

**6.542J, 24.966J, HST.712J LABORATORY ON THE PHYSIOLOGY,  
ACOUSTICS, AND PERCEPTION OF SPEECH  
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Lab 9

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**Techniques for Measuring Respiration during Speech**  
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**References**

**Required Reading**

Banzett, RB; Mahan, ST; Garner, DM; Brughera, A; and Loring, SH (1995) *A simple and reliable method to calibrate respiratory magnetometers and RespiTrace*, **Journal of Applied Physiology**, 79(6), 2169-76.

**Suggested Reading**

Rothenberg, M (1977) *Measurement of airflow in speech*, **Journal of Speech and Hearing Research**, 20, 146-154.

Winkworth, AL; Davis, PJ; Ellis, E; Adams, RD (1994) *Variability and consistency in speech breathing during reading: Lung volumes, speech intensity, and linguistic factors*, **Journal of Speech and Hearing Research**, 37, 535-556.

Loring, SH (1998) *Mechanics of the lungs and chest wall*, in **Physiological Basis of Ventilatory Support**, J.J. Marini and A.S. Slutsky (eds.), New York: Marcel Dekker, 177-208.

**Procedure**

The respiration system provides the energy supply for the creation of sound sources during speech. Physiological variables related to respiratory system function during speech include: lung volume, air flow, air pressure, and muscular activity. A wide range of measurement techniques are available to measure or infer these variables, where some techniques are more invasive than others. This laboratory will (1) provide an overview of some of the measurement techniques (2) examine, in the laboratory setting, the calibration process for estimating lung volume from measures of

ribcage and abdomen movement (using respiratory inductive plethysmography) during a set of calibration maneuvers, (3) verify the calibration results and examine some examples from read speech, and (4) make some observations on airflow measures in connected speech.

### In the pre-lab lecture: Overview of measurement techniques

1. Airflow: Rothenberg mask
2. Air pressure: water manometers and esophageal balloon
3. Muscular activity: hooked-wire EMG and surface EMG
4. Lung volume: RespiTrace and magnetometers

**In the lab:** You will have the opportunity to consider some of the issues involved in the calibration process for observing lung volume, and will examine some calibrated data for air flow in connected speech.

All of the analyses will be done in MATLAB. Login to your account. In the labc account, copy the directory *6.542/Lab16\_Respiration* to your group's working directory. All of the filenames referenced in the following sections refer to files in the *Lab16\_Respiration* folder. Start MATLAB.

### Calibration of lung volume from raw data

**A. Isovolume maneuvers:** These maneuvers assume that lung volume is controlled by two essentially independent mechanisms – the abdomen and the ribcage. The files *isovol1.mat* and *isovol2.mat* each contain an example of an isovolume maneuver from a male speaker. Each file contains a separate vector for the abdomen trace (*respiabd*) and for the ribcage trace (*respirc*). During these maneuvers, the speaker fixed the amount of air in the lungs by closing the glottis, and then 'sloshed' the air back and forth between the ribcage and the abdomen. First, determine a scale factor for the ribcage trace such that both traces have the same excursion (in voltage) to reflect the constant volume used in the maneuver. **Use at least three of the following four methods, and both of the isovolume files with each method:**

1. Use the script 'plot\_isovols' to plot an overlay of the two traces plotted versus time. Print the plot. Choose at least three pairs of points along the traces and estimate a scale factor. You can estimate the points 'by eye' or 'by pencil' from your printout, or you can use the MATLAB function 'ginput' to select the points (e.g. `ginput(2)`, lets you click on two points and then displays the coordinates). Estimate a scale factor for the ribcage trace. Include in your report plots on which you have indicated the points that you selected.
2. Use the script 'compute\_rc\_scale' to plot the abdomen trace (y-axis) versus the ribcage trace (x-axis). The script will expect you to select five points, by clicking on them, as representative of the slope. Estimate a scale factor for the ribcage trace. Include a printout of each plot.
3. Use the script 'polyfit' to fit a line to all of the data. (See the MATLAB help file for an explanation on using this function. Type 'help polyfit' at the MATLAB prompt.) Use the ribcage trace as the x-data and the abdomen trace as the y-data. Set the order of the curve to '1' (a straight line). Estimate a scale factor for the ribcage trace.
4. Use the method suggested in Banzett et al., 1995. Estimate a scale factor for the ribcage trace.

In your report, comment on the differences, if any, observed between the two isovolume files. Comment on the advantages of each approach. Which method for estimating the ribcage scale factor is most representative of the ‘truth’? What are some of the limitations in this approach?

**B. Vital capacity maneuvers:** Once the ribcage scale factor is set, the ribcage trace and the abdomen trace can be added to obtain a single voltage trace representative of the total lung volume change. The next step is to convert from voltage to liters. In a vital capacity maneuver, the subject is asked to inhale as much air as possible and exhale as much as possible into a spirometer. The experimenter reads the liters of air exhaled from the spirometer. These data can be used to convert from respitrace volts to liters.

There are three vital capacity files (Table 1). Each file contains a single vital capacity maneuver which has been edited to represent only 80% of the recorded vital capacity, i.e. the portion of the maneuver representing the final 20% of the exhalation has been removed. (At very low lung volumes, the respiratory system can move in ways that violate the assumed independence of the ribcage and abdomen.)

Filename	Liters (80%VC)
<i>VC01.mat</i>	3 liters
<i>VC02.mat</i>	3.4 liters
<i>VC03.mat</i>	3.6 liters
Table 1: Vital capacity files and associated liter readings.	

Load in a vital capacity file into MATLAB (>load VC01.mat <ret>). Measure the voltage span for the maneuver and compute a liters/volt scale factor. Repeat the process for each vital capacity file. Decide on a conversion factor for your calibration. Include in your report the reasoning behind your decision process. Given these vital capacity measures for a single subject, what is the vital capacity of this subject?

**C. Check your calibration:** The files *Spiro009.mat* and *Spiro010.mat* contain additional calibration maneuvers in which the speaker inhaled and exhaled into a spiropack. This bag holds 0.8 liters of air and the subject was instructed to fill the bag on the exhale without forcefully exhaling into the bag. Convert these files to lung volume in liters using your calibration factors. Comment on your results.

**D. Lung volume during speech** There are three isolated utterances in three separate files: *utt1.mat*, *utt2.mat* and *utt3.mat*. For each utterance: Calibrate the lung volume. How much air is expended in each utterance? Plot lung volume (as a percentage of vital capacity) versus time for each utterance, and include these plots in your report. Discuss why plots of lung volume are usually displayed as percentage vital capacity. How do the values for this subject compare with the normal range of lung volumes used in speech? These utterances are read utterances. What types of differences do you expect for spontaneous speech?

### Observations from calibrated measures of air flow

The plot in Figure 1 contains audio and calibrated air flow data for the same subject used in the lung volume portion of the lab. The segment of speech is from the end of an isolated utterance for the text “...to bring in this season is a good umbrella.” From the figure, you will be asked to estimate some airflow parameters and comment on possible articulator configurations. For these questions, assume that the subglottal pressure is relatively constant.

A. Fricatives

1. For the geminate /s/ in “this season,” estimate the peak airflow. Speculate why the airflow dips ‘between’ the two /s/’s. Why do you think the audio signal shows an increase in amplitude during the ‘dip’?
2. Locate a voiced fricative. Estimate the peak airflow. How does this value compare to the voiceless fricative?

B. Stop consonants.

1. There are five stop consonants in this speech segment. Can you estimate a peak airflow for each one? Would you consider any of the stops to be produced as a flap; why or why not?
2. In the stop closure for the /g/ in ‘good’, the airflow dips below zero in the assumed closure region. How do you interpret this observation?

C. Vowels.

1. Examine the airflow in the schwa following ‘is’. Speculate on the vocal fold configuration.
2. Estimate the average airflow during vowel production. How does this value compare to data available in the literature?
3. For some of the vowels, the airflow crosses below zero. How do you interpret this observation?

D. End of the utterance. What is the peak airflow achieved after the end of the utterance? How do you interpret this observation, especially in relation to how the speaker may have planned the utterance?

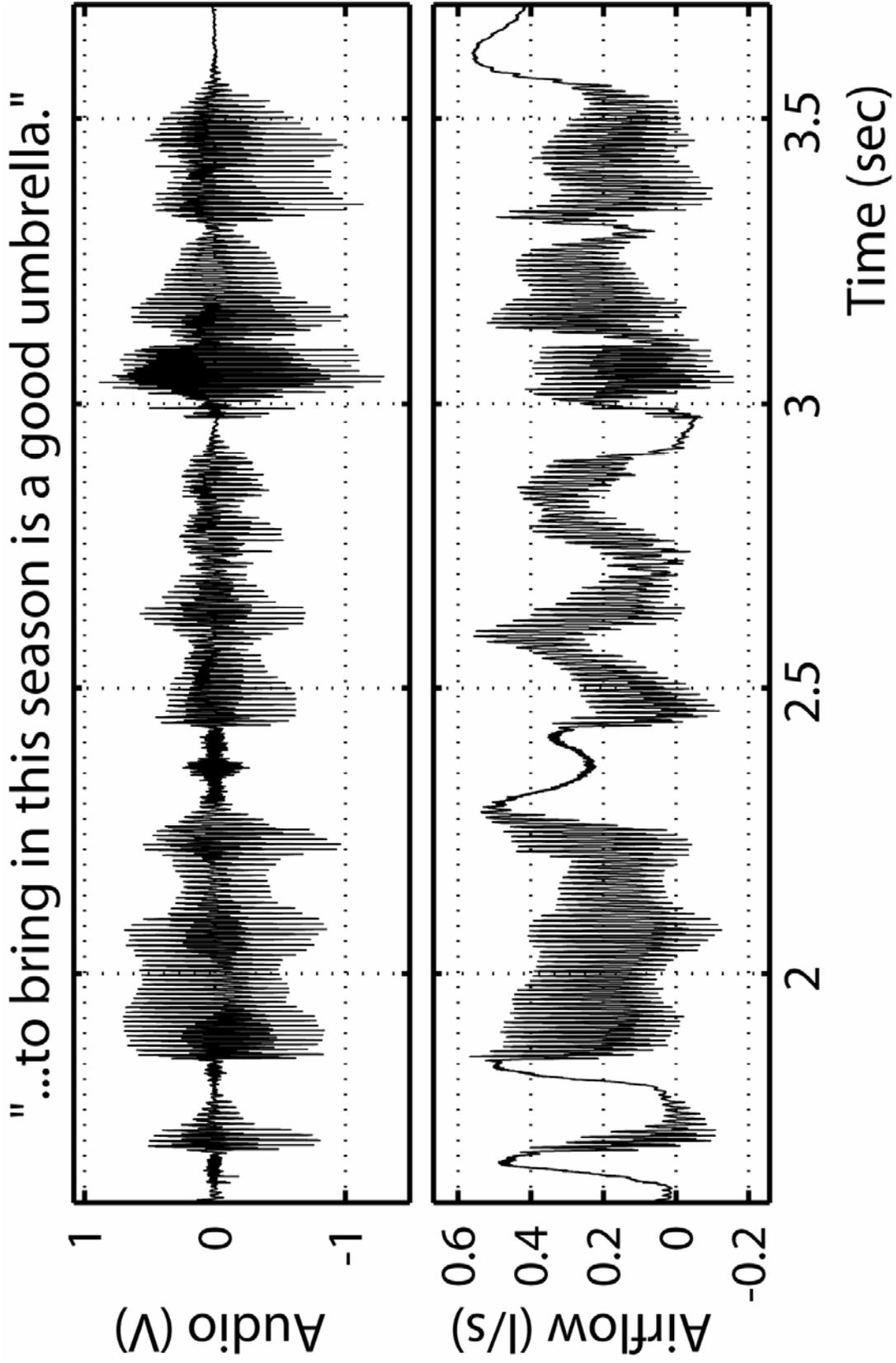


FIGURE 1