

1 **Sensory Exploitation, Sexual Dimorphism, and Human Voice Pitch**

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28 **Abstract**

29 Selection for low male voice pitch is generally assumed to occur
30 because it is a valid cue of formidability. Here we summarize recent empirical
31 challenges to this hypothesis. We also outline an alternative account in which
32 selection for low male voice pitch is a byproduct of sensory exploitation.

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34 **Main text**

35 The most popular hypothesis for why men have lower voice pitch than
36 women do is that low male voice pitch has been selected for because it is a
37 valid cue of critical aspects of formidability, such as physical strength and
38 large body size, meaning that men with lower voice pitch will be more
39 successful in intrasexual competition [2]. This hypothesis is based on the
40 results of studies showing that experimentally lowering pitch in recordings of
41 men's voices increases perceptions of both their dominance and physical size
42 [2]. A small number of studies have also reported that men with lower voice
43 pitch tend to have greater upper body strength and larger body size [e.g., 2].

44 Although this hypothesis has been highly influential, the results of
45 many recent empirical studies have challenged the claim that low voice pitch
46 is a valid cue of men's formidability. For example, several studies have found
47 no evidence for a significant negative relationship between voice pitch and
48 measures of men's upper body strength [3]. Indeed, the correlations between
49 voice pitch and upper body strength reported previously would not have been
50 significant if corrected for multiple comparisons, suggesting they were not
51 robust. Moreover, a meta-analysis of the putative relationship between voice
52 pitch and body size estimated that a sample size of at least 610 men would be
53 required to detect a significant negative relationship between men's voice
54 pitch and body size [4]. Such a relationship would explain, at most, ~2% of
55 variance, suggesting that the relationship between men's body size and voice
56 pitch is unlikely to be ecologically meaningful. Collectively, these results
57 suggest there is little compelling evidence for a relationship between voice
58 pitch and formidability in men, challenging the claim that low voice pitch is a
59 valid cue of men's formidability.

60 If low voice pitch is not a valid cue to men's formidability, why are men
61 with lower pitched voices perceived to be more dominant and why has low

62 male voice pitch been selected for? One possibility is that selection of low
63 male voice pitch simply reflects sensory exploitation of an evolutionarily old
64 pre-existing bias for organisms to react to objects that emit lower-frequency
65 vibrations [6].

66 Sensory exploitation theories of sexual selection suggest that males
67 with traits that elicit high amounts of stimulation from sensory systems are
68 more successful [5]. Over evolutionary time, selection ramps up the frequency
69 and size of those traits via female choice [5]. In the sensory exploitation
70 theory of sexual selection, preferences for traits do not have to be adaptive in
71 their own right, but can be byproducts of neural responses that evolved to
72 deal with different (i.e., unrelated) evolutionary pressures [5].

73 When struck with a stick, larger rocks emit lower-frequency vibrations.
74 This tendency for larger objects to emit lower-frequency vibrations is a simple
75 physical property of the world [1]. In line with this rule, people implicitly ascribe
76 largeness to low pitch in non-biological auditory stimuli, such as pure tones
77 [6], in exactly the same way as they do to men's voices [7]. In fact, people
78 continue to ascribe greater largeness to lower-pitched voices when the
79 pitches of these voices are well outside of the human vocal range [8]. The
80 perception that low pitch is large and frightening is evident across the animal
81 kingdom, suggesting it is evolutionarily old [6]. The tendency to perceive men
82 with lower voice pitch to be larger is equally evident in congenitally blind and
83 sighted participants, further suggesting it requires no visual learning [9].

84 The results described above suggest that people apply a general "low
85 pitch is large" heuristic when processing auditory stimuli. Thus, the tendency
86 to ascribe greater size and dominance to lower-pitched voices may simply be
87 a byproduct of this heuristic [10]. Further evidence that low pitch influences
88 size perception via such a heuristic, rather than because it is a valid cue of
89 body size, comes from research investigating the effects of voice cues on the
90 neural representation of body size. Voice pitch influences size representations
91 via different neural processes than those used to process valid cues of body
92 size in humans [11].

93 How might this general "low pitch is large" heuristic lead to selection for
94 male voices with low pitch? We propose two possible, non-mutually exclusive
95 routes. First, the "low pitch is large" heuristic could lead to selection for male

96 voices with low pitch via female choice if, all other things being equal, men
97 with low pitched voices exploit the sensory bias for women to be attracted to
98 large sounding men. Consistent with this possibility, experimentally lowering
99 voice pitch in men's voices has a positive effect on their attractiveness,
100 particularly to women [12]. Second, the "low pitch is large" heuristic could lead
101 to selection for male voices with low pitch via intrasexual selection if, all other
102 things being equal, men with lower voice pitches are more likely to succeed in
103 competition for resources because they exploit a bias that makes them sound
104 larger and more intimidating to other men. Consistent with this possibility,
105 experimentally lowering voice pitch in men's voices has a positive effect on
106 their perceived dominance [12]. Crucially, neither of these possibilities
107 requires voice pitch to be a valid cue of body size or formidability, meaning
108 that they are perfectly compatible with research suggesting voice pitch is not
109 related to men's body size or strength. Selection against low voice pitch in
110 women would also be expected under this account since perceptions of large
111 body size are typically negative correlated with women's attractiveness [13].
112 The possibility that voice pitch is a cue of men's immunocompetence,
113 previously discarded [2], might also be re-evaluated, although evidence for an
114 association between men's immunocompetence and voice pitch is equivocal
115 [14,15]

116 In summary, some empirical work challenges the common assumption
117 that selection for low male voice pitch occurs because it is a valid cue of
118 formidability. We suggest that sensory exploitation is a more parsimonious
119 explanation for the marked difference in men's and women's voice pitch.
120 Studies and experiments testing competing predictions from these honest
121 signaling and sensory exploitation accounts are likely to be a fruitful line of
122 inquiry into the reasons for sex differences in voice pitch.

123

124 **Text box**

125 **What is human voice pitch?**

126 Voice pitch is the perception of vocal fundamental frequency and/or the
127 corresponding harmonics that result from vocal fold vibration [1]. Larger,
128 thicker vocal folds produce vocalizations with lower fundamental frequency
129 [1]. Human vocal folds change in length and thickness as we age. Voice pitch

130 changes particularly dramatically during puberty, when reproductive
131 hormones accelerate vocal fold growth [1]. There is a striking sex difference in
132 human voice pitch; men's voices are typically an octave lower in pitch than
133 are women's voices [1]. Much of the research on human voice production and
134 perception attempts to understand the factors that drove the evolution of this
135 large and reliable sex difference.
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