THE PERCEPTUAL EFFECT OF AIR SACS

BART DE BOER

Amsterdam Center for Language and Communication, Universiteit van Amsterdam, Spuistraat 210, 1012VT, Amsterdam, the Netherlands

1. Introduction

This paper presents work on air sacs that extends the work presented by de Boer, (2008a). In that paper, and before (Fitch, 2000) air sacs were identified as a likely feature of our evolutionary ancestors that may have been lost because of the evolution of speech. In the mean time, a more accurate understanding of air sac acoustics has been achieved (de Boer, 2008b; Riede *et al.*, 2008). Ape-like air sacs modify the acoustics of a vocal tract in three ways: they add a low-frequency resonance (near the resonance frequency of the air sac itself), they shift up the resonances of the vocal tract without the air sac, and they shift these resonances closer together. The question that is addressed in the present paper is how these changes influence perception of the difference between vocalizations.

2. The experiment

Two sets of three stimuli were generated with a simple two-tube model (Chiba & Kajiyama, 1942) that modeled [a], [ə] and [y] with and without air sacs. Subjects (22 undergraduate students with normal hearing) were asked in two tasks to identify whether stimuli with noise were either [a] or [ə] and [a] or [y] using an unforced-choice adaptive threshold method (Kaernbach, 2001). This method

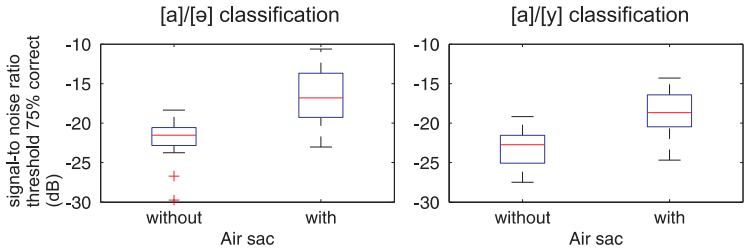

Figure 1. Box plots of classification performance on stimuli with and without air sac.

establishes the signal-to-noise ratio at which subjects perform halfway between chance and perfect classification (for two stimuli this is at 75% correct).

Figure 1 illustrates that subjects performed significantly better at classifying the stimuli without an air sac than at classifying those with an air sac ($p < 0.001$ with the Wilcoxon rank sum test). The difference in median threshold was 4.7 dB for classifying [a] and [ə] and 4.1 dB for [a] and [y].

3. Discussion

The higher signal-to-noise ratio required to classify stimuli with air sacs indicates that the perceptual distance between these stimuli is lower and that air sacs therefore reduce the acoustic difference that exists between articulations. This means that more articulatory effort is needed to make distinctive speech sounds when an air sac is present, lending support to the theory that humans have lost air sacs because of the evolution of speech. On the other hand, the difference is not very big. Therefore, other factors may be important as well. The extra resonance that air sacs provide has low frequency and this helps to exaggerate size. This might be less important for modern humans, and as air sacs do have important disadvantages (they can become infected, Lawson *et al.*, 2006), this might therefore also be a contributing factor to their disappearance.

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