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1 **Title: Sex-biased sound symbolism in French first names**

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12 **Summary: Low and high-frequency vowels in the stressed syllable of French first names may**
13 **respectively project impressions of largeness/masculinity and smallness/femininity.**

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32 **Abstract**

33 Given that first names can have a lifelong impact on the bearer, parents should choose a name
34 based on the impressions they want their offspring to evoke in other people. This name-to-mental-
35 image association can be mediated through sound symbolism: a natural link between the sounds
36 and meaning of a word. From an evolutionary perspective, parents should pick names which sounds
37 convey traits advantageous in human sexual selection: largeness and masculinity for males through
38 lower-frequency sounds as opposed to smallness and femininity for females through higher-
39 frequency sounds. Using a database of French first names from 1900 to 2009, we observed a sex-
40 biased sound symbolism pattern in the last syllable, which is the perceptually prominent one in
41 French. Male names were more likely to include lower-frequency vowels (e.g. /o/, /ã/) and female
42 names higher-frequency vowels (e.g. /i/, /e/). Unexpected patterns in consonants were observed in
43 masculine names with higher-frequency sounds (e.g. /s/, /f/) in the last syllable and lower-
44 frequency sounds (e.g. /b/, /g/) in the first syllable. However, little variance was explained and the
45 modest size effect suggest that cultural traits influence these sex differences. Lastly, exploratory
46 analyses revealed a phonetic masculinization in women's first names that increased since the
47 1960's.

48 Keywords: Sound symbolism; first names; femininity; masculinity; voice.

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68 Introduction

69 Arbitrariness, the notion that the sound and the meaning of a word are independent, has long been
70 considered one of the most widely shared principles in linguistics. However, a growing body of
71 evidence challenges this view, stating that there is a natural link between the sound units of a word
72 – known as phonemes – and the mental image they evoke (see Svantesson, 2017 for an overview).
73 This principle, referred to as sound symbolism, is well illustrated by the ‘kiki-bouba’ and ‘maluma-
74 takete’ experiments, in which participants are asked to associate such non-words to two figures of
75 different shapes: results show above-chance matchings of ‘bouba’ and ‘maluma’ with a round
76 silhouette, and ‘kiki’ and ‘takete’ with a sharp one (Ramachandran and Hubbard, 2001; Werner,
77 1957; Köhler, 1947). Although it is uncertain to generalize the ‘kiki-bouba’ effect across cultures
78 (see Bremner *et al.*, 2013 and Cuskley *et al.*, 2017), other similar sound-meaning mappings have
79 been recorded in thousands of the world’s languages, suggesting an underlying universal cognitive
80 association mechanism (Blasi *et al.*, 2016). Sexual selection for body size offers one possible
81 explanation for why sound symbolism might be so ubiquitously distributed.

82 The first clue was provided by the ‘Motivational-Structural Role’ theory (Morton, 1977),
83 after observing that many animals modulate their vocalizations during competitive encounters: they
84 use low-pitched vocalizations when their intention is to be threatening and dominant, and high-
85 pitched vocalizations if they wish to appear conciliatory or submissive. The hypothesized reason is
86 that the frequency of vocalizations reflects a projection of the individual’s body size, a key
87 determinant in the outcome of physical contests but also courtship interactions (Bradbury and
88 Vehrencamp, 2011). This notion was then extended to humans in the ‘Frequency-code’ theory
89 (Ohala, 1984), which provides a plausible explanation for the observed vocal dimorphism in human
90 voices. Before puberty, boys and girls exhibit similar vocal frequencies, until males experience a
91 significant enlargement of their larynx and vocal folds under the influence of androgens, which
92 lowers their vocal pitch and resonant frequencies to the point that they practically do not overlap
93 with those of adult females (Titze, 1989). Such findings hint towards the action of sexual selection
94 and can be interpreted as a result of different selective pressures acting on each sex (Puts, 2010). In
95 males, lower-frequency voices could have been favoured within intra-sexual contests because they
96 are perceptually associated to largeness (Pisanski *et al.*, 2014; Xu *et al.*, 2013; Pisanski and
97 Rendall, 2011; Rendall *et al.*, 2007; van Dommelen and Moxness, 1995), more masculine and more
98 socially and physically dominant men (Hodges-Simeon *et al.*, 2014; Puts *et al.*, 2006; Puts *et al.*,
99 2007; Xu *et al.*, 2013; although see Armstrong *et al.*, 2019 for why voice pitch may not be an
100 honest signal of dominance). In contrast, higher frequencies in female voices could have been
101 selected in mate-choice dynamics as such frequencies were shown to be associated to perceived

102 smallness, femininity and more attractive women (Xu *et al.*, 2013; Fraccaro *et al.*, 2011; Puts *et al.*,
103 2011; Jones *et al.*, 2010; Feinberg *et al.*, 2008; Collins and Missing, 2003).

104 Although naming practices are assumed to be highly driven by sociocultural factors, few
105 studies have underpinned the ultimate causes that have driven most male and female names to not
106 overlap phonetically (Pitcher *et al.*, 2013). As observed for other dimorphic traits in humans such
107 as the body size and stature (Geary, 1998; Puts, 2010), one can reasonably assume that these two
108 different sexual selective pressures on human voices could have driven the attested sexual phonetic
109 dimorphism. Preliminary evidence has shown that across languages as diverse as English, Japanese,
110 Chinese, Korean, and several Native American and Australian languages, high and low frequency
111 vowels are respectively associated to perceived smallness and largeness (Haynie *et al.*, 2014;
112 Shinohara and Kawahara, 2010; Ultan, 1978; Newman, 1933; Sapir, 1929), as well as perceived
113 femininity and masculinity (Wu *et al.*, 2013; Klink, 2000). Thus, indexical cues that are known to
114 be relevant to human mating (e.g. body size, masculinity and femininity) may be conveyed or
115 projected in first names through sound symbolism, using an array of different phonemes that can
116 differ in their intrinsic fundamental frequency (i.e., the perceptual correlate of pitch), formant
117 frequencies (i.e., resonances of the vocal tract) and their dispersion (i.e., a proxy of the vocal tract
118 length) (Knoeferle *et al.*, 2017; Ohala, 1994; Ultan, 1978).

119 Although parents may not volitionally seek a large or small, dominant and attractive
120 sounding name for their offspring, they might display an unconscious preference for either a more
121 masculine or feminine name to suit their child's sex. This behaviour can be explained by the fact
122 that gendered naming is an important tool of categorization in humans. Indeed, sex is one the most
123 pervasive characteristic individuals first infer when interacting with others: distinguishing it by
124 using different phonetic material for first names may find benefits in that it increases cognitive
125 efficiency by allowing individuals to rapidly infer properties of sex category, even with little or no
126 first-hand experience with that person. In turn, it enables individuals to tailor their expectations
127 about the behaviours and capacities linked to the biological composition of that individual.
128 Additionally, masculine and feminine names take on great importance in the reinforcement of an
129 individual's sexual identity and gender role (Pilcher, 2016). Although first names are not inherited
130 and no studies have tackled yet the issue of their influence on reproductive success, it has been
131 reported that first names can impact their bearers on several aspects: its physical perception
132 (Zwebner *et al.*, 2017; Hartung, 2018; Perfors, 2004; Erwin, 1993; Hassebrauck, 1988; Hensley and
133 Spencer, 1985), inferences on personality (Mehrabian, 2001; Mehrabian and Piercy, 1993; Leirer *et*
134 *al.*, 1982), attitudes and behaviors (Figlio, 2007; Pelham *et al.*, 2002), social desirability (Gebauer
135 *et al.*, 2012; Busse and Seraydarian, 1978) and social outcomes (Cotton *et al.*, 2008; Figlio, 2005;
136 Hodson and Olson, 2005; Harari and McDavid, 1973). Thus, it can be suggested that this cognitive

137 bias could interfere during the naming process, since the phonetic peculiarities of forenames may
138 underline and reinforce the perceptual associations of the biological and social characteristics
139 linked to each sex through sound symbolism, which ultimately might be relatively important
140 towards competitors and potential mates. Furthermore, to our knowledge, no societies
141 (industrialized or not) currently use, or have been using, the same set of names for males and
142 females. Lastly, it is worth noting that even though cultural evolution drives popularity and the
143 emergence of novel names (e.g. Berger *et al.*, 2012), it merely explains why individuals primarily
144 perceive them as either male or female.

145 Sound symbolism has already been observed in the phonetic composition of English first
146 names (Sidhu and Pexman, 2015; Pitcher *et al.*, 2013; Cassidy *et al.*, 1999; Cutler *et al.*, 1990). So
147 far, only one study has formally tested these evolutionary hypotheses through the lens of sexual
148 selection using a database of the thousand most popular English, American and Australian first
149 names between 2001 and 2010 (Pitcher *et al.*, 2013). In accordance with the evolutionary
150 predictions, high-frequency vowels such as /i/ or /e/ were mostly attested in female names and low-
151 frequency ones such as /u/ or /o/ in male names. Such differences were found on the first syllable,
152 where stress is generally located and which is consequently perceptually prominent in English.
153 However, the authors did not investigate consonant patterns nor take a look on the last syllable to
154 ensure that no phonetic dimorphism was also present there.

155 The goal of the present study is to quantify the hypothesized phonetic dimorphism of male
156 and female names, using a large sample size of popular first names in France that extends over the
157 last century. In this context, this study extends on the results that have been already observed in
158 English first names. However, two major differences exist between French and English. First the
159 lexical stress falls on the last syllable in French and most of the time on the first syllable in English.
160 Secondly, all phonological units are not equally represented in French and English. For example,
161 nasal vowels are attested in the former but absent in the latter. Moreover, analyses can be expanded
162 by including consonants, for which patterns of sound symbolism have been previously reported
163 (Nielsen and Rendall, 2013; Maurer *et al.*, 2006). Consequently, we expect to find sex-bias sound
164 symbolic patterns in the phonemes of the stressed syllable in French names, namely back and nasal
165 vowels and voiced consonants in male names, as they are produced at lower frequencies, as
166 opposed to front vowels as well as voiceless consonants in female names, since their articulation
167 produces noise in relatively higher frequencies (Knoeferle *et al.*, 2017; Ohala, 1994; Ultan, 1978).
168 Lastly, we will conduct exploratory analyses of the temporal variations of these sound symbolic
169 patterns from 1900 to 2009 in order to examine whether they have remained constant or have
170 evolved over time for each sex.

171 **Material and methods**

172 **a. Data pre-treatment**

173 Data was retrieved on September 2014 from the Institut National de la Statistique et des Études
174 Économiques. We selected the most popular 100 female and 100 male names for each decade,
175 ranging from 1900-1909 to 2000-2009. In order to control for population size, popularity was
176 estimated by calculating the annual ranking position of each name and adding these up per decade.
177 Although this approach excludes rare names, it captures naming practices properly for a given
178 decade (Pitcher *et al.*, 2013).

179 All retrieved names were subsequently transcribed independently by two native French-
180 speaking phoneticians, following the International Phonetic Alphabet principles. When no
181 agreement arose for certain transcriptions or when pronunciation was unknown, different web
182 sources were used (e.g. <https://fr.wiktionary.org/wiki>). For each syllable of a name, we recorded the
183 following articulatory features:

- 184 - The vowel place of articulation, which corresponds to the position of the tongue in the oral
185 cavity during its articulation. As the tongue is closer to the lips, the sounds produced have
186 an overall higher frequency spectrum (i.e., front vowels such as /i/). Conversely, sounds that
187 are produced with the tongue retracted at the back of the mouth (i.e., back vowels such as
188 /u/) have an overall lower spectral distribution. Central vowels (i.e., /a/) correspond to a
189 position where the tongue is placed in the middle of the mouth. Acoustically, vocalic
190 frontness and/or backness correspond to the frequencies of the second formant (i.e., the
191 spectral peaks of the sound spectrum). The vowel height, which corresponds to the degree
192 of aperture of the mandible (i.e., the open/close dimension, corresponding acoustically to
193 the first formant), was not retained here, as it would produce redundant information with
194 vowel articulation (i.e., multicollinearity in the statistical analyses).
- 195 - The vowel's nasality, which is determined by the low position of the velum during
196 articulation, leads the air to flow through the nose as well as the mouth. This extra
197 resonance, which results from the intervention of the nasal cavity during phonation, lowers
198 the frequency of the sound in comparison to its non-nasal counterpart. Note that only one
199 type of vowel (oral or nasal) can be found in each syllable.
- 200 - The consonant's manner of articulation, which is determined by the way the airflow escapes
201 from the vocal tract during articulation. Here, we focused on plosives, which are produced
202 by a complete closing of the airflow that causes its blocking before the air is suddenly
203 released. This type of sound produces a burst noise that is typical of consonantal stops. We
204 also focused on fricatives, which are produced with a major constriction of the airflow,
205 which acoustically causes a turbulent noise. Due to their manner of articulation, plosives
206 generally produce lower frequencies than fricatives.

207 - The consonant's voicing, which is determined by whether the vocal folds vibrate or not
208 during articulation. This new source of laryngeal noise explains why voiced consonants are
209 lower in frequencies than voiceless ones.

210 All phonemes coded with examples of first names are given in Table 1.

211 **b. Statistical analyses**

212 Analysis on sound symbolism

213 The aim of this analysis is to study and quantify sex differences in first names' phonetic
214 composition. According to our predictions, we expect to find in the stressed syllable of male names
215 either back or nasal vowels and voiced consonants, as opposed to front, non-nasal vowels and
216 unvoiced consonants in female names. In order to test these predictions, we aggregated all the first
217 names spanning over the century, giving only one list of first names (e.g. 'Marie' was found in
218 several decades). Within sexes, only one version of phonetically equivalent names in each sex (e.g.
219 'Danielle' and 'Daniele', homophones non-homographs, i.e., names pronounced alike but not
220 written alike) was collated. Compound names (e.g. 'Jean-Marie', 'Marie-Pierre') were discarded as
221 they represent a particular set of names mostly composed of a masculine name joint to a feminine
222 name. Monosyllabic names were also discarded from the analysis because it would preclude
223 comparing the first and last syllable. This resulted in a sample size of 275 female and 197 male
224 popular unique names distributed across the century. A generalized linear model was then used to
225 investigate the existence of sex-biased sound symbolic patterns in French male vs. female names.
226 Because the response variable 'sex' was binary, a binomial distribution with a logit link function
227 was specified. The explanatory variables were the articulatory features aforementioned, each
228 repeated for the first and the stressed last syllable:

229 - The vowel's place of articulation: fixed factor with 3 modalities (i.e., front, central or back
230 vowel).

231 - The vowel's nasality: fixed factor with 2 modalities (i.e., nasal and non-nasal vowel).

232 - Counts of voiced and unvoiced consonants (plosives and fricatives): covariates that were
233 standardized.

234 Finally, post-hoc comparisons (Tukey's range test) with a Bonferroni correction were
235 performed for the vowel's place of articulation in order to assess comparisons between the sexes in
236 each syllable. The general size effect was computed using Cohen's f^2 . A symbolic representation of
237 the regression formula is given in the supplementary material (Figure S1).

238 Temporal analyses

239 We assessed if the potential significant sound symbolic patterns found in the previous
240 analysis have evolved or remained constant over time between male and female French first names.
241 Pseudo-replication was allowed but phonetically equivalent, compound and monosyllabic names

242 were still excluded, as the aim is to study temporal variations in both the first and last syllable. This
243 resulted in a sample size of 897 female and 790 male names distributed across all decades. To
244 address the time series nature of the data, we first calculated all autocorrelations and partial
245 correlations between each time lag in order to assess if the frequency of a given phonetic variable is
246 dependent of its previous frequency. Vowel articulation was accounted as the number of each type
247 of vowel in each syllable and were centered around 0; with 0 corresponding to central vowels, 1 to
248 front vowels and -1 to back vowels. For vowel nasality, it was accounted as the proportion of each
249 vowel type: if values are close to 0, first names contain overall fewer nasal vowels, and conversely,
250 if values are close to 1, they contain more nasal vowels. For voiced and voiceless consonants, the
251 mean number in each syllable was studied. Linear models were then used to describe all the
252 temporal trends. To study possible non-linear effects of time, we modelled a cubic and quadratic
253 effect of decade. Sex was included as another explanatory variable and was put in interaction with
254 time. Model comparisons using the Akaike Information Criterion were then used to assess the best
255 describing model of the temporal variations.

256 All statistical analyses were performed using the R software (version 3.4.4).

257 **Results**

258 **a. Sex-bias sound symbolism**

259 We found a sex-bias sound structure in first names as a function of the syllable under study (Table
260 2).

261 In the last stressed syllable, significant clues of masculinity were given by the vowel place
262 of articulation ($\chi^2_2 = 11.82, p < 0.01$), nasality ($\chi^2_1 = 65.41, p < 0.001$) and voiceless fricatives (χ^2_1
263 $= 13.23, p < 0.001$). Namely, male names were significantly more prone to contain back vowels
264 like /o/ or /ɔ/ (e.g. ‘Enzo’, ‘Renaud’), instead of front or central ones such as /i/, /y/ or /a/
265 (respectively $t = 1.17, p < 0.01$; $t = 1.35, p < 0.01$; e.g. ‘Jackie’, ‘Luc’, ‘Bernard’). Although back
266 vowels can be found in female names (e.g. ‘Simone’, ‘Laure’), front and central vowels are more
267 common (e.g. ‘Emilie’, ‘Julie’, ‘Léa’, ‘Maria’) along with mid-front vowels such as /ɛ/ (e.g.
268 ‘Claire’, ‘Hélène’). Male names were also significantly more likely to contain nasal vowels such as
269 /ã/ or /õ/ (e.g. ‘Roland’, ‘Raymond’; female counter-examples: ‘Fernande’, ‘Marion’) and voiceless
270 fricatives such as /s/ or /ʃ/ (e.g. ‘Fabrice’, ‘Michel’; female counter-examples: ‘Clemence’,
271 ‘Blanche’). Probabilities of being a male name as a function of the type of vowel (oral and nasal)
272 are given in Figure 1.

273 Unexpectedly, in the first syllable, the probability of being a male name significantly
274 increased as a function of the number of voiced plosives ($\chi^2_1 = 12.59, p < 0.001$) such as /b/, /d/ or
275 /g/ (e.g. ‘Bernard’, ‘Dimitri’, ‘Gustave’; female counter-examples: ‘Brigitte’, ‘Deborah’,
276 ‘Gwenaëlle’). Within the first syllable, vowel articulation and nasality did not differ between sexes,

277 nor did the number of voiceless fricatives (all $p > 0.05$). Eventually, articulatory features explained
278 14% of the variation in sex differences and the Cohen's f^2 (0.17) suggests a moderate size effect
279 (Cohen, 2013).

280 **b. Temporal analyses from 1900 to 2009**

281 Trends investigated were the vowel's place of articulation, vowel's nasality, the number of voiced
282 plosives and voiceless fricatives in both the first and last syllable. All trends are shown in Figure 2.

283 Analyses of the autocorrelations and partial correlations revealed that the frequency of each
284 articulatory feature at a given timepoint is mostly independent of its previous frequency (most $p >$
285 0.05, all autocorrelations and partial correlations are given in the supplementary material, Table
286 S1).

287 The proportion of oral vowels across time in the last syllable of both male and female
288 names showed a cubic change ($F_{1,1686} = 14.01$, $p < 0.01$, Figure 2a) and the overall difference in
289 proportion between the sexes was significant ($F_{1,1686} = 33.41$, $p < 0.001$). Interestingly, female
290 names tended to be 'masculinized' (i.e., contained more central and back vowels, especially the
291 former) over time starting from the 1960's with convergent values between male and female names
292 towards 2009. In the first syllable, no overall difference in proportion was observed between the
293 sexes ($F_{1,1686} = 1.62$, $p = 0.22$), but both followed a quadratic temporal change ($F_{1,1686} = 38.71$, $p <$
294 0.001, Figure 2b). In the last syllable, the difference in proportion of names with nasal vowels was
295 different between male and female names ($F_{1,1686} = 117.25$, $p < 0.001$) and both remained more or
296 less constant over time ($F_{1,1686} = 1.46$, $p = 0.24$, Figure 2c). In the first syllable, a slight difference
297 of proportion was observed ($F_{1,1686} = 6.34$, $p < 0.05$), and both sexes followed a quadratic change
298 over time ($F_{1,1686} = 51.59$, $p < 0.001$, Figure 2d).

299 In the last syllable, no sex difference and no temporal change in the mean number of voiced
300 plosives were observed (respectively $F_{1,1686} = 1.11$, $p = 0.30$; $F_{1,1686} = 4.24$, $p = 0.054$, Figure 2e).
301 In the first syllable, overall difference in voiced plosives between the sexes was significant ($F_{1,789} =$
302 87.81, $p < 0.001$), but no change was observed over time (Figure 2f), although the interaction
303 between sex and a quadratic effect of time was significant ($F_{1,1686} = 8.48$, $p < 0.01$). Overall
304 differences in the mean number of voiceless fricatives between the sexes was found in the last
305 syllable ($F_{1,1686} = 60.09$, $p < 0.001$). In both sexes, the mean number of voiceless fricatives
306 followed a cubic evolution through time ($F_{1,1686} = 12.46$, $p = 0.023$, Figure 2g), and an interaction
307 between sex and time revealed significant ($F_{1,1686} = 30.66$, $p < 0.001$). Lastly, the mean number of
308 voiceless fricatives in the first syllable for both sexes linearly varied over time ($F_{1,1686} = 31.50$, $p <$
309 0.001, Figure 2h) and an overall difference between the sexes was observed (respectively $F_{1,1686} =$
310 103.32, $p < 0.001$). The interaction between sex and time was also significant ($F_{1,1686} = 55.59$, $p <$
311 0.001).

312 Discussion

313 French first names exhibited sex differences in the distribution of vocalic sounds: low
314 frequency vowels (i.e., back and nasal) were more likely to be found in masculine names while
315 higher frequency vowels (i.e., front and non-nasal) as well as central vowels (i.e., /a/) were more
316 frequent in female names.

317 This sex-biased sound symbolism pattern was found in the last syllable, which is
318 perceptually prominent in French, while in English, a similar sex-biased symbolism was reported
319 for the first stressed syllable (Pitcher *et al.*, 2013). However, regarding consonants, our results were
320 more unexpected. Indeed, the mean number of voiceless fricatives (i.e., /f/, /s/ and /ʃ/; e.g. ‘Joseph’,
321 ‘Alexis’, ‘Michel’) was higher in male than female names within the final stressed syllable (e.g. of
322 female names: ‘Delphine’, ‘Clarisse’). This is surprising according to the ‘Frequency-Code’ theory
323 since their higher domain of frequency, relatively to voiced consonants, would rather be associated
324 with indexical cues of smallness. The second unexpected finding was the presence of voiced
325 plosives in the first syllable (i.e., /b/, /d/ and /g/; e.g. ‘Bernard’, ‘David’, ‘Gabriel’; e.g. of female
326 names: ‘Brigitte’, ‘Geraldine’), which is theoretically perceptually non-prominent in French. A
327 possible explanation is that these consonantal patterns may perceptually compensate each other, by
328 which the presence in masculine names of voiceless fricatives in the last stressed syllable is
329 perceptually counterbalanced by the presence of voiced consonants in the unstressed one.
330 Otherwise, in a more general manner, vowels and consonants in the first and last syllable may be
331 perceptually associated to different physical qualities. In this sense, while oral and nasal vowels
332 could refer to body size, consonants might evoke other qualities such as shape or speed (Berlin,
333 2006). For instance, it has been shown that people perceive a form as rounder if its signifier
334 contains voiced consonants (such as /b/, /m/, /l/ or /n/) and as sharper if it contains voiceless stops
335 (such as /k/, /p/, /t/) (Sidhu and Pexman, 2015; Nielsen and Rendall, 2013; Maurer *et al.*, 2006). In
336 the case of voiced plosives in the first syllable of male names, another explanation can be invoked
337 as it is in accordance with results observed in American and Indian forenames (Slepian and
338 Galinsky, 2016). The authors showed a voiced gender naming effect, whereby the initial phonemes
339 of masculine first names were voiced, as opposed to unvoiced in feminine names. They argued that
340 voiced phonemes would sound ‘harder’ as a consequence of the vocal folds vibrating during
341 pronunciation, whereas unvoiced phonemes will sound ‘softer’ to the ear as a consequence of
342 unmodulated airflow, which in both cases would perceptually reinforce the stereotyped
343 representations of males and females having respectively ‘tougher’ vs. ‘tender’ personalities and
344 behaviors. Interestingly, the endorsement of these traditional gender stereotypes related to these
345 ‘tougher/harder’ vs. ‘softer/tender’ dimensions moderated the influence of voiced and unvoiced
346 phonemes on masculine vs. feminine judgments.

347 The name selected by parents for their offspring is, most of the time, linked to the assigned
348 sex at birth, probably because such an information takes on great importance in both the perception
349 of the bearer's sex properties by conspecifics in the social environment, and in the bearer's
350 reinforcement of sexual identity and gender role (Pilcher 2016). In human societies, males and
351 females have distinct roles and different reproductive strategies (Schmitt, 2015). Due to the
352 associated sex-sound symbolism, giving a masculine or feminine name to conform to sex
353 stereotypes could thus be seen as a form of parental investment with a lifelong lasting effect.
354 Although these effects have not been measured yet in reproductive value, it remains to be shown
355 whether or not it influences fitness-related traits. But the fact that most first names are sex-specific
356 suggest that they are not fully socially neutral, and many studies have disclosed the influence of
357 given names on some social trait, such as social desirability (Gebauer *et al.*, 2012; Busse and
358 Seraydarian, 1978) and social outcomes (Cotton *et al.*, 2008; Figlio, 2005; Hodson and Olson,
359 2005; Harari and McDavid, 1973). For instance, several studies have shown that having only the
360 information of a masculine or feminine name already influences the bearer's job's and career's
361 outcomes (Kasof, 1993; Moss-Racusin *et al.*, 2012; Steinpreis *et al.*, D., 1999).

362 But while our results support the idea that humans possess a cognitive bias to assign
363 different phonetic material to either sex, the relatively small amount of variance explained in sex
364 differences (~14%) and the relatively modest size effect (Cohen's $f^2 = 0.17$) suggest that other
365 factors other than sexually sound symbolic patterns need to be considered when parents choose a
366 particular name for their child. Evidence shows that the cultural environment is undeniably one of
367 them (Acerbi and Bentley, 2014; Barucca *et al.*, 2015; Bentley *et al.*, 2004; Berger *et al.*, 2012; Xi
368 *et al.*, 2014). For instance, Bentley *et al.* (2004) have shown that name distributions and changes
369 over time followed power laws, which were predicted by a simple mechanism of cultural drift and
370 random copying between individuals, assuming that names are value-neutral in regards to fitness.
371 Other models have been used to describe their distributions across time and space, the rate of
372 innovation and their diversity, such as activation-inhibition processes (Zanette, 2012), individual
373 preferences and social influence (Xi *et al.*, 2014) and spatial-temporal homogeneity (Bentley and
374 Ormerod, 2012). Most interestingly, Berger *et al.* (2012) have shown that names are more likely to
375 be chosen when similar-sounding names in terms of phonetic similarity (i.e., sharing phonemes and
376 their position within the name) have been popular the previous year, regardless of the names'
377 gender. For instance, their model predicted that the popularity of the name 'Karen' depended on
378 popular names that possessed the same first phoneme (i.e., /k/), such as 'Carl' (a male name) and
379 'Katie' (a female name). Predicted popularity was also correlated to other cultural items such as
380 hurricanes' names (i.e., 'Katrina'), suggesting a strong effect of other cultural items on naming
381 processes.

382 In this context, the temporal variations of the articulatory features suggest a strong effect of
383 culture, given the somewhat stochastic variations of some phonetic variants, such as the frequency
384 of occurrence of voiced plosives and voiceless fricatives. Nonetheless, we feel that a particular
385 attention should be given to the vowel's place of articulation. Its evolution in the stressed syllable
386 of female first names suggests that high frequency sounds were considered as most feminine in the
387 1960's, a period after which we notice an increase of phonetic masculinization that continues up to
388 2009. For instance, names with front vowels (e.g. 'Marie') in the early 1900's are more frequent
389 than those with central and back vowels (e.g. 'Léa', 'Manon'), which increase in frequency in
390 1960's up to the 2000's. Interestingly, an earlier study dealing with the evolution of feminization
391 across the last century has shown that the 'ideal' waist-to-hip ratio (WHR), an important
392 component of men's mate preferences, seemed to have followed the same trend in a westerner
393 society. This 'ideal' WHR, as assessed through Playboy models and Miss pageants from 1920 to
394 2014, is most feminine in the 1960's (lower WHR values) then becomes less and less feminine
395 until the 2010's (higher WHR values) (Bovet and Raymond, 2015). Additionally, a meta-analysis
396 on the self-perception of femininity and masculinity, as assessed through the Bem Sex-Role
397 Inventory and the Personal Attributes Questionnaire, showed that American women perceived
398 themselves as more masculine over time from the early 1970's to the mid 1990's (Twenge, 1997),
399 with additional findings demonstrating a decrease in endorsing feminine traits in women after the
400 2000's (Donnelly and Twenge, 2017). Two other meta-analyses investigating women's own
401 assertiveness from 1931 to 1993 showed that it decreased from 1946 to 1967, but increased from
402 1968 to 1993 (Twenge, 2001). Such changes from the 1960's might be closely linked to historical
403 political feminists' movements particularly active in this era during which awareness of inequalities
404 in civil rights and social positions has been increasing. We hypothesize that one possible strategy to
405 compensate such inequalities is to masculinize some traits in women in order to compete against
406 men for the same rights and privileges, at least in industrialized and traditionally male-dominated
407 societies.

408 **Conclusions**

409 Overall, the present study offers some promising opportunities for follow-up studies that would
410 lead to a better understanding of naming processes. An interesting avenue for further research
411 would be to model the relative importance of different selective pressures (sexual and cultural, or a
412 joint effect) acting on the phonetic dimorphism, names' frequency and the emergence of novel
413 names. Most importantly, to fully acknowledge the action of sexual selection on the phonetic
414 dimorphism, a study on names and their relationship to reproductive value is required. One
415 limitation is that not all names from each decade were analyzed and a particular attention should be
416 given to rare names in order to strengthen the present results. Moreover, particular attention should

417 also be given to syllables between the first and last ones, as they can potentially play a particular
418 role. Further inquiries in sound symbolic patterns in first names in dead and modern languages
419 should be investigated, so as to find some universal components in vowel quality to convey
420 perceived masculinity and femininity.

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426 **Author contributions**

427 A.S. and A.B.M. wrote the paper. A.S. and M.B.D. transcribed the data. A.S., A.B.M and M.R.
428 analyzed the data. M.B.D. and M.R. supervised the study.

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432 **Conflict of Interest**

433 None.

434 **Data access**

435 The data and the R code are available at <https://figshare.com/s/5618e367fae4c5774272>

436

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671 **List of figures and tables**

672 Table 1. Examples of first names for each phoneme investigated (underlined).

Type of phoneme	Phonemes	Frequency domain	Name examples
Front vowels	/i/, /y/, /e/, /ø/, /ɛ/	High	<u>Ma</u> rie, <u>Lu</u> c, Cécile, <u>Eug</u> ène, <u>Od</u> ette
Central vowels	/a/, /ə/	Central	<u>Je</u> anne, <u>De</u> nise
Back vowels	/u/, /o/, /ɔ/	Low	<u>Lo</u> , <u>Re</u> naud, <u>Pa</u> ul
Nasal vowels	/ã/, /ẽ/, /õ/	Low	<u>Ant</u> oine, <u>Syl</u> vain, <u>Ray</u> mond
Voiced plosives	/b/, /d/, /g/	Low (voicing) Low (manner of articulation)	Nor <u>be</u> rt, <u>Clau</u> de, <u>Guy</u>
Voiced fricatives	/ʒ/, /v/, /ʁ/, /z/	Low (voicing) High (manner of articulation)	<u>Je</u> an, <u>Val</u> érie, <u>Suz</u> anne, <u>Clai</u> re
Voiceless plosives	/p/, /t/, /k/	High (unvoiced) Low (manner of articulation)	<u>Pie</u> rré, <u>Thi</u> bault, <u>Ni</u> colas
Voiceless fricatives	/ʃ/, /f/, /s/	High (unvoiced) High (manner of articulation)	<u>Cha</u> rlotte, <u>Fabri</u> ce, <u>Sola</u> nge,

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674 Table 2. Results of the generalized linear model. For each predictor, the estimate, standard error of
 675 the mean, the χ^2 , the degrees of freedom and the p values associated from the likelihood ratio test
 676 of the comparison between the full model and the model without the predictor are given. For the
 677 categorical variables ‘Vowel place of articulation’ and ‘Nasality’, the estimates are given compared
 678 to the reference category (front and non-nasal vowels, respectively) for both syllables. Pseudo-R² is
 679 the variance explained by the model (adjusted by the number of predictors) and Cohen’s f^2 the
 680 overall size effect. Significant p values are in bold.

Pseudo-R ² = 0.14 Cohen’s f^2 = 0.17 N total = 472 n female = 275 n male = 197	Estimate	Standard error	χ^2	df	p
	Intercept	-0.69	0.18		

First syllable

Vowel place of articulation			0.27	2	0.87
Central vowel	-0.12	0.25			
Back vowel	-0.11	0.29			
Nasality			0.33	1	0.56
Nasal vowel	0.31	0.54			
Voiced plosives	0.38	0.11	12.59	1	<0.001
Voiced fricatives	0.16	0.10	2.33	1	0.12
Voiceless plosives	0.10	0.10	0.96	1	0.32
Voiceless fricatives	-0.09	0.11	0.74	1	0.38
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Last syllable					
Vowel place of articulation			11.82	2	<0.01
Central vowel	-0.18	0.24			
Back vowel	1.17	0.38			
Nasality			65.41	1	<0.001
Nasal vowel	2.62	0.38			
Voiced plosives	0.14	0.10	1.83	1	0.17
Voiced fricatives	0.12	0.10	0.41	1	0.23
Voiceless plosives	0.04	0.10	0.12	1	0.72
Voiceless fricatives	0.39	0.10	13.23	1	<0.001

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682 Figure 1. Estimates of the generalized linear model, log back-transformed to provide the
683 probabilities of a name belonging to a male in function of the presence of a particular A) oral vowel
684 and B) nasal vowel. Bars represent the mean probability associated with 95% confidence intervals.
685 Significance code from the post-hoc comparisons: ‘***’ $p < 0.01$; ‘*’ $p < 0.05$; ‘NS’ non-significant.
686 Figure 2. Barplots (mean \pm standard-error) of the temporal variations for each decade from 1900 to
687 2009 of each articulatory feature that revealed significant in the sound symbolic patterns analysis.
688 Female first names are represented in light blue and male first names in deep blue. The vowel’s
689 place of articulation is represented in a) last syllable and b) first syllable. Vowel’s nasality in the c)
690 last syllable and d) first syllable. Mean number of voiced plosives are represented in the e) last
691 syllable and f) first syllable. Lastly, mean number of voiceless fricatives are represented in the g)
692 last syllable and h) first syllable. Vowel articulation accounts for the number of each type of vowel
693 in each syllable and were centered around 0; with 0 more central vowels, 1 more front vowels and -
694 1 more back vowels. For vowel nasality, it accounts for the number of each vowel type: if values
695 are close to 0, first names contain fewer nasal vowels, and conversely, if values are close to 1, they
696 contain more nasal vowels.