Effects of Speech Intensity on Acoustic and Kinematic Articulatory Working Space

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Rationale

Acoustic measures calculated from the formant frequencies of corner vowels, such as the vowel space areas of triangles or quadrilaterals, have often been used as a window into articulatory function. Other measures, such as the formant centralization ratio or the vowel articulation index (Roy, Nissen, Dromey & Sapir, 2009), have been suggested as more sensitive alternatives.

The purpose of this study was to compare changes in acoustic and kinematic measures of articulation across soft, comfortable, and loud speech conditions using both corner vowel-based and sentence-level metrics. Because louder speech has been associated with larger articulatory movements (Schulman, 1989), it was reasoned that these conditions would result in movement changes that would be reflected in the dependent measures.

Method

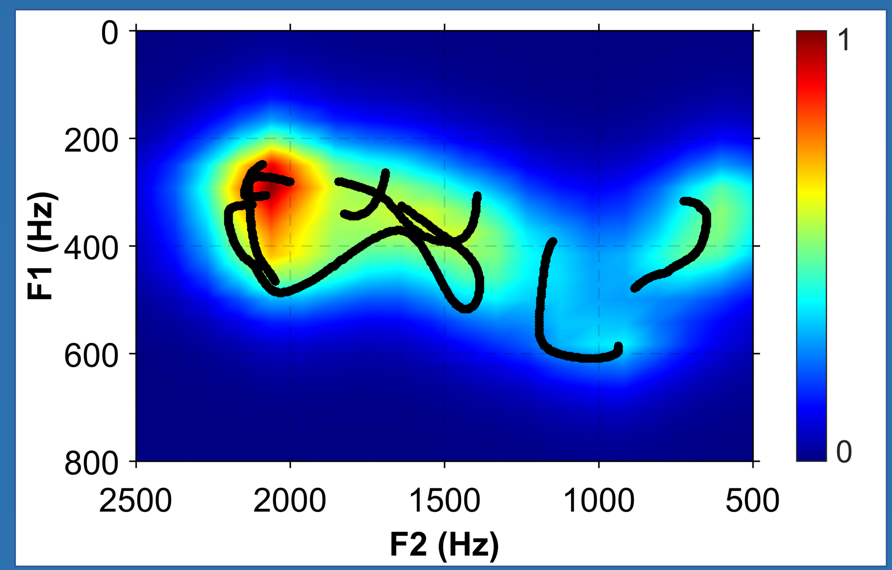
There were 19 participants, 9 male and 10 female, ranging in age from 20 to 34 years. Each participant had electromagnetic sensors attached to their tongue, jaw, and lips.

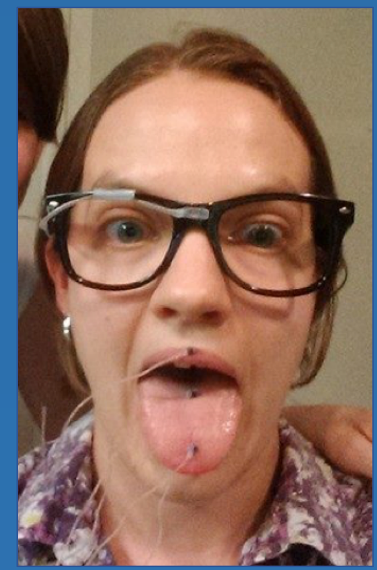
Vowel space area (VSA) and vowel articulation index (VAI – based on formant ratios) were computed from the three corner vowels, /ɑ, i, u/. Articulatory-acoustic vowel space (AAVS), a sentence-level acoustic measure (Whitfield & Goberman, 2014), was computed from the continuous formant histories of all voiced segments in a sentence.

Kinematic vowel space area (KVSA), kinematic vowel articulation index (KVAI), and articulatory kinematic vowel space (AKVS) were the kinematic equivalents of the acoustic measures, and were newly developed for the present study.

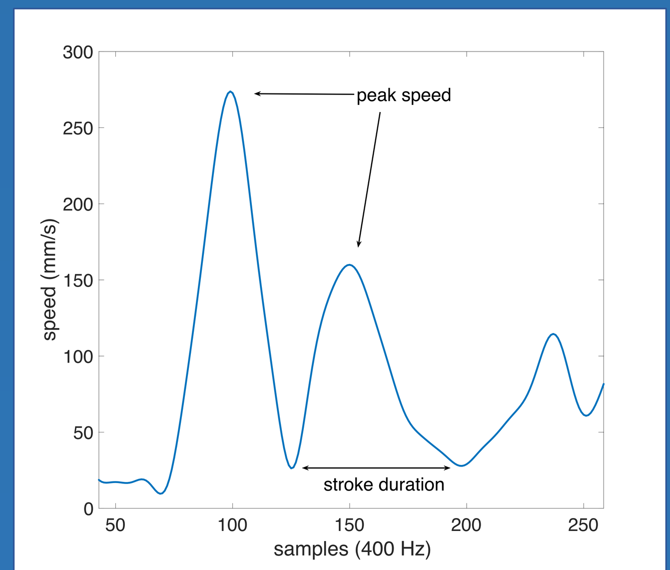
Stroke metrics based on the speed history of the lingual movements (Tasko & Westbury, 2002) were also used to reveal average kinematic features of the articulatory gestures in each participant's speech.

It was anticipated that the acoustic measures would parallel the changes observed in the kinematic measures as articulation changed across intensity levels.





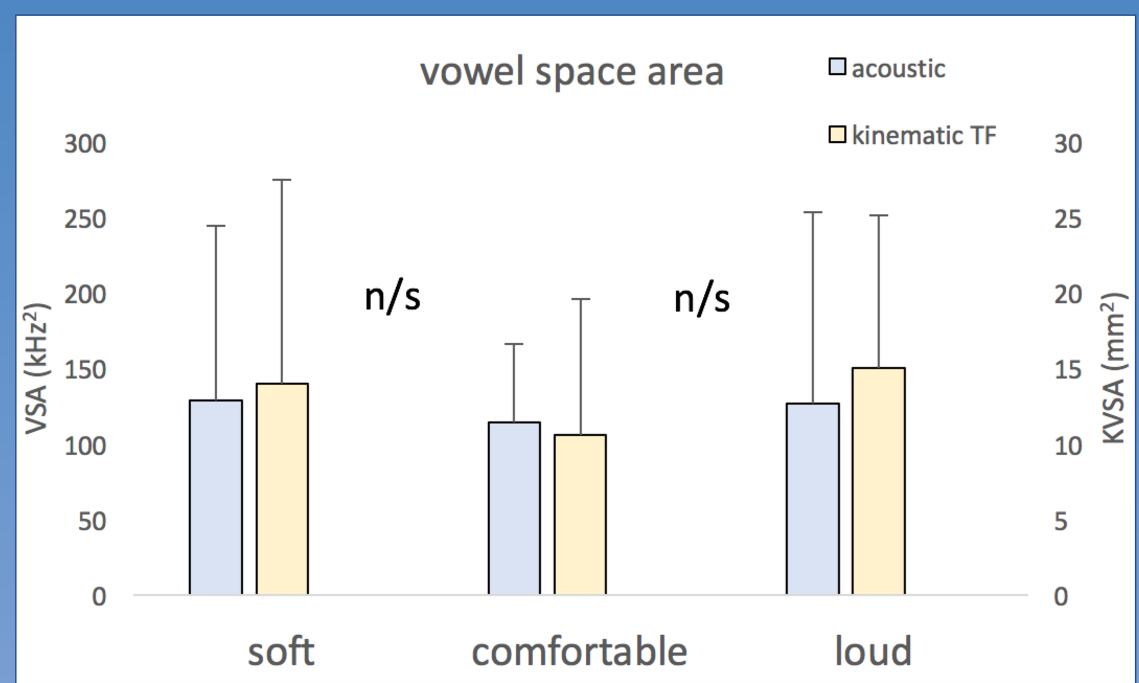
formant trajectory trace for a sentence showing the formant coordinates and normalized density distribution in F1-F2 space

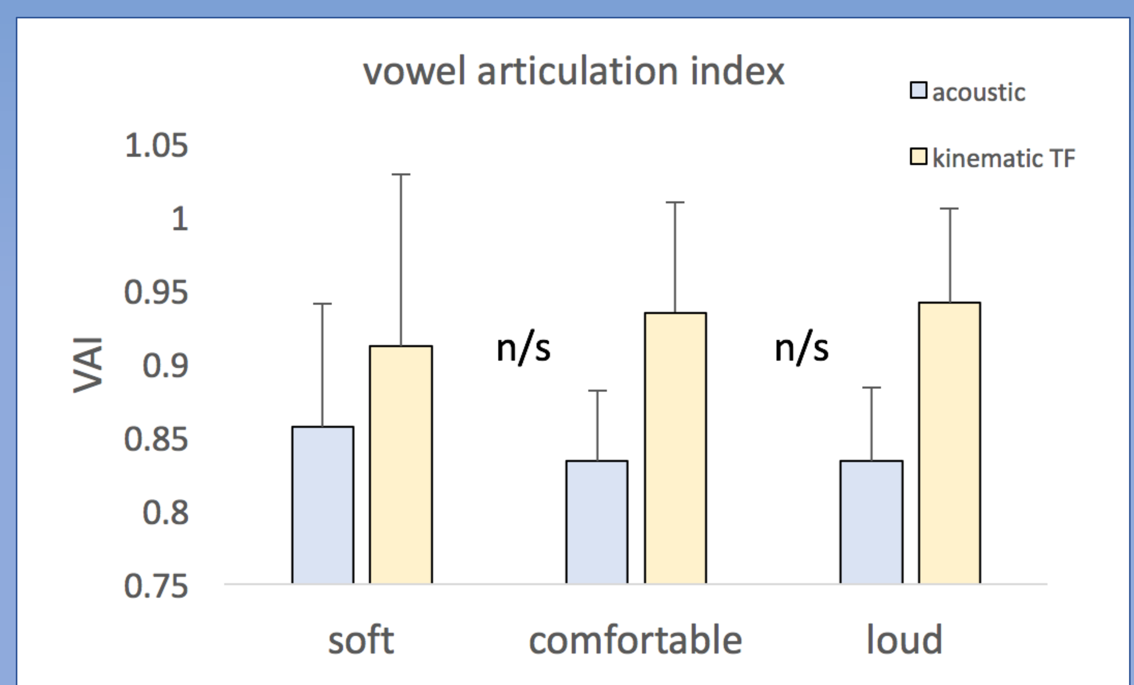


stroke measures from approx. 500 ms of speech

Results – Corner Vowels

The isolated acoustic and kinematic measures that were based on the segmented corner vowels (VSA, VAI, KVSA, KVAI) did not change significantly across the three intensities.

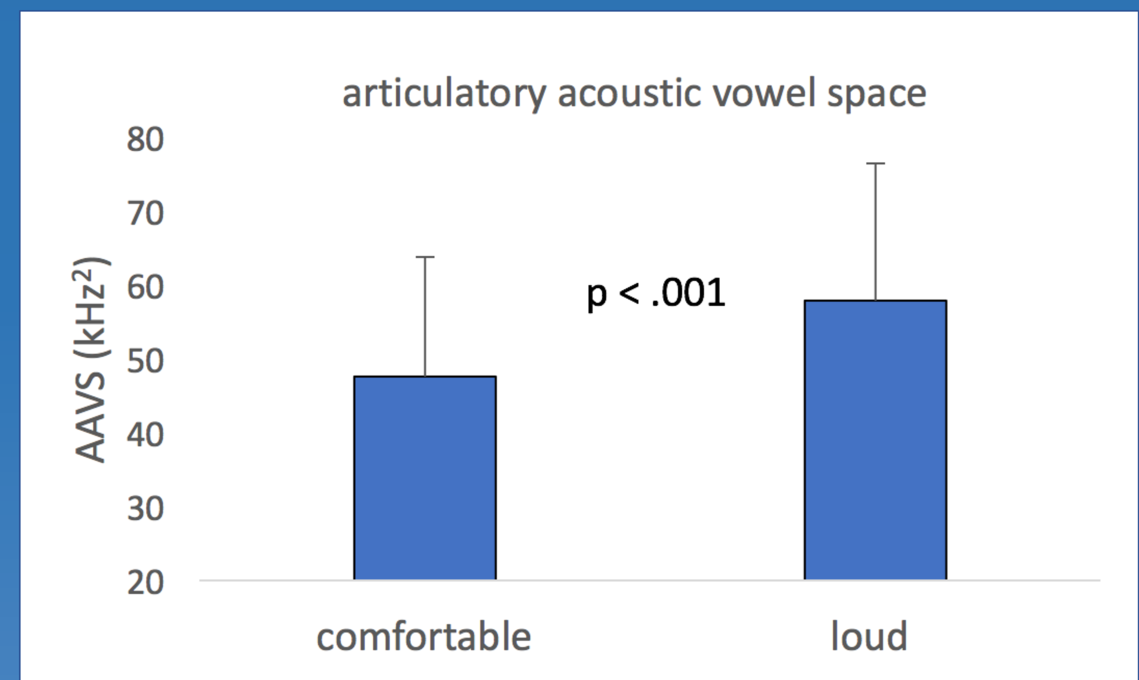




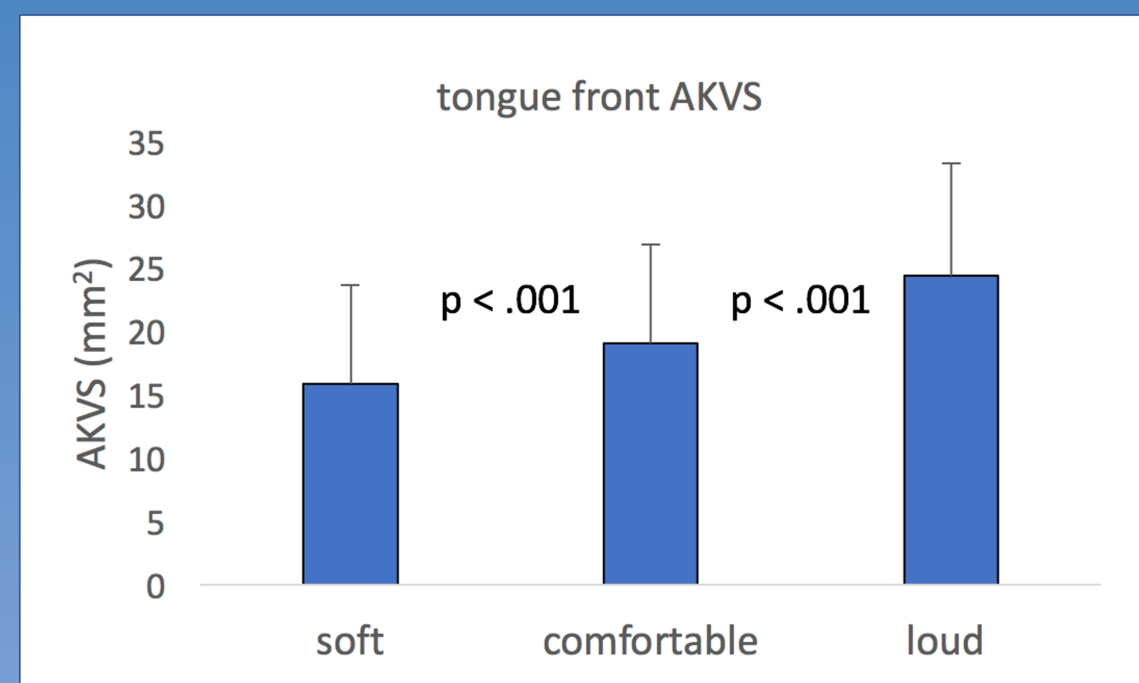
Results – Sentences

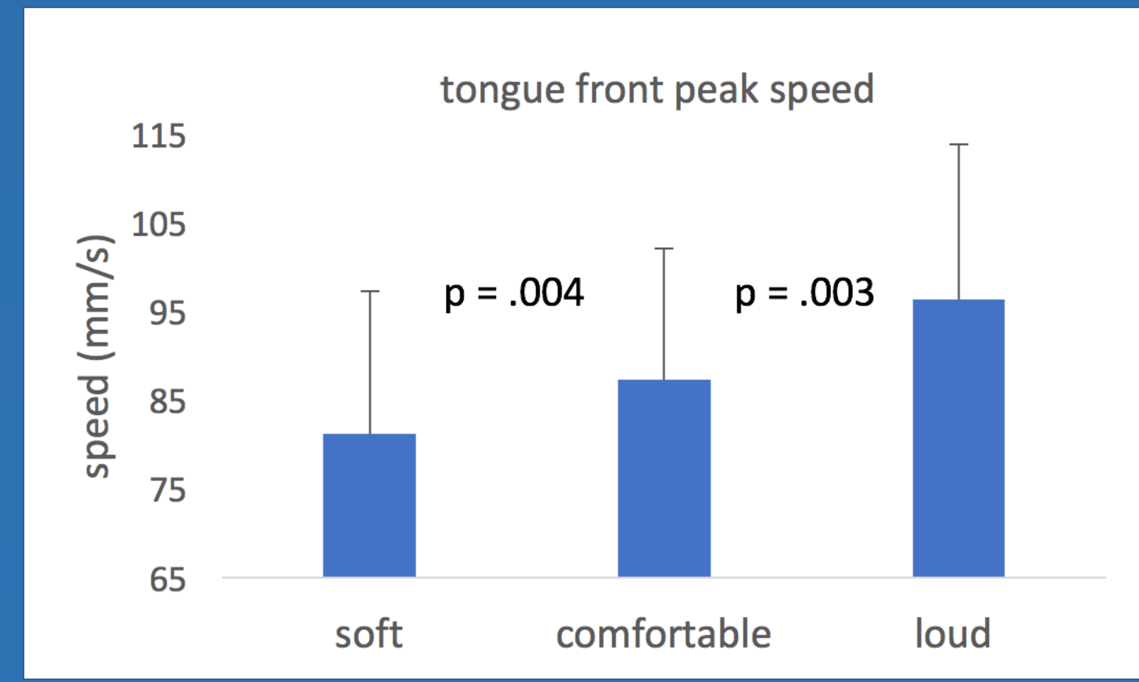
The sentence-level continuous measures of articulatory working space (AAVS and AKVS) increased with speech intensity. AAVS was not available for the soft condition because of formant tracking difficulties.

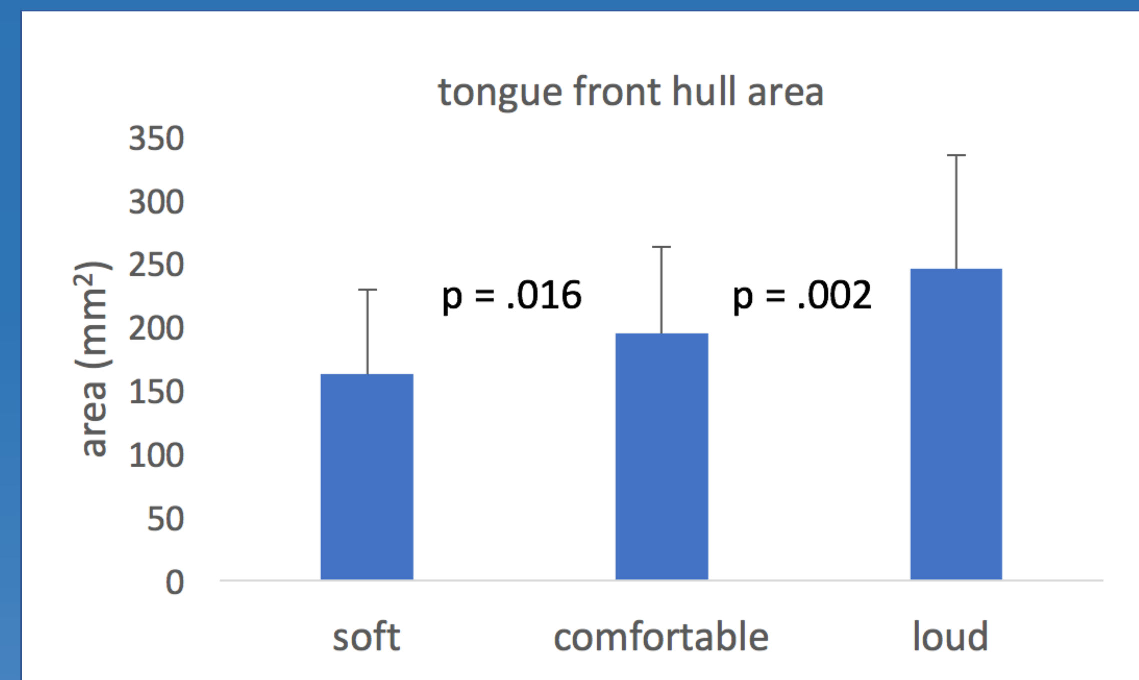
The sentence-level stroke metrics based on the kinematic lingual speed history also changed significantly with intensity, including increased onset speed, peak speed, mean speed, and distance of the articulatory strokes. Stroke duration decreased as speech intensity increased, while hull area increased.



all data figures show means and standard deviations







Discussion

These findings suggest that both acoustic and kinematic measures based on segmented corner vowels are not as sensitive to loudness-related changes in articulation as the more continuous sentence-level measures.

Metrics that include the dynamic contributions of both consonant and vowel articulation may better capture relevant changes that are not detected by measures based on vowel midpoints.

There was general agreement between acoustic and kinematic measures at the vowel and sentence level, suggesting that sentence-level acoustic measures have the potential to reflect articulatory changes without the invasiveness of kinematic recording technologies.

References

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