A CINEFLUOROGRAPHIC STUDY OF UVULAR CONSONANTS IN SWEDISH AND IN WEST GREENLANDIC INUIT

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ABSTRACT

The articulation of uvular consonants is studied with particular reference to quantal aspects of speech production. Data from X-ray motion films are presented. Two speakers of Southern Swedish give examples of [ʀ], and one speaker of West Greenlandic Inuit gives examples of [ʀ] and [q]. The traditional view that uvular consonants are produced by articulating the dorsum against the uvula ought not to work, owing to the presence of free air passages either side of the uvula. The formant transitions to vowels adjacent to these consonants suggest instead that the place of articulation is in the upper pharynx, at the same place as is constricted for [o]-like vowels. The X-ray films confirm that these three subjects constricted the upper pharynx for these consonants.

INTRODUCTION

This study questions the classical account of uvular consonant production (e.g. Jones, 1964), that the tongue dorsum is raised towards the uvula, and that the uvula vibrates for a rolled [ʀ].

It is not clear how a vibrating uvula would produce the acoustic energy of a typical rolled [ʀ]. A likely process exploits a Bernoulli force in the constricted passage to chop the voiced sound into pulses when air pressure and tissue elasticity are suitably balanced. This assumes that intermittent occlusion is possible between pulses. Unfortunately, there are free air passages either side of the uvular that should prevent this from happening. Similarly, these passages should prevent complete occlusion for a uvular stop, and they should not allow a Reynolds number sufficiently small for the turbulence of uvular fricatives.

If the uvula is not a good place for producing consonants known as “uvular”, how else might they be produced? Wood (1974) observed that the spectra of vowel-to-consonant transitions immediately adjacent to uvular consonants were very similar to the spectra of [o, ɔ]-like vowels, or to their respective unrounded counterparts [ɤ, ʌ], and concluded that they shared the same place of location, i.e. the upper pharynx. The upper pharyngeal constriction for [o, ɔ]-like vowels was confirmed by Wood (1979), and it is hypothesized that uvular consonants also constrict the same region. Mrayati et al (1988) studied the spectral consequences of systematic deformations along an acoustic tube, and also concluded that the upper pharynx was a favorable location for consonants. Observations like this are obviously relevant for discussions of the quantal nature of speech (Stevens 1972, 1989). Clarifying the production of uvular consonants is not just a matter of correcting a possible misconception about a place of articulation. It concerns fundamental issues of phonetic theory.

Cinefluorography is a method that allows tongue body movement to be followed in relation to the entire vocal tract, not just the oral region. Undisputed sources of uvular consonants are the southern dialect of Swedish ([ʀ]) and Greenlandic Inuit ([ʀ, q, χ]), and the subjects of the films are native speakers of these languages.

BACKGROUND

Swedish /r/

The regional variant of the southernmost provinces is usually described as a voiced uvular fricative [ʁ]. In some districts, a postvocalic /r/ is weakened to schwa. A uvular trill is rare. Elsewhere in Sweden, /r/ is apical or retroflexed, with a range of local rolled, flapped, fricative or approximant variants. The two subjects used voiced uvular approximants in the films. The IPA alphabet does not offer a character for this, and [ʀ] is used in this report.

Greenlandic Inuit

There are voiceless stops at four places: /p, t, k, q/. There are four voiced glides at the same places: /w, l, ɰ, ʀ/ (again, ʀ does not denote a trill here, and w denotes a labial approximant). When geminated, these glides become long voiceless fricatives [fː, ɬː, çː xː, χː] respectively (see Rischel, 1974, for Greenlandic phonology). This provides three uvular consonants for this study: [ʀ, χː, q]. One source of gemination is consonant assimilation, which is only of interest here when the second consonant is uvular, for example /ʀq/ is [qq] or [qː], yielding a longer version of the assimilating consonant.

PROCEDURE

X-ray films

Wood (1979) gives details of how the films were made. One reel of 35mm film was exposed per subject at 75 image frames/second (1 frame every 13.3ms), allowing about 40 seconds. Each frame received a 3ms exposure.

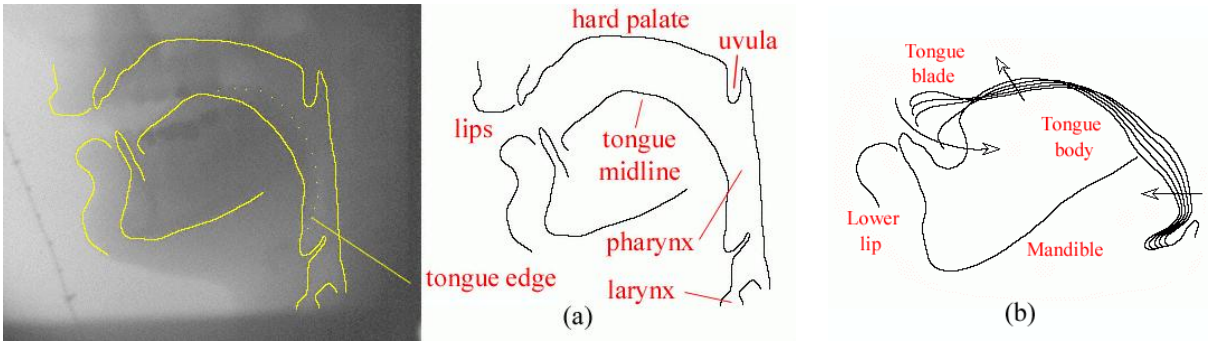

Figure 1. (a) Example of profile tracing and identification of prominent features. Note difference between the tongue midline and edge contours. (b) Examples of tongue body and tongue blade maneuvers (five successive film frames in this instance).

A film scanner was used to digitize film frames, and each profile was then traced on a new image layer in an image editor (Figure 1a). Articulator maneuvers are identified and tracked by comparing profiles in adjacent film frames, relating each articulator to the structure it is attached to. For example, tongue body movement is related to the mandible, tongue blade movement to the tongue body etc. (Figure 1b). Since this study concerns uvular consonants, particular attention is paid to tongue body movements and the parts of the vocal tract they are directed to.

Subjects

The subjects are adult males, aged 30-40 years. All spoke at typical everyday articulation rates of around 5 syllables/second. Swedish subject SweA is from Lund; some material from this film has already been published in Lindblad (1980) and Wood (1991). The Swedish subject SweB is from Helsingborg; some material from this film has already been published in Wood (1995, 1998). The Inuit subject is from Godthåb; some material from this film has already been published in Wood (1996a, 1996b, 1997a, 1997b, 1998). Results for SweB are presented in this report. Results for SweA and the Inuit subject will be presented in the poster.

Language materials

The Swedish materials consist of grammatical sentences composed of nonsense words, in which certain phonemes are systematically varied.

In the film by SweA, Swedish sibilants are placed in different vowel environments. The uvular /r/ occurs in the present indicative verb ending {/ar/} followed by the proposition {/i:/}, yielding several tokens of the sequence [aʀi].

In the film by SweB, the long vowels of Swedish (diphthongized in this dialect) are placed in a /bVd/ environment. The uvular /r/ occurs where the subject recited the date and location of the film session. The number “four”, *fyra*, (/fy:ra/) is reported here, yielding the sequence [yʀa].

The polysynthetic character of Inuit morphology does not lend itself to the simple commutation of experiment elements and fixed environments. For the film by the Inuit subject, a long word list was compiled to provide examples of vowels in a variety of uvular and nonuvular environments.

RESULTS

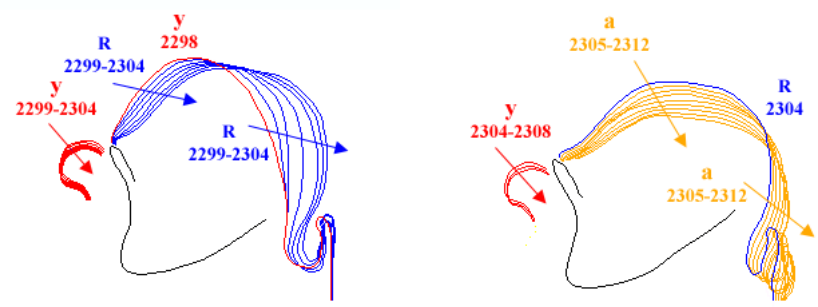

Figure 2. Subject SweB. Frame by frame tongue body movement (13.3ms for each step) in the transition from [y] to [ʀ] (left) and [ʀ] to [a] (right). The numbers refer to frames on the film. Red is activity for /y:/, blue for /r/, and orange for /a/.

The frame by frame tongue body movement by SweB in [yʀa] is recorded in Figure 2. The sequence of profiles from [y] through [ʀ] to [a] is shown in Figures 3-5 (every other film frame, i.e. about 27ms between each illustration). This commentary continues in the figure captions.

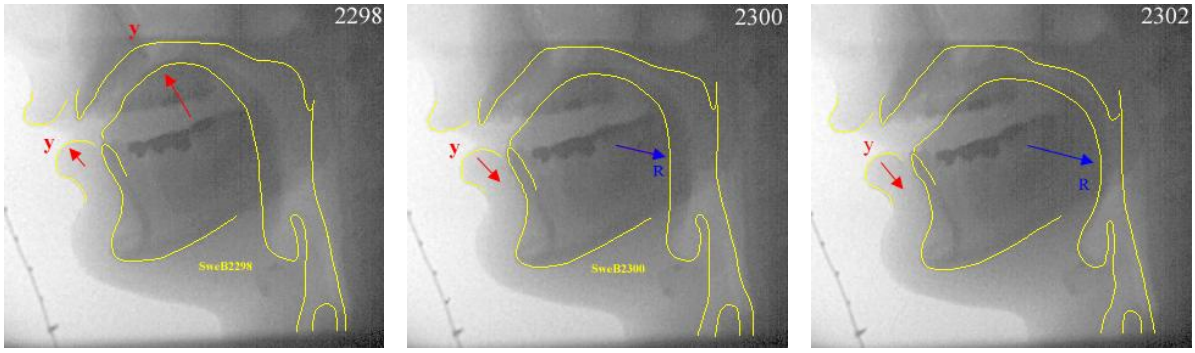

Figure 3. every other profile from the sequence [yʀa], starting from the most complete /y:/ profile (left, frame 2298): tongue body raised towards the hard palate and lips rounded (red detail for /y:/). The tongue body was then retracted for the transition to [ʀ], and the lip rounding withdrawn (2300 centre, 2302 right, blue detail for /r/ activity).

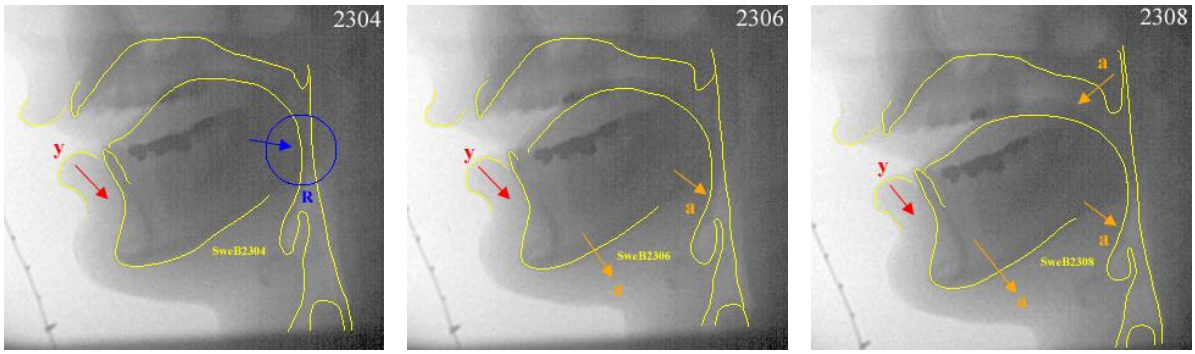

Figure 4. Profiles from the sequence [yʀa], continued from Figure 3. The transition to [ʀ] continued to frame 2304 (left), concluding with a narrow pharyngeal constriction (blue circle). This retraction was accompanied by slight depression, so that the tongue dorsum passed below the uvula and was directed into the upper pharynx. The lip rounding of /y:/ is still being withdrawn. Activity for /a/ was then commenced (orange detail), continuing through frames 2306, centre, and 2308, right. The tongue body gesture of /a/ is directed towards the lower pharynx, accompanied by mandibular depression. The velar port opened slightly in frame 2308 (right); this sequence is phrase final and was followed by a breathing pause.

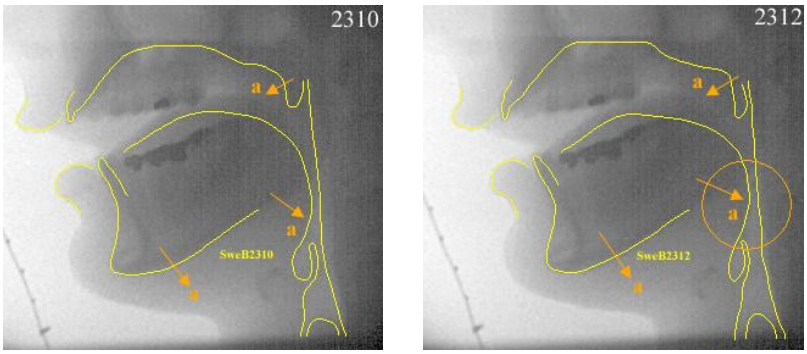

Figure 5. Profiles from the sequence [yRa], continued from Figure 4. The transition from [R] to [a] continued through frame 2310 (left, orange detail) to frame 2312 (right), concluding with a narrow low pharyngeal constriction (orange circle), as expected from Wood (1979).

DISCUSSION AND CONCLUSIONS

The retracting tongue body maneuver from [y] to [R], seen in Figure 2 (left) and in profiles 2300 to 2304 in Figures 3 and 4, was depressed slightly. Consequently it passed below the uvula and continued into the pharynx. For this instance of [R], the subject did not elevate the tongue dorsum towards the uvula. Similar behavior was exhibited by the other two subjects, whose results will be shown on the poster.

The target of the tongue body gesture of [R] was the upper pharynx, as hypothesized. This was also the case in the other data to be reported in the poster. The upper pharynx is also the region that is constricted for [o] and [ɔ]-like vowels.

The upper pharynx is a more suitable place than the uvula for producing stops, fricatives and trills. The soft smooth elastic surfaces of the posterior part of the tongue and the opposing posterior pharyngeal wall allow perfect occlusion or the creation of apertures narrow enough for the generation of turbulence. Conditions should also be present here for a myoelastic aerodynamic membrane vibration similar to glottal vibration for voicing, allowing production of trills.

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