On production mechanisms of group howling by Canis lupus: A case study

Conference Paper · July 2024

3 authors, including:

Axel G. Ekström
University of Neuchâtel
48 PUBLICATIONS **108** CITATIONS

SEE PROFILE

Linda Scheider Oña
Leipzig University
33 PUBLICATIONS **539** CITATIONS

SEE PROFILE

On production mechanisms of group howling by *Canis lupus*: A case study

Axel G. Ekström[1], *Manon Delaunay*[2], *Linda Oña*[2]

[1]KTH Royal Institute of Technology, Sweden [2]Leipzig University, Germany

axeleks@kth.se

Abstract

We present early work on the production of howls by Hudson Bay wolves (*Canis lupus hudsonicus*). During vocalizations, jaw height appears mostly constant at a distinctly lowered position. We computed predicted first formants for a vocal tract length of appropriate size, with a flared oral cavity. Results are consistent with the grey wolves engaging in formant tuning, matching the fundamental frequency of phonation with the first resonant frequency of the vocal tract, amplifying the signal and increasing its loudness.

Index Terms: animal vocalization, phonetics, biomechanics, fundamental frequency, vocal tract

1. Introduction

In speech, the voice source from the vocal folds of the larynx is filtered by the shape of the supralaryngeal vocal tract, resulting in changes to its resonant properties or *formants, F_n* [1]. When the fundamental frequency (f_0) of a sound source (such as the human voice) is close to or matches the frequency of a formant, the perceived loudness of the sound can increase, making the sound seem more resonant and powerful. This phenomenon is referred to as formant tuning and is primarily known for its use in singing [2].

In nature, too, animals may engage in similar f_0–formant tuning to increase the loudness of a call or utterance. This behavior has been observed in other species, such as gibbons (*Hylobatidae* spp) [3] and Common marmosets (*Callithrix jacchus*) [4]. Here, we provide an interim report on work on the production mechanisms of affiliative howling in a Hudson Bay wolf (*Canis lupus hudsonicus*). We report on early results of a grey wolf articulator computational model, which provides support for the hypothesis that grey wolves may actively alter their jaw positions to tune F_1 to f_0.

2. Methods

2.1. Sample

The grey wolf (*Canis lupus*) is the largest extant canid species. The Hudson Bay wolf is one of over 30 extant subspecies of the genus, and is native to the tundra landscapes of the Queen Elizabeth Islands, northern Canada. Our data was collected by LO from a captive pack housed at Osnabrück, Germany during a period in January, 2023. Here, we sampled a single isolated howl as the focus of this case study.

2.2. Acoustics

f_0 was assessed manually using correlograms [5], a method based on waveform matching, known for its robustness to noise.

Figure 1: *Hudson Bay wolf (Canis l. hudsonicus) howling. Note that, the oral tract is visibly flared, as opposed to narrowed or rounded. In sustained howls, jaw height appears stable with little change throughout the utterance, suggesting non–randomness.*

This was done because the presence of multiple vocalizing individuals in the recordings, renders reliable estimation from automatic methods unrealistic.

2.3. Articulator model

To model vocal tracts, we used the *TubeN* software [6], based on [7], which computes vocal tract transfer functions based on the circuit theory established in [1] with wall losses by [8]. The mathematical bases of the program are described in [7].

2.3.1. Grey wolf vocal tract data

To our knowledge, there is no reported vocal tract length for any non–domestic dog (*Canis l. familiaris*) subspecies of grey wolf in the relevant literature. However, values reported for domestic dogs allow for a rough estimation. In particular, there is a near uniform correlation between the length of the skull and vocal tract length ($r = .962$), which is highly statistically significant at $p < .001$ [9]. The skull length for a Grey wolf has been measured at 23.6 cm [10], within the ranges reported for German shepherd specimens by [9]. These data allow for a rough estimate of a Grey wolf VTL at ≈ 22 cm; we assumed an otherwise linear tube at 4 cm^2. These length values may be overestimates as grey wolves are the largest extant canid, and Hudson Bay wolves are a medium-sized subspecies.

2.3.2. Oral tract flaring

Most mammals do not appear to move their tongue to affect formants [11]. However, in speech, F_1 is tied to jaw height [12]. Visual inspection of our howling strongly illustrates that howls

are produced with flared oral cavities (Figure 1), suggesting exploitation of a similar phenomenon. Namely, Flaring has the effect of shortening the effective length of the tract. Here, we estimated the effect of flared tubes according to the equation provided by Lindblom and colleagues in their work on the acoustics of spread lips and "notched" tubes [13]. In their framework, the effect of a "notched" segment can modeled as a shorter uniform segment, added to the length of the un–notched tube sequence.

Because attaining measurements of the length of the oral cavity flare from in–vivo vocalizing subjects is not feasible, we posited a "floor" at 3 cm, and a "ceiling" at 5 cm. According to computations by [13], a notch of 3 cm is approximated as a new segment of roughly 1.25 cm, added to the length of the "short" tube; a notch of 5 cm is approximated as a new segment of roughly 1.75 cm. The relationship is mostly consistent across segments of different diameter settings. Ultimately, it will be necessary to attain these measurements from the animals directly (i.e., by measuring the distance in cm from the labial commissures to the anteriormost portion of the face in a diseased specimen). Finally, as a control condition, we also computed F_1 for schwa for a vocal tract length of 22 cm.

3. Results

3.1. Fundamental frequency

For our selected howling utterance (approximately 3.36 s), we observed a largely consistent f_0 maintained throughout the utterance ($M = 459$ Hz, $SD = 16.57$ Hz).

3.2. Effect of flaring

Our computer models predicted an upward–shifting effect of flaring on F_1. For the "floor" (flare = 3 cm) $F_1 = 436$ Hz; for the "ceiling" (flare = 5 cm), $F_1 = 471$ Hz. Consistent with the hypothesis that howling involves tuning f_0 and F_1, the formant frequencies predicted by the flared models closely approximated the estimated f_0 – markedly more so than F_1 predicted for a schwa at vocal tract length = 22 cm (Figure 2).

4. Discussion

Much remains unexplored about how sounds are produced by animals. The present work contributes to this emergent picture by positing a framework capable both of reconstructing (or reverse engineering) animal vocalization resonance frequencies, and explaining them as factors of mammalian articulation. In this case study, we made several simplistic assumptions informing our vocal tract models. In the future iterations, letting real–life anatomical data inform our models would provide for more reliable results. Finally, howling is a stereotypically social behavior that typically engages several members of a pack. Our results, if verified, may indicate that a pack of howling grey wolves maintain territorial boundaries [14] by engaging in simultaneous formant tuning.
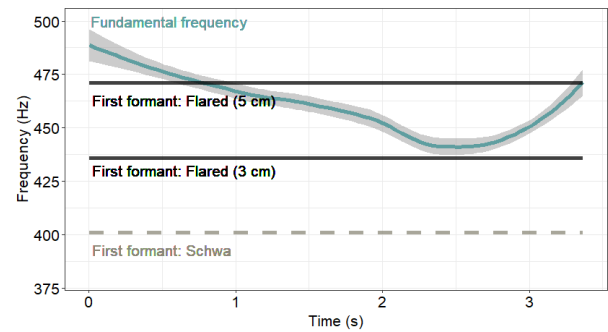
5. Acknowledgements

Figure 2: *Assuming a "flare" of 3 to 5 cm results in a computer model predicted F_1 which more closely approximates f_0 than that predicted for schwa. This is consistent with the hypothesis that grey wolves tune the resonant properties of the oral tract to the f_0.*

6. References

[1] G. Fant, *The acoustic theory of speech production.* The Hague: Mouton, 1960.

[2] J. Sundberg, *The science of the singing voice.* Northern Illinois University Press, 1987.

[3] H. Koda, T. Nishimura, I. T. Tokuda, C. Oyakawa, T. Nihonmatsu, and N. Masataka, "Soprano singing in gibbons," *American Journal of Physical Anthropology*, vol. 2, no. 149, pp. 347–355, 2012.

[4] H. Koda, I. T. Tokuda, M. Wakita, T. Ito, and T. Nishimura, "The source-filter theory of whistle-like calls in marmosets: Acoustic analysis and simulation of helium-modulated voices," *The Journal of the Acoustical Society of America*, vol. 6, no. 137, pp. 3068–3076, 2015.

[5] S. Granqvist and B. Hammarberg, "The correlogram: A visual display of periodicity." *The Journal of the Acoustical Society of America*, vol. 114, pp. 2934–2945, 2003.

[6] K. Zhang, R. Song, R. Tu, J. Edlund, J. Beskow, and A. G. Ekström, "Modeling, synthesis and 3D printing of tube vocal tract models with a codeless graphical user interface," in *Proceedings from FONETIK 2024*, Stockholm, Sweden, June 2024, pp. 155–160.

[7] J. Liljencrants and G. Fant, "Computer program for VT-resonance frequency calculations," *STL-QPSR*, pp. 15–21, 1975.

[8] G. Fant, "Vocal tract wall effects, losses, and resonance bandwidths," *STL–QPSR*, vol. 2, pp. 28–52, 1972.

[9] T. Riede and W. T. Fitch, "Vocal tract length and acoustics of vocalization in the domestic dog (canis familiaris)," *Journal of Experimental Biology*, vol. 202, pp. 2859–2867, 1999.

[10] B. van Valkenburgh, B. Pang, D. Bird, A. Curtis, K. K. Yee, C. J. Wysocki, and B. A. Craven, "Respiratory and olfactory turbinals in feliform and caniform carnivorans: The influence of snout length," *The Anatomical Record Advances in Integrative Anatomy and Evolutionary Biology*, vol. 297, pp. 2065–2079, 2014.

[11] W. T. Fitch, "The phonetic potential of nonhuman vocal tracts: comparative cineradiographic observations of vocalizing animals," *Phonetica*, vol. 2-4, no. 57, pp. 205—-218, 2000.

[12] B. E. Lindblom and J. E. Sundberg, "Acoustical consequences of lip, tongue, jaw, and larynx movement," *The Journal of the Acoustical Society of America*, vol. 4B, no. 50, pp. 1166–1179, 1971.

[13] B. Lindblom, J. Sundberg, P. Branderud, and H. Djamshidpey, "On the acoustics of spread lips," in *In Proceedings of Fonetik 2007.* Stockholm, Sweden: TMH-QPSR, 50, 2007, pp. 13–16.

[14] F. H. Harrington, "Aggressive howling in wolves," *Animal Behaviour*, vol. 35, pp. 7–12, 1987.