Folk physiology and talking hyoids

SIR—In the past it was generally believed that human speech derived solely from properties of the brain and that no special vocal anatomy was involved. Although much has changed, Marshall, as is evident from his recent News and Views article[1], has failed to follow this progress.

The issue in contention is whether Neanderthal speech ability was equivalent to ours, not whether they possessed speech and language. Marshall overlooks that we have consistently emphasized that they possessed these attributes[2-4] and seems misinformed on even the basic theory of speech production — Muller's 'source-filter' model. The supralaryngeal vocal tract (SVT) acts as an acoustic filter letting peak energy through at 'formant frequencies' (refs 5 and 6), the main determinants of phonetic quality[7]. The filtering effects of the SVT are thus independent of the larynx. Marshall's comment that humans can produce 'intelligible' speech after surgical removal of the larynx is therefore irrelevant. As ape larynges are similar to ours with respect to sound-producing capabilities, we can assume that Neanderthal larynges were also similar. The debate therefore concerns the SVT, not specific laryngeal anatomy.

Marshall is in error concerning a number of points of speech anatomy and physiology. He incorrectly states that 11 muscles connect the larynx and hyoid when only one pair does — the thyrohyoids. Marshall also apparently believes that ". . humans can learn to produce intelligible speech after surgical removal of the tongue . .". Talking or swallowing food normally is impossible when the tongue is removed. In speech pathology folklore there is a tale of a person talking with the entire tongue removed. Marshall seems to have swallowed the fable, confusing removal of the tongue 'body' (the main part of the tongue, extending into the throat) with the much less compromising removal of the tongue 'blade' (the protrudable part), although even this affects speech intelligibility. Marshall also asserts that "severe deformity of the vocal tract is compatible with human speech if a human brain is in command thereof." Many studies show that patients with normal brains and anomalous SVTs (such as palatal insufficiency, cleft palate) produce speech that is not as intelligible as normal speech owing to phonetic deficits, shown by acoustic analysis, psychoacoustic tests and computer modelling based on cephalometric X-rays[8].

Marshall criticizes SVT computer-implemented modelling on the basis that the Neanderthal model did not account for laryngeal mobility. He overlooks that the model expressly gave Neanderthals the full modern range of laryngeal mobility[2]. He asserts that modelling inaccurately predicts which vowels chimpanzees can make. Many studies have validated computer modelling for chimpanzees[9], as well as normal human newborns[10] and adults[11], humans with deformed vocal tracts[8], and macaques[5], and have affirmed that non-human primates cannot produce the 'point vowels' of human speech — [i], [u] and [a].

Marshall's claim that Jordan[12] showed that "real, live" chimpanzees produce [a] and [u] is not supported by the data. Instead of a sound spectrograph, Jordan used an octave-band analyser, with a limited high-frequency resolution, that reported formant bandwidths exceeding 1 kHz (vowel formant bandwidths range between 60 and 300 Hz). His spectra, therefore, cannot resolve the formant frequency patterns that differentiate vowels; for example his putative [a] and [o] spectra are almost identical except for irrelevant overall amplitudes. Jordan, in fact, never claimed that chimpanzees produced human vowels, stating that their "sounds were not identical with those made by humans, but only resembled them." Although these deficiencies were noted seven years ago[13], Marshall neglects this.

Marshall's comment concerning mynah birds misses the point of the paper he references[14]. Mynah birds mimic speech by producing energy peaks close to the formant frequencies, which human listeners are disposed to 'hear' as speech. Controlled psychoacoustic experiments with similar, computer-generated signals showed that they were as readily perceived as 'science-fiction noises' when listeners were not told that they would be hearing speech signals[15].

Marshall implies that our work is irrelevant because the brain, which we supposedly ignore, is the biological basis of human speech. We have, however, consistently stated that the brain mechanisms necessary for human speech evolved in concert with the anatomy. The human SVT is relatively maladapted for swallowing and breathing[4,16] but is able to produce the full range of human speech sounds, which would be impossible without specialized brain mechanisms.

The discovery of new fossil material, such as the Kebara hyoid by Arensburg *et al.*[17] on which Marshall was commenting, is cause for excitement, but the authors' conclusions about Neanderthal speech may be premature. Nowhere do they show (except by dubious embryonic associations) how an unattached hyoid could be used to reconstruct the entire vocal tract. The hyoid is a free floating bone, suspended by muscles and ligaments, so knowledge of its exact position, and that of the larynx and the shape of the tongue, cannot easily be achieved[18]. Their assertion that the Kebara hyoid resembles in some measures some modern humans, does not mean that its position in the neck was also similar. As we do not know what the hyoids of other fossil hominids looked like, it is possible that hyoid morphology was similar as far back as early members of *Homo*, if not earlier. If so, then the hyoid would be an irrelevant indicator of vocal tract evolution. Without other fossil hyoids to compare Kebara with, conclusions are meaningless.

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MARSHALL REPLIES—I do not believe that ablation of the tongue (body or blade) is a good idea (unless there is a compelling medical reason); and I agree with Lieberman and his colleagues that abnormality of the human vocal tract will reduce the intelligibility of speech. What I find startling is the 'plasticity' of the motor programs that can produce a 'fair approximation' to normal speech through a variety of articulatory manoeuvres over structurally-distinct anatomies. Ventriloquism and the ability to talk with a pipe in one's mouth are well-known examples.

More pertinent to the current argument is the study by Wheeler *et al.*[19] whereby ten patients with oral cancer had 10–90% of the tongue ablated. After surgery, the intelligibility of the patients dropped by only 9–18%. In an earlier paper, Massengill *et al.*[20] reported a case who had 95% of his tongue removed but was "still able to communicate fairly well". The effects of human-vocal-tract abnormalities are addressed by Huskie[21] in a recent book about cleft-palate speech. Huskie writes: "Some speakers are capable of surmounting seemingly major anomalies of the vocal tract to produce acceptable speech, while other speakers, with minimal structural defects present with marked dysfunction and atypical speech which appears to be out of proportion to the structural problem observed." I doubt that anyone with clinical experience would dispute this.

With regards to mynahs and chimpan-