The effect of vocal tract tremor on resonance frequencies

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1. Introduction

- The presence of voice tremor in the acoustic speech signal may result from involuntary modulation of speech-related muscles that, in turn, generate rhythmic oscillation of anatomical structures involved in producing speech. These oscillations modulate the sound in both frequency and amplitude.
- One type of voice tremor can occur when a structure such as the tongue, velum, lips, or larynx oscillates involuntarily, modulating the shape of the vocal tract, and resulting in periodic increase and decrease of the resonance frequencies (cf., Inbar & Eden, 1976; Eden & Inbar, 1978; Gillivan-Murphy & Miller, 2011; Lagos-Villaseca et al., 2023).
- Figure 1 shows two cases of vocal tract tremor in which the cross-sectional areas in a selected region of the vocal tract were modulated by 50 percent (i.e., modulation **extent** = 50%). The effect of the area modulation on the first three resonance frequencies is shown for each case.
- These two cases were simulated with computational model of speech production (cf., Story, 2013 - TubeTalker); the resulting waveforms and narrow-band spectrograms of the simulations are in the lower part of Figure 1.
- The extent of modulation of each resonance frequency depends on the location of the tremor within the vocal tract.

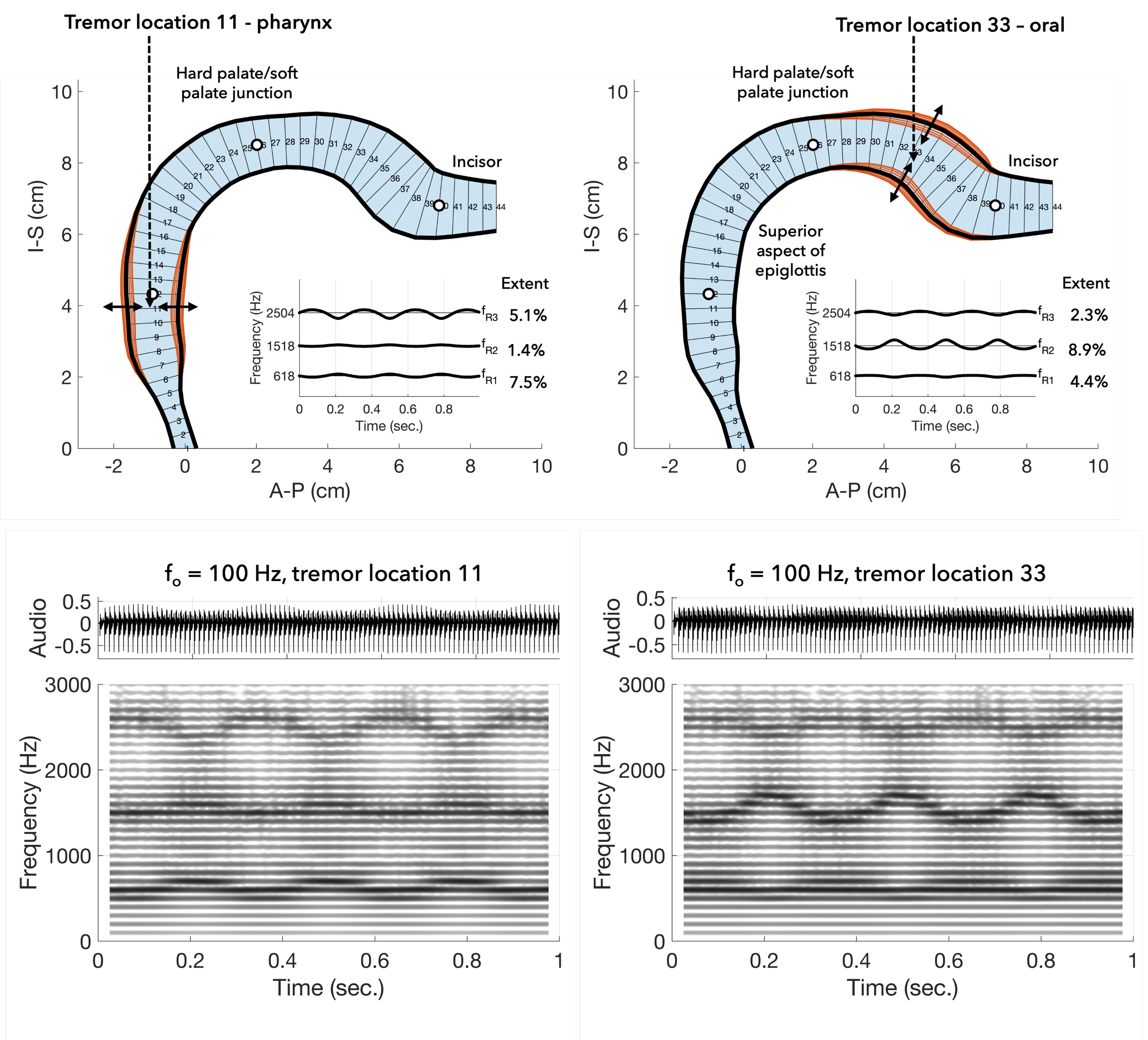

Figure 1: Examples of vocal tract tremor in two locations along the length axis (note: the vocal tract configuration is represented by 44 area sections where section 1 is just superior to the glottis and section 44 is at the lips.) The upper panel shows pseudo-midsagittal plots of a neutral vowel representative of an adult male with tremor indicated; the inset plots show calculated vocal tract resonance frequencies. The lower panel shows NB spectrograms of simulated vowels with the two tremors.

Specific Aim

To quantify the effects of vocal tract tremor on the resonance frequencies relative to the location of the modulation.

2. Simulations of vocal tract tremor

- Using an area function model of the vocal tract, a 3.5 Hz sinusoidal tremor was imposed on the cross-sectionals areas at 44 locations along the extent of the vocal tract from glottis to lips. Tremor was imposed on four different vocal tract configurations: neutral vowel, /ɑ/, /i/, and /u/.
- The extent of the vocal tract tremor was 50% of the x-sect area at a particular location.
- Vocal tract frequency response functions were calculated based on the time-varying vocal tract configuration using a transmission-line approach (Sondhi & Schroeter, 1987, Story, et al., 2000) that included energy losses due to yielding walls, viscosity, heat conduction, and acoustic radiation at the lips. Resonance frequencies were determined with a peak-picking algorithm applied to the frequency response functions.
- For each case, the modulation extent of the temporal variation of the first three vocal tract resonances was measured.

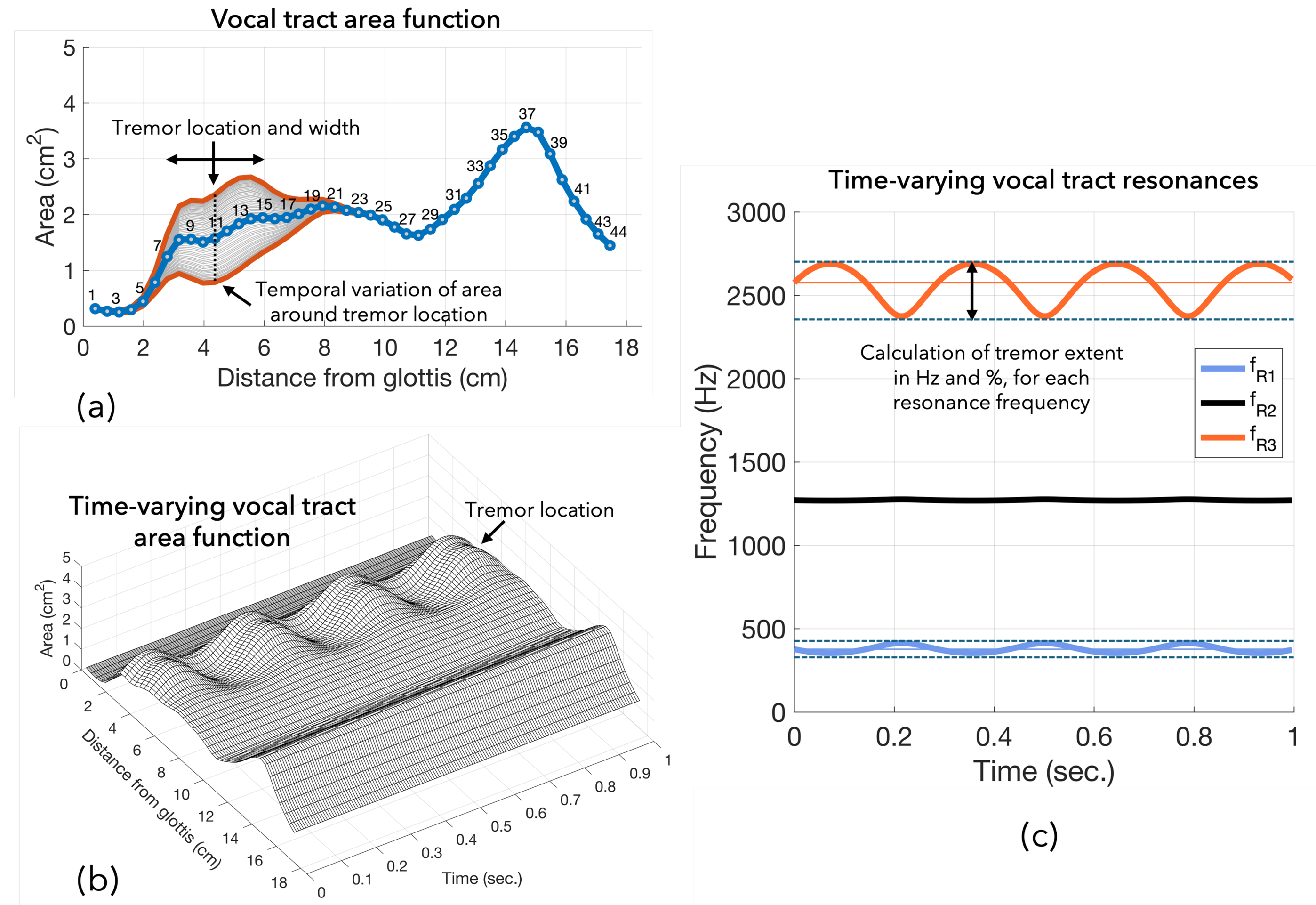

Figure 2: Demonstration of simulating a vocal tract tremor at a specific location along the tract length (section 11, 4.4 cm from glottis). The same process was used to simulate a tremor at each of 44 locations extending from glottis to lips. (a) Vocal tract area function for a neutral vowel with imposed tremor (gray and orange lines); tremor is 50% extent of the area section 11. (b) Same area function but shown with temporal dimension to show variation with time. (c) First three resonance frequencies calculated of the time course of the simulated tremor; tremor extent (absolute in Hz and relative in % was measured for each resonance).

3a. Effect of vocal tract tremor on resonance frequencies

- Area functions, frequency response functions of the baseline area function (inset) and extents of the resulting resonance frequency tremors, in Hz and percent, are shown for each vowel configuration in the left set of plots in Figs. 3-6.
- Pseudo-midsagittal plots for each vowel are shown in the right panels of Figs. 3-6. The color coding indicates the tremor extent in percent (blue is lowest, yellow is highest). The three channels (strips) represent each of the three resonances, as labeled.
- The effect of a vocal tract tremor centered at a specific location on the resonances is highly dependent on the overall configuration of the vocal tract.

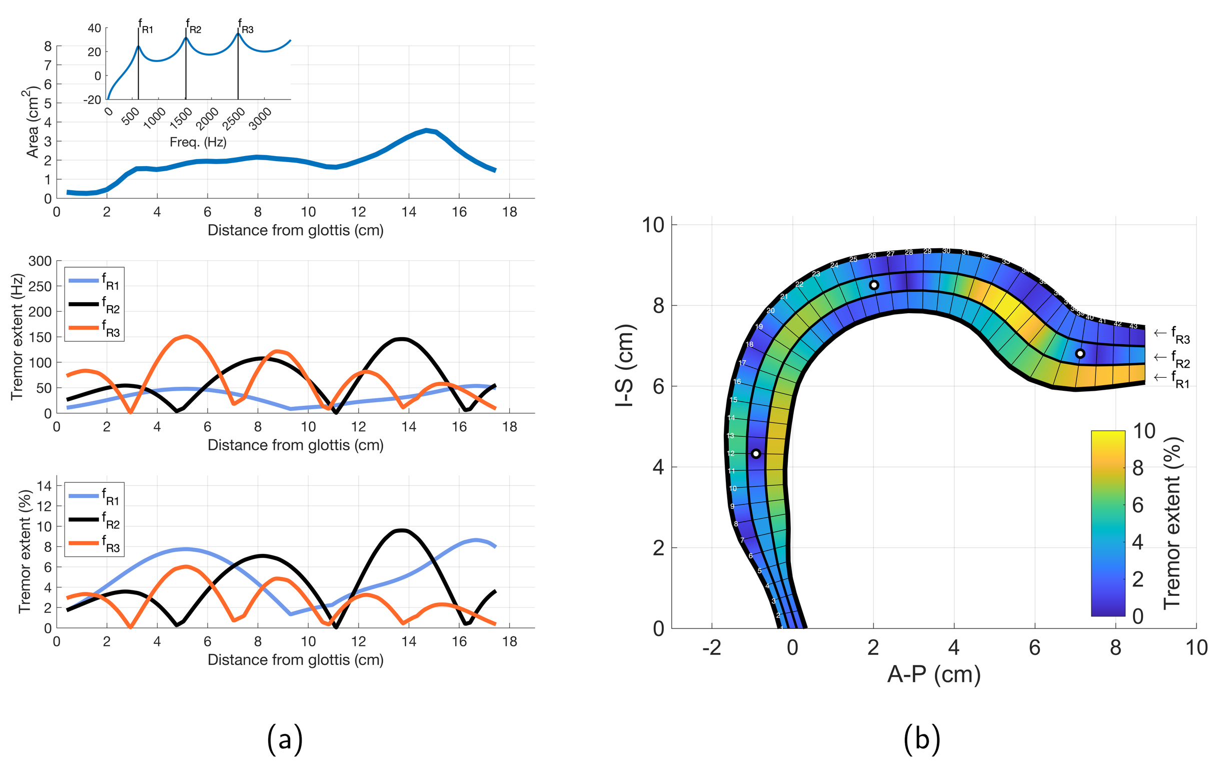

Figure 3: Neutral vowel: (a) Plot of area function and resonance frequency tremor extents (in Hz and %). (b) Pseudo-midsagittal plot showing tremor extent in %.

3b. Effect of vocal tract tremor on resonance frequencies

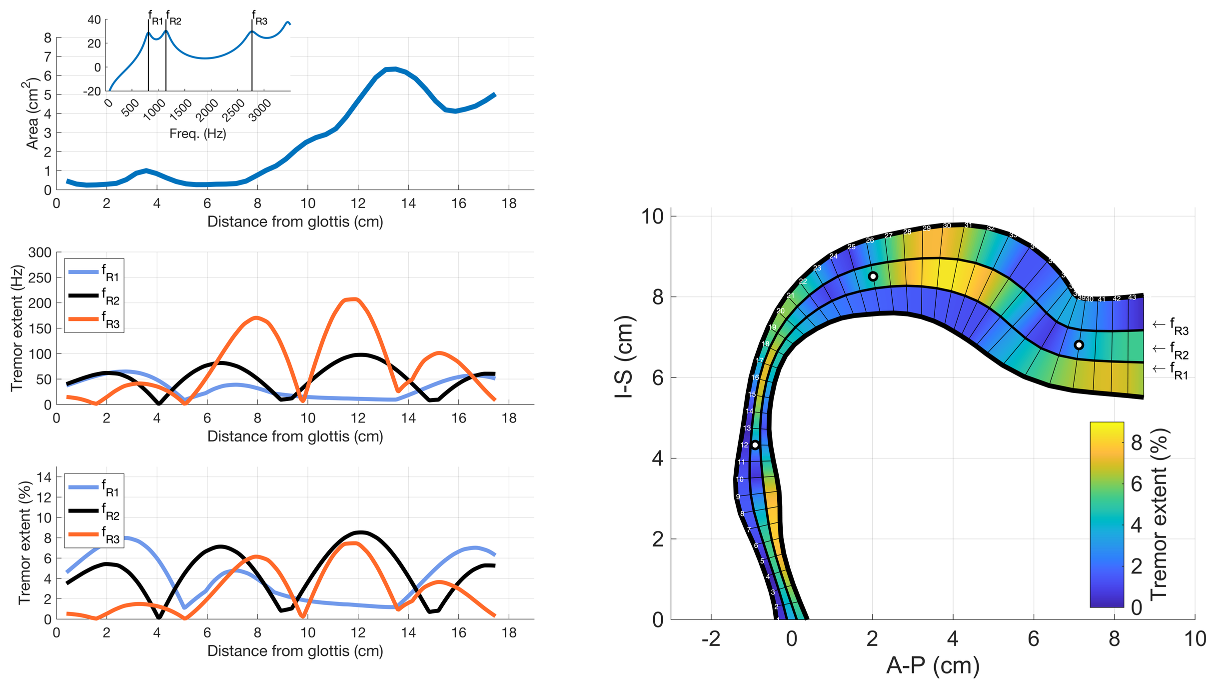

Figure 4: Vowel /ɑ/: (a) Plot of area function and resonance frequency tremor extents (in Hz and %). (b) Pseudo-midsagittal plot showing tremor extent in %.

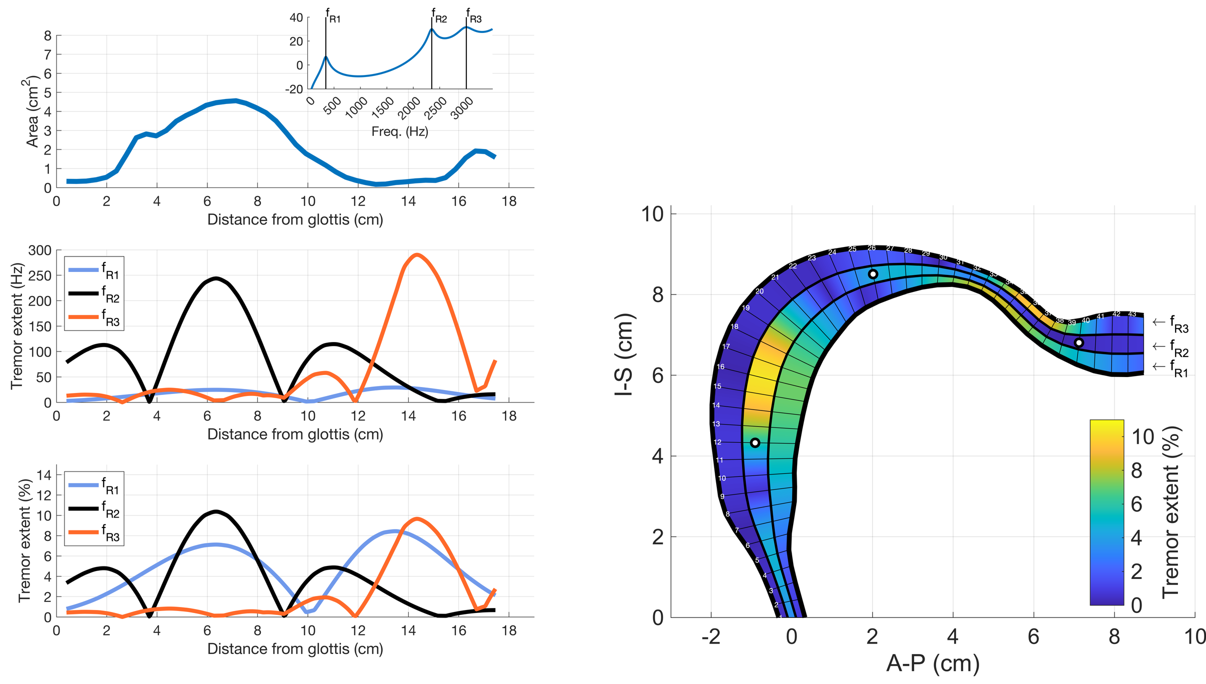

Figure 5: Vowel /i/: (a) Plot of area function and resonance frequency tremor extents (in Hz and %). (b) Pseudo-midsagittal plot showing tremor extent in %.

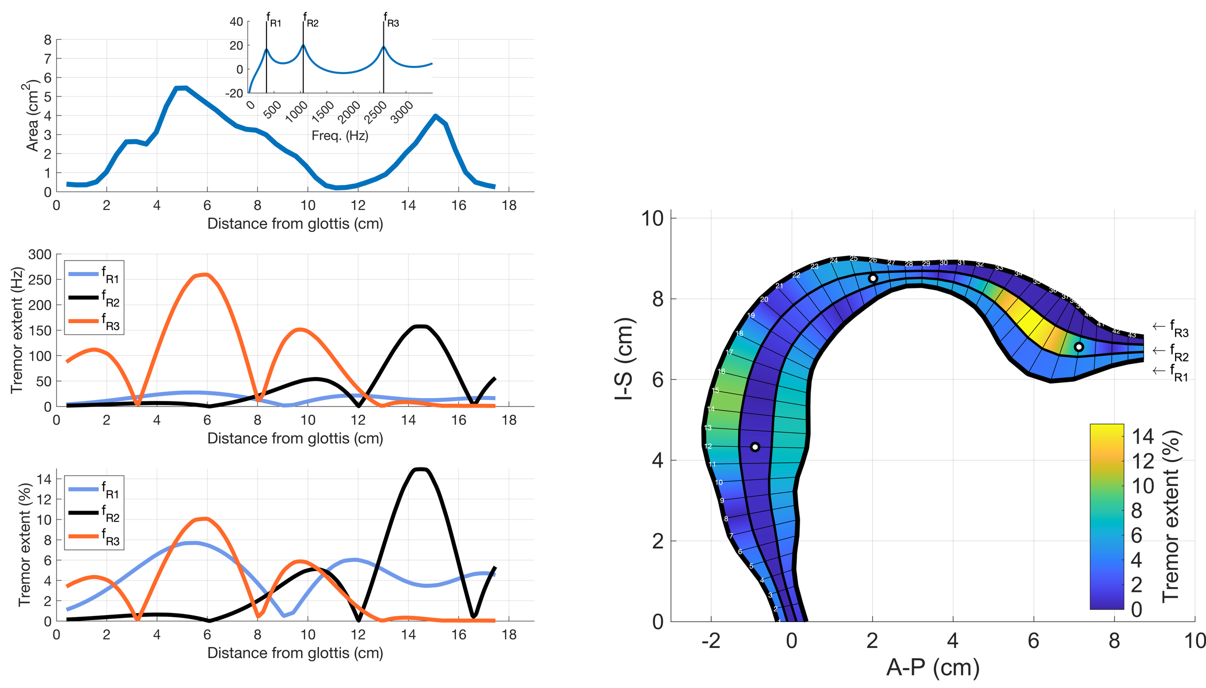

Figure 6: Vowel /u/: (a) Plot of area function and resonance frequency tremor extents (in Hz and %). (b) Pseudo-midsagittal plot showing tremor extent in %.

4. Future work

- Using real-time magnetic resonance imaging, temporal variations of the cross-sectional area of a selected location in the vocal tract can be measured.
- The example in Fig. 7 shows the cross-sectional area measurement at the location of the imaging plane for an 8 second duration. ≈ 4 Hz tremor is apparent in the initial 3 seconds.
- Vocal tract tremor (area variation) can be integrated into the vocal tract model and simulated for comparison to natural speech, potentially enhancing our understanding of this type of vocal tremor.

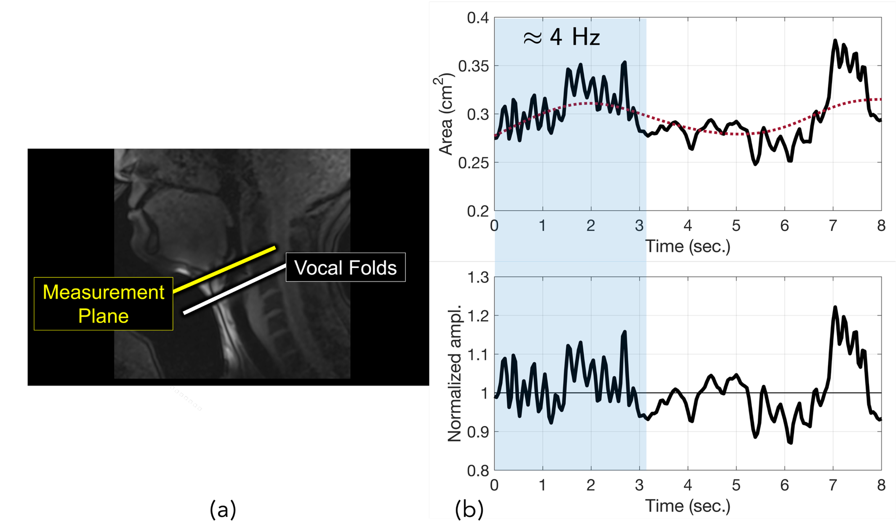

Figure 7: Real-time MRI measurement of cross-sectional area variation due to tremor.

Acknowledgements

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