Using digital ultrasound to investigate trill vibration

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In the production of apical trills, tongue tip tension and effective mass are adjusted so that high velocity airflow will initiate vibration of the tip (McGowan, 1992). Tongue tip vibration frequency varies between 20 and 40 Hz (Ladefoged et al., 1977; Lindau, 1985), therefore if the duration of a particular trill is about 150 ms, the individual closure and opening parts of each cycle will each last somewhere between 10 to 30 ms. Due to the rapid nature of this aerodynamically-driven activity, it has been quite difficult to study trill articulation and acoustic-articulatory relations in trills (Ladefoged and Maddieson, 1996). In this work we show that it is possible to use digital ultrasound to investigate the articulatory details of apical trills, and in combination with spectral analysis, to investigate acoustic-articulatory relations. We used the Haskins Digital Ultrasound System, imaging at 127 Hz to investigate apical trills in Russian and Spanish (Proctor, 2009). Ultrasound data and acoustic recording wee synchronized using a triggering circuit. Data from 2 Spanish and 2 Russian subjects were analyzed. Trills were produced in a VCV environment, where V varied between /a/, /e/, and /u/. Edges were extracted using Edgetrak (Li, 2005). Apical vibration was measured by tracking the intersection between the tongue edge and a polar gridline extending from the center of the crystal array in the probe to the blade area of the tongue, since the tip cannot be resolved. The trills are acoustically measured by calculating RMS Energy of the synchronized acoustic signal filtered into 3 bands (200-1000 Hz, 1000-2000 Hz, 3000-4000 Hz). This energy is high when the tip is down in the open portion of the vibration and is low when the tip is up. When the time series of tongue vibration (measured at the blade) is then compared to the RMS energy, the same number of vibrations can be measured in each. This is despite the fact that the measurement is in the blade region, not the tip region—apparently there is also sufficient vibration in the blade region. Therefore the acoustic and articulatory measures are in agreement, validating the use of digital ultrasound for this purpose. We show that it is not possible to resolve the vibrations if the conventional 29.9 frame rate is used. Furthermore it is shown that in natural productions the tongue tip does not always tap against the alveolar ridge, similar to breathiness in vocal fold vibration, where the tissue moves towards the flow, but does not collide with other tissue. In such cases, it is shown that the greater the upward motion of the tongue, the higher the frequency band that shows the same downward and upward change in energy corresponding to each cycle of the vibration. It is shown that this is explainable on aeroacoustic grounds.

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