ACOUSTIC AND PERCEPTUAL EFFECTS OF AIR SACS

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All apes except humans have air sacs. Air sacs are large pouches that are connected to the vocal tract (figure 1A). Although there is debate about the function of air sacs, most authors agree that they have a function in vocalization. Their exact role in the evolution of speech has been identified by Fitch (2000) as an important open question. Air sacs are especially interesting, because there appears to be a direct correlation between the shape of the hyoid bone (a small bone to which the muscles of the larynx and the tongue are connected) and the presence or absence of air sacs in primates. When an air sac is present, the front of the hyoid bone has a distinctive concave shape, the *bulla*. In human hyoid bones as well as those of Neanderthals (Arensburg *et al.*, 1989) and *Homo heidelbergensis* (Martínez *et al.*, 2008) the bulla is absent, while in the hyoid bone of an infant *Australopithecus afarensis* (Alemseged *et al.*, 2006) it is present. Because of air sacs' potential relevance to vocalization, it is important to understand their effect on the acoustics and the perception of speech.

De Boer (2008) has developed mathematical and computational models. Air sacs have two important acoustic effects (figure 1B). The first is that the air sac creates an extra low-frequency resonance (around 200 Hz for the size of ape air sacs). The second is that the existing resonance frequencies of the vocal tract are shifted up and closer together. A priori, one would expect two effects: the extra low-frequency resonance might help an animal to sound bigger, and the shifting formant frequencies might make it harder to produce distinct speech sounds.

However, because of the extra resonance, the spectrum of a vocal tract with an air sac is qualitatively different from that of a vocal tract without an air sac and results from perception of human speech cannot be directly transferred to perception of signals generated with air sacs. This paper therefore presents first results of listening experiments that measure the difference between perception of signals generated by vocal tracts with and without air sacs. Three vocal tract models (corresponding to [a], [ə] and [y]) were constructed, and two sets of stimuli were generated, one with an air sac attached, and the other without. These stimuli will be presented to experimental subjects using adaptive threshold estimation (Kaernbach, 2001) to measure the signal-to-noise threshold for which distinctions between the signals can still be heard. Results from a first subject from a pilot study are given in figure 1C. It can be observed that the threshold for signals with an air sac is about 5dB higher than for signals without an air sac.

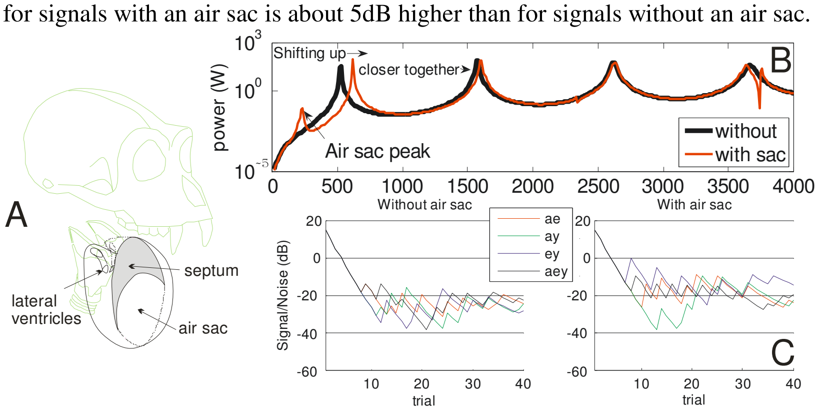

Figure 1. Schematic air sac anatomy of a gibbon (A), the acoustic effect of an air sac (B) and the threshold shift caused by the presence of an air sac (C).

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