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What Signals Physical Strength in a Voice?

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In the animal world, physical strength is more often signaled than tested in outright combat. Bigger is generally synonymous with stronger, which is why the bullfrog inflates his throat with an air sac, a cobra widens its neck from the frontal aspect, an elk grows a large rack of antlers, and furry or feathered animals puff themselves up. It also is understood in the animal world that low-pitched sounds usually emanate from larger species (e.g., the great cats or elephants) and high-pitched sounds emanate from small species (e.g., insects and birds). But several confounding factors challenge a universal rule that low pitch predicts large body size, which in turn predicts physical strength.

One problem is that sound has to be radiated from an opening in the body. Physical laws of acoustics dictate that higher frequencies radiate better from a small opening (like the mouth or the nostrils) than lower frequencies. Thus, high-pitched sounds are released with greater intensity, all else being equal. Given that loudness is also part of the perception of physical size and strength (bigger sound sources drive more air, acoustically, and might produce more intensity), there is at once a conflict in the judgment of size by sound intensity alone. Is the sound intense because of its high frequency or because there is a lot of air in motion? By the intensity criterion alone, a mosquito buzzing around your head might appear more threatening than a croaking frog nearby.

A second problem is that flexing muscles, a typical gesture to beef up and show larger size, stiffens body tissues. But in the larynx, stiffening tissue generally raises pitch (neglecting some slackening of vocal fold cover tissue when the thyroarytenoid muscle contracts). Thus, a high pitch may signal muscular prowess. The Rocky Mountain elk stag is known for his display of high-pitched bugle calls (around 1000 Hz, roughly the soprano high C, or C_6) during the rut season. Apparently this signals strength to a competing male or a courted female. The European red deer, about the same size and very similar in appearance, does not bugle. His courting vocalizations are low-pitched roars.

In humans, the confusion is equally present. In some cultures or settings, authority and dominance is signaled by high-pitched vocalization (e.g., the Japanese Samurai or the Nazi Gestapo), while in others authority is conveyed by low-pitched vocalization (e.g., American advertisement of manly products, such as beer and trucks).

In nineteenth century opera, strength is portrayed with so-called dramatic voices. These voices, loud and rich in timbre, can encode deep emotions. In Verdi's operas, the men and women of strength (the heroes and heroines) are

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mostly tenors and sopranos, preferably the spinto types (somewhat driven in their production). The spinto characteristic may signal muscle strength. There is often a bit of inharmonicity (noise between the harmonics) in spinto voices, perhaps suggesting to the listener that "I can drive the system hard without doing damage." But there is also strength in wisdom and authority, for which a low voice (*basso profundo*) was preferred by Mozart in the role of Sarastro in *Die Zauberflöte*.

There is yet another factor that must be considered, our auditory capability. The human auditory system is most responsive in the 1000–3000 Hz region. This means that the energy we produce with the fundamental frequency (the lowest frequency in the complex frequency spectrum we produce) generally doesn't get the preferential treatment by a listener. It is the higher harmonics that reside in the "sweet spot" of the ear. Hence, singers have learned to cultivate the singer's formant cluster, a special ring in the voice. This ring often signals vocal strength on the opera stage. Judging by its pitch alone, this ring should emanate from a small bird or a mosquito, not from a large human.

In summary, there is not clear feature in a voice that signals physical strength. There are trade-offs in frequency and air volume set into motion that affect the physics of sound radiation and transmission to the listener. Intense sounds do not always come from the largest objects, nor is perceived loudness directly related to intensity. This gives us all a chance to portray strong and weak characteristics with our voice, regardless of our body size.

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