.33	0.40	0.72	0.39

B.

Predicting past-year mating success (courtship recording)

R^2 = 0.26	Estimate	SE	χ^2	p-Value
Intercept	0.53	0.15	/	/
Mean F0	0.16	0.15	0.37	0.54
F0-SD	−0.13	0.13	0.82	0.36
Jitter	0.05	0.33	1.14	0.28
HNR	−0.43	0.12	14.68	**0.0001*****
Speaking rate	−0.02	0.13	0.03	0.86
Articulation rate	0.02	0.14	0.02	0.87
Speech duration	−0.31	0.11	7.45	**0.006****
Intensity	−0.06	0.11	0.35	0.55
Mean F0: jitter	0.26	0.29	0.81	0.36
Mean F0: HNR	−0.01	0.16	0.009	0.92
F0-SD: jitter	−0.22	0.23	0.94	0.33
F0-SD: HNR	−0.14	0.09	2.42	0.12
Age	0.12	0.09	1.66	0.19

(continued on next page)

Table 2 (*continued*)

B.

Predicting past-year mating success (courtship recording)

R^2 = 0.26	Estimate	SE	χ^2	*p*-Value
Relationship status Yes/No	−0.18	0.23	0.68	0.40

Predicting past-year mating success (competitive recording)

R^2 = 0.06	Estimate	SE	χ^2	*p*-Value
Intercept	0.50	0.15	/	/
Mean F0	−0.02	0.13	0.05	0.82
F0-SD	−0.12	0.13	0.76	0.38
Jitter	−0.013	0.18	0.08	0.77
HNR	−0.31	0.18	2.89	0.09
Speaking rate	−0.14	0.13	1.04	0.31
Articulation rate	−0.02	0.14	0.01	0.89
Intensity	0.10	0.13	0.61	0.43
Speech duration	−0.01	0.13	0.01	0.90
Mean F0: jitter	0.07	0.17	0.19	0.65
Mean F0: HNR	−0.007	0.15	0.002	0.95
F0-SD: jitter	−0.24	0.18	1.86	0.17
F0-SD: HNR	−0.04	0.22	2.86	0.09
Age	0.22	0.10	4.46	**0.03***
Relationship status Yes/No	−0.02	0.26	0.008	0.92

Significant *p* values are in bold.

in Table 2B. In the courtship context, HNR and speech duration negatively predicted mating success (respectively $\chi^2 = 14.68$, df = 1, $p < 0.05$; $\chi^2 = 7.45$, df = 1, $p < 0.05$). Women who displayed less breathy voices (i.e., higher HNR values) and spoke less during the game segment reported significantly fewer past-year sexual partners. None of the other explanatory and control variables were significant ($p > 0.05$). In the courtship context, only age was significantly correlated to mating success ($\chi^2 = 4.46$, df = 1, $p < 0.05$).

4. Discussion

The present findings show that only acoustic inter-individual differences within the courtship context are correlated to self-reported past-year mating success in both men and women.

Men displaying faster articulation rate reported significantly more sexual partners over the past-year. Articulation rate determines the pace at which speech segments are actually produced. It has been previously reported that increased speech tempo also increases the perception of competence and social attractiveness (Smith et al., 1975; Street Jr & Brady, 1982; Street Jr, Brady, & Putman, 1983). Conversely, slower speech tempo is being perceived as less truthful, less fluent, less persuasive and more passive (Apple, Streeter, & Krauss, 1979; Smith & Shaffer, 1995); moreover, it has been associated with anxiety, sadness and depression (Siegman & Boyle, 1993; Smith & Shaffer, 1995). Others have also reported that it diminishes the perception of benevolence (Brown et al., 1973; Ray, 1986). It has been systematically reported that individuals in poor health conditions suffering from physiological and/or psychological disorders have slower speaking rates as it affects cognitive capacities (e.g., Caligiuri, 1989; France, Shiavi, Silverman, Silverman, & Wilkes, 2000; Turner, Tjaden, & Weismer, 1995). Moreover, faster speech tempo may constitute an honest cue of mate quality, since for these individuals, it requires less cognitive effort and time to produce speech. As earlier research indicates, liars pause frequently, speak slowly, and make many mistakes when they are giving cognitively complex speeches (Knapp, Hall, & Horgan, 2013). This is corroborated by the fact that deception is often inferred from these paralinguistic complexity cues because they imply that the speaker is concocting a lie (Vrij, 2000). Faster speech tempo may also generally indicate a more forceful and, possibly, a more frequent and skillful use of the vocal organs (Hillman, Holmberg, Perkell, Walsh, & Vaughan, 1990; Jiang & Titze, 1994).

Furthermore, men who displayed louder voices reported significantly more sexual partners over the past year. Zuckerman and Miyake (1993) found that perceived louder voices were positively associated with attractiveness. Scherer (1978) showed that male speakers were rated as emotionally stable and extroverted by their peers when they spoke with a louder and possibly more nasal voice; it appears that louder speech (but more intermediate in loudness) using a greater range of loudness variation increases credibility. Indeed, in a later study, Ketrow (1990) found that moderately louder voices lead to greater perception of credibility and social attractiveness, which in turn should play upon persuasiveness and compliance of the target (although see Burgoon, Birk, & Pfau, 1990). This corroborates results found by Scherer, London, and Wolf (1973) where confidence was expressed by increased loudness of voice, rapid rate of speech, and infrequent, short pauses. Moreover, another study showed that in ratings of short samples of music and speech, loud excerpts were judged as more pleasant, energetic, and tense than soft excerpts (Ilie & Thompson, 2006). We suggest that relatively louder voices should be correlated to displays of power, authoritarian and higher social statuses in men, as deep loud voices are expected to be associated with larger and taller individuals, thereby increasing attention and acting as a possible marker of self-confidence or dominance. Nonetheless, louder speech (and thus loudness) is also associated with emotional states such as anger and anxiety (Laukka et al., 2008), which emphasizes its role in conveying information about the current emotional and affective state of the speaker.

As suggested and discussed in Hodges-Simeon et al. (2011) for intonation, men displaying faster articulation rate and relatively louder voice in this study had higher previous success with women; these men would presumably feel more self-assured when placed in a mating or competitive context. This self-confidence may have relaxed male subjects, stabilizing their tempo and vocal intensity across speech. If so, this suggests that when men feel confident, they speak with faster and louder speech. Both these prosodic and acoustic components may be one modality through which confidence is communicated to others, since both are commonly used to express emotion and affective states.

The results showed that in men with greater intonation (i.e., F0-SD), the more negative the effect of higher roughness and lower breathiness on their mating success. On one hand, higher jitter values can be detrimental in the context of courtship, leading to a perception of creaky voices, which is a marker of pathological voices (Wolk, Abdelli-Beruh, & Slavin, 2012). Although not common in men, it has been previously reported that in women, this leads to the perception of hesitancy (Yuasa, 2010). Coupled with a greater intonation, this may be even more disadvantageous; it has been previously reported that more monotonous speeches in men have been found to be positively correlated to mating success (Hodges-Simeon et al., 2011). As previously stated, intonation is one modality through which one can express self-confidence, dominance and experience. On the other hand, although breathiness has been recently correlated to perceived attractiveness (Šebesta et al., 2017; Xu et al., 2013), its interaction with intonation can also lead to unattractive voice as breathiness diminishes in higher intonation. In any case, perceptual studies are needed to better understand such interactions when men are trying to attract potential mates.

The results show that women displaying less breathy voices (i.e., higher HNR values) reported significantly fewer past-year sexual partners. Two studies indicated that vocal breathiness was positively related to perceived vocal attractiveness (Fraccaro et al., 2013; Xu et al., 2013) and seemed to be restricted to female voices only (Babel, McGuire, & King, 2014). Moreover, it has been argued that breathiness is a female attribute (Henton & Bladon, 1985; Van Borsel et al., 2009) because it “softens” some other aspects of speech such as F0 and formants, although in this study, it did not interact with voice pitch or intonation. Breathiness has also been associated with youth; Ferrand (2002) and Gorham-Rowan and Laures-Gore (2006) showed that young women are perceived as significantly more breathy than elderly women. Thus, HNR could reflect a signal of fertility, since it is correlated to youth in women (Hawkes, O'Connell, Jones, Alvarez, & Charnov, 1998).

Several authors have recently argued that intra-sexual competition has mainly driven the evolution of several morphological traits in men, including voice pitch and its resonant frequencies (Hill et al., 2013; Kordsmeyer et al., 2018; Puts, 2010). However, the present findings suggest that mate choice may be at least as important as same-sex competition in shaping speech acoustic features in both men and women. In general, the different types of sexual selection may have shaped acoustic and prosodic speech features differently, leading to different vocal qualities that can be important in one context and not in another (i.e., courtship and same-sex competition). Moreover, in the human species, mate choice should still be an important type of selection, as the sex that invests more in reproduction (i.e., female) has the right of scrutiny when choosing a mate. The fact that we did not replicate the findings of Hodges-Simeon et al. (2011), where intra-sexual competition is more important in shaping men's acoustic features, may be due to a difference in sample size; our study had half the number of participants as their study, which potentially results in less power to detect the observed effect. Furthermore, such differences can be attributed to the fact that variation in courting mates and repelling competitors can be language-dependent. Nonetheless, further studies are needed to better understand such aspects.

The lack of findings for women within the competitive context may lie in the fact that this type of sexual selection was not strong enough to shape their vocal behavior. Indeed, past research has shown that competition among women relies very little on physical combat or aggression; women are assumed to be more prone to use indirect aggression (i.e., attempting to cause harm while simultaneously trying to make it appear as though there was no harmful intention). Such attempts may include social manipulation and shenanigans, for instance by spreading false information about one's reputation or interfering with friendships and group inclusion of competitors (see Fisher, 2015 for an extensive review). Therefore, it seems rather logical that this kind of competition does not lead to larger, taller and stronger statures in women, and thus, women do not need to convey impressions of dominance or largeness through their vocal features against competitors.

A potential limitation of the present study is that we relied on self-reported mating success, which is subject to imperfect memory or intentional distortion. Another measure would have been to ask the subjects about their lifetime numbers of sexual partners; however, this measure is more prone to memory error than recollections from the past year. In theory, we should expect men and women to have the same mean number of sexual partners over a lifetime. However, it has been regularly shown that lifetime self-reported number of sexual partners leads to considerable discrepancies between men and women (Brewer et al., 2000; Brown & Sinclair, 1999; Morris, 1993; Wiederman, 1997), where men tend to overestimate and women to underestimate such numbers. Thus, such biases can be partly accounted for by reducing the interval over which participants recollect their number of sexual partners, producing an equal mean number of sexual partners. In this study, no discrepancy was observed between our sampled men and women. Another potential limitation is that the interest of each participant for the potential lunch date was not evaluated. Although mates' preferences can vary from one individual to another, the use of only two actors allows for control of potential changes in acoustic parameters due to interest varying if several stimuli were used.

In summary, this study provides some original findings on vocal behavior within different contexts related to sexual selection. It is, to the best of our knowledge, the first study to report evidence that men's articulation rates and vocal intensity can reliably predict their mating success when courting, while women may use vocal breathiness to potentially signal attractiveness. Further studies are needed to understand the underlying proximate mechanisms linking articulation rate, intensity and breathiness to phenotypic quality.

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Declaration of interest

The authors have no competing interests to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.evolhumbehav.2018.07.001.

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