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Vocal tract growth during ontogenesis: consequences for the debate on speech origins

Guillaume BARBIER, Louis-Jean BOË, Anne VILAIN

Département Parole et Cognition, GIPSA-lab, UMR 5216 (CNRS/INP) Grenoble, FRANCE

ELEMENTS OF THE DEBATE

Pharynx size is a controversial point for the study of the emergence of speech: **Is it necessary to have a low larynx to produce a sufficient contrast between the cardinal vowels [i], [a], and [u]?**

Vocal tract growth from birth to adulthood offers an observable variation in which the ratio between pharyngeal and oral cavity is evolving.

Ontogenetic data on the vocal tract morphology allow to test the influence of the size of the pharynx on speech production.

DATA

Longitudinal data: X-rays of head and neck of 68 subjects: 33 females, 35 males, from 1 month to 25 years.

Each 6 month/each year: A total of 966 X-rays.

Data from the orthodontic growth studies of Denver, Iowa, Michigan, and Oregon.

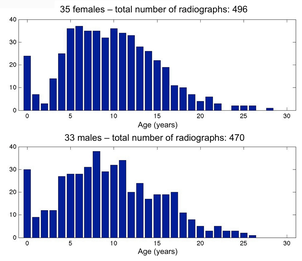


Figure 1 – Number of radiographs per age

LANDMARKS

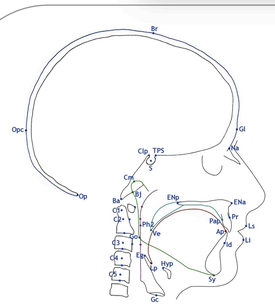


Figure 2 – The bony landmarks used in the study

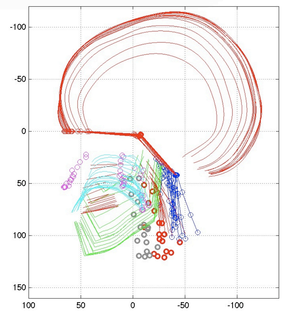


Figure 3 – The growth of a man from 1 month to 21 years

We have plotted 49 bony landmarks (fig. 2) and drawn the outlines of the skull, mandible, palate, pharyngeal wall and tongue.

It enables us to study the growth of the bony structures and of the vocal tract for each subject (fig. 3), for the male group, for the female group, and for the whole 68 subject group.

MAIN RESULTS

The descent of the hyoïd bone and of the glottis is correlated with the growth of the cervical vertebrae, as shown on fig. 4.

For males, this correlation is less important after 12 years, because of the growth of the thyroïd cartilage at puberty.

For females, the correlation between the vertical position of the cervical vertebrae and the glottis is very high for all ages.

This vertical co-evolution shows that pharynx size is correlated with the growth of the vertebrae. The average vocal tract length depends on pharynx size, because oral cavity length growth is very slow, fig. 6.

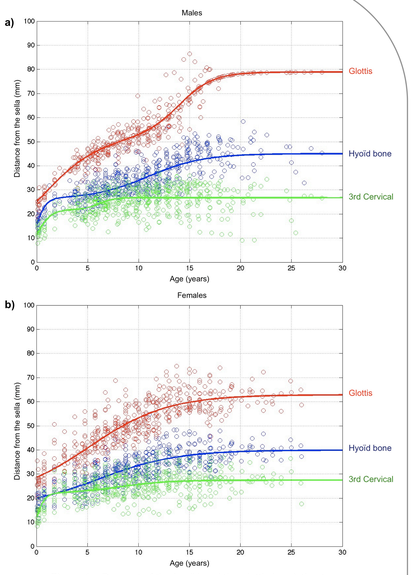


Figure 4 – Descent of the hyoïd and the glottis in relation to cervical vertebrae, for males (a) and females (b)

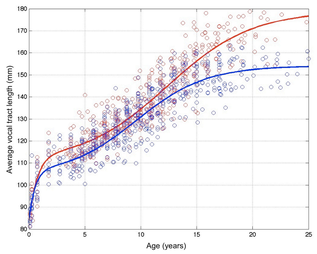
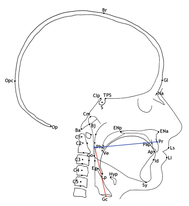


Figure 5 – Average vocal tract length for males (red) and for females (blue) from birth to adulthood



Oral Cavity Length is defined as the distance between the prosthion (Pr) and the pharyngeal point (Ph2). Larynx Height is defined as the distance between the pharyngeal point and and the center of the glottis (Gc).

Fig. 6 – Measurement of Oral Cavity Length (OCL, in blue) and Larynx Height (LH, in red)

We observe (fig. 7) an important growth period during the first two years of life, for the oral cavity length and the larynx height.

For males, there is a second important period of growth for the larynx height during puberty.

Note that the oral cavity length is increasing very slowly with regard to larynx height. So, vocal tract growth is principally vertical.

The average vocal tract length growth is very important during the first two years of life, and during puberty (fig. 5).

The differences between males and females for this measure become significant at the age of 15 (*p=0,001*), because of the larynx height growth at puberty for males.

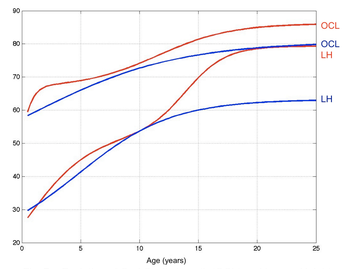


Fig. 7 – Evolution of Oral Cavity Length (OCL) and Larynx Height (LH) for males (red) and females (blue)

At the age of 2, the pharyngeal cavity is still very short: about 35 mm vs. 65 mm for the oral cavity.

At this age, it is well known that a child is able to contrast [i], [a] and [u] sufficiently.

PERSPECTIVES

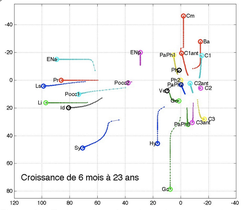


Figure 8 – Trajectories of the bony landmarks during ontogenesis

The goal of this study is to use this craniometric data to calibrate an articulatory model of the vocal tract from birth to adulthood.

Vocal tract modeling is a powerful tool to study the evolution of morphology, and its implications on acoustic productions.

An articulatory model can simulate the potential maximal vowel space permitted by the studied vocal tract. Also, we can measure the influence of morphology on speech production. By comparing real acoustic productions with acoustic simulations, we can study the emergence of motor control, and observe which articulators are recruited.

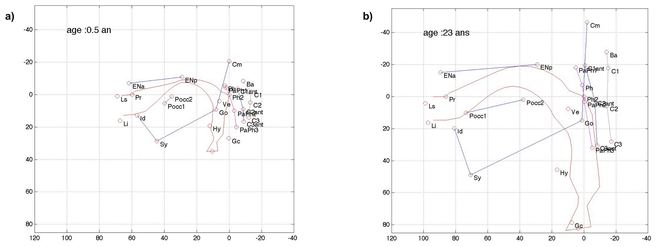


Figure 9 – The articulatory model calibrate for males at 6 month (a) and at 23 years (b)

DISCUSSION

The average vocal tract length, the size of the pharynx, and the length of the oral cavity, are increasing significantly from birth to 2 years of age.

This study offers new data to observe with accuracy the morphological evolution of the vocal tract during ontogenesis.

To test the influence of this evolution on speech production, articulatory modelling is essential.

Simulations with an articulatory model show that a newborn, if its motor control was mature, would be able to produce a sufficient contrast between the cardinal vowels (Ménard, Schwartz and Boë, 2004).

To understand the emergence of motor control, these data applied to an articulatory model could help us to understand how speech articulators are progressively controlled in acquisition.

Therefore, speech production and speech emergence seem to depend more on motor control than on vocal tract morphology.