Use of Ultrasound to Study Differences in the Tongue Dorsum of Voiced vs. Voiceless Fricatives: a Comparison to MRI Data

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In a recent MRI study (Proctor et al., in press) of four subjects uttering the eight English fricatives in cardinal vowel context, the tongue was found to be advanced in voiced fricatives relative to their voiceless counterparts in the majority of cases. We would like to know if this effect is generally true both for other subjects, and for more natural experimental conditions. An earlier study using MRI to image fricatives (Narayanan et al., 1995) reported similar results for four subjects with the fricatives in schwa context only. But MRI requires both a supine posture and for the speech sound to be held unnaturally long: 2 minutes on average for each image plane orientation for the Narayanan et al. study, and 35 seconds for that of Proctor et al. Tiede et al. (2006) found that articulators needed for a certain speech sound are held in position, even against gravity, while those not essential will be allowed to fall back or down depending on the subject's position. We must conclude, then, that the advanced tongue root is essential for voiced fricatives, though the reasons why are unclear.

Engwall (2006) found that the long acquisition times of MRI lead to hyperarticulation. The tongue position was more extreme for fricatives, but was less subject to coarticulation for MRI than EMA; the lip and jaw varied more with phonetic context in MRI. However, these conclusions were based on a single Swedish subject, and five voiceless Swedish fricatives. Given that our MRI subjects varied in the effect of vowel context on fricatives (Shadle et al. 2008), it seems possible that other subjects might show different patterns of adjustment to the constraints of an MRI study.

Subtelny et al. (1972), in contrast, studied sibilants of 10 subjects using cine X-ray. The pharynx was restricted for /s/ compared to /z/ on average. The corpus was limited, but spoken at a normal rate, and the subjects were sitting.

In this study, we used ultrasound of the tongue dorsum to investigate whether the tongue is advanced in voiced fricatives when the subject is sitting, and speaking at a normal conversational rate. We used two corpuses: nonsense word sequences with voiced and voiceless fricatives alternating, e.g. /pasa baza pasa baza/, as well as sentences with real words and voiced/voiceless fricatives alternating in the same pitch-accented position, e.g. "The Grecian sauce is known. The lesion's cause is known."

An Aloka SSD-5500 ultrasound scanner was used at the frame rate of 127 Hz. The ultrasound probe (intercostal 7.5 MHz), supported by a spring-mounted probe holder, was positioned midsagittally, angled to image the tongue dorsum. Edgetrak was used for tongue edge extraction. A polar grid was superimposed on the edges; the intersection of the sibilant edges with a gridline in the upper pharyngeal region was measured. Voiced and voiceless fricatives were compared by using the horizontal projection of the intersection point. Results will be presented for two of the original MRI subjects.

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