

Male Vocal Quality and Its Relation to Females' Preferences

Alexandre Suire, Michel Raymond, Melissa Barkat-Defradas

▶ To cite this version:

Alexandre Suire, Michel Raymond, Melissa Barkat-Defradas. Male Vocal Quality and Its Relation to Females' Preferences. Evolutionary Psychology: an International Journal of Evolutionary Approaches to Psychology and Behavior, 2019, 17 (3), pp.147470491987467. 10.1177/1474704919874675 . hal-02352935

HAL Id: hal-02352935 https://hal.science/hal-02352935

Submitted on 12 Nov 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1	Title: Male vocal quality and its relation to females' preferences
2	<u>Authors</u> : Alexandre Suire ^{1*} , Michel Raymond ¹ , Melissa Barkat-Defradas ¹
3	*Corresponding author: Alexandre Suire
4	E-mail: alexandre.suire@umontpellier.fr
5	<u>Fax:</u> +33 4 67 14 36 22
6	<u>Tel:</u> +33 4 67 14 49 66
7	¹ ISEM, Univ. Montpellier, CNRS, EPHE, IRD, Montpellier, France.
8	Email addresses: michel.raymond@umontpellier.fr; melissa.barkat-defradas@umontpellier.fr
9	
10 11	
12	
12	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	

27 Abstract

In both correlational and experimental settings, studies on women's vocal preferences have 28 29 reported negative relationships between perceived attractiveness and men's vocal pitch, emphasizing the idea of an adaptive preference. However, such consensus on vocal 30 31 attractiveness has been mostly conducted with native English speakers, but a few evidence 32 suggest that it may be culture-dependent. Moreover, other overlooked acoustic components of vocal quality, such as intonation, perceived breathiness and roughness may influence vocal 33 34 attractiveness. In this context, the present study aims to contribute to the literature by 35 investigating vocal attractiveness in an underrepresented language (i.e., French) as well as 36 shedding light on its relationship with understudied acoustic components of vocal quality. 37 More specifically, we investigated the relationships between attractiveness ratings as assessed 38 by female raters and male voice pitch, its variation, the formants' dispersion and position, and the harmonics-to-noise and jitter ratios. Results show that women were significantly more 39 40 attracted to lower vocal pitch and higher intonation patterns. However, they did not show any 41 directional preferences for all the other acoustic features. We discuss our results in light of the 42 adaptive functions of vocal preferences in a mate choice context.

43 Keywords

44 Attractiveness; fundamental frequency; formants; intonation; breathiness; roughness; mate45 choice.

- 46
- 47
- 48
- 49
- 50
- 51

52 Introduction

53 Voice is one of the fundamental aspects of human communication. Indeed, research has 54 reported that acoustic signals provide listeners with information on the quality or condition of 55 the speaker such as sex (Bachorowski and Owren, 1999; Gelfer and Bennett, 2013; Gelfer and 56 Mikos, 2005; Hillenbrand and Clark, 2009), age (Linville and Fisher, 1985; Ptacek, and 57 Sander, 1966; Shipp, Qi, Huntley, and Hollien, 1992), sexual orientation (Lyons, Lynch, Brewer, and Bruno, 2014; Munson, McDonald, DeBoe, and White, 2006), physical strength 58 59 (Sell, Bryant, Cosmides, Tooby, Sznycer, von Rueden, Krauss and Gurven, 2010), sexual 60 behavior and body configuration (Hughes, Dispenza, and Gallup, 2004). In this context, 61 numerous studies have explored the relationships between acoustic features of speech and 62 several auditory impressions, among which, attractiveness as assessed by opposite-sex members. Focus has especially been given to sexually dimorphic acoustic traits such as the 63 64 fundamental frequency (i.e., F0, the acoustic correlate of voice pitch) and the formant 65 frequencies (i.e., the resonances of the vocal tract, the acoustic correlate of perceived timbre) 66 (Titze, 1989).

67 In both correlational and experimental settings, most studies have reported a consistent negative relationship between men's F0 and attractiveness, that is, women are attracted to 68 relatively low-pitched voices (Bruckert, Lienard, Lacroix, Kreutzer, and Leboucher, 2006; 69 70 Collins, 2000; Feinberg, Jones, Little, Burt, and Perrett, 2005; Hodges-Simeon, Gaulin, and 71 Puts, 2010; Hughes, Farley, and Rhodes, 2010; Jones, Feinberg, DeBruine, Little, and Vukovic, 2010; Pisanski and Rendall, 2011; Vukovic, Feinberg, Jones, DeBruine, Welling, 72 73 Little and Smith, 2008; Xu, Lee, Wu, Liu, and Birkholz, 2013). Relatively lower formants' 74 dispersion (i.e., Df, the relative distance between two consecutive formants, which is 75 correlated to the vocal tract length), were also found to be more attractive in male voices (Hodges-Simeon et al., 2010; Pisanski and Rendall, 2011). Although two studies have found 76

77 non-significant relationships (Babel, McGuire, and King, 2014; Feinberg et al., 2005), the former reported that larger females tended to prefer increased apparent vocal tract size (which 78 79 positively correlates with a larger body size) while the latter reported that lower first 80 formants' frequencies for the vowels /i/ and /u/ were judged as more attractive; still, both 81 studies suggested that apparent vocal tract size influences vocal attractiveness. Additionally, 82 although it has received little attention compared to the F0 and Df, one study has reported that lower F0-SD (i.e., the evolution of F0 through time, which acoustically correlates to micro 83 84 variations of intonation patterns in continuous speech) was more attractive in men (Hodges-85 Simeon et al., 2010), although two other studies have reported the opposite relationship (Bruckert et al., 2006; Leongómez, Binter, Kubicová, Stolařová, Klapilová, Havlíček, and 86 87 Roberts, 2014).

88 Under the scope of human sexual selection, three ultimate accounts can be invoked to 89 explain the relationships between females' preferences and men's voices. Firstly, there is 90 intersexual selection, which corresponds to the selection exerted by one sex over another. For 91 instance, lower F0s were found to be positively associated to higher circulating testosterone 92 levels in men (Dabbs and Mallinger, 1999; Evans, Neave, Wakelin, and Hamilton, 2008; 93 Hodges-Simeon, Gurven, and Gaulin, 2015; Jost, Fuchs, Loeffler, Thiery, Kratzsch, Berger, 94 and Engel, 2018; although see Arnocky, Hodges-Simeon, Ouellette, and Albert, 2018; 95 Bruckert et al., 2006; Puts, Apicella, and Cardenas, 2012), which is known to act as an 96 immunosuppressant (Foo, Nakagawa, Rhodes, and Simmons, 2017). As men possessing high 97 testosterone levels should have a better immune system to bear its costs, lower FOs may thus 98 signal health status as a result of possessing 'good genes' (Folstad and Karter, 1992). If so, 99 females may then be attracted to such men as they represent higher genetic quality mates 100 (Arnocky et al., 2018; Hodges-Simeon et al., 2015). Secondly, there is intrasexual selection, 101 which corresponds to competition among same-sex individuals. For instance, it has been

102 regularly shown that lower FOs and Dfs were perceptually associated to larger, stronger, more 103 masculine and more socially and physically dominant men (Hodges-Simeon et al., 2010; 104 Pisanski, Fraccaro, Tigue, O'Connor, and Feinberg, 2014a; Puts, Gaulin, and Verdolini, 2006; 105 Puts, Hodges, Cárdenas, and Gaulin, 2007; Rendall, Vokey, and Nemeth, 2007; Sell et al., 106 2010), with F0 being recently argued to signal formidability (Puts and Aung, 2019; although 107 see Feinberg, Jones, and Armstrong, 2019). Additionally, lower F0-SD (i.e., monotonous 108 voices) has been hypothesized to be a marker of self-confidence and experience and is also 109 associated to perceived dominance in men (Hodges-Simeon et al., 2010). In this context, if 110 women are attracted to more dominant and formidable men, then the formers might display a 111 preference for lower F0s and Dfs. Lastly, a sensory bias may explain vocal attractiveness 112 relationships. Humans possess a cognitive bias to associate deeper vocal frequencies to 113 perceptually larger individuals (Pisanski and Rendall, 2011; Rendall, Vokey, and Nemeth, 2007; Xu et al., 2013), although the relationships between vocal pitch and resonant 114 115 frequencies with height and weight are relatively weak (Pisanski, Fraccaro, Tigue, O'Connor, 116 Röder, Andrews, Fink, DeBruine, Jones, and Feinberg, 2014b). Nonetheless, if women 117 actually prefer larger men as mates, then they might also prefer men with perceptually deeper 118 vocal features.

119 According to the source-filter theory of speech production (Taylor and Reby, 2010), 120 the underlying mechanisms of phonation in humans rests on the larynx (the source) and the 121 subsequent filtering of vocal signals by the supralaryngeal vocal tract (the filter). The airflow 122 expelled from the lungs and forced out through the glottis causes mechanical oscillations of 123 the vocal folds within the larynx (i.e., Bernoulli's principle). The tension, length and thickness 124 of vocal folds determine the vocal height, which acoustically correlates to the fundamental 125 frequency (i.e., F0). Namely, the sound waves produced by the vocal folds' oscillations travel 126 through the pharyngeal, the oral and (possibly) the nasal cavities before being expelled.

127 During this process, the vocal tract configuration filters the larvngeal flow generated at the 128 glottis by amplifying some frequencies to the detriment of others and, thereby, producing the 129 formant frequencies that lead to the perception of vocal timbre. Moreover, the movements of 130 the articulatory organs involved in speech production such as the tongue, the lips and the 131 palate modify the shape of the vocal tract, which determine the frequencies associated to the 132 different speech sounds. In humans, both pitch and resonant frequencies display salient sex 133 differences. Indeed, at puberty, males experience a significant influence of androgens, 134 especially testosterone, which entails important consequences on larynx size and vocal folds 135 thickness and length, which acoustically lower the voice pitch, deepen the resonant 136 frequencies and reduce their spacing. This proximate mechanism explains why before 137 puberty, boys and girls exhibit similar vocal frequencies (Fitch, 1999), until the former 138 practically do not overlap with those of adults females (Titze, 1989). Additionally, in the adult 139 life, inter-individual variations in vocal features are influenced by age (Linville and Fisher, 140 1985; Shipp et al., 1992), circulating androgens level (Abitbol, Abitbol, and Abitbol, 1999; 141 Akcam, Bolu, Merati, Durmus, Gerek, and Ozkaptan, 2004; Dabbs and Mallinger, 1999) and, 142 possibly, to the exposure of testosterone in-utero (Fouquet, Pisanski, Mathevon, and Reby, 143 2016).

144 Fundamental and formant frequencies aside, a few understudied vocal features also 145 seem to contribute to vocal quality, such as vocal breathiness and vocal roughness. Firstly, 146 vocal breathiness can be captured by the harmonics-to-noise ratio (HNR), which corresponds 147 to a ratio between periodic components (i.e., the harmonics, which are multiple integer of the 148 F0) and a non-periodic component (i.e., noise) comprising a segment of voiced speech 149 (Teixeira, Oliveira, and Lopes, 2013). More specifically, this ratio reflects the efficiency of 150 speech production. The greater the airflow expelled from the lungs into energy of vibration of 151 the vocal folds, the higher the HNR, which is perceptually associated with a more sonorant 152 and harmonic voice. Conversely, a lower HNR is generally associated with a perceptually 153 asthenic, dysphonic and breathier voice. Secondly, vocal roughness can be captured by the 154 jitter, a measure of the F0 disturbance, which is defined as the parameter capturing the 155 frequency variation at the glottis from cycle to cycle in the sound wave (Hillenbrand, 1988; 156 Rabinov, Kreiman, Gerratt, and Bielamowicz, 1995; Wendahl, 1966). More specifically, the 157 jitter measures the regularity of the vocal folds during successive periods of oscillations. The 158 higher the jitter, the "rougher" sounds the voice. Although little is known about their 159 physiological mechanisms, it has been suggested that both acoustic components may be 160 sensitive to hormonal influx as they both relate to the oscillations of the vocal folds, which 161 possess receptors to circulating androgens (Pisanski, Jones, Fink, O'Connor, DeBruine, Röder, 162 and Feinberg, 2016).

163 Vocal breathiness has been suggested to be an important component of vocal 164 attractiveness in female voices (Babel et al., 2014; Van Borsel, Janssens, and De Bodt, 2009), but significant relationships have been reported in both sexes (Šebesta, Kleisner, Tureček, 165 166 Kočnar, Akoko, Třebický, and Havlíček, 2017; Xu et al., 2013). Thus, lower HNR profiles 167 (i.e., breathy voices) have been suggested be more attractive. Additionally, it has been 168 suggested to soften the aggressiveness of males with larger body size (Xu et al., 2013), which 169 in turn could increase their overall attractiveness towards females. On the other hand, little 170 evidence is actually known on whether vocal roughness (as measured with the jitter) 171 significantly contributes to perceived vocal attractiveness as studies that have directly tackled 172 the topic have led to mixed results (Babel et al., 2014; Hughes, Mogilski, & Harrison, 2014; 173 Hughes, Pastizzo, & Gallup, 2008).

174 Interestingly, experimental consensus regarding the F0 strongly suggests that women's 175 vocal preferences are consistent independently of the culture under study. Negative 176 relationships have been mostly reported in English-speaking populations such as Americans

177 (Hodges-Simeon et al., 2010), Canadians (Feinberg et al., 2005; Pisanski and Rendall, 2011), 178 British (Jones et al., 2010; Vukovic et al., 2008), Scottish (Saxton, Debruine, Jones, Little, 179 and Roberts, 2009), and Australians (Simmons, Peters, and Rhodes, 2011), but also in Dutch 180 (Collins, 2000), German (Weiss and Burkhardt, 2010), Czech (Valentová, Roberts, and 181 Havlíček, 2013), Latvians (Skrinda, Krama, Kecko, Moore, Kaasik, Meija, Lietuvietis, 182 Rantala, and Krams, 2014) and in a small sample of French speakers (Bruckert et al., 2006). 183 Although evidence is scarce, a few findings challenges this view, suggesting that vocal 184 attractiveness may rest on different acoustic cues depending on the culture under study. For 185 instance, one study reported that in a Filipino-speaking group sample, both nulliparous and 186 breastfeeding women showed a preference for feminized (i.e., higher F0) rather than 187 masculinized voice pitch (i.e., lower F0) (Shirazi, Puts, and Escasa-Dorne, 2018). In the 188 Hadzas, it has also been reported that women who are breastfeeding prefer men with higher 189 pitch voices as mates, those who are not breastfeeding preferring lower pitch male voices 190 (Apicella and Feinberg, 2009). Interestingly, another study found that Namibian men's vocal 191 attractiveness could be predicted by their degree of vocal breathiness (measured through the 192 HNR) and not by their voice pitch (Šebesta et al., 2017).

In this context, the aim of this replication study is to investigate culture-dependency for vocal attractiveness in an underrepresented language (i.e., French) as well as investigating attractiveness relationships with understudied acoustic features of vocal quality.

196 Material and Methods

197 This study was conducted in Montpellier, France. The French National Commission of 198 Informatics and Liberty approved the experimental designs of the present study (CNIL 199 number 2-17029). Prior to the study, all participants provided the investigator with their 200 written consent.

a. Stimuli

202 An aggregate of 58 male participants (mean age = 23; SD = 3.36), native speakers of French, 203 produced the vocal stimuli. These participants were drawn from another study (Suire, 204 Raymond, and Barkat-Defradas, 2018; two of which were not included in that study). They were seated in a quiet, anechoic, soundproof room equipped with a Sennheiser[™] BF 515 205 206 microphone connected to a PC located in another room. Vocal samples consisted in the 207 recording of a short utterance 'Dans la vie, je pense toujours prendre les bonnes decisions et 208 c'est pour cela que je vais gagner' (i.e., 'In life, I always think I'll make the right decision 209 and that is why I will win'). To control for intensity, participants were asked to speak at a 210 constant distance of 15 cm from the microphone. All recordings were encoded using the 211 Adobe© Audition CS6 at a sampling rate of 44 kHz – 32 bit – mono then saved as .wav files.

212

b. Acoustic analyses

213 All recordings were analyzed using the Praat[®] voice analysis software (version 6.0.31, Boersma and Weenink, 2018). The mean fundamental frequency (F0) and its variation (F0-214 215 SD) were measured using the autocorrelation method with a pitch floor of 75 Hz and a ceiling 216 of 300 Hz (Praat's recommendation), with other settings kept as default. The harmonics-to-217 noise ratio (HNR, in dB) and the local jitter (%), which corresponds to the average absolute 218 difference between consecutive periods, divided by the average period, and calculated in 219 percentage, were measured across the entire utterance using the same settings as the F0. The 220 local jitter corresponds to the jitter ratio, which is commonly used to describe vocal 221 perturbations (Jones, Trabold, Plante, Cheetham, and Earis, 2001). Additionally, intensity 222 (dB) was retrieved using Praat's default settings. Formant frequencies (F1 to F4) were 223 measured at each glottal pulse, targeting voiced speech only, using a formant ceiling of 5000 224 Hz (Praat's recommendation), then averaged across the entire utterance. Then, the formants' 225 dispersion (Df) was calculated using the following formula (Fitch, 1997):

$$Df = \frac{\sum_{i=1}^{N-1} F_{i+1} - F_i}{N-1}$$

where Df is the formant dispersion (in Hz), *N* is the total number of formants measured, and *Fi* is the frequency (in Hz) of formant *i*. Lastly, we computed the formants' position (Pf) using the method described in Puts et al. (2012), which has been argued to be sexually more dimorphic than Df. To compute the formants' position, we used female vocal stimuli that were drawn from the same study of the male vocal stimuli ($n_{female} = 68$, Suire et al. 2018).

231 Descriptive statistics of the male vocal stimuli for each acoustic feature are reported in 232 Table 1 and their zero-order correlations in Table 2. Mean F0 was positively correlated with 233 F0-SD (r = 0.56, p < 0.001). Df was positively associated to Pf (r = 0.31, p = 0.019) and HNR 234 (r = 0.35, p = 0.008). Lastly, HNR was negatively correlated with jitter (r = -0.57, p < 0.001). 235 All these correlations are consistent with those reported in the literature (for F0 and F0-SD, see Hodges-Simeon et al., 2010; for Df and Pf see the open data of Han, Wang, Fasolt, Hahn, 236 Holzleitner, Lao, DeBruine, Feinberg and Jones, 2018; for jitter and HNR, see de Krom, 237 1993), except the correlation between Df and HNR, which to our knowledge was not reported 238

239 elsewhere.

n = 58	Mean	SD	Ranges
$M_{2000} = EO(H_Z)$	114 47	11.94	<u>95 44 140 07</u>
$\frac{1}{100} \frac{1}{100} \frac{1}$	114.47	11.0 4 5.06	63.44 - 140.07
F0-SD(HZ)	1006 70	3.00	0.97 - 28.31
Df (HZ)	1086.78	<mark>36.60</mark>	<u>1005 – 1181</u>
Pf (Hz)	<mark>-1.61</mark>	<mark>0.47</mark>	<mark>-2.47 – -0.65</mark>
HNR (dB)	11.32	1.37	7.93 - 14.94
Jitter (%)	2.68	0.47	1.83 - 4.41
Intensity (dB)	64.73	3.61	53.96 - 76. 93

240 <u>Table 1.</u> Descriptive statistics of the acoustic characteristics of the vocal stimuli.

241

	Mean F0 (Hz)	F0-SD (Hz)	Df (Hz)	Pf (Hz)	HNR (dB)	Jitter (%)	Intensity (dB)
Mean F0 (Hz)	1						
F0-SD (Hz)	0.56***	1					
Df (Hz)	<mark>-0.16</mark>	<mark>-0.13</mark>	1				
Pf (Hz)	<mark>0.16</mark>	<mark>0.10</mark>	<mark>0.31*</mark>	1			
HNR (dB)	0.13	-0.24	<mark>0.35**</mark>	<mark>-0.06</mark>	1		
Jitter (%)	-0.15	0.20	<mark>0.13</mark>	<mark>-0.14</mark>	-0.57***	1	

242 <u>Table 2.</u> Zero-order correlations between each acoustic feature for the vocal stimuli.

- 243 Significance code: *** p < 0.001; ** p < 0.01; * p < 0.05.
- 244 c. Experimental procedure

245 The experimental procedure was automated on an online computer-interfaced program, 224 246 French female raters participated in a perceptual study after they self-reported in a 247 questionnaire their age, origins of parents and grandparents (to control for potential cultural preferences), sexual orientation (to control for sexual preferences) and whether they suffered 248 249 from a hearing impairment (note that other information were reported but are not used in the 250 present study). After filling out the questionnaire, female raters were presented with a series of 11 choices each including a pair of voices. For each pair, two stimuli were randomly 251 252 selected from the whole pool of vocal stimuli. The two vocal stimuli were randomized in their 253 position presented in each pair (left or right position) on the computer screen. Judges were 254 asked to choose the most attractive vocal stimulus by clicking on it. Participants were allowed 255 to listen to the stimuli as much as they wanted. However, when the female judge made her 256 choice, she could not go back to the previous one anymore. To measure intra-rater reliability, 257 the second and third pairs were the same as the tenth and eleventh pairs.

258 Although a forced choice paradigm is usually implemented with experimentally 259 manipulated vocal stimuli (e.g. Jones et al., 2010; Re, O'Connor, Bennett, and Feinberg, 260 2012), there is fundamentally no advantage or disadvantage between a forced-choice 261 paradigm and a correlational rating study for either manipulated or non-manipulated stimuli. 262 Crucially, it does not yield different results (e.g. for women's preferences of men's F0, for 263 experimental designs see: Vukovic et al. 2008; Jones et al. 2010; Re et al. 2012; and for correlational designs see: Feinberg et al. 2005; Hodges-Simeon et al. 2010; Pisanski and 264 265 Rendall 2011).

266

We stopped collecting data when each voice of the 58 voices was heard at least 40

times in order to obtain statistically relevant data. In the end, the mean number of times a
voice has been heard is M ± SD = 54.14 ± 6.55, with 72 and 42 times respectively for the
most and least heard voices.
Out of the 225 female participants who completed the questionnaire, 137 participants
completed all 11 decisions, 28 participants skipped some of the decisions (mean number of
skipped decisions = 8.75), for a total of 1570 decisions in our analyses. Description of the

judges' characteristics that completed at least one pair (n = 165, M \pm SD = 28.95 \pm 14.16) are

274 given in Table 3.

	n
Completed the full test	
No	28
Yes	137
Ancestry	
European	135
Non-European	30
Sexual orientation	
Heterosexual	142
Homosexual	4
Bisexual	11
Not reported	8
Hearing impairment	
No	161
Yes	3
Not reported	1

<u>Table 3.</u> Number of judges for each of the following categories: those who completed the full
test (i.e., heard all the pairs), grandparents' ancestry, sexual orientation and hearing
impairments.

d. Data analysis

To analyze women's preferences for men's voices, a generalized linear mixed model (GLMM) was used with the response variable being if the female judge chose or not the voice presented to her on the left position. The GLMM was fitted with a binomial error structure since the response variable consisted in a discrete probability distribution of the number of 283 successes in a sequence of several independent trials. In order to explore acoustics' 284 preferences, seven predictor variables were computed and corresponded to the differences 285 observed in mean F0, F0-SD, Df, Pf, HNR, jitter and intensity between the two vocal stimuli 286 (numerical variables that were standardized). Judges' age (standardized variable), ancestry 287 (i.e., European or non-European grandparents') and sexual orientation (i.e., heterosexual and 288 non-heterosexual) were added as control variables and put in interaction with the differences 289 in acoustics characteristics to assess their influence on voice preferences. Judges' identities 290 and the vocal stimuli were added as random effects as intercepts only. A symbolic 291 representation of the GLMM is given in the supplementary material.

292 GLMMs with and without the control variables were performed to explore any 293 statistical differences. Moreover, we performed two additional GLMMs, one without 294 individuals with hearing impairment and one without individuals who did not report sexual 295 orientation (these individuals were treated as non-heterosexual in the main GLMM). The 296 significance of each predictor in all GLMMs was assessed from the comparison of the model 297 excluding the predictor with the model including all the other predictors (i.e., likelihood-ratio 298 chi-square tests, ANOVA type III). Additionally, since some acoustic variables are highly 299 correlated (see Table 2), we conducted multicollinearity checks on the GLMMs using the 300 variation inflation factors (VIFs).

All statistical analyses were performed under the R software (version 3.4.0), using the following packages: 'Ime4' to build the generalized linear models with random effects (Bates, Mächler, Bolker, and Walker, 2014), 'car' to compute the statistical significance of each predictor and check potential multicollinearity problems for the GLMMs (Fox, Weisberg, and Fox, 2011) and 'MuMIn' to compute the pseudo-R² (Bartoń, 2018). In order to illustrate the results with figures, we used 'boot' to transform the coefficients of the GLMMs back into probabilities (Canty and Ripley, 2012), 'dplyr' to compute the predictions of the model

308 (Wickham, François, Henry, and Müller, 2018) and 'ggplot2' for the resulting figures

309 (Wickham, 2009).

310 Results

311 Descriptive statistics of the mean difference in acoustic features are reported in Table 4.

	Mean	SD	Ranges
Difference in mean F0	-0.38	16.70	-53.28 - 49.84
Difference in F0-SD	-0.066	6.89	-20.79 - 20.43
Difference in Df	1.25	51.73	-176.66 - 176.66
Difference in Pf	0.003	0.66	-1.81 - 1.81
Difference in HNR	-0.0086	1.91	-5.73 - 5.58
Difference in jitter	0.013	0.64	-2.58 - 2.58
Difference in intensity	0.065	5.06	-20.63 - 22.97

312 <u>Table 4.</u> Descriptive statistics for the unstandardized mean difference for each acoustic feature

summarized over the total number of observations (n = 1570).

We computed intra-rater reliability scores by calculating the proportion of identical chosen vocal stimuli between the second and third first pairs with the tenth and eleventh pairs. Intra-rater reliability was high: $M \pm SD = 0.791 \pm 0.257$, i.e., judges considered on average more than 2/3 the same voices as attractive. Results of the main GLMM are reported in Table 5. VIFs were all inferior to 4, indicating no problems of multicollinearity. When presented with two voices, women preferred lower F0 ($\chi_1^2 = 24.89$, p < 0.001), higher F0-SD profiles ($\chi_1^2 = 34.00$, p < 0.001) and

321 louder stimuli ($\chi_1^2 = 7.52$, p = 0.006).

	Estimate	SE	χ^2	p value
Intercent	0.09	0.06	/	/
Difference in mean F0	-0.49	0.00	24.89	<0.001
Difference in F0-SD	0.53	0.09	34.00	<0.001
Difference in Df	0.18	0.10	3.26	0.070
Difference in Pf	-0.06	0.08	0.56	0.452
Difference in HNR	-0.12	0.10	1.23	0.266
Difference in jitter	-0.04	0.09	0.27	0.602
Difference in intensity	0.18	0.06	7.52	0.006
Interactions with age				
Difference in F0	0.16	0.09	2.86	0.090

	Difference in F0-SD	0.04	0.09	0.25	0.616
	Difference in Df	0.13	0.09	2.06	0.151
	Difference in Pf	-0.06	0.07	0.70	0.399
	Difference in HNR	-0.11	0.09	1.31	0.251
	Difference in jitter	0.10	0.08	1.61	0.204
	Difference in intensity	0.15	0.06	5.65	0.017
	Interactions with ancestry				
	Difference in F0	-0.008	0.22	0.001	0.968
	Difference in F0-SD	-0.41	0.20	3.97	0.046
	Difference in Df	0.04	0.23	0.03	0.863
	Difference in Pf	-0.17	0.18	0.82	0.364
	Difference in HNR	-0.01	0.25	0.003	0.953
	Difference in jitter	0.06	0.21	0.09	0.752
	Difference in intensity	-0.10	0.17	0.37	0.539
	Interactions with sexual orientation				
	Difference in F0	0.15	0.24	0.38	0.534
	Difference in F0-SD	-0.54	0.23	5.49	0.019
	Difference in Df	-0.14	0.23	0.36	0.544
	Difference in Pf	-0.10	0.18	0.28	0.593
	Difference in HNR	-0.11	0.28	0.15	0.691
	Difference in jitter	0.18	0.24	0.60	0.436
	Difference in intensity	0.27	0.18	2.29	0.130
323	58, $n_{judges} = 165$, $n_{observations} = 1570$). For	each variable,	the χ^2 and	the p value	s associated from
224	des 1955-1955 and matter all the second starts of the	· · · · · · · · · · · · · · · · · · ·	1	L . C. 11	
324	the likelihood-ratio chi-square test of the	e comparison	between t	he full mod	el and the model
324	the likelihood-ratio chi-square test of the	e comparison	between t	he full mod	lel and the model
324 325	the likelihood-ratio chi-square test of the without the predictors and the control	e comparison variables ar	between t e given (1	he full mod ANOVA ty	lel and the model ype III). For the
324 325 326	the likelihood-ratio chi-square test of the without the predictors and the control	e comparison variables ar	between t e given (n' the esti	he full mod ANOVA ty	lel and the model ype III). For the iven compared to
324325326	the likelihood-ratio chi-square test of the without the predictors and the control categorical variables' 'ancestry' and 'sex	e comparison variables ar ual orientation	between t e given (n', the esti	he full mod ANOVA ty mates are g	lel and the model ype III). For the iven compared to
324325326327	the likelihood-ratio chi-square test of the without the predictors and the control categorical variables' 'ancestry' and 'sex the reference category (1 = European and	e comparison variables ar ual orientation cestry and 1 =	between t e given (n', the esti heterosex	he full mod ANOVA ty mates are g ual). P valu	lel and the model ype III). For the iven compared to es are considered
 324 325 326 327 328 	the likelihood-ratio chi-square test of the without the predictors and the control categorical variables' 'ancestry' and 'sex the reference category (1 = European and significant at the 0.05 threshold (in bold)	e comparison variables ar ual orientation cestry and 1 = . The degrees	between t e given (n', the esti heterosex of freedom	he full mod ANOVA ty mates are g ual). P valu n is 1 for even	lel and the model ype III). For the iven compared to les are considered ery test.
 324 325 326 327 328 329 	the likelihood-ratio chi-square test of the without the predictors and the control categorical variables' 'ancestry' and 'sex the reference category (1 = European and significant at the 0.05 threshold (in bold) For easier understanding of the	e comparison variables ar ual orientation cestry and 1 = . The degrees the model's o	between t e given (n', the esti heterosex of freedom utput, the	he full mod ANOVA ty mates are g ual). P valu n is 1 for eve predicted	lel and the model ype III). For the iven compared to es are considered ery test. probabilities of
 324 325 326 327 328 329 330 	the likelihood-ratio chi-square test of the without the predictors and the control categorical variables' 'ancestry' and 'sex the reference category (1 = European and significant at the 0.05 threshold (in bold) For easier understanding of the considering a voice more attractive than	e comparison variables ar ual orientation cestry and 1 = The degrees the model's o the other wit	between t e given (n', the esti heterosex of freedom utput, the hin the sa	he full mod ANOVA ty mates are g ual). P valu is 1 for even predicted me pair we	lel and the model ype III). For the iven compared to les are considered ery test. probabilities of re plotted against
 324 325 326 327 328 329 330 331 	the likelihood-ratio chi-square test of the without the predictors and the control categorical variables' 'ancestry' and 'sex the reference category (1 = European and significant at the 0.05 threshold (in bold) For easier understanding of the considering a voice more attractive than the range of differences in mean F0, F0-S	e comparison variables ar ual orientation cestry and 1 = The degrees the model's o the other wit	between t e given (n', the esti heterosex of freedom utput, the hin the sa ty betweer	he full mod ANOVA ty mates are g ual). P valu i is 1 for eve predicted me pair we i the two vo	lel and the model ype III). For the iven compared to les are considered ery test. probabilities of re plotted against ices (Figure 1).
 324 325 326 327 328 329 330 331 332 	the likelihood-ratio chi-square test of the without the predictors and the control categorical variables' 'ancestry' and 'sex the reference category (1 = European and significant at the 0.05 threshold (in bold) For easier understanding of the considering a voice more attractive than the range of differences in mean F0, F0-S <u>Figure 1.</u> Probabilities of being picked	e comparison variables ar ual orientation cestry and 1 = . The degrees the model's of the other with SD and intensi as more attra	between t e given (n', the esti heterosex of freedom utput, the hin the sa ty betweer active plot	he full mod ANOVA ty mates are g ual). P valu is 1 for eve predicted me pair we the two vo ted against	lel and the model ype III). For the iven compared to les are considered ery test. probabilities of re plotted against ices (Figure 1). the standardized
 324 325 326 327 328 329 330 331 332 333 	the likelihood-ratio chi-square test of the without the predictors and the control categorical variables' 'ancestry' and 'sex the reference category (1 = European and significant at the 0.05 threshold (in bold) For easier understanding of the considering a voice more attractive than the range of differences in mean F0, F0-S <u>Figure 1.</u> Probabilities of being picked differences between the two voices heard	e comparison variables ar ual orientation cestry and 1 = . The degrees the model's of the other with SD and intensi as more attra l in a) mean F	between t e given (n', the esti heterosex of freedom utput, the hin the sa ty betweer active plot 0, b) FO-S	he full mod ANOVA ty mates are g ual). P valu is 1 for even predicted me pair we the two vo ted against D and c) int	lel and the model ype III). For the iven compared to es are considered ery test. probabilities of re plotted against ices (Figure 1). the standardized tensity. The black



340

341 We also computed the predicted probability that a voice would be considered more attractive when it is 1 standard deviation lower and 1 standard deviation higher than the 342 343 opposite one on the basis of their F0, F0-SD and intensity (Figure 2). A voice with a mean F0 344 that is one standard deviation lower than the other in the same pair has a probability of being picked as more attractive up to ~65%, likewise, a voice with a F0-SD which is 1 standard 345 346 deviation higher has a probability of being picked as more attractive up to $\sim 65\%$.

347 Figure 2. Barplots of the predicted probabilities that a voice would be considered more 348 attractive when it is 1 standard deviation lower and 1 standard deviation higher than the other 349 voice, as a function of its a) mean F0, b) F0-SD and c) intensity. Bars are associated with 95% 350 confidence intervals.

351



356 Additionally, female judges did not show directional preferences for Df, Pf, HNR or jitter (all p values > 0.05). Judges' age had a significant influence on their preferences for 357 intensity ($\chi_1^2 = 7.52$, p = 0.006), i.e., relatively older women preferred louder vocal profiles. 358 359 Women with non-European ancestry and non-heterosexual women showed a preference for lower F0-SD profiles (respectively $\chi_1^2 = 3.97$, p = 0.046; $\chi_1^2 = 5.49$, p = 0.019). The model 360 361 explained 12% of the variance in vocal preferences, including fixed and random effects. 362 Lastly, the variance of the random intercept for judges was higher than the vocal stimuli ($\sigma_{judges} = 0.07$; $\sigma_{stimuli} = 0.01$). 363

The model without ancestry and the one without sexual orientation were not

statistically different from the full model (respectively $\chi_7^2 = 10.42$, p = 0.165; $\chi_7^2 = 9.96$, p = 0.190). Removing age from the model was statistically different from the full model ($\chi_7^2 =$ 18.74, p = 0.009). The models without judges with hearing impairment and without judges who did not report sexual orientation did not qualitatively change the results. In all models, the main results remained the same: female judges still considered voices with lower F0, higher F0-SD and higher intensity as more attractive. All models without the control variables are given in the supplementary material.

372 Discussion

373 Women significantly preferred lower vocal pitch in men. This result is consistent with 374 previous findings in English-speaking populations (Feinberg et al., 2005; Hodges-Simeon et 375 al., 2010; Hughes et al., 2010; Jones et al., 2010; Pisanski and Rendall, 2011; Vukovic et al., 376 2008) and several other languages (Bruckert et al., 2006; Skrinda et al., 2014; Valentová et 377 al., 2013; Weiss and Burkhardt, 2010). Moreover, this finding has been replicated with a 378 similar or higher number of stimuli and judges than most of these studies (see Hodges-Simeon 379 et al., 2010 for an example of a study with a higher number of stimuli). As vocal height 380 correlates to several biological and social information about men, such as testosterone levels 381 (Dabbs and Mallinger, 1999; Evans et al., 2008; Hodges-Simeon et al., 2015), sexually related 382 behaviors (Hughes et al., 2004), body size assessments (Pisanski et al., 2014a), as well as 383 signaling social dominance (Puts et al., 2007) and social rankings (Cheng, Tracy, Ho, and 384 Henrich, 2016), women may rely on this salient acoustic cue as an assessment of sexual 385 partner quality. Several studies have reported that men exhibiting relatively low-pitched 386 voices reported a higher mating success in industrialized societies (Hodges-Simeon, Gaulin, 387 and Puts, 2011; Puts, 2005; Puts et al., 2006; although see Suire et al., 2018) and a higher 388 reproductive success in a hunter-gatherer society (Apicella, Feinberg, and Marlowe, 2007; 389 although see Smith, Olkhov, Puts, and Apicella, 2017).

390 Moreover, French women also significantly preferred higher F0-SD profiles in men, 391 that is, more expressive (or less monotonous) voices. Although our study had a higher number of judges and stimuli than the two others that reported the same relationship (Bruckert et al., 392 2006; Leongómez et al., 2014), another study had a higher number of stimuli but less judges 393 394 (Hodges-Simeon et al., 2010). Nonetheless, while self-confidence and experience can be 395 expressed through monotonous voices, to which some women may be more attracted to 396 (Hodges-Simeon et al., 2010), our results do not follow the same tendency. A possible 397 explanation may be that more marked intonation patterns might be perceived as more 398 attractive as it is a marker of perceived state-dependent qualities such as positive emotions 399 (e.g. joy and happiness) (Banse and Scherer, 1996), conversational interest as well as 400 emotional activation (i.e., arousal) and intensity (Laukka, Juslin, and Bresin, 2005). 401 Ultimately, expressive voices could reflect the speaker's current mental-health state since it 402 has been previously reported that clinically depressed patients show typically reduced F0-SD 403 values (Ellgring and Scherer, 1996). Thus, higher F0 variability may be associated to more 404 enthusiastic and extroverted individuals, to which women may be more attracted. In this 405 sense, our result is consistent with previous findings in both men and women (Bruckert et al., 406 2006; Leongómez et al., 2014). Although it has been suggested to be a cue of femininity, as 407 women display twice as much F0 variation, we suggest that irrespective of sex, higher F0-SD 408 profiles should be perceived as more attractive.

No directional preferences were observed for the formants' dispersion and position,
which corroborates some previous findings (Babel et al., 2014; Feinberg et al., 2005), using a
higher or similar number of stimuli and a higher number of judges. Several studies have
suggested that Df may be a more important vocal cue to assess in human competitive settings.
Indeed, it has been reported that lower Df patterns were associated to perceived dominance in
men (Puts et al., 2007; Wolff and Puts, 2010). This can be explained by the fact that lower Df

415 patterns are associated to larger body size (Pisanski et al., 2016) and to perceived larger 416 individuals (Bruckert et al., 2006; Collins, 2000; Rendall et al., 2007). Interestingly, females 417 were also found to be more sensitive to this vocal cue than men after hearing women's voices 418 (Puts, Barndt, Welling, Dawood, and Burriss, 2011). Such results emphasize the idea that 419 same-sex individuals may use Df to track competitor's masculinity and/or femininity. 420 Similarly, some research suggest that the formants' position may signal threat potential 421 among men (Puts et al., 2012), although a recent study found no correlations to physical 422 strength (Han et al., 2018).

423 Our results also indicated that vocal breathiness and roughness (assessed respectively through the HNR and the jitter ratio) did not significantly contribute to men's vocal 424 425 attractiveness, using a higher number of stimuli and judges than previous studies (Babel et al., 426 2014; Hughes et al., 2014, 2008). Although one study reported that breathier voices were 427 found to be more attractive in Namibian men, ours did not (Šebesta et al., 2017). Another 428 study found that perceived 'breathy' voices were significantly more attractive in both sexes (Xu et al., 2013), although the underlying acoustic component was not clearly identified in 429 430 this study. Lack of significant findings for breathiness suggests that it is more associated with 431 feminine vocal quality, as previously suggested (Henton and Bladon, 1985; Van Borsel et al., 432 2009). It is also possible that when assessing attractiveness, women may be particularly 433 attuned to the vocal features that are indicative of one's heritable mate quality, such as the F0. 434 In this context, breathiness and roughness may not reliably indicate mate or competitor 435 quality for listeners, at least in men. Although they are correlated to other body features (see 436 Pisanski et al., 2016 for an extensive study on that matter), further studies are needed to 437 understand whether these two acoustic components of the human voice are perceptually 438 salient in influencing vocal attractiveness. Otherwise, it has been suggested that HNR and jitter may be indicative of current hormonal profiles as both parameters relate to the 439

440 oscillations of the vocal folds, which possess many cellular receptors to androgens (Pisanski441 et al., 2016).

442 An important limitation to the current study is that we did not investigate the effects of 443 women's menstrual cycle upon perceived vocal attractiveness. Indeed, there was more 444 variations between females judges than between vocal stimuli ($\sigma_{judges} = 0.07$; $\sigma_{stimuli} = 0.01$), 445 suggesting, for example, that the timing of the ovulatory cycle may play a role. In fact, it has 446 been long suggested that menstrual phase and mating contexts may influence women's 447 preferences for masculine vocal attributes (Feinberg et al., 2006; Pisanski, Hahn, Fisher, 448 DeBruine, Feinberg, and Jones, 2014c; Puts, 2005). Under the 'good genes ovulatory shift 449 hypothesis', women in their fertile phase are predicted to shift their preferences towards mates 450 indicating high genetic quality (i.e., more masculine men, to which women may be 451 particularly attracted to for a short-term relationship, such as a one-night stand), as opposed to 452 mates indicating high parental investment in their non-fertile phase (i.e., less masculine men, 453 to which women may be particularly attracted to for a long-term, committed and romantic 454 relationship) (Jünger, Kordsmeyer, Gerlach, and Penke, 2018). These shifting preferences 455 have been suggested to be an adaptive strategy in order to maximize fitness benefits for 456 women.

457 For instance, Puts (2005) found that females judged lowered pitch voices more 458 attractive than the same voices raised in pitch in their fertile phase of their ovulatory cycle 459 with respect to a short-term context. Similarly, Feinberg et al. (2006) found that women's 460 masculinity preferences for low-pitched voices were stronger during the fertile phase. 461 Although the effect was not significant, Pisanski et al. (2014c) also reported stronger 462 preferences for masculinized voice pitch. Lastly, one study has reported that women in their 463 fertile phase significantly preferred lowered Df when questioned for both short- and long-term 464 relationships (Hodges-Simeon et al., 2010). The authors also found that mean F0 and

465 attractiveness was strongest for fertile-phase women rating short-term attractiveness, while 466 F0-SD was more attractive for non-fertile phase female rating short-term attractiveness and 467 fertile females rating long-term attractiveness. However, recent evidence have suggested that 468 women menstrual cycle does not influence their preferences for masculinized bodies and 469 faces (Jones, Hahn, Fisher, Wang, Kandrik, Han, Fasolt, Morrison, Holzleitner, O'Shea, 470 Roberts, Little, and DeBruine, 2017; Marcinkowska, Galbarczyk, and Jasienska, 2018). Using 471 a large sample size and a more methodologically grounded procedure, Jünger et al. (2018) 472 found no effect of the cycle phase, conception risk and steroid hormone levels on women's 473 auditory preferences for men's voices. Further research is thus needed to reliably investigate 474 if the menstrual cycle has a significant effect over shifted preferences. In any case, not 475 controlling for this factor will only provide conservative results, under the hypothesis that the 476 time of the menstrual cycle is randomly distributed among the participating women.

477 Other limitations include the difference in age between men who provided the vocal stimuli and the female judges. However, in our sample both the youngest individual who 478 479 provided the vocal stimuli and the youngest female judge were aged 18, which is largely 480 above the age where mate preferences develop and become relevant (age 13-15, Saxton, 481 Caryl, and Craig Roberts, 2006; Saxton, DeBruine, Jones, Little and Roberts, 2009). 482 Moreover, an interesting perspective for future research would be to investigate possible non-483 linear effects of preferences as a function of vocal parameters. Indeed, extreme values for a 484 particular vocal parameter may be perceived as pathological (as it is the case for high values 485 of jitter and low values of HNR, Teixeira et al., 2013) or perceived as immature and/or too 486 feminine (e.g. high F0). To our knowledge, only one study has tackled this topic in women's 487 preferences for men's F0, and it was found that women did not prefer vocal pitches below the 488 ~96 Hz threshold. This suggests that preferences may contribute to stabilizing selection pressure for low pitch in men's voices (Re et al., 2012 IL Y AUSSI LETUDE DE SAXTON). 489

22

490 Interestingly, in men's preferences for the F0 of women, one study reported a non-linear

491 relationship with attractiveness ratings starting to decrease when the F0 is higher than ~260

492 Hz (Borkowski and Pawlowski 2011), although two studies have reported that there was no

493 upper limit (Feinberg, DeBruine, Jones, and Perrett, 2008; Re et al., 2012).

494 **Conclusions**

495 The current study adds to the body of literature on vocal attractiveness in an underrepresented language (i.e., French). Although voice pitch findings were replicated, 496 497 confirming women's preferences for low-pitched masculine voices, most of the other acoustic 498 features investigated in this study did not yield to significant results, leading us to conclude 499 that variations in resonant frequencies' spacing, breathiness and roughness do not seem to be 500 important contributors of men's vocal attractiveness, at least in a French-speaking sample. 501 Further studies should explore these relationships in other cultures so as to reaffirm these 502 findings.

503 Funding sources

504 This research did not receive any specific grant from funding agencies in the public, 505 commercial, or not-for-profit sectors.

506 **Declaration of conflicting interests**

507 The authors declare that there is no conflict of interest.

508 **Data availability**

- 509 The data and the R code from this study can be found at:
- 510 https://figshare.com/s/cab62d1e411503982c91

511 **References**

- 512 Abitbol, J., Abitbol, P., & Abitbol, B. (1999). Sex hormones and the female voice. Journal of
- 513 Voice, 13(3), 424- 446. https://doi.org/10.1016/S0892-1997(99)80048-4
- 514 Akcam, T., Bolu, E., Merati, A. L., Durmus, C., Gerek, M., & Ozkaptan, Y. (2004). Voice

- 515 Changes after Androgen Therapy for Hypogonadotrophic Hypogonadism: *The Laryngoscope*,
- 516 *114*(9), 1587-1591. https://doi.org/10.1097/00005537-200409000-00016
- 517 Apicella, C. L., & Feinberg, D. R. (2009). Voice pitch alters mate-choice-relevant perception
- 518 in hunter-gatherers. Proceedings of the Royal Society B: Biological Sciences, 276(1659),
- 519 1077- 1082. https://doi.org/10.1098/rspb.2008.1542
- 520 Apicella, C. L., Feinberg, D. R., & Marlowe, F. W. (2007). Voice pitch predicts reproductive
- 521 success in male hunter-gatherers. *Biology Letters*, 3(6), 682-684.
 522 https://doi.org/10.1098/rsbl.2007.0410
- 523 Arnocky, S., Hodges-Simeon, C. R., Ouellette, D., & Albert, G. (2018). Do men with more
- 524 masculine voices have better immunocompetence? *Evolution and Human Behavior*.
- 525 https://doi.org/10.1016/j.evolhumbehav.2018.06.003
- Babel, M., McGuire, G., & King, J. (2014). Towards a More Nuanced View of Vocal
 Attractiveness. *PLoS ONE*, 9(2), e88616. https://doi.org/10.1371/journal.pone.0088616
- 528 Bachorowski, J. A., & Owren, M. J. (1999). Acoustic correlates of talker sex and individual
- 529 talker identity are present in a short vowel segment produced in running speech. *The Journal*
- 530 of the Acoustical Society of America, 106(2), 1054-1063.
- 531 Banse, R., & Scherer, K. R. (1996). Acoustic profiles in vocal emotion expression. *Journal of*
- 532 *personality and social psychology*, 70(3), 614.
- 533 Bartoń, K. (2018). MuMIn: Multi-Model Inference. R package version 1.42.1. Consulté à
- 534 l'adresse https://CRAN.R-project.org/package=MuMIn
- 535 Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting Linear Mixed-Effects Models
- using lme4. ArXiv:1406.5823 [Stat]. Consulté à l'adresse http://arxiv.org/abs/1406.5823
- 537 Bruckert, L., Lienard, J.-S., Lacroix, A., Kreutzer, M., & Leboucher, G. (2006). Women use
- 538 voice parameters to assess men's characteristics. Proceedings of the Royal Society B:
- 539 Biological Sciences, 273(1582), 83- 89. https://doi.org/10.1098/rspb.2005.3265

- 540 Canty, A., & Ripley, B. (2012). boot : Bootstrap R (S-Plus) functions. (Version R package 541 version, 1(7).).
- 542 Cheng, J. T., Tracy, J. L., Ho, S., & Henrich, J. (2016). Listen, follow me : Dynamic vocal
 543 signals of dominance predict emergent social rank in humans. *Journal of Experimental*544 *Psychology: General*, 145(5), 536- 547. https://doi.org/10.1037/xge0000166
- 545 Collins. (2000). Men's voices and women's choices. *Animal Behaviour*, 60(6), 773-780.
- 546 Dabbs, J. M., & Mallinger, A. (1999). High testosterone levels predict low voice pitchamong
- 547 men. Personality and Individual Differences, 27(4), 801- 804. https://doi.org/10.1016/S0191-
- 548 8869(98)00272-4
- 549 de Krom, G. D. (1993). A cepstrum-based technique for determining a harmonics-to-noise
- ratio in speech signals. Journal of Speech, Language, and Hearing Research, 36(2), 254-266.
- 551 Ellgring, H., & Scherer, K. R. (1996). Vocal indicators of mood change in depression.
- 552 Journal of Nonverbal Behavior, 20(2), 83- 110. https://doi.org/10.1007/BF02253071
- Evans, S., Neave, N., Wakelin, D., & Hamilton, C. (2008). The relationship between
 testosterone and vocal frequencies in human males. *Physiology & Behavior*, 93(4-5),
 783-788. https://doi.org/10.1016/j.physbeh.2007.11.033
- 556 Feinberg, David R, DeBruine, L. M., Jones, B. C., & Perrett, D. I. (2008). The Role of
- 557 Femininity and Averageness of Voice Pitch in Aesthetic Judgments of Women's Voices.
- 558 Perception, 37(4), 615- 623. https://doi.org/10.1068/p5514
- 559 Feinberg, D.R., Jones, B. C., & Armstrong, M. M. (2019). No Evidence That Men's Voice
- 560 Pitch Signals Formidability. *Trends in Ecology & Evolution*, 34(3), 190-192.
 561 https://doi.org/10.1016/j.tree.2018.12.014
- 562 Feinberg, D.R., Jones, B. C., Law Smith, M. J., Moore, F. R., DeBruine, L. M., Cornwell, R.
- 563 E., ... Perrett, D. I. (2006). Menstrual cycle, trait estrogen level, and masculinity preferences
- 564 in the human voice. Hormones and Behavior, 49(2), 215-222.

- 565 https://doi.org/10.1016/j.yhbeh.2005.07.004
- 566 Feinberg, D.R., Jones, B. C., Little, A. C., Burt, D. M., & Perrett, D. I. (2005). Manipulations
- 567 of fundamental and formant frequencies influence the attractiveness of human male voices.
- 568 Animal Behaviour, 69(3), 561- 568. https://doi.org/10.1016/j.anbehav.2004.06.012
- 569 Fitch, W. T. (1997). Vocal tract length and formant frequency dispersion correlate with body
- size in rhesus macaques. *The Journal of the Acoustical Society of America*, 102(2),
 1213-1222.
- Foo, Y. Z., Nakagawa, S., Rhodes, G., & Simmons, L. W. (2017). The effects of sex
 hormones on immune function: A meta-analysis: Sex hormones and immune function. *Biological Reviews*, 92(1), 551- 571. https://doi.org/10.1111/brv.12243
- Fouquet, M., Pisanski, K., Mathevon, N., & Reby, D. (2016). Seven and up: Individual
 differences in male voice fundamental frequency emerge before puberty and remain stable
 throughout adulthood. *Royal Society Open Science*, *3*(10), 160395.
 https://doi.org/10.1098/rsos.160395
- Fox, J., Weisberg, S., & Fox, J. (2011). An R companion to applied regression (2nd ed).
 Thousand Oaks, Calif: SAGE Publications.
- 581 Gelfer, M. P., & Bennett, Q. E. (2013). Speaking Fundamental Frequency and Vowel Formant
- 582 Frequencies: Effects on Perception of Gender. Journal of Voice, 27(5), 556-566.
- 583 https://doi.org/10.1016/j.jvoice.2012.11.008
- 584 Gelfer, M. P., & Mikos, V. A. (2005). The Relative Contributions of Speaking Fundamental
- 585 Frequency and Formant Frequencies to Gender Identification Based on Isolated Vowels.
- 586 Journal of Voice, 19(4), 544- 554. https://doi.org/10.1016/j.jvoice.2004.10.006
- 587 Han, C., Wang, H., Fasolt, V., Hahn, A., Holzleitner, I. J., Lao, J., ... Jones, B. (2018). No
- 588 clear evidence for correlations between handgrip strength and sexually dimorphic acoustic
- 589 properties of voices. *BioRxiv*. https://doi.org/10.1101/227165

- Henton, C. G., & Bladon, R. A. (1985). Breathiness in normal female speech : Inefficiency
 versus desirability. *Language & Communication*.
- Hillenbrand, J. (1988). Perception of aperiodicities in synthetically generated voices. *The Journal of the Acoustical Society of America*, 83(6), 2361-2371.
 https://doi.org/10.1121/1.396367
- 595 Hillenbrand, J. M., & Clark, M. J. (2009). The role of f 0 and formant frequencies in
- 596 distinguishing the voices of men and women. Attention, Perception, & Psychophysics, 71(5),
- 597 1150- 1166. https://doi.org/10.3758/APP.71.5.1150
- 598 Hodges-Simeon, C. R., Gaulin, S. J. C., & Puts, D. A. (2010). Different Vocal Parameters
- 599 Predict Perceptions of Dominance and Attractiveness. Human Nature, 21(4), 406-427.
- 600 https://doi.org/10.1007/s12110-010-9101-5
- 601 Hodges-Simeon, C. R., Gaulin, S. J. C., & Puts, D. A. (2011). Voice Correlates of Mating
- 602 Success in Men: Examining "Contests" Versus "Mate Choice" Modes of Sexual Selection.
- 603 Archives of Sexual Behavior, 40(3), 551- 557. https://doi.org/10.1007/s10508-010-9625-0
- Hodges-Simeon, C. R., Gurven, M., & Gaulin, S. J. C. (2015). The low male voice is a costly
- 605 signal of phenotypic quality among Bolivian adolescents. *Evolution and Human Behavior*,
- 606 *36*(4), 294- 302. https://doi.org/10.1016/j.evolhumbehav.2015.01.002
- Hughes, S. M., Dispenza, F., & Gallup, G. G. (2004). Ratings of voice attractiveness predict
 sexual behavior and body configuration. *Evolution and Human Behavior*, 25(5), 295-304.
 https://doi.org/10.1016/j.evolhumbehav.2004.06.001
- 610 Hughes, S. M., Farley, S. D., & Rhodes, B. C. (2010). Vocal and Physiological Changes in
- 611 Response to the Physical Attractiveness of Conversational Partners. Journal of Nonverbal
- 612 Behavior, 34(3), 155- 167. https://doi.org/10.1007/s10919-010-0087-9
- Hughes, S. M., Mogilski, J. K., & Harrison, M. A. (2014). The Perception and Parameters of
- 614 Intentional Voice Manipulation. Journal of Nonverbal Behavior, 38(1), 107-127.

- 615 https://doi.org/10.1007/s10919-013-0163-z
- 616 Hughes, S. M., Pastizzo, M. J., & Gallup, G. G. (2008). The Sound of Symmetry Revisited :
- 617 Subjective and Objective Analyses of Voice. *Journal of Nonverbal Behavior*, 32(2), 93-108.
- 618 https://doi.org/10.1007/s10919-007-0042-6
- 619 I. Folstad, & Karter A.J. (1992). Parasites, bright males, and the immunocompetence
 620 handicap. *The America Naturalist*, *139*(3), 603- 622.
- Jones, B. C., Feinberg, D. R., DeBruine, L. M., Little, A. C., & Vukovic, J. (2010). A domain-
- 622 specific opposite-sex bias in human preferences for manipulated voice pitch. Animal
- 623 Behaviour, 79(1), 57- 62. https://doi.org/10.1016/j.anbehav.2009.10.003
- Jones, B. C., Hahn, A. C., Fisher, C. I., Wang, H., Kandrik, M., Han, C., ... DeBruine, L. M.
- 625 (2017). No compelling evidence that preferences for facial masculinity track changes in
 626 women's hormonal status. *BioRxiv*. https://doi.org/10.1101/136549
- Jones, T. M., Trabold, M., Plante, F., Cheetham, B. M. G., & Earis, J. E. (2001). Objective
 assessment of hoarseness by measuring jitter. *Clinical Otolaryngology and Allied Sciences*,
 26(1), 29- 32. https://doi.org/10.1046/j.1365-2273.2001.00413.x
- 630 Jost, L., Fuchs, M., Loeffler, M., Thiery, J., Kratzsch, J., Berger, T., & Engel, C. (2018).
- 631 Associations of Sex Hormones and Anthropometry with the Speaking Voice Profile in the
- 632 Adult General Population. Journal of Voice, 32(3), 261-272.
- 633 https://doi.org/10.1016/j.jvoice.2017.06.011
- Jünger, J., Kordsmeyer, T. L., Gerlach, T. M., & Penke, L. (2018). Fertile women evaluate
- 635 male bodies as more attractive, regardless of masculinity. *Evolution and Human Behavior*,
- 636 *39*(4), 412- 423. https://doi.org/10.1016/j.evolhumbehav.2018.03.007
- 637 Jünger, J., Motta-Mena, N. V., Cardenas, R., Bailey, D., Rosenfield, K. A., Schild, C., ...
- 638 Puts, D. A. (2018). Do women's preferences for masculine voices shift across the ovulatory
- 639 cycle? Hormones and Behavior, 106, 122-134. https://doi.org/10.1016/j.yhbeh.2018.10.008

- 640 Laukka, P., Juslin, P., & Bresin, R. (2005). A dimensional approach to vocal expression of
- 641 emotion. Cognition & Emotion, 19(5), 633- 653. https://doi.org/10.1080/02699930441000445
- 642 Leongómez, J. D., Binter, J., Kubicová, L., Stolařová, P., Klapilová, K., Havlíček, J., &
- 643 Roberts, S. C. (2014). Vocal modulation during courtship increases proceptivity even in naive
- 644 listeners. *Evolution and Human Behavior*, 35(6), 489-496.
 645 https://doi.org/10.1016/j.evolhumbehav.2014.06.008
- 646 Linville, S. E., & Fisher, H. B. (1985). Acoustic characteristics of perceived versus actual
- 647 vocal age in controlled phonation by adult females. *The Journal of the Acoustical Society of*
- 648 America, 78(1), 40- 48. https://doi.org/10.1121/1.392452
- 649 Lyons, M., Lynch, A., Brewer, G., & Bruno, D. (2014). Detection of Sexual Orientation
- 650 ("Gaydar") by Homosexual and Heterosexual Women. Archives of Sexual Behavior, 43(2),
- 651 345- 352. https://doi.org/10.1007/s10508-013-0144-7
- 652 Marcinkowska, U. M., Galbarczyk, A., & Jasienska, G. (2018). La donna è mobile ? Lack of
- 653 cyclical shifts in facial symmetry, and facial and body masculinity preferences—A hormone
- based study. *Psychoneuroendocrinology*, 88, 47-53.
- Munson, B., McDonald, E. C., DeBoe, N. L., & White, A. R. (2006). The acoustic and
- 656 perceptual bases of judgments of women and men's sexual orientation from read speech.
- 657 Journal of Phonetics, 34(2), 202- 240. https://doi.org/10.1016/j.wocn.2005.05.003
- 658 Pisanski, K., Fraccaro, P. J., Tigue, C. C., O'Connor, J. J. M., & Feinberg, D. R. (2014a).
- 659 Return to Oz: Voice pitch facilitates assessments of men's body size. Journal of
- 660 Experimental Psychology: Human Perception and Performance, 40(4), 1316-1331.
- 661 https://doi.org/10.1037/a0036956
- 662 Pisanski, K., Fraccaro, P. J., Tigue, C. C., O'Connor, J. J. M., & Feinberg, D. R. (2014b).
- 663 Return to Oz: Voice pitch facilitates assessments of men's body size. *Journal of* 664 *Experimental Psychology: Human Perception and Performance*, 40(4), 1316-1331.

- 665 https://doi.org/10.1037/a0036956
- 666 Pisanski, K., Fraccaro, P. J., Tigue, C. C., O'Connor, J. J. M., Röder, S., Andrews, P. W., ...
- 667 Feinberg, D. R. (2014). Vocal indicators of body size in men and women : A meta-analysis.
- 668 Animal Behaviour, 95, 89- 99. https://doi.org/10.1016/j.anbehav.2014.06.011
- 669 Pisanski, K., Hahn, A. C., Fisher, C. I., DeBruine, L. M., Feinberg, D. R., & Jones, B. C.
- 670 (2014). Changes in salivary estradiol predict changes in women's preferences for vocal
- 671 masculinity. *Hormones and Behavior*, 66(3), 493- 497.
- 672 Pisanski, K., Jones, B. C., Fink, B., O'Connor, J. J. M., DeBruine, L. M., Röder, S., &
- 673 Feinberg, D. R. (2016). Voice parameters predict sex-specific body morphology in men and
- 674 women. Animal Behaviour, 112, 13- 22. https://doi.org/10.1016/j.anbehav.2015.11.008
- 675 Pisanski, K., & Rendall, D. (2011). The prioritization of voice fundamental frequency or
- 676 formants in listeners' assessments of speaker size, masculinity, and attractiveness. The
- 677 Journal of the Acoustical Society of America, 129(4), 2201-2212.
- 678 https://doi.org/10.1121/1.3552866
- Ptacek, P. H., & Sander, E. K. (1966). Age recognition from voice. *Journal of speech and hearing Research*, 9(2), 273- 277.
- Puts, D. A., Apicella, C. L., & Cardenas, R. A. (2012). Masculine voices signal men's threat
- 682 potential in forager and industrial societies. *Proceedings of the Royal Society B: Biological*
- 683 Sciences, 279(1728), 601- 609. https://doi.org/10.1098/rspb.2011.0829
- 684 Puts, David A., & Aung, T. (2019). Does Men's Voice Pitch Signal Formidability? A Reply 685 to Feinberg et al. **Trends** in Ecology & Evolution, 34(3), 189-190. https://doi.org/10.1016/j.tree.2018.12.004 686
- Puts, David A., Barndt, J. L., Welling, L. L. M., Dawood, K., & Burriss, R. P. (2011).
 Intrasexual competition among women : Vocal femininity affects perceptions of attractiveness
- 689 and flirtatiousness. Personality and Individual Differences, 50(1), 111-115.

- 690 https://doi.org/10.1016/j.paid.2010.09.011
- 691 Puts, David Andrew. (2005). Mating context and menstrual phase affect women's preferences
- 692 for male voice pitch. *Evolution and Human Behavior*, 26(5), 388-397.
 693 https://doi.org/10.1016/j.evolhumbehav.2005.03.001
- 694 Puts, David Andrew, Gaulin, S. J. C., & Verdolini, K. (2006). Dominance and the evolution
- 695 of sexual dimorphism in human voice pitch. *Evolution and Human Behavior*, 27(4), 283-296.
- 696 https://doi.org/10.1016/j.evolhumbehav.2005.11.003
- 697 Puts, David Andrew, Hodges, C. R., Cárdenas, R. A., & Gaulin, S. J. C. (2007). Men's voices
- as dominance signals: Vocal fundamental and formant frequencies influence dominance
 attributions among men. *Evolution and Human Behavior*, 28(5), 340-344.
 https://doi.org/10.1016/j.evolhumbehav.2007.05.002
- 701 Rabinov, C. R., Kreiman, J., Gerratt, B. R., & Bielamowicz, S. (1995). Comparing Reliability
- of Perceptual Ratings of Roughness and Acoustic Measures of Jitter. *Journal of Speech Language and Hearing Research*, 38(1), 26. https://doi.org/10.1044/jshr.3801.26
- Re, D. E., O'Connor, J. J. M., Bennett, P. J., & Feinberg, D. R. (2012). Preferences for Very
 Low and Very High Voice Pitch in Humans. *PLoS ONE*, 7(3), e32719.
 https://doi.org/10.1371/journal.pone.0032719
- Rendall, D., Vokey, J. R., & Nemeth, C. (2007). Lifting the curtain on the Wizard of Oz:
 Biased voice-based impressions of speaker size. *Journal of Experimental Psychology: Human*
- 709 Perception and Performance, 33(5), 1208-1219. https://doi.org/10.1037/0096710 1523.33.5.1208
- 711 Saxton, T. K., Caryl, P. G., & Craig Roberts, S. (2006). Vocal and Facial Attractiveness
- Judgments of Children, Adolescents and Adults : The Ontogeny of Mate Choice. Ethology,
- 713 *112*(12), 1179- 1185. https://doi.org/10.1111/j.1439-0310.2006.01278.x
- 714 Saxton, T. K., Debruine, L. M., Jones, B. C., Little, A. C., & Roberts, S. C. (2009). Face and

- voice attractiveness judgments change during adolescence. *Evolution and Human Behavior*,
- 716 *30*(6), 398- 408. https://doi.org/10.1016/j.evolhumbehav.2009.06.004
- 717 Šebesta, P., Kleisner, K., Tureček, P., Kočnar, T., Akoko, R. M., Třebický, V., & Havlíček, J.
- 718 (2017). Voices of Africa: Acoustic predictors of human male vocal attractiveness. Animal
- 719 Behaviour, 127, 205- 211. https://doi.org/10.1016/j.anbehav.2017.03.014
- Sell, A., Bryant, G. A., Cosmides, L., Tooby, J., Sznycer, D., von Rueden, C., ... Gurven, M.
- 721 (2010). Adaptations in humans for assessing physical strength from the voice. *Proceedings of*
- 722 the Royal Society B: Biological Sciences, 277(1699), 3509-3518.
 723 https://doi.org/10.1098/rspb.2010.0769
- Shipp, T., Qi, Y., Huntley, R., & Hollien, H. (1992). Acoustic and temporal correlates of
 perceived age. *Journal of Voice*, 6(3), 211-216. https://doi.org/10.1016/S08921997(05)80145-6
- 727 Shirazi, T. N., Puts, D. A., & Escasa-Dorne, M. J. (2018). Filipino Women's Preferences for
- Male Voice Pitch : Intra-Individual, Life History, and Hormonal Predictors. *Adaptive Human Behavior and Physiology*, 4(2), 188- 206. https://doi.org/10.1007/s40750-018-0087-2
- 730 Simmons, L. W., Peters, M., & Rhodes, G. (2011). Low Pitched Voices Are Perceived as
- 731 Masculine and Attractive but Do They Predict Semen Quality in Men? *PLoS ONE*, 6(12),
- 732 e29271. https://doi.org/10.1371/journal.pone.0029271
- 733 Skrinda, I., Krama, T., Kecko, S., Moore, F. R., Kaasik, A., Meija, L., ... Krams, I. (2014).
- Body height, immunity, facial and vocal attractiveness in young men. Naturwissenschaften,
- 735 101(12), 1017-1025. https://doi.org/10.1007/s00114-014-1241-8
- 736 Smith, K. M., Olkhov, Y. M., Puts, D. A., & Apicella, C. L. (2017). Hadza Men With Lower
- 737 Voice Pitch Have a Better Hunting Reputation. Evolutionary Psychology, 15(4),
- 738 147470491774046. https://doi.org/10.1177/1474704917740466
- 739 Suire, A., Raymond, M., & Barkat-Defradas, M. (2018). Human vocal behavior within

- 740 competitive and courtship contexts and its relation to mating success. *Evolution and Human*741 *Behavior*, *39*(6), 684- 691. https://doi.org/10.1016/j.evolhumbehav.2018.07.001
- Taylor, A. M., & Reby, D. (2010). The contribution of source-filter theory to mammal vocal
 communication research : Advances in vocal communication research. *Journal of Zoology*,
 280(3), 221- 236. https://doi.org/10.1111/j.1469-7998.2009.00661.x
- Teixeira, J. P., Oliveira, C., & Lopes, C. (2013). Vocal Acoustic Analysis Jitter, Shimmer
 and HNR Parameters. *Procedia Technology*, 9, 1112-1122.
 https://doi.org/10.1016/j.protcy.2013.12.124
- Titze, I. R. (1989). Physiologic and acoustic differences between male and female voices. *The Journal of the Acoustical Society of America*, 85(4), 1699-1707.
 https://doi.org/10.1121/1.397959
- 751 Valentová, J., Roberts, S. C., & Havlíček, J. (2013). Preferences for Facial and Vocal
- 752 Masculinity in Homosexual Men: The Role of Relationship Status, Sexual Restrictiveness,
- and Self-Perceived Masculinity. *Perception*, 42(2), 187-197. https://doi.org/10.1068/p6909
- Van Borsel, J., Janssens, J., & De Bodt, M. (2009). Breathiness as a Feminine Voice
 Characteristic: A Perceptual Approach. *Journal of Voice*, 23(3), 291-294.
 https://doi.org/10.1016/j.jvoice.2007.08.002
- 757 Vukovic, J., Feinberg, D. R., Jones, B. C., DeBruine, L. M., Welling, L. L. M., Little, A. C.,
- 8 Smith, F. G. (2008). Self-rated attractiveness predicts individual differences in women's
- preferences for masculine men's voices. Personality and Individual Differences, 45(6),
- 760 451- 456. https://doi.org/10.1016/j.paid.2008.05.013
- 761 Weiss, B., & Burkhardt, F. (2010). Voice Attributes Affecting Likability Perception. *Eleventh*
- 762 Annual Conference of the International Speech Communication Association, 4.
- 763 Wendahl, R. W. (1966). Some Parameters of Auditory Roughness. Folia Phoniatrica et
- 764 *Logopaedica*, 18(1), 26- 32. https://doi.org/10.1159/000263081

- 765 Wickham, H. (2009). *Ggplot2 : Elegant graphics for data analysis*. New York: Springer.
- 766 Wickham, H., François, R., Henry, L., & Müller, K. (2018). Dplyr: A Grammar of Data
- 767 Manipulation. R package version 0.7.8. Consulté à l'adresse https://CRAN.R768 project.org/package=dplyr
- 769 Wolff, S. E., & Puts, D. A. (2010). Vocal masculinity is a robust dominance signal in men.
- 770 Behavioral Ecology and Sociobiology, 64(10), 1673-1683. https://doi.org/10.1007/s00265-
- 771 010-0981-5
- Xu, Y., Lee, A., Wu, W.-L., Liu, X., & Birkholz, P. (2013). Human Vocal Attractiveness as
- 773 Signaled by Body Size Projection. PLoS ONE, 8(4), e62397.
- 774 https://doi.org/10.1371/journal.pone.0062397

775