Phonetic equifinality: Why an evolutionary timeline of phonological features is more challenging than we thought

This study introduces the concept of "phonetic equifinality" in speech evolution, highlighting how different species with differently shaped vocal tracts can produce acoustically similar sounds despite distinct articulatory constraints. Specifically, we investigate the production of [u]-like vowel sounds in great apes (Grawunder et al., 2022) and explore their articulatory strategies compared to human speech. The study consists of two parts: first, an acoustic analysis of [u]-like vocalizations in chimpanzees, gorillas, and orangutans; second, computer simulations of chimpanzee vocal tract configurations based on MRI data to determine the articulatory feasibility of producing such sounds.

Our findings indicate that great apes achieve [u]-like formant dispersions within boundaries imposed by species-specific constraints on articulation, including tongue retraction and subsequent "bunching" of the tongue root, and lip protrusion. However, their vocal tract morphology—characterized by a short pharynx and flat tongue—precludes identical articulation to human speakers speaking [u], which is characterized by a raised and "bunched" tongue body. These results challenge claims that primates possess a "speech-ready" vocal tract solely based on overlapping

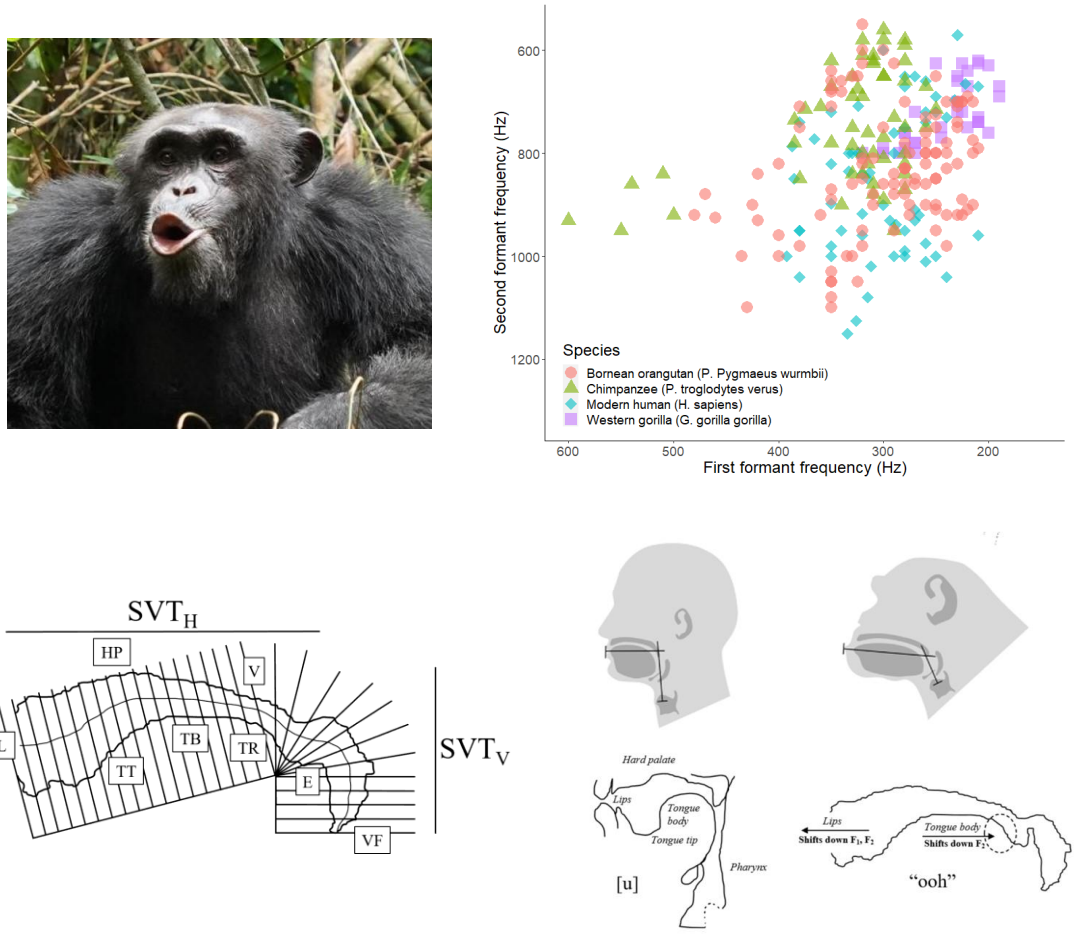

Figure 1. (Top Left) Chimpanzee "hoo's" exhibit apparent continuity with human rounded vowels. Photography credit @ Liran Samuni. (Top Right) Vowel-like spaces of adult chimpanzee, gorilla, orangutan males producing hoots, and modern human males speaking [u] (Peterson & Barney, 1952). (Bottom Left) The source of this apparent continuity can be addressed by analyzing and sectioning a chimpanzee vocal tract (tracing after Nishimura, 2005) as a sequence of equidistant segments. (Bottom Right) Such a comparative articulatory analysis reveals that, because humans and chimpanzees possess distinctly disparate vocal tract shapes , human [u] (Fant, 1971) and the chimpanzee hoo, reflect species-unique constraints on articulation.

acoustic properties. Instead, this study emphasizes that biomechanical constraints must be considered when evaluating the evolutionary potentials of speech production.

Our research contributes to the debate on speech evolution by demonstrating that acoustic similarity alone is insufficient to establish a phylogenetic link between primate vocalizations and human speech. The phonetic equifinality problem underscores the need for articulatory verification in comparative vocal production studies. Our findings suggest that speech evolution involved not only neural changes (as has been consistently argued) but also significant modifications to the vocal tract, allowing for greater articulatory flexibility in early hominins.

These insights call for a reassessment of claims regarding primate speech potential and emphasize the importance of integrating anatomical and biomechanical perspectives in the study of vocal evolution. Our study also advances the understanding of how articulatory constraints shape vocal output across species, reinforcing the complexity of speech evolution beyond "mere" acoustic resemblance.

References

Grawunder, S., Uomini, N., Samuni, L., Bortolato, T., Girard-Buttoz, C., Wittig, R. M., & Crockford, C. (2022). Chimpanzee vowel-like sounds and voice quality suggest formant space expansion through the hominoid lineage. *Philosophical Transactions of the Royal Society B, 377*(1841), 20200455. doi: 10.1098/rstb.2020.0455

Fant, G. (1971). *Acoustic theory of speech production: with calculations based on X-ray studies of Russian articulations*. Mouton de Gruyter.

Nishimura, T. (2005). Developmental changes in the shape of the supralaryngeal vocal tract in chimpanzees. *American Journal of Physical Anthropology*, *126*(2), 193-204. doi: 10.1002/ajpa.20112

Peterson, G. E., & Barney, H. L. (1952). Control methods used in a study of the vowels. *The Journal of the Acoustical Society of America*, *24*(2), 175-184. doi: 10.1121/1.1906875