A COMPARATIVE APPROACH TO THE LARYNGEAL SOUND SOURCE OF PRIMATES: IMPLICATIONS FOR THE EVOLUTION OF SPEECH

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Human beings have the capacity of rapid changes in the shape of their vocal tract during speech production. This allows the production of formants providing the acoustic basis of vowels. Much research has been done to identify the capacity of non-primates to produce vowels (e.g. Fitch et al. 2016). However it would be erroneous to assume that the sound production of primates is limited to resonances in the vocal tract. There are many researches into the call of monkeys and apes showing that various species produce complex patterns of vocalizations for communication. The comparative anatomy and physiology of the monkeys and apes larynx reveal many important features on the sound source. The monkeys and apes larynges differ one from another and those of humans in size, intranarial position and also by the presence of air sacs. There is little doubt that most monkeys and apes produce laryngeal sound source for specific purposes. Grunts hoot barks, pant-hoot, loud calls and chuckles are well known. Current views suggest that the non-human primate source generates an unstable glottal source. Some observations on the shape and structure of the vocal folds by Schön Ybara (1995) on platyrrhines, Starck and Schneider (1960) on Chimpanzees and Hirano (1991) reveal some characteristic features and the sound-producing capabilities of the non-human primate vocal folds. According to Schön Ybarra (1995), the non-human primate larynx appears to have more phonatory range, but less phonatory precision that that of humans. The comparison the acoustic output of gibbons, muriqui, chimpanzees, orangutan, bonobos and human vocalizations reveal some interesting features. Gibbons have long been recognized as producing elaborate and loud sounds. One interesting feature of these calls is that the sound source is predominantly produced by a whistled source (i.e. with an almost pure sinusoidal waveform (Figure 1)).

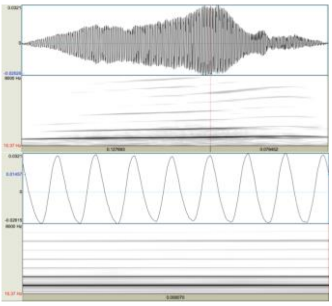

Figure 1. Audio waveform, narrowband spectrogram and a zoom of the waveform taken at the level of the cursor for a Gibbon whistled sound.

The fundamental frequency (F0) of these calls is often above 500 Hz and produces a spectrum with distant harmonics. This high F0 is intense and likely ideal for long distance propagation in dense rain forest. The best explanation so far for this whistled sound source is that it is produced between two stretched and non-oscillating vocal folds. The space between the arytenoids and the vocal folds acts as a kind of whistle. This type of whistled sound source is also observed among various monkeys and apes species such as muriqui, chimpanzees and bonobos. The comparative anatomy of gibbon, chimpanzee, bonobo and human show that the thickness of the vocal folds and the ratio between the respiratory glottis, made of the inter-arytenoid space, and the membranous glottis varies from one species to the other. This configuration of the glottis is found in other species where whistled sound sources are observed (it is even found with horses). Bonobos where the inter-arytenoid space occupies a large part of the glottis show an interesting feature that is the combination of a whistled and a low frequency sound source, i.e. a double source (Figure 2).

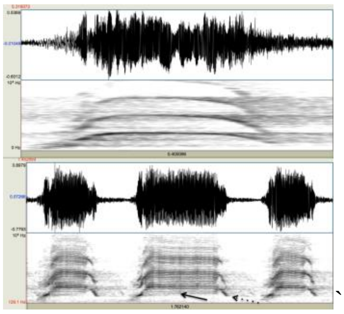

Figure 2. Audio waveform and narrowband spectrogram of a whistled Bonobo vocalization and three repetitions of a double source Bonobo vocalization. Arrows show the harmonics produced by the membranous glottis and by the whistled source between the inter-arytenoid space.

This is the combination of a whistled source produced in the inter-arytenoid space and the vibration of the membranous glottis situated in front of the arytenoid cartilages. These observations resulting from the comparison of anatomical data and the acoustics of non-human primate vocalizations suggest that one aspect the sound source's evolution in primates could have been the evolution from a whistled sound source with a high F0 to a lower frequency sound source. The change from whistled sources to lower frequency vibrations produced by oscillating vocal folds would eventually be the result of the increase in the size of the membranous glottis and the shortening of the arytenoids length. The lower frequency is also the result of a larger, thicker and less stiff membranous glottis (Harrison 1995). These anatomical changes were also accompanied by slight changes in the nerve supply of the larynx. These comparative data suggest that small changes in the anatomy and physiology of the vocals folds and glottis dimensions played an important role in the evolution of the sound source in primates.

References

Fitch, W.T., de Boer, B., Mathur, N. & Ghazanfar, A.A. (2016). Monkey vocal tracts are speech-ready. *Sci. Adv*. 2016; 2: e1600723.

Harrison, D.F.N. (1995). *The anatomy and physiology of the mammalian larynx*. Cambridge. Cambridge University Press.

Hirano, M. (1991. Phonosurgical anatomy of the larynx. In '*Phonosurgery, assessment and surgical management of voice disorders*'. C.N. Ford & D.M. Bless (eds.). Raven Press. New-York.

Starck, D. & Schneider, R. (1960). Respirationsorgane. In *Primatologia* III/2. H. Hofer, A.H. Schultz and D. Starck (eds.). S. Karger Basel.

Schön Ybarra, M. A. (1995). A comparative approach to the non-human primate vocal tract: implications for sound production. In E. Zimmerman & J.D. Newman & U. Jurgens (eds.) *Current topics in primate vocal communication*. Plenum Press. New-York.