Effects of Vocal Effort on Respiratory and Articulatory Kinematics

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Introduction

- **Vocal effort** is vocal exertion experienced by a speaker
- Vocal effort negatively impacts quality of life and is experienced by:
  - Healthy speakers who are high voice users (e.g. teachers, singers)
  - Speakers with voice disorders (e.g. vocal hyperfunction)
- Mechanisms underlying vocal effort are not well understood:
  - Laryngeal level changes studied extensively in both speakers with typical and disordered voice[1]
  - Investigations of respiratory and articulatory subsystems are limited
  - Speech intensity shows changes with vocal effort in prior work[2-3], but speakers with voice disorders report vocal effort at typical intensities

Purpose

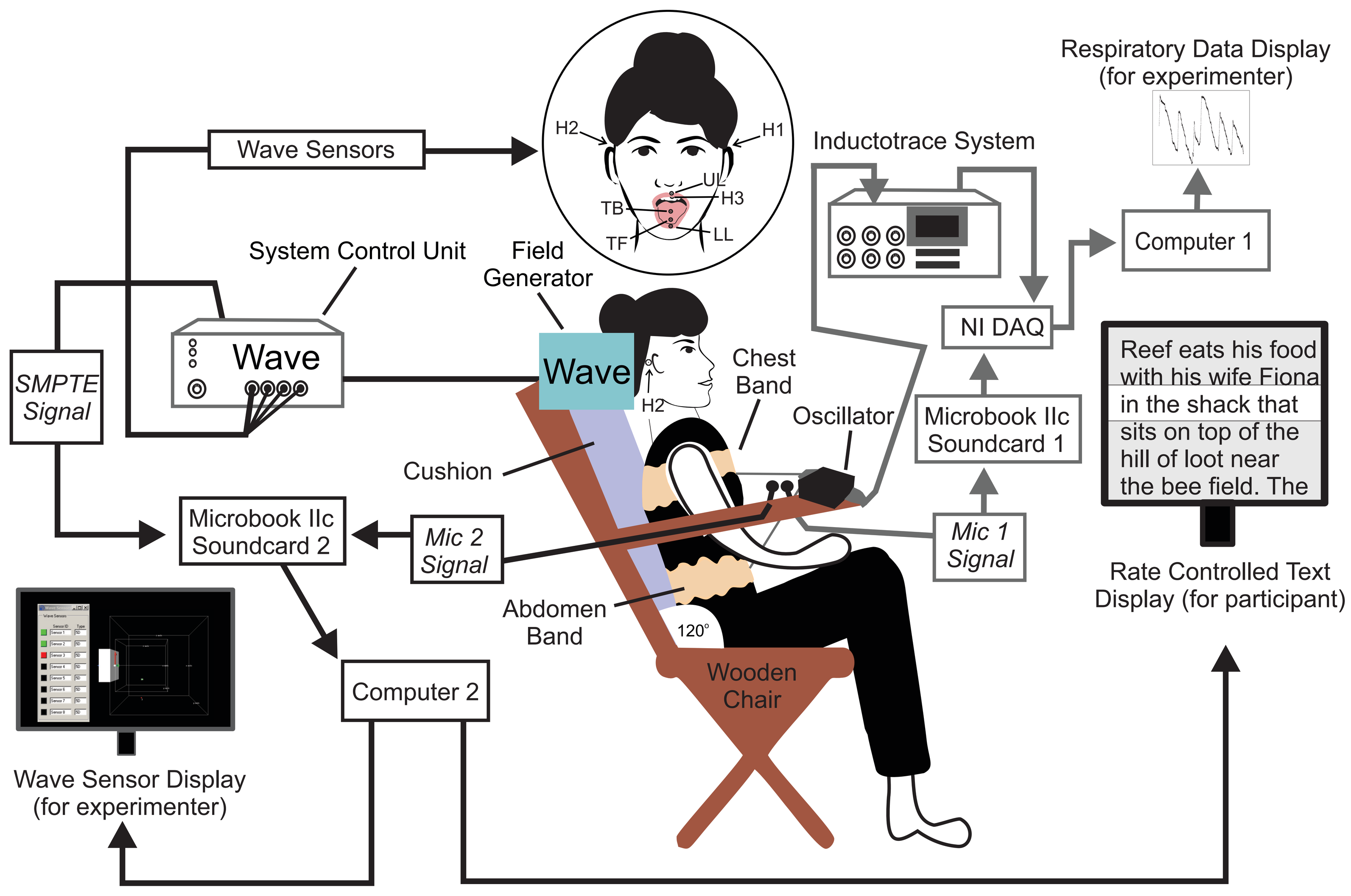
Here, we investigate how increases in vocal effort, with *steady* speech intensity, impact 1) respiratory kinematics during speech initiation and termination, and 2) articulatory kinematics of the tongue and lips

Hypotheses

Increased vocal effort with steady speech intensity will result in:
- Reduced articulatory-kinematic working space (AKVS) of tongue sensors (based on acoustic evidence for reduced vowel space with increased vocal effort[4])
- Reduced lip aperture
- Greater lung volumes at speech initiation (LVSI)
- Lower lung volumes at speech termination (LVST)

Methods

Data collection
- 10 American English speakers (4 cisgender females, 1 non-binary female, 5 cisgender males) aged 17 - 29 (mean = 21.3 years)
- Exclusions: neurological, speech, language, hearing, respiratory disorders, history of smoking and singing/wind instrument experience
- Vocal effort training: speakers underwent training using experience anchoring for **mild** and **maximal** vocal effort ("Think of when you experienced **mild**/**extreme** effort, strain, discomfort and/or fatigue while speaking, e.g. when you spoke for a long time without losing your voice, or when you had to speak through laryngitis")



- Articulatory data collection: sensors on the tongue back (TB), tongue front (TF), upper lip (UL) and lower lip (LL), behind the left and right mastoid (H1 and H2) for head correction
- Respiratory data collection: Respi-bands placed on chest and abdomen to examine movement during speech breathing
- Two microphones to time-align articulatory and respiratory data
- Experimental task:
  - Started 10 min after sensor placement to allow habituation[5]
  - One trial = 3 repetitions of rate-controlled reading passage (typical, mild vocal effort, and max vocal effort)
  - 5 trials run
  - Maintain steady speech intensity, monitored to ensure within 2.5 dB[6] fluctuations

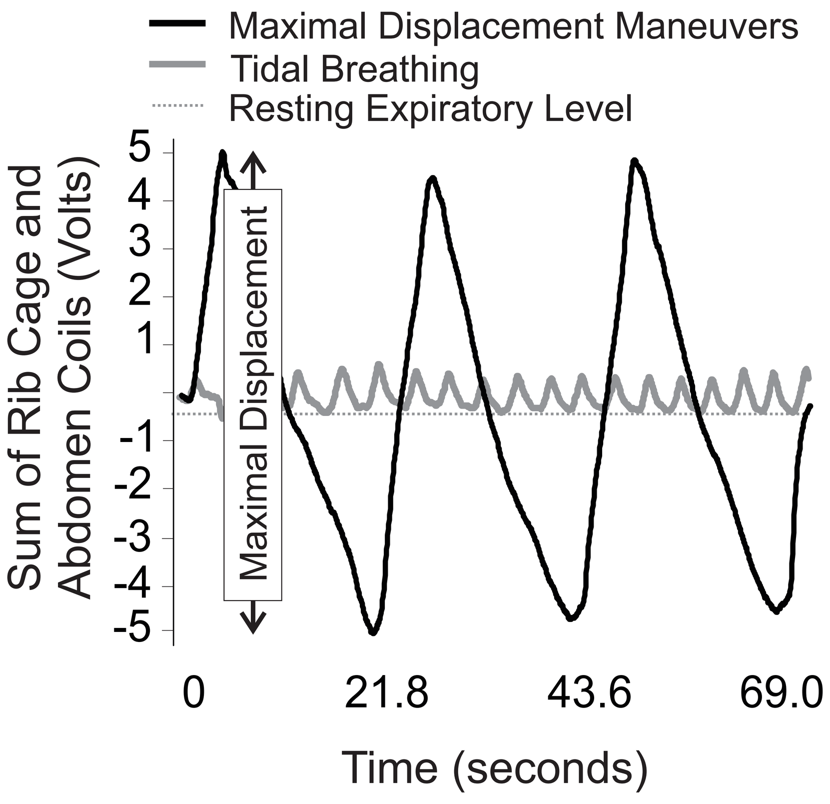
Methods

***Articulatory-kinematic* measures:**
- Data referenced to each speaker's maxillary occlusal plane
- y-(vertical) and z-(anterior-posterior) trajectories were extracted
- AKVS was calculated for the tongue base (TB) and front (TF)[7]
  - AKVS = square root of generalized variance of y- and z- trajectories
  - Generalized variance = product of variance in y, variance in z, and proportion of unshared variance between the two trajectories
- Lip aperture = displacement between the upper lip (UL) and lower lip (LL)

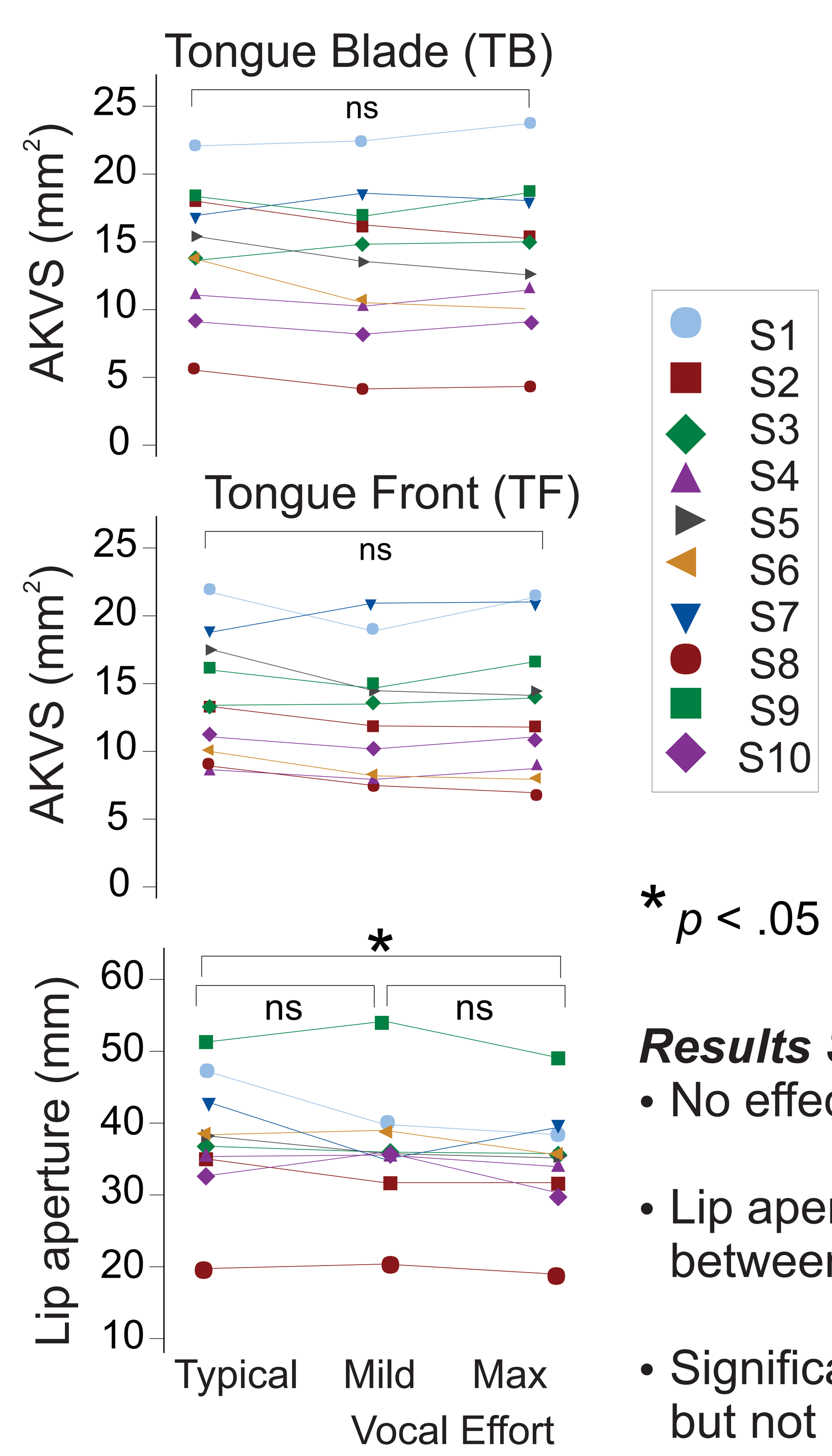
Respiratory-kinematic measures:
- Weighted sum of coils (2:1)[8] used
- Tidal breathing
- 3 x maximal displacement (MD)
- Resting expiratory level (REL)
- Lung volume at speech initiation (LVSI) and speech termination (LVST) determined as:

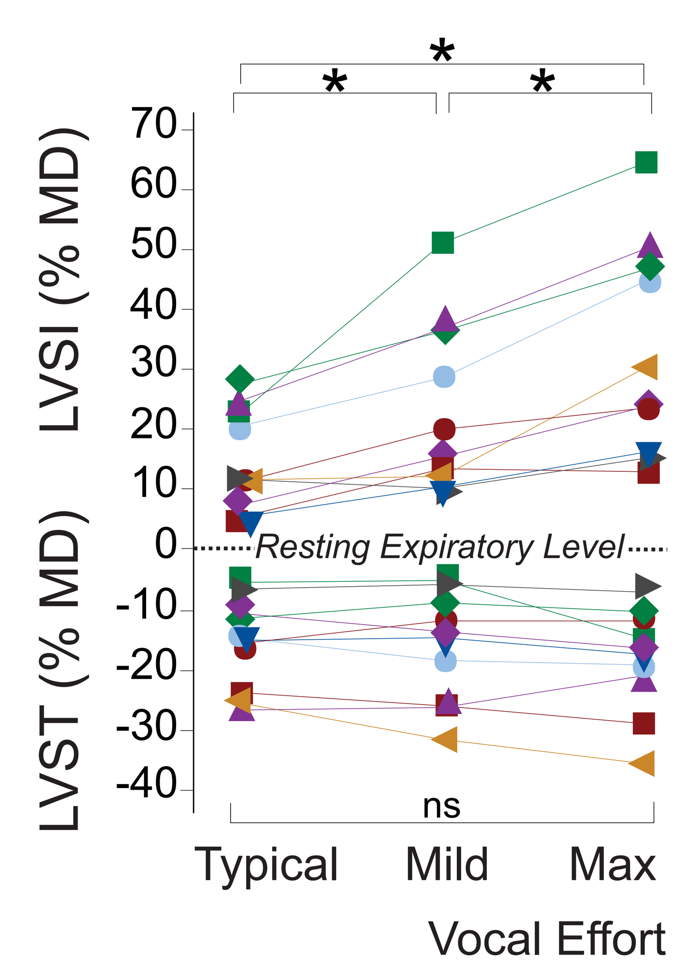
$$LVSI = \frac{(Maximal\ Inspiration - REL)}{MD} * 100$$

$$LVST = \frac{(Maximal\ Expiration - REL)}{MD} * 100$$



Results





Results Summary:
- No effect of vocal effort on AKVS
- Lip aperture was significantly reduced between typical and max vocal effort
- Significant effect of vocal effort on LVSI but not LVST

Discussion

Articulatory-kinematic findings:
- Lip aperture decreased with vocal effort increases at level intensity; this may indicate compensation to control intensity
- Tongue AKVS did not change with vocal effort, in contrast with evidence of decreased vowel space in speakers with voice disorders

Respiratory-kinematic findings:
- Speakers increased LVSI with vocal effort but did not decrease LVST
- Findings contrast with prior work in speakers with voice disorders (showing both reduced LVSI and LVST compared to controls)

These results suggest there may be different mechanisms for chronic (e.g. in voice disorders) vs. experimental increases in vocal effort or speaker-specific strategies

Future work should examine impact of vocal effort on all subsystems together in speakers with and without voice disorders

Acknowledgments

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