A Dynamics-Inspired Model for Phonation-Induced Aerosolization

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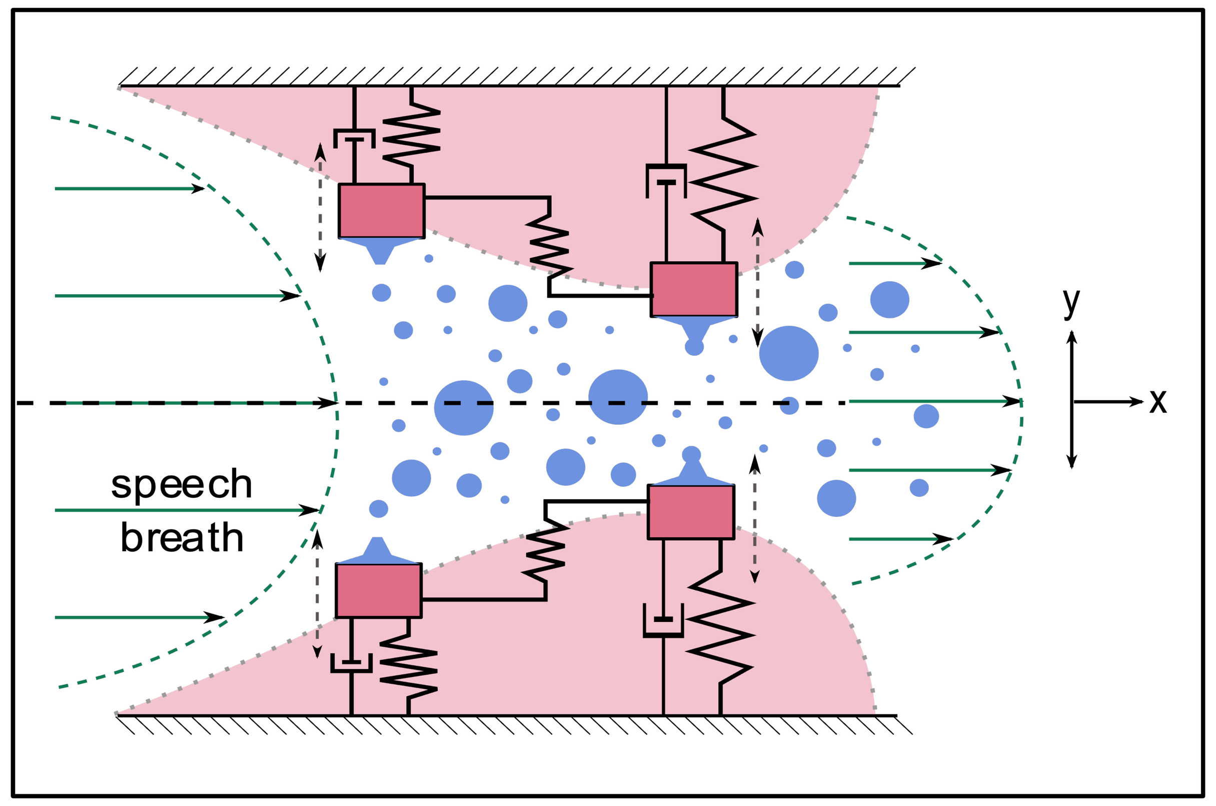
Vibration-Induced Atomization Model



Two-mass Vocal Fold Oscillation Model [2]

$$\begin{cases} m_1\ddot{x}_1 + \beta_1\dot{x}_1 + k_1x_1 + \hat{k}_{ij}(x_1 - x_2) = f_1 \\ m_2\ddot{x}_2 + \beta_2\dot{x}_2 + k_2x_2 + \hat{k}_{ij}(x_2 - x_1) = f_2 \end{cases}$$

Vibration-Induced Droplet Ejection Model [3]

$$m_i = f(m_{i,t}, \overline{m_i})$$

$$\dot{m}_i = \begin{cases} 0, & \ddot{x} \le a_c \\ -r(\ddot{x} - a_c), & \ddot{x} > a_c \end{cases}$$

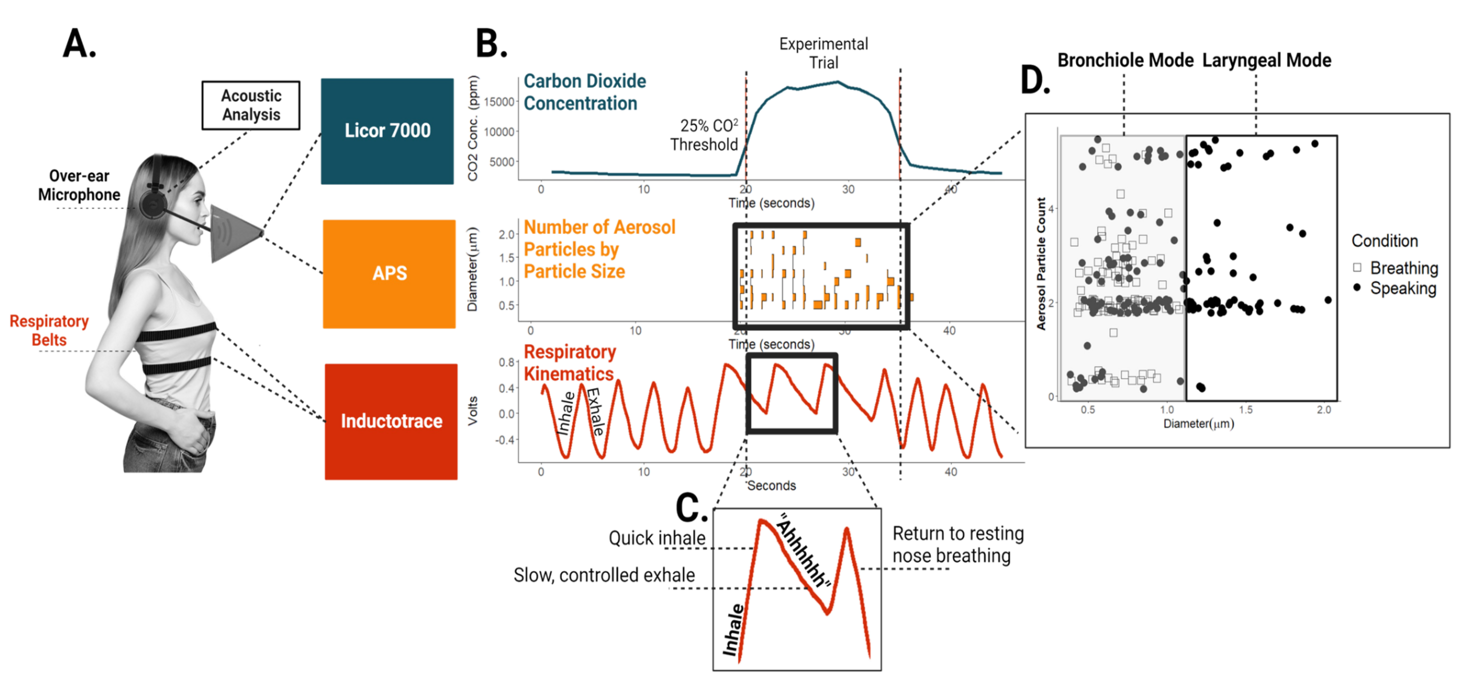
Highlights

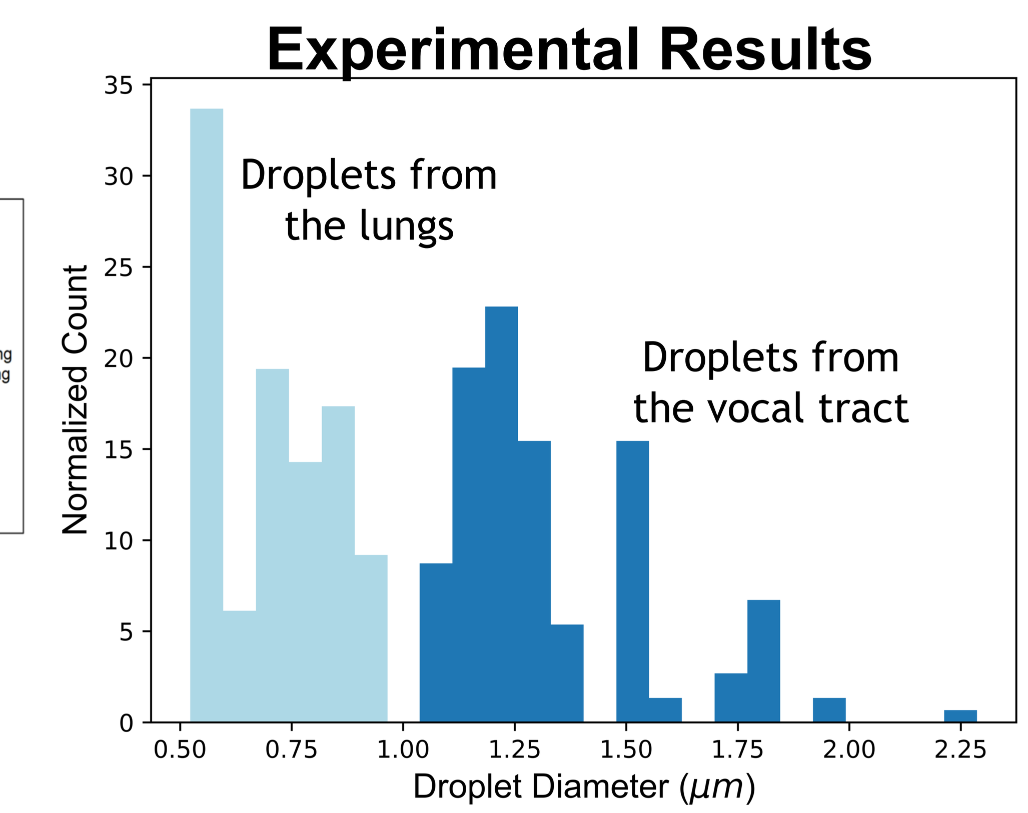
- Vocal-fold oscillation models predict aerosol particles from 0 – 25 μm diameter.
- **Geometry Matters:** mass, stiffness, and damping of the tissue affect the ejection process.
- Novel aerosolization/fluid/structure model validated with experimental aerosol particle data from speech.

Motivation

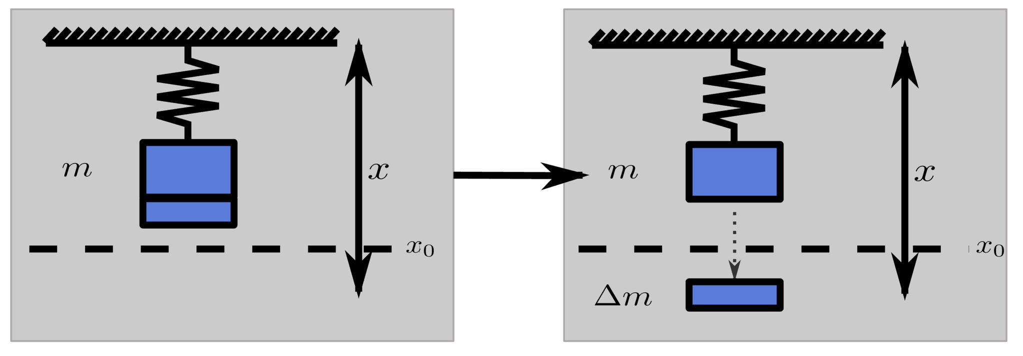
- Exhaled aerosols originate in three locations: the lungs, the larynx, and the mouth.
- Vibration ejects sessile fluid from the surface of the vocal folds.
- **We need better mechanistic insight into the role of phonation in aerosol generation and transmission.**

Experimental Validation





Shaw's Leaky Faucet Experiments



In 1984, Robert Shaw modeled a leaky faucet as a harmonic oscillator ejecting some mass, Δm, with each oscillation.

This model **inspired** our model for droplet ejection.

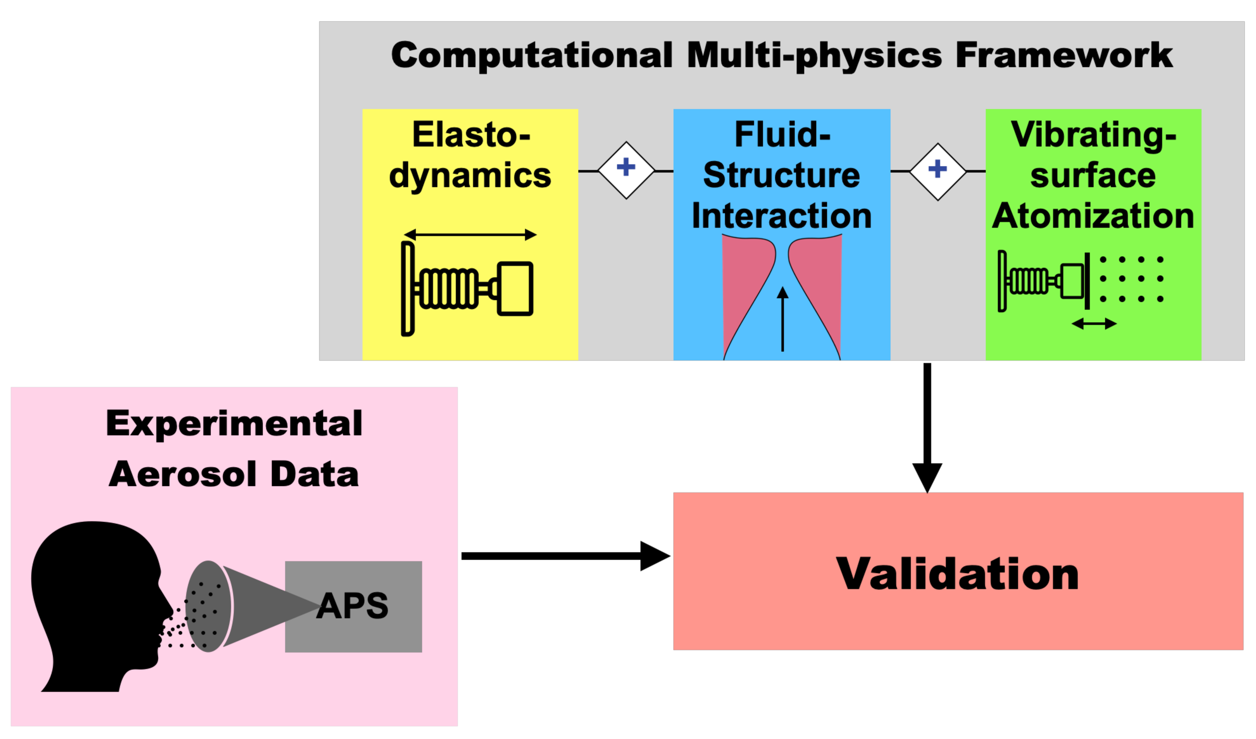
This application requires tailoring Shaw's model to account for:

- free parameters
- acceleration normal to gravity
- fluid-structure interaction

Challenges:

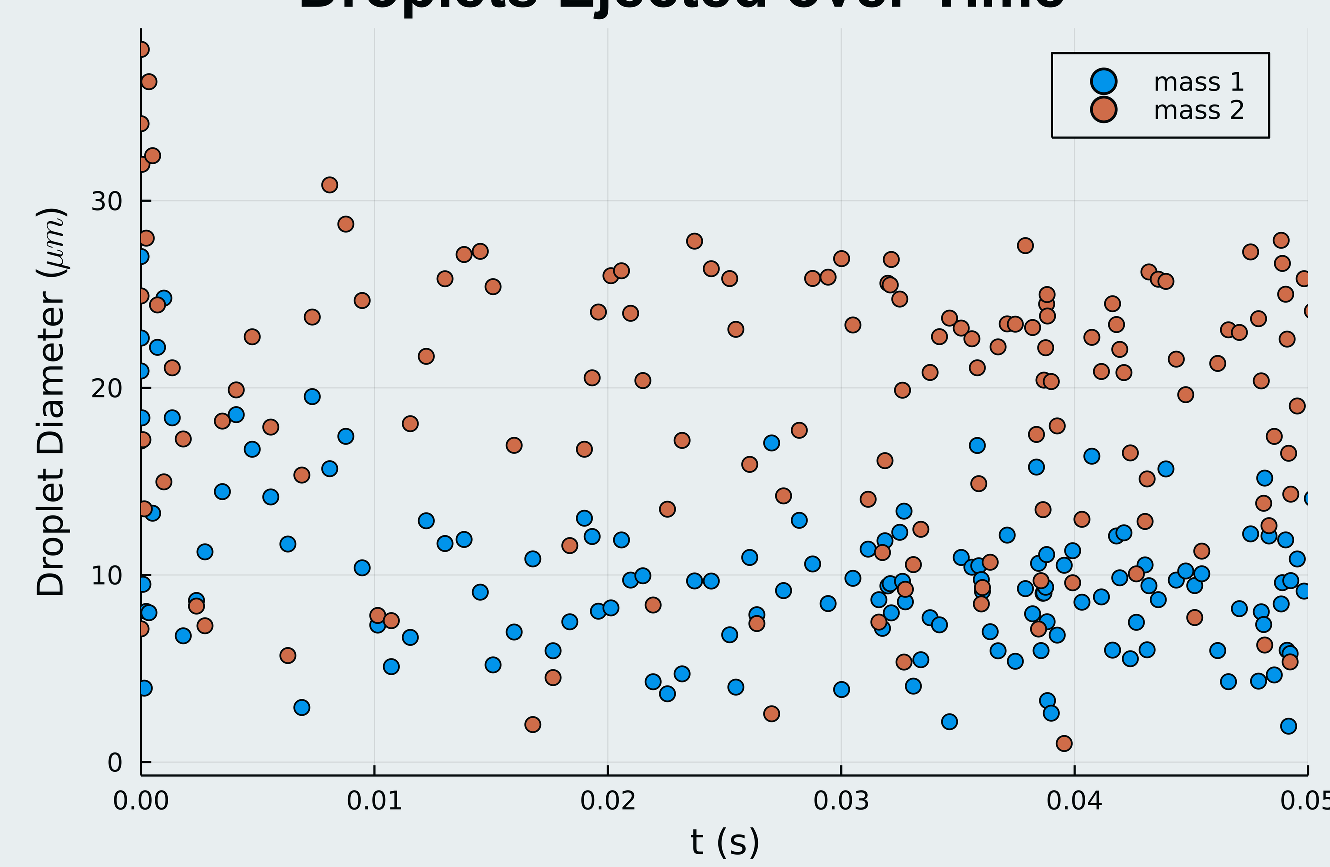
- *Parameter values*
- *Validation*

Aerosolization Framework



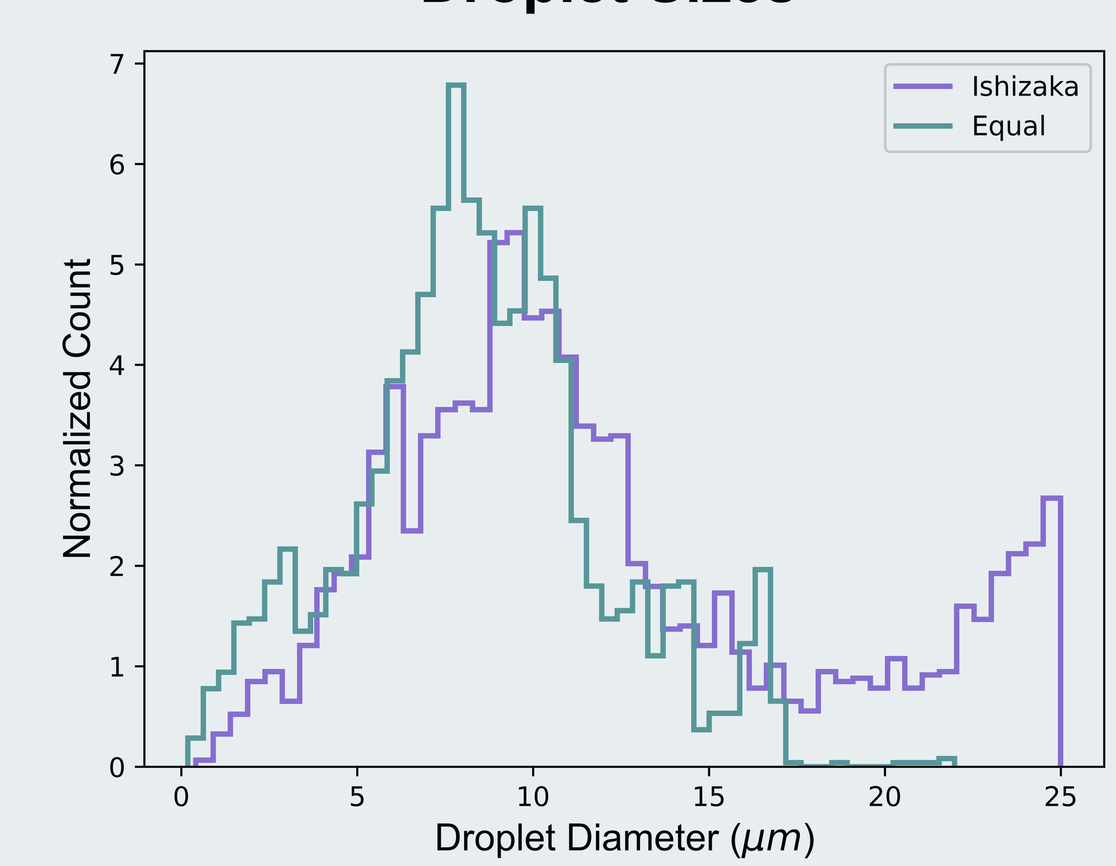
Model Results

Droplets Ejected over Time



*Diameter of droplets ejected over time using parameters from [2].

Droplet Sizes



*Droplet size histogram from two models: an equal mass model and a model using parameters from [2].

Future Work

We will extend this computational framework to a multi-mass oscillatory system, adding in unsteady fluids forcing and fluid-structure interaction. We will validate this approach further by comparing our histogram outputs with experimental aerosol data collected during experimental speech trials with an aerosol particle sizer.

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