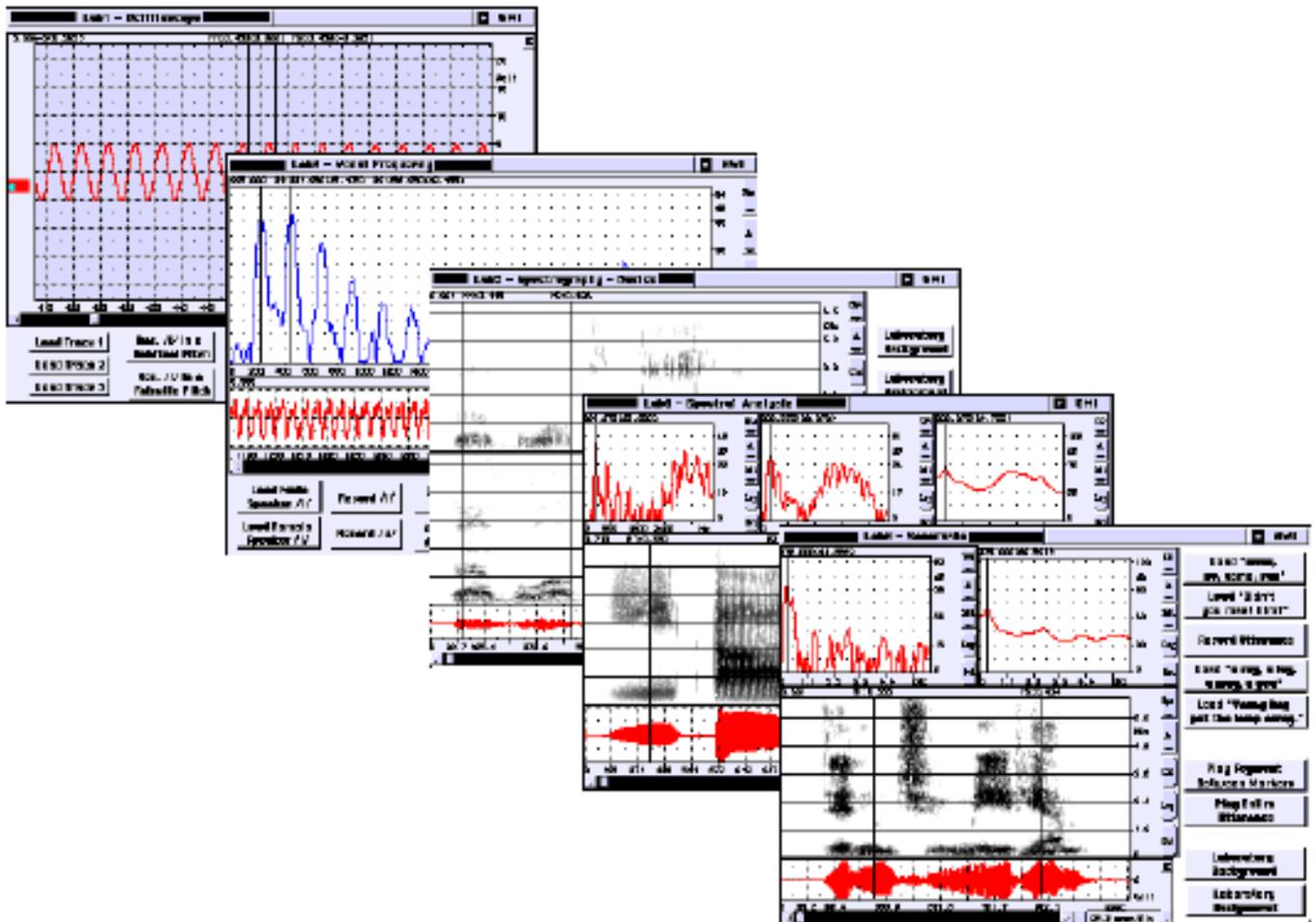


SOUNDSCOPE INSTRUMENTS FOR TEACHING AND LEARNING SPEECH SCIENCE

BY

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PREFACE

The following manual and accompanying instruments are tools which I have developed over the past two years primarily for use in my undergraduate speech science course. These activities and instruments are used as an introduction to the acoustic analysis of speech and voice. My general guiding principle has been to keep these analysis techniques as simple as possible while retaining a meaningful analysis experience for the novice student. Upon completion of these ten basic laboratory activities (and the accompanying course), several of my students have embraced more complex analyses using more involved (less prescriptive) instruments. Many of these individuals have transferred some of these analysis techniques into their clinical practice and/or their graduate research.

In developing these instruments for dissemination by G.W. Instruments, I thought it wise to simplify the data collection (journaling) and printing functions that I typically include in my labs. This is the result of some frustrating experiences of sharing some more involved instruments which I have developed. The specific set of instruments in this collection is intended to be durable and easy to use by novice users on “any” Macintosh configuration which supports SoundScope.

I encourage you, if you have some basic skills and desire, to use the Option/F key combination (while in one of my lab instruments) to expose the full SoundScope menu. This full menu will enable you to explore the development of these basic instruments (e.g., waves, displays, tasks, & controls). Feel free to modify these instruments to better meet your needs or to develop your “programming” skills. I have found it very useful to find an existing task in an instrument in the G.W. library (instruments shipped with SoundScope) to model (program) a desired task in an instrument I am designing. This borrowing will enhance your instruments as well as improve your programming abilities.

In closing, it is with some fear that I permit G.W. Instruments to disseminate this manual and instruments. I have simplified some complex analyses, terms, and procedures for teaching purposes which some “experts” may find offensive. However, I have attempted to stay “in line” with the spirit of the related scientific principles, techniques, and definitions in the development of these teaching tools. I would be happy to receive feedback and suggestions related to these tools.

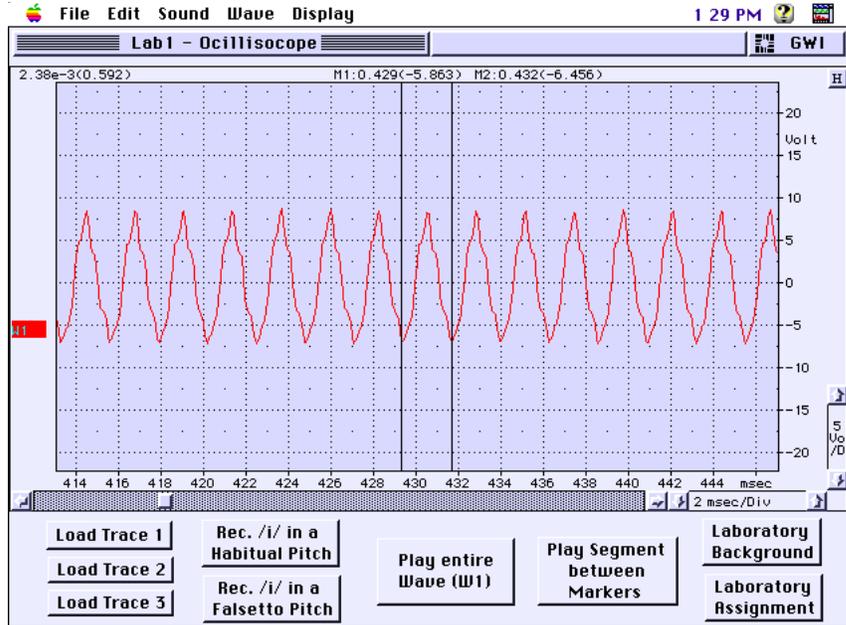
Sincerely,

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Lab 1: OSCILLOGRAMS

Purpose:

The purpose of this lab is to practice displaying and interpreting sound pressure waveforms using a basic “oscilloscope.”



BACKGROUND INFORMATION:

The *oscilloscope* has been a basic tool used for the analysis of various physical events. Any physical phenomenon that can be translated into an electrical voltage may be displayed as a two-dimensional (amplitude over time) waveform (oscillogram). In the case of sound or speech analysis a microphone translates the physical sound pressure levels into an electrical voltage which is in turn displayed as a sound pressure waveform on the oscilloscope. Although this SoundScope instrument is not exactly like a oscilloscope, it has a similar function. Like the oscilloscope, this instrument displays an “oscillogram” which can be used to determine the duration and relative amplitude of the signal. While neither the oscilloscope nor the oscillogram analyzes signals, each facilitates subsequent measurement and analyses by providing a visualization of the waveforms.

The major components of the SoundScope “Oscilloscope” instrument includes two controls; the horizontal or “time base” control adjusts the time scale of the display, and the other, the vertical amplifier, regulates the sensitivity of the amplitude (vertical scale). A grid is in place in the “analysis” window to provide horizontal and vertical “divisions” to assist in the interpretation of the waveform. The signal trace in the “analysis” window is made up of a series of points on the screen. Each point on the horizontal axis of the screen display represents a point in time during a sweep of the signal.

SoundScope “Oscilloscope” Instrument

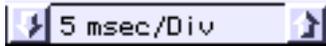
1. To begin, examine the SoundScope Oscilloscope instrument. Notice that the *analysis display* window occupies a large portion of the screen. Also identify the following controls:

H

The *auto horizontal scale adjust button* located in the upper right corner of the instrument adjusts the time display to include the entire duration of the signal trace (wave) in the *analysis display*. Click (using the mouse) on this button after you have loaded or recorded a wave into the instrument to center the wave in the display window.



The *vertical scale adjust control* located on the right side of the instrument near the bottom of the *analysis display* has arrows pointing up and down. Clicking on the arrow pointing up increases the voltage (amplitude) divisions in the analysis display resulting in a “shrinking” of the wave in the vertical aspect. Clicking on the arrow pointing down decreases the voltage (amplitude) divisions which enlarges the wave in the vertical aspect. Note that the center of this control identifies the voltage increment of the adjustable vertical divisions.



The *horizontal scale adjust control* located on the right side of the screen below the *analysis display* functions in a manner similar to the *vertical scale adjust control*. Clicking on the arrow pointing up increases the time divisions in the *analysis display* resulting in the compacting (squashing) of the wave in the horizontal aspect. Clicking on the arrow pointing down decreases the time divisions which “stretches out” the wave in the horizontal aspect. This is useful to identify the individual cycles of the waveform. As with the *vertical scale adjust control*, this adjust control displays the time increment of the adjustable horizontal divisions of the analysis display.



The *horizontal scroll control* located just below the *analysis display* controls the horizontal position of the *analysis display* over the wave. The small box in this control represents the *analysis display* and the grey background represents the wave. With the box positioned to the far left, the beginning of the wave is displayed in the *analysis display*. The box can be dragged changing the segment of the wave displayed in the analysis display, e.g., dragging it to the right side of the control would display the end of the wave. The left and right arrows can be clicked on to move the display along the wave in small increments in the direction of the activated arrow.

In the *analysis display* there are two adjustable vertical lines (markers) which can be positioned in the vertical aspect of this display. These markers are moved by placing the mouse cursor over the line and dragging them (while holding the mouse button down) to the left or right. As you adjust the horizontal/time scale you may notice that one or both of the markers may disappear. Actually, the markers are located at a point in time (note the times where the markers are located). As the horizontal/time scale is adjusted, the analysis display shows only a section of the signal. You may need to use the *horizontal scroll control* to scroll along the signal to “find” the markers which have disappeared. Notice that the *marker name, horizontal (time) values and vertical (amplitude) values* (displayed in parentheses) are displayed just above the *analysis display* for each marker. Also note that the time and amplitude differences between the markers are displayed to the left of the individual marker values. The amplitude value is again displayed in parentheses. Note that when SoundScope displays small numbers, it uses “scientific” notation (e.g., 5.0e-3). This is .005 seconds or 5 milliseconds. The e-3 notation means that you move the decimal point 3 places in a negative (to the left) direction.

The markers can be used to measure the duration and/or amplitude of aspects of or the entire signal captured by SoundScope. By measuring the duration of an individual cycle or period of the signal, you can calculate the frequency of the signal. The **period (T)** of a signal is defined as the amount of time, in seconds, that is required to complete one cycle. **Frequency (F)** is defined as the rate, in hertz, at which the signal repeats itself.

Therefore, we can measure the period (T) and calculate frequency (F) using the following formula: $1 \text{ cycle/Period (T)} = \text{Frequency (F)}$; e.g., $1 \text{ cycle} / .005 \text{ seconds} = 200 \text{ Hertz}$
The buttons found across the bottom of the screen are used to load and record a wave, play a portion of or the entire wave, and to provide information related to the laboratory activity. These buttons are activated by clicking on them.

Exercises:

Activity 1. **Input** Trace 1 by clicking on the *Load Trace 1* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire wave in the analysis display. **[A]** What is the approximate duration of this wave? **[B]** What is the approximate amplitude range (peak-to-peak) of this wave?

Locate the two Markers (M1 & M2) located in the analysis display. **Move** them, by dragging with the mouse, close together to the left side of the analysis display at approximately 70 msec. With the markers in place, **adjust** the time scale (using the *horizontal scale adjust control*) so you can easily identify individual cycles (wave length) of this waveform. **Adjust** the amplitude scale (using the *vertical scale adjust control*) so the waveform occupies $\frac{2}{3}$ to $\frac{3}{4}$ of the analysis display window. **[C]** What type of wave is this? (sine/simple or complex)

[D] Measure the period (T) and **[E]** peak-to-peak amplitude of this waveform using the markers and then **[F] calculate** the frequency of this wave. **Period (T):** Position M1 at a point in the waveform (try the zero-crossing point, the point where the signal crosses 0 amplitude) and M2 at the point where the segment between the markers (M1 & M2) represents one cycle. **Record** the durational difference which is listed on the left side of the screen just above the analysis display. This value is the period of the wave. **Notice** that the time location and amplitude (in parentheses) of the wave at the point it intersects the marker are listed following the marker label just above the analysis display. **Peak-to-peak amplitude: Position** M1 at the highest peak of this signal (all peaks may be equally high) and M2 at the lowest "valley" which may also be equally low. **[G] Note** the amplitude difference (absolute difference) which is displayed in parenthesis near the left side of the screen the screen above the analysis display window. **Frequency (F):** Knowing the value of the period (T), **[H] calculate** the Frequency (F) of this wave.

Activity 2. **Input** Trace 2 by clicking on the *Load Trace 2* button. **Repeat** the steps of Activity 1 determining: **[A]** What is the approximate duration of this wave? **[B]** What is the approximate amplitude range (peak-to-peak) of this wave? **[C]** What type of wave is this? (sine/simple or complex) **[D] Measure** the period (T) of this wave. **[E]** What is the peak-to-peak amplitude of this waveform? and **[F]** Calculate the frequency of this wave.

- Activity 3. Input** Trace 3 by clicking on the *Load Trace 3* button. **Note** that this wave differs from the first two waves as it is a complex wave. **Repeat** the steps of Activity 1 determining: **[A]** What is the approximate duration of this wave? **[B]** What is the approximate amplitude range (peak-to-peak) of this wave? **[C]** What type of wave is this? (sine/simple or complex) **[D] Measure** the period (T) of this wave. **[E]** What is the peak-to-peak amplitude of this waveform? and **[F] Calculate** the frequency of this wave.
- Activity 4. Record** the vowel /i/ using a habitual voice by clicking on the corresponding button and following the directions provided by the instrument. Again, using the steps of Activity 1, **determine:** **[A]** What is the approximate duration of this wave? **[B]** What is the approximate amplitude range (peak-to-peak) of this wave? **[C]** What type of wave is this? (sine/simple or complex) **[D] Measure** the period (T) of this wave. **[E]** What is the peak-to-peak amplitude of this waveform? and **[F] Calculate** the frequency of this wave.
- Activity 5. Record** the vowel /i/ using a falsetto (high) vocal pitch by clicking on the corresponding button and following the directions provided by the instrument. Again, using the steps of Activity 1, **determine:** **[A]** What is the approximate duration of this wave? **[B]** What is the approximate amplitude range (peak-to-peak) of this wave? **[C]** What type of wave is this? (sine/simple or complex) **[D] Measure** the period (T) of this wave. **[E]** What is the peak-to-peak amplitude of this waveform? and **[F] Calculate** the frequency of this wave.

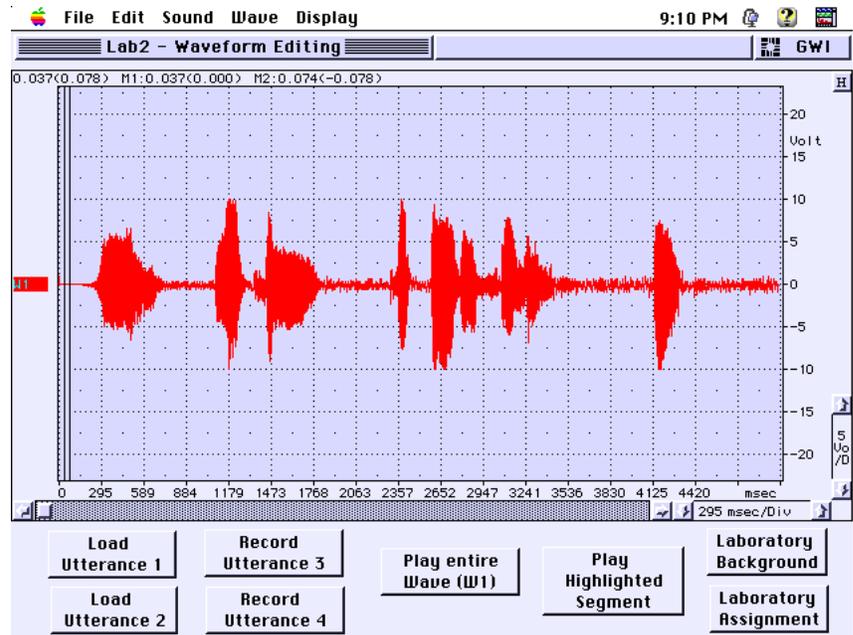
Read More About It:

- Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp.78-89). Boston: Little, Brown.
- Decker, T. N. (1990). *Instrumentation: An introduction for students in the speech and hearing sciences* (pp. 59-64). New York: Longman.
- Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 62-66). San Diego: Singular Publishing Group.
- Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 87-117). San Diego: Singular Publishing Group.
- Speaks, C. E. (1992). *Introduction to sound: Acoustics for the hearing and speech sciences* (pp. 43-76). San Diego: Singular Publishing Group.

Lab 2: Waveform Editing

Purpose:

The purpose of this lab is to practice editing waveforms using *cut*, *copy*, and *paste* menu commands.



Background Information:

We can use computer technology to digitize speech by turning it into a numerical code and plotting it on a screen as a waveform. We have digitized speech by recording the vowel /i/ in Lab 1. When the digitized speech waveform is displayed, we can select (highlight) a portion of (or the entire) waveform and manipulate it by copying or cutting (deleting) this numerical code and pasting (moving) it to a different location. This is a useful feature that is frequently used in “cleaning up” a wave to be analyzed and making (editing) stimuli for various types of perceptual tasks. In the past, experimenters edited tape recordings by actually cutting the tape with a razor blade and splicing it back together. With current technology we can highlight a segment of the waveform (using mouse movements) and precisely cut, copy, and/or paste desired aspects of the waveform. You will find this a useful activity that will be used in several of the following lab activities.

SoundScope “Waveform Editing” Instrument

This instrument is very similar to the “Oscilloscope” used in Lab 1. With this instrument and lab activity, you will become familiar with the menu bar across the top of the instrument (screen). Explore the pull down sub-menus of the five main menu items. Note that the cut, copy, and paste commands are items found under the Edit menu.

Exercises:

Activity 1. **Input** Utterance 1 by clicking on the *Load Utterance 1* button. **Press** the *auto horizontal scale adjust* button (top right side of the screen). This adjusts the time scale to include the entire utterance waveform in the analysis display. **[A]** What is the approximate duration of this waveform? **Play** the utterance by clicking on the *Play Entire Wave (W1)* button. **[B]** **Transcribe** this utterance. **Highlight** a segment of the waveform by positioning the

cursor (arrow) on the waveform and dragging the mouse (hold down the mouse button). **Play** this highlighted segment by clicking on the *Play Highlighted Segment* button.

Notice that this instrument has a different mouse cursor than Lab 1. Lab 1's cursor was the "Move Marker" mouse cursor. Lab 2's cursor is the "Edit" cursor. Although this lab automatically has switched the cursor types based on the function desired, you can change these cursor types under the Mouse item in the Display menu. There are actually five mouse cursor types based on different functions.

[C] Edit this waveform by cutting (deleting) "not Bill" from the utterance. To do this, **highlight** the portion of the utterance that you think is "not Bill." This may take some trial and error playing the highlighted sections until you have the desired portion selected. **Adjust** the time scale (using the *horizontal scale adjust* control) to expand the waveform which will allow a more precise selection of the "not Bill" segment. When you have the desired segment highlighted, **select** Cut from the Edit menu (you can use a shortcut by holding down the command () and the "x" key). **Play** the edited waveform by clicking on the *Play Entire Wave (W1)* button.

[D] Edit this same waveform by deleting (cutting) the prolonged silence found between "shoe bench" and "out" using methods similar to those in the above paragraph. **Listen** to the entire edited utterance.

Activity 2. Input Utterance 2 by clicking on the *Load Utterance 2* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire utterance waveform in the analysis display. **[A]** What is the approximate duration of this waveform? **Play** the utterance by clicking on the *Play Entire Wave (W1)* button. **[B] Transcribe** this utterance. Especially note the aspirated /th/ occurrences in this utterance. **Highlight** one of these aspirated segments of the waveform by positioning the cursor (arrow) on the waveform and dragging the mouse (hold down the mouse button). You may need to adjust the time base (horizontal scale adjust control) to expand the waveform making it easier to identify the aspirated segments. **Play** this highlighted segment by clicking on the *Play Highlighted Segment* button.

[C] Delete (cut) the three aspirated segments found in this utterance using similar procedures to those used in Activity 1 (above).

Activity 3. Record the utterance "Bev loves Bob" by clicking on the *Record Utterance 3* button and following the instructions provided. Again, using the steps of Activity 1, **[A] select** (highlight) "Bev" and **cut** this segment out. **Position** the cursor at a point just before "bob" in the waveform. **[B]** Using the Paste command found in the Edit menu (you can use a shortcut by holding down the command () and the "v" key), **insert** "Bev" at this point in the waveform between "loves" and "Bob." **[C]** Then **highlight** "Bob" in the waveform and

cut and paste the segment of the waveform in front of the “loves” portion of the wave. **[D] Play** the entire utterance. At this point, Who loves whom? **Note** that when you cut a segment of the waveform it is held on the “clipboard” (a portion of the computer’s memory). This segment is retained on the “clipboard” until something else is placed there or the computer is shut down.

Activity 4. **Record** the utterance “Mary and Bruce went to the movie” by clicking on the *Record Utterance 4* button and following the instructions provided. Again, using the steps of Activity 1, **[A] select** (highlight) “Bev” and **cut** this segment out. **Position** the cursor at a point just after “Mary” in this waveform. **[B]** Using the Paste command found in the Edit menu (you can use a shortcut by holding down the command () and the “v” key), **insert** “Bob” at this point in the waveform between “Mary” and “and.” Remember, items remain on the clipboard until something else is placed there; therefore, “Bob” was still on the clipboard from Activity 3. **[C]** Who went to the movie? Play the utterance to listen to this edited utterance.

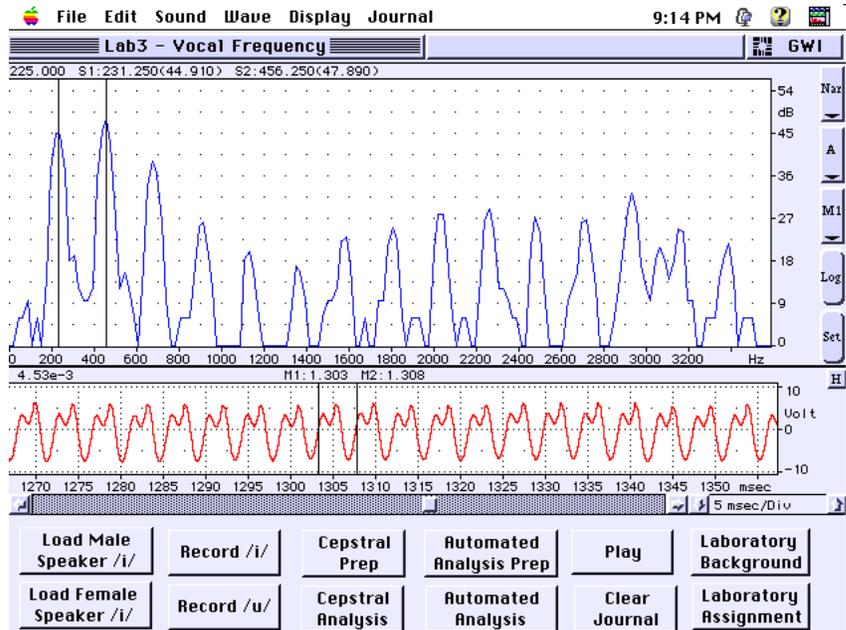
Read More About It:

Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 63-64). San Diego: Singular Publishing Group.

Lab 3: Vocal Frequency

Purpose:

The purpose of this lab is to obtain measures of fundamental frequency using a variety of measurement approaches.



Background Information:

Vocal fundamental frequency (F_0), which is determined by the rate of vocal fold vibration, is the most important contributor to perceived pitch. Fundamental frequency measures are typically obtained by computer-based pitch extraction; however, it is possible to calculate F_0 by “hand.” By measuring the period (T) of the speech waveform we can use the formula ($1 \text{ cycle/period} = \text{frequency}$) to calculate frequency.

A second manner to calculate fundamental frequency (F_0) is to use a narrow band Fast Fourier Transform (FFT). This procedure is based on Fourier’s Theorem which states a complex wave (such as speech) can be analyzed as the sum of an infinite series of sinusoidal components. Each of these components is an integer multiple of the fundamental (F_0). The narrow band FFT yields a spectrum displaying the amplitude of each harmonic of the F_0 . A harmonic is a whole number (integral) multiple of the F_0 . To calculate F_0 using a narrow band FFT, you measure the difference between two adjacent peaks in the FFT spectrum. This difference should represent the F_0 .

Another method of F_0 analysis is known as cepstral analysis. Cepstral analysis involves Fourier transformations. A Fourier transformation moves between the time domain and the frequency domain. By applying this transformation again, cepstral analysis reverses this transformation back to a time domain. That is, cepstral analysis starts with the speech waveform (time axis), transforms it to a frequency axis (Fourier spectrum), and then transforms it back to a time axis (the cepstrum). Thus, in a cepstral display, the horizontal (time) axis should display a prominent peak representing the period (T) of the F_0 .

Most computer-based F_0 analyses are based on some form of automated pitch extraction. Among these methods of F_0 analyses are autocorrelation, pattern recognition, and peak picking.

SoundScope “Vocal Frequency” Instrument

Unlike the previous two labs (Lab 1 & Lab 2), this instrument involves two displays: a time waveform (oscillograph) and a snapshot display. The oscillograph display provides a waveform (time by amplitude) similar to that found in the oscilloscope labs. The snapshot display is located just above the waveform display. The snapshot display plots a wave which corresponds to a specific point (in time) in the waveform display. This point in time is selected by the marker (M1) which can be moved in the waveform display. The snapshot display has five buttons located to the right side of this display. The top button is the analysis options button which allows you to select the type of analysis that is plotted in this display. You will use this button in this lab to switch between the narrow band FFT and Cepstrum analyses. The other four buttons are the Source Wave, Source Marker, Log, and Setup buttons from top to bottom. You will not need to use the bottom four buttons in this lab.

In this instrument, you will encounter journals which will display data. You will need to close these journal dialog boxes by clicking on the small boxes located on the top left of their title bars before performing the lab activity.

As with the instruments from Labs 1 & 2, there are a series of buttons across the bottom of the screen which will facilitate the completion of lab activities.

Exercises:

Activity 1. **Input** Trace 1 by clicking on the *Load Male Speaker /i/* button. **Press** the *auto horizontal scale adjust* button (top right side of the screen). This adjusts the time scale to include the entire wave in the analysis display. **[A]** What is the approximate duration of this wave?

Locate the two Markers (M1 & M2) located in the time waveform display. Move them, by dragging with the mouse, close together to a position in the center of the prolonged vowel waveform. With the markers in place, note their approximate (time) location. **Adjust** the time scale (using the *horizontal scale adjust control*) so you can easily identify individual cycles (wave length) of this waveform. You will probably need to use the horizontal scroll control to **locate** the portion of the waveform that contains the markers (scroll the box to the location you have previously noted).

[B] Measure the period (T) of this waveform using the markers and then **[C] calculate** the fundamental frequency (F_0) of this wave. **Period (T):** **Position** M1 at a point in the waveform (try the zero-crossing point, the point where the signal crosses 0 amplitude) and M2 at the point where the segment between the markers (M1 & M2) represents one cycle (where the wave repeats itself). **Record** the durational difference which is listed on the left side of the screen just above the waveform display. This value is the period of the wave. **F₀:** Knowing the value of the period (T), **calculate** the F_0 of this wave.

Examine the Snapshot display. **Identify** the type of analysis being plotted in this display by clicking on the Analysis button on the top right of this display. **Select** Narrowband FFT (“Nar” on the button). You should know that this Narrowband FFT displays a spectrum (frequency by amplitude representation). The main peaks of this analysis procedure represent the harmonic relations of the signal. Each harmonic is an integral multiple of the F_0 which means they should be spaced apart by a frequency value equal to the F_0 . **Move** markers S1 & S2 (“S” because they are in the Snapshot display) to two adjacent peaks in the narrow band FFT. **[D] Record** the F_0 value using this method of F_0 analysis.

A third method of F_0 analysis is cepstral analysis. **Click** on the *Cepstral Prep* button and follow the instructions provided. As you will see with this task, it is difficult to identify a significant point in some wave plots. In the cepstral analysis procedure you will need to find a prominent peak which corresponds to the Period (T) of the waveform. In some cases this is very simple; however, in others the peak does not stand out. You will need to consider the period you calculated above to assist you in determining the peak of interest in some cases. **[E] Record** the period (T) of the waveform using this cepstral analysis and then **calculate** the F_0 using the formula you used above. You need to **close** the *Cursor dialog box* when you are done with this measure to continue this lab.

The last method of F_0 analysis used in this lab is an automated analysis. To prepare for this automated analysis, again **adjust** the time scale so you have at least one second of the vowel waveform showing in the time display. **Click** on the *Automated Analysis Prep* button and follow the instructions provided. Following these instructions will yield a Voice Journal display which provides you measures of percentage of voiced and unvoiced elements, F_0 average, F_0 range, and F_0 standard deviation. **[F] Examine** these measures and **record** the F_0 average.

[G] Compare the F_0 measures made by each of these analysis procedures. Were your measures consistent? Which one would you guess is most valid?

Activity 2. **Input** Trace 2 by clicking on the *Load Female Speaker /i/* button. Repeat the steps of Activity 1 to determine F_0 in the four different ways. **[A]** What is the approximate duration of this wave? **[B] Measure** the period (T) of this waveform using the markers and then **[C] calculate** the fundamental frequency (F_0) of this wave. **[D] Record** the F_0 value using the narrowband FFT method of F_0 analysis. **[E] Record** the period (T) of the waveform using a cepstral analysis and then **calculate** the F_0 using the formula ($1/T = F_0$). **[F] Acquire** and **examine** the measures using the automated F_0 analysis and **record** the F_0 average. **[G] Compare** the F_0 measures made by each of these analysis procedures. Were your measures consistent? **[H] Compare** the F_0 measures made for the male and female speakers. Is one higher than the other? If yes, why?

Activity 3. Record Trace 3 by clicking on the *Record /i/* button. **Repeat** the steps of Activity 1 to determine F_0 of your sustained production of /i/. **[A]** What is the approximate duration of your utterance? **[B] Measure** the period (T) of this waveform using the markers and then **[C] calculate** the fundamental frequency (F_0) of this wave. **[D] Record** the F_0 value using the narrowband FFT method of F_0 analysis. **[E] Record** the period (T) of the waveform using a cepstral analysis and then calculate the F_0 using the formula ($1/T = F_0$). **[F] Acquire** and **examine** the measures using the automated F_0 analysis and **record** the F_0 average. **[G] Compare** the F_0 measures made by each of these analysis procedures. Were your measures consistent? **[H] Compare** the F_0 measures of your utterance to those made by an individual of your same sex (from Activity 1 or 2 above). Were your measures consistent with those of the waveform from Activity 1 or 2?

Activity 4. Record the vowel /u/ using the *Record /u/* button. **Repeat** the steps of Activity 1 to determine F_0 of /u/ using the four different analysis procedures. **[A]** What is the approximate duration of this wave? **[B] Measure** the period (T) of this waveform using the markers and then **[C] calculate** the fundamental frequency (F_0) of this wave. **[D] Record** the F_0 value using the narrowband FFT method of F_0 analysis. **[E] Record** the period (T) of the waveform using a cepstral analysis and then **calculate** the F_0 using the formula ($1/T = F_0$). **[F] Acquire** and **examine** the measures using the automated F_0 analysis and record the F_0 average. **[G] Compare** the F_0 measures made by each of these analysis procedures. Were your measures consistent? **[H] Compare** the F_0 measures made for the /i/ and /u/ productions. Is one larger than the other? If yes, why?

Read More About It:

Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp.125-196). Boston: Little, Brown.

Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 75-86). San Diego: Singular Publishing Group.

Lass, N. J. (1996). *Principles of experimental phonetics* (pp. 470-474). St. Louis: Mosby Yearbook, Inc.

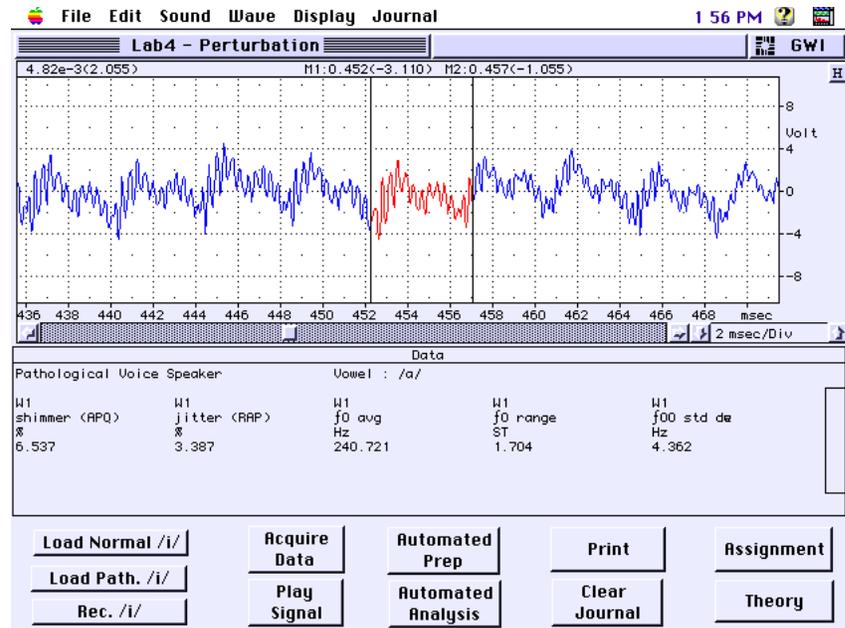
Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 129-146). San Diego: Singular Publishing Group.

Speaks, C. E. (1992). *Introduction to sound: Acoustics for the hearing and speech sciences* (pp. 43-76). San Diego: Singular Publishing Group.

LAB 4: Perturbation

Purpose:

The purpose of this lab is to become familiar with the various commonly used F_0 and amplitude perturbation measures.



Background Information:

The F_0 of a normal speaker's voice varies from one glottal cycle to the next. This period variability is known as frequency perturbation or jitter. Jitter is used as an index of vocal stability. Jitter tends to increase in individuals with vocal pathology. Shimmer is analogous to jitter as it measures short-term amplitude perturbation. Shimmer is also used as an index of vocal stability. Excessive shimmer, like jitter, has been tied to the perception of hoarseness and harshness. There are a variety of indices of both jitter and shimmer that are used in vocal analysis. Orlikoff and Baken (1993) provide the following descriptions of these indices.

MEAN ABSOLUTE JITTER - This is simply the mean absolute difference between sequential vocal periods measured during a SUSTAINED PHONATION.

MEAN PERCENT JITTER and **JITTER RATIO** - These measures are obtained by taking the Mean Absolute Jitter and dividing it by the Mean Vocal Period used during the sustained phonation. This proportion is then multiplied by 100 to yield a percentage. If the proportion is multiplied by 1000, the index is called the **JITTER RATIO (JR)**.

MEAN JITTER FACTOR - This is the mean absolute difference between sequential vocal Fundamental Frequencies (in Hz) divided by the mean frequency of the sustained phonation. This proportion is then multiplied by 100. The mean Jitter Factor (JF) is the frequency equivalent of Mean Percent Jitter.

RELATIVE AVERAGE PERTURBATION - SoundScope and other analysis tools generates Relative Average Perturbation (RAP) which is a relative jitter measure. RAP employs a mathematical technique called linear smoothing or averaging. The absolute difference between a given period and the mean of that period and two to four

adjacent periods is determined for each cycle in the sample. The average difference is then divided by the mean period. The RAP proportion is then multiplied by 100 to yield a percentage.

MEAN SHIMMER IN PERCENT - Percent shimmer is the mean absolute cycle-to-cycle difference in vocal amplitude (in an arbitrary unit, usually volts) divided by the mean amplitude (in the same unit of measurement). The proportion is then multiplied by 100 to yield a percentage.

AMPLITUDE PERTURBATION QUOTIENT - Analogous to the RAP jitter measure, the Amplitude Perturbation Quotient (APQ) attempts to capture cycle-to-cycle amplitude variation during SUSTAINED PHONATION. SoundScope and other analysis tools typically employ a multi-point (3, 5, or 11 points) averaging approach to APQ. The average cycle-to-cycle amplitude difference from the derived "trend line" is then divided by the mean period. This proportion is then multiplied by 100 to yield a percentage.

SoundScope "Perturbation" Instrument:

This instrument returns to a basic time waveform display, because we are interested in analyzing the cycle-to-cycle variation of the speech (vowel) waveform. This instrument is similar to the previous instruments in that there are the various control activity buttons across the bottom of the screen. Unlike Lab 3 where the data journal "popped up" and could be closed, the area between the waveform display and the buttons is an area to display data which can't be closed. This instrument is designed to allow you to explore the calculation of various jitter and shimmer measures. Realize that to have valid and reliable measures you need to calculate the period differences across hundreds of cycles, not just the few like you will do.

Exercises:

Activity 1. **Input** Trace 1 by clicking on the *Load Normal /i/* button. **Adjust** the time scale to enable you to easily identify individual cycles. **[A] Acquire** the periods of 10 consecutive cycles from the middle portion of the sustained vowel waveform displayed. To acquire these measures, **move** both markers to the center of the waveform and **adjust** the horizontal (time) display to enable you to identify the individual cycles. **Relocate** the markers and **use** their placement to **measure** the period of each of the ten cycles. **[B]** With the one cycle segment marker, **click** on the *Acquire Data* button which records the desired information into the Journal "DATA" which is shown on the front panel of this instrument. **[C] Move** the Marker on the left side of the highlighted cycle to the right of the right marker to isolate the next consecutive cycle. With this next cycle highlighted, click the *Acquire Data* button again. **[D] Repeat** step "c" until you have data in your journal for 10 consecutive cycles. **[E]** After you have the data for 10 consecutive cycles, **click** on the *Automated Prep* button and **follow** the instructions to highlight a 500 msec segment of the waveform. **[F] Click** the *Automated Analysis* button to acquire SoundScope's automated analysis; results will also be sent to the journal "DATA". **[G] Click** on the *"Print"* button to print your journal. (If you do not have the capacity to print, scroll to the top of the Data journal

and write down this information.) You will need these measures to calculate the various perturbation indices. After your journal is printed, **click** on the "Clear Journal" button to prepare for data acquisition of another vowel production.

Activity 2. Input Trace 2 by clicking on the *Load Path /i/* button. **Repeat** the steps of Activity 1 [A] through [G] for this second vowel production.

Activity 3. Record Trace 3 by clicking on the *Record /i/* button. Repeat the steps of Activity 1 [A] through [G] for this third vowel production.

Activity 4. Calculate the following indices using the data you have acquired from the three vowel productions (Data journal) in Activities 1 through 3: [A] mean vocal period (average the 10 periods obtained) for each waveform; [B] mean Fundamental Frequency (obtain the Fundamental for each cycle by dividing 1 by the period (1/t)); [C] mean absolute vocal jitter (average the absolute difference between each cycle and the next consecutive cycle ($|t_n - t_{n+1}|$), then multiply this average by 100 to get a percentage); [D] mean percent jitter (take the mean absolute vocal jitter and divide by the mean vocal period; multiply this proportion by 100 to get a percentage); [E] mean jitter factor (divide the mean absolute vocal jitter by mean fundamental frequency and then multiply by 100 to get a percentage); and [F] Relative Average Perturbation (RAP) which is obtained as part of the automated analysis conducted in SoundScope.

Activity 5. Calculate the following indices using the data you have acquired from the three vowel productions (Data journal) in Activities 1 through 3: [A] mean cycle-to-cycle difference in vocal amplitude (average the absolute sum of the min and max voltages for each cycle $|A_{min} + A_{max}|$); [B] mean shimmer in percent (average the absolute amplitude difference of between each cycle and the next consecutive cycle $|A_n - A_{n+1}|$ and divide by the mean cycle-to-cycle difference in vocal amplitude) (this is the value of "a" above). Then multiply this value by 100 to get a percentage. [C] Amplitude Perturbation Quotient (APQ) is obtained as part of the automated analysis conducted in SoundScope.

Read More About it:

Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp.113 - 119; 171 - 188). Boston: Little, Brown.

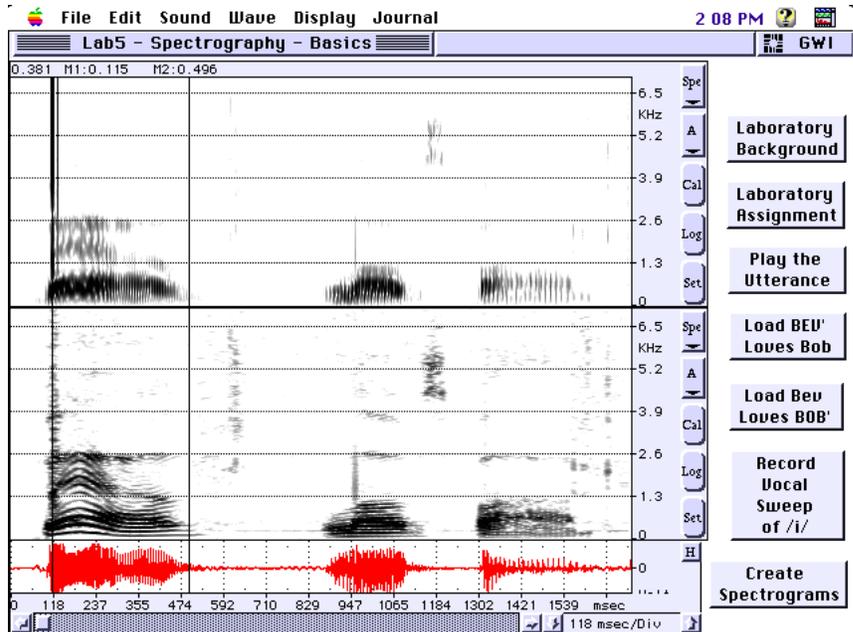
Lass, N. J. (1996). *Principles of experimental phonetics* (pp. 144-145). St. Louis: Mosby Yearbook, Inc.

Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 147-162; 197-203). San Diego: Singular Publishing Group.

LAB 5: Spectrography: The Basics

Purpose:

The purpose of this lab is to learn how to interpret sound spectrograms and how to select analysis filter bandwidths which are appropriate for the type of analysis you want to perform.



Background Information:

Sound spectrography is one of the most useful analysis tools available for speech research. A spectrogram (the graphic output of a spectrograph) displays the frequency components of speech over time. More specifically, the spectrogram displays frequency on the vertical axis, time on the horizontal axis, and amplitude is represented as a function of trace darkness (the greater the amplitude of an aspect of the spectrogram, the darker it is on the spectrogram).

Prior to using the spectrograph “instrument,” you must decide on the type of information you are interested in obtaining. There are basically two types of structures which can be investigated using a spectrogram: (1) harmonic (source) structure, and (2) resonance (filter) structure. If your interest is in examining the source of speech, you will need to configure the spectrograph to do a narrowband spectrogram. This is accomplished by adjusting the analysis filter to a narrow band width. The narrowband filter width available in SoundScope are 45 Hz or 59 Hz (45 Hz is generally considered to be appropriate for this purpose). A narrowband spectrogram displays narrow horizontal bands which represent the harmonics of the glottal source. The darker bands represent the harmonics that are closest to peaks of vocal tract resonance. Lighter bands represent harmonics which are further away from these resonance peaks. If harmonics are far enough away from these resonance peaks, they may be too weak to show up on the spectrogram. The complete absence of harmonic bands (at any frequency) indicates that there is no periodic (harmonic) source waves exiting the vocal tract. This occurs during the production of voiceless sounds, such as /s/, /f/, and /p/. Narrowband spectrograms are used to display F_0 and intonation, although variations in the first harmonic are often hard to detect. The resolution of a spectrogram displaying 5 to 8 kHz is not great enough to display a 10 Hz variation; however, the 10 Hz variation is more salient in higher frequency harmonics. The 10 Hz variation in the 1st harmonic will result in a 50 Hz shift in the 5th or a 100 Hz shift in the 10th harmonic. With this in mind, the shapes of intonation contours are easiest to

detect in the higher harmonics that in the F_0 itself. It should also be noted that the response characteristics of the narrowband spectrogram result in the inability to use narrowband spectrograms to make temporal (duration) measures.

Many speech researchers are interested in the changing resonances associated with the vocal tract filter function. Wideband spectrograms display information about formant frequencies (resonance) and the timing of changes in the vocal tract output (speech). The wideband spectrograms have relatively broad bands of energy that depict formant frequencies. As with the narrowband spectrograms, the relative darkness of each energy (formant) band can be used as an estimate of the intensity of the signal. There are also relatively large horizontal blank areas on the spectrogram which represent antiresonances and zero energy areas in the signal. Blank spaces in the temporal dimension indicate silence (pauses and stop gaps) in the speech signal.

The bandwidth of the analysis filter of a wideband spectrogram is generally between 300 and 500 Hz. SoundScope allows you to select either 300, 450, or 600 Hz filter band widths. A general “rule” when selecting a wideband filter width is that it should be about twice the F_0 of the speech being analyzed (300 Hz is usually the correct selection for adult males while the 600 Hz setting is “typical” for most females and children). The wideband filter setting will have one, two, three or more harmonics that fit within the frequency range of its bandwidth. This results in a lack of harmonic specificity. This lack of specificity results in the representation of formant frequencies (dark horizontal bands) on the spectrogram which are the result of vocal tract filtering. These formants characterize a particular sound for a particular vocal tract shape, regardless of what the F_0 or harmonic structures are. That is, formants are associated with the effects of vocal tract resonance/filtering and are “independent” of the sound source.

Another use of wideband spectrograms relates to its ability to quickly respond to the onset and termination of a sound. It can represent each glottal pulse which appear as vertical striations on the spectrogram. The rapid response time of the wideband spectrogram allows you to make accurate temporal (duration) measurements of the speech signal.

SoundScope “Spectrography - The Basics” Instrument:

This instrument consists of a time waveform display and two analysis displays. These three displays are linked on the time axis with two markers (M1 & M2) which are synchronized across the displays. The two analysis displays have five buttons along their right side. The top button allows you to select the type of analysis you desire to perform. The second button, from the top, is the source wave button (most typically our source wave is labeled “A”). The middle of “Cal” button needs to be activated (clicked on) to execute the analysis chosen by the top button. The “Log” button logs analysis data into a journal and the “Set” or bottom button lets you alter various parameters for the analysis you have chosen. It is this “Set-up” button that you will use to adjust the analysis filter bandwidths in the following exercises.

Exercises:

Activity 1. **Click** on the “*Set*” (Set-up) button on the top analysis display. **Set** the analysis filter bandwidth to “300 Hz (5 ms)” which is a wideband filter setting and will yield a wideband spectrogram. **Close** this settings dialog box by clicking on the “*OK*” button. **Repeat** this procedure by clicking on the “*Set*” (set-up) button on the bottom analysis display. **Set** this display’s analysis filter to a narrowband (45 Hz (33 ms)) filter bandwidth. **Note** that this instrument will display a wideband spectrogram in the top analysis display and a narrowband spectrogram in the bottom analysis display. A speech (time) waveform will be displayed in the bottom waveform (oscillograph) display. Also **note** that the Markers (M1 & M2) are linked across the three displays to facilitate durational comparisons across displays.

Input Trace 1 by clicking on the *Load BEV’ Loves Bob* button. **Adjust** the time scale by clicking on the *automatic horizontal scale adjust* button (“H”) to effectively display the trace in the waveform display. **Click** on the *Create Spectrograms* button which will yield wideband (top) and narrowband (bottom) analysis displays. **Examine** these displays. **[A]** What is the duration of the utterance? **[B]** What are the frequency ranges of the two analysis displays? **[C]** **Identify** which of the spectrograms (wideband or narrowband) best represents (1) harmonic lines, (2) formant bands, (3) vertical striations, and (4) durational components. **Listen** to the utterance (click on the *Play the Utterance* button). **Identify** the element of the utterance that carries a prosodic emphasis (stress). **[D]** What spectrographic evidence can you observe of this prosodic emphasis? Is it in a narrow- or wideband spectrogram?

Activity 2. **Input** Trace 2 by clicking on the *Load Bev Loves BOB’* button. **Adjust** the time scale by clicking on the *automatic horizontal scale adjust* button (“H”) to effectively display the trace in the waveform display. **Click** on the *Create Spectrograms* button which will yield wideband (top) and narrowband (bottom) analysis displays. Again **examine** the displays. **[A]** What is the duration of the utterance? **[B]** What are the frequency ranges of the two analysis displays? **[C]** **Identify** which of the spectrograms (wideband or narrowband) best represents (1) harmonic lines, (2) formant bands, (3) vertical striations, and (4) durational components. **Listen** to the utterance (click on the *Play the Utterance* button). **Identify** the element of the utterance that carries a prosodic emphasis (stress). **[D]** What spectrographic evidence can you observe of this prosodic emphasis? Is it in a narrow- or wideband spectrogram?

Activity 3. **Record** a 3 second vocal “sweep” of the vowel /i/ (begin at a low vocal pitched production of /i/ and gradually increase the pitch through your pitch range to end up with a high pitch production) by clicking on the *Record Vocal Sweep of /i/* button. Again, **adjust** the time scale by clicking on the *automatic horizontal scale adjust* button (“H”) to effectively display the trace in the waveform display. **Click** on the *Create Spectrograms* button which will yield

wideband (top) and narrowband (bottom) analysis displays. Again **examine** the displays. **[A]** What is the duration of the utterance? **[B]** What are the frequency ranges of the two analysis displays? **[C]** **Identify** which of the spectrograms (wideband or narrowband) best represents (1) harmonic lines, (2) formant bands, (3) vertical striations, and (4) durational components.

Activity 4. Based on the previous activities, **identify** which analysis filter setting (narrow- or wideband) is best for examining the following: **[A]** the glottal source, **[B]** vocal tract resonance (filtering), **[C]** duration, **[D]** intonation contours, and **[D]** diadochokinesis (the rapid repetitive production of a sound or syllable).

Read More About it:

Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp. 315-392). Boston: Little, Brown.

Kent R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 44-59; pp. 66-78). San Diego: Singular Publishing Group.

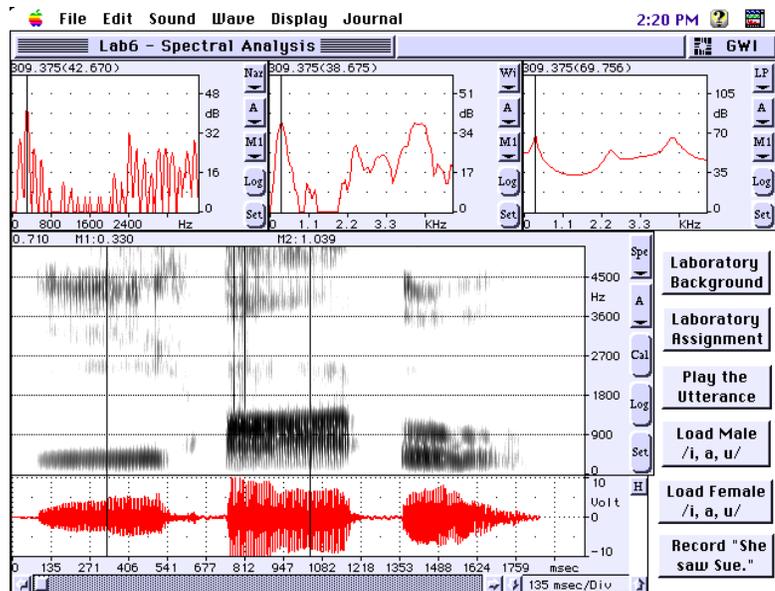
Lass, N. J. (1996). *Principles of experimental phonetics* (pp. 248-253). St. Louis: Mosby Yearbook, Inc.

Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 367-393). San Diego: Singular Publishing Group.

LAB 6: Spectral Analysis - Spectrograms, FFTs & LPCs

Purpose:

The purpose of this lab is gain an understanding of the usefulness of spectral analyses (FFTs & LPCs) that can be used (usually in conjunction with spectrograms) to analyze the glottal source and vocal tract filter characteristics of speech.



Background Information:

Often we are interested in a more quantified representation of the amplitudes of the component acoustic features of a speech sample. These representations can be useful in interpreting the elements of interest (F_0 and formant frequencies) in spectrograms. Most computer-based analysis systems, including SoundScope, enable you to calculate fast Fourier transforms (FFTs) and linear predictive codings (LPCs) which each yield an amplitude by frequency display. As stated in Lab 3, FFTs are based on Fourier's Theorem which states a complex wave, such as speech, can be analyzed as the sum of an infinite series of sinusoidal components. This FFT result is often referred to as a power spectrum. Like a spectrogram, the FFT procedure involves the setting of a filter bandwidth similar to those set in the spectrograms in the previous lab. SoundScope provides seven filter bandwidth selections ranging from 45 Hz to 600 Hz. By default the narrowband FFT filter setting is 59 Hz and the wideband FFT filter's setting is 184 Hz. When you are interested in measuring the F_0 and its harmonics, you would use the narrowband FFT (similar to narrowband spectrograms). If you are more interested in analyzing formant frequencies (associated with vocal tract resonance), a wideband FFT may be useful in isolating these frequencies.

Although Fourier analysis provides you with options for examining spectra associated with speech, there is a more recently developed method of spectral analysis called linear prediction or linear predictive coding (LPC). LPCs are based on statistical time-series analysis. Linear prediction is the hypothesis that any sample is a linear function of the elements which precedes it. Linear predictive coding is a model of the sequence of samples that make up the signal over time. This coding is equally valid in terms of interpretation of frequency components. LPC analysis, like FFTs, present an amplitude by frequency display based on the analysis of a point in time in the speech waveform (the point where a marker is positioned in the waveform). The LPC spectrum represents formant frequencies

and their amplitudes at that place in time. The accuracy of the LPC analysis is based on the number of preceding samples used in the prediction. The number of these samples used in LPC analysis for speech is usually on the order of 10 to 30 for speech analysis.

SoundScope “Spectrography - The Basics” Instrument:

This instrument provides you with five displays: three snapshot displays (a data plot representing a single point in time), an analysis display, and a waveform display. The intent of this instrument is to enable you to examine the relationships between FFTs, LPCs, and spectrograms. As with previous lab instruments, you again have buttons to input or record utterances as well as analyzing and playing back these elements of speech.

Exercises:

Activity 1. **Input** Trace 1 by clicking on the *Load Male /i, a, u/* button. **Adjust** the time scale by clicking on the *automatic horizontal scale adjust* button (“H”) to effectively display the trace in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to 45 Hz (narrowband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **Examine** the five displays on your screen. **[A] Identify** the type of analysis plot/display in each window. **[B]** Which displays are useful to interpret information about the harmonic relationships of this utterance? **[C]** What are the frequency ranges of the main analysis displays and the three snapshot displays? **[D]** Are these frequency ranges the same for all displays? **[E] Identify** which of the snapshot displays best corresponds to the spectrogram displayed in the main analysis display.

Reset (by clicking on the *Set (Set up)* button) the analysis filter to 300 Hz (wideband) and create a new spectrogram by clicking on the *Cal (Calculate)* button on the right side of the main analysis display. **[F] Examine** the formant bands for each of the vowels (/i, a, u) produced in this utterance. **[G] Identify** the approximate frequencies of the first 3 formants of each vowel. **[H] Move** the M1 marker to the durational midpoint of the vowel /i/. With this marker in position, examine the Wideband FFT (middle) and LPC (right) snapshot displays. **[I] Move** the Marker in either of these displays (the markers are linked across the 3 snapshot displays) to measure the peaks of F_1 and F_2 . Are the formant values the same (close) in these two snapshot displays? **[J] Move** marker M1 to the durational midpoint of the vowel /a/ and **[K] repeat** steps **[G, H, & I]**. **[L] Move** marker M1 to the durational midpoint of the vowel /u/ and **[M] repeat** steps **[G, H, & I]**.

Activity 2. **Input** Trace 2 by clicking on the *Load Female /i, a, u/* button. **Adjust** the time scale by clicking on the *automatic horizontal scale adjust* button (“H”) to effectively display the trace in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window.

Set this display's analysis filter to 600 Hz (wideband setting which should be roughly twice the F_0 of the speaker). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **Examine** the five displays on your screen.

[A] Repeat steps **[F]** through **[M]** from **Activity 1** above.

Activity 3. **Record** the utterance "She saw Sue" by clicking on the *Record "She saw Sue"* button. Again, **adjust** the time scale by clicking on the *automatic horizontal scale adjust* button ("H") to effectively display the trace in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display's analysis filter to a wideband setting which should be roughly twice your F_0 . **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **Examine** the five displays on your screen. **[A]** **Move** marker M1 to each phoneme (not only the vowels) in this utterance. **[B]** **Examine** the spectrum of each phoneme in the three snapshot displays. **[C]** **Describe** the difference in spectra shape between the consonants and vowels of this utterance.

Read More About it:

Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp. 315-392). Boston: Little, Brown.

Kent R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 44-59; pp. 66-78). San Diego: Singular Publishing Group.

Lass, N. J. (1996). *Principles of experimental phonetics* (pp. 248-253). St. Louis: Mosby Yearbook, Inc.

Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 367-393). San Diego: Singular Publishing Group.

Lab 7: VOWELS & DIPHTHONGS

Purpose:

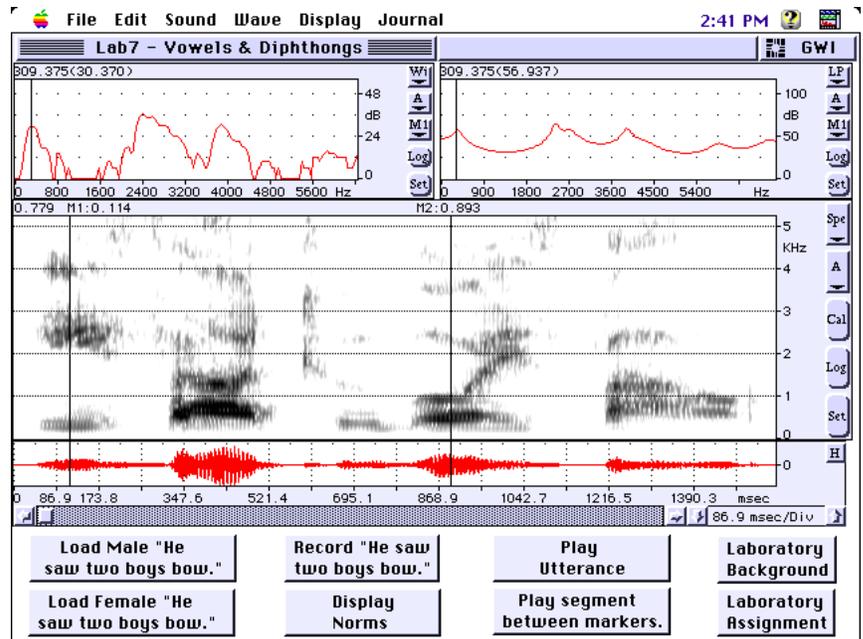
The purpose of this lab is to learn how to analyze vowels and diphthongs focusing on formant frequency peak values, bandwidths, and transitions.

Background Information:

Vowels (monophthongs) are sounds with steady-state acoustic patterns which are produced with a single (relatively open) vocal tract shape. This steady state acoustic pattern yields a single and predictable formant frequency pattern. In this lab we will examine acoustic parameters of vowel productions, focusing on their formant frequencies, paying special attention to formant frequency (peak) values, bandwidths, and transitions. A general understanding related to the formant frequencies of vowel articulation is that F_1 varies mostly with tongue height while F_2 varies mostly with the antero-posterior position (advancement) of the tongue. This is a general understanding and we must be aware that there are exceptions to this "rule." Further, we will discover that low vowels have high F_1 values and high vowels have low F_1 values. Back vowels have a low F_2 value and usually a small F_2-F_1 difference. Also, front vowels have a relatively high F_2 value and a large F_2-F_1 difference. Given this information, it should become apparent that a vowel's formant pattern (position of F_1 and F_2) can be used to identify a vowel and give insight into the perceptual as well as the acoustic parameters of vowel production.

In examining vowel formants we can obtain a variety of values. Three common measures obtained, related to vowel analysis are formant frequency (peak) values, bandwidth, and formant amplitudes. Because bandwidth and amplitude interact, they frequently are not specified individually. Each vocal tract formant associated with speech (vowel) production has a certain bandwidth. To measure a formant's bandwidth (range of frequency) we measure the width of the formant band between the "3 dB down-point" on either side of the peak formant amplitude. Based on previous published research, we know formant bandwidth increases as the formant number increases; therefore, the higher formants have larger bandwidths than do the lower ones.

As stated previously, vowels are steady-state productions made with a stable vocal tract shape. However, speech is a dynamic process and the vocal tract continually changes shape during speech production (articulation). These vocal tract configuration changes are



signaled acoustically by changes in the vocal tract resonances. These events, as they relate to vowel productions are formant transitions which can be visualized by the upward or downward sloping of the formant bands as there is a transition from the production of one phoneme to the next.

Diphthongs, like vowels, are produced with an open vocal tract and thus, have a well-defined formant structure. However, diphthongs are unlike vowels in that they have a dynamic nature to their productions. They are produced with a relative slowly changing vocal tract shape (thus, formant pattern as well). Although the formant bands of diphthongs change, as a result of their dynamic manner of production, these formant shifts are not considered true formant transitions. The phonetic description of diphthongs specifies the onglide (starting sound) and offglide (final sound) of the production. For example, /aI/ has an onglide /a/ and an offglide /I/. A similar approach can be used to describe diphthongs acoustically. Each diphthong can be represented in a F_1 - F_2 two dimensional representation with trajectories that originate at the F_1 - F_2 onglide values and end with the F_1 - F_2 values of the offglide.

SoundScope “Vowel & Diphthong” Instrument

This instrument provides you with four displays: two snapshot displays (a data plot representing a single point in time), an analysis display, and a waveform display. The intent of this instrument is to enable you to analyze vowels and diphthongs using a wideband FFT, LPC, and spectrogram. As with previous lab instruments, you again have buttons to input or record utterances as well as analyzing and playing back these elements of speech.

Exercises:

Activity 1. Input Trace 1 by clicking on the *Load Male “He saw two boys bow”* button. **Press** the *auto horizontal scale adjust* button (top right side of the screen). This adjusts the time scale to include the entire wave in the analysis display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A]** Using marker movements (M1 & M2) determine the duration of this utterance. **[B]** **Identify** the three vowels and two diphthongs and the formant bands of each.

Notice the formant transitions from each consonant to the following vowel and from the vowel to the following consonant. **[C]** **Measure** peak F_1 and F_2 for each of the three vowels (/i, a, u/) by moving marker M1 to the durational midpoint of the vowel. **[D]** **Record** these values and clearly **label** the vowel and the sex of the speaker. **[E]** Compare these values to published norms (listed below) or by clicking on the *Display Norms* button. **[F]** **Identify** the onglide and offglide of each of the two diphthongs. **[G]** **Measure** the peak F_1 and F_2 value of each of these diphthong’s onglides and offglides.

Activity 2. Input Trace 2 by clicking on the *Load Female “He saw two boys bow”* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire wave in the analysis display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to 450 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A] Repeat** steps [A] through [G] from Activity 1. **[B] Compare** the recorded F_1 and F_2 values for the male and female speaker.

Activity 3. Record the utterance “He saw two boys bow” by **clicking** on the *Record “He saw two boys bow”* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire wave in the analysis display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to a wideband setting (300 Hz for males; 450 or 600 Hz for females). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A] Repeat** steps [A] through [G] from Activity 1. **[B] Compare** the recorded F_1 and F_2 values of the vowels and diphthongs from your production to those of the previously obtained speaker of your same sex. Are these measures consistent?

Read More About It:

Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp.353-365). Boston: Little, Brown.

Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 87-104). San Diego: Singular Publishing Group.

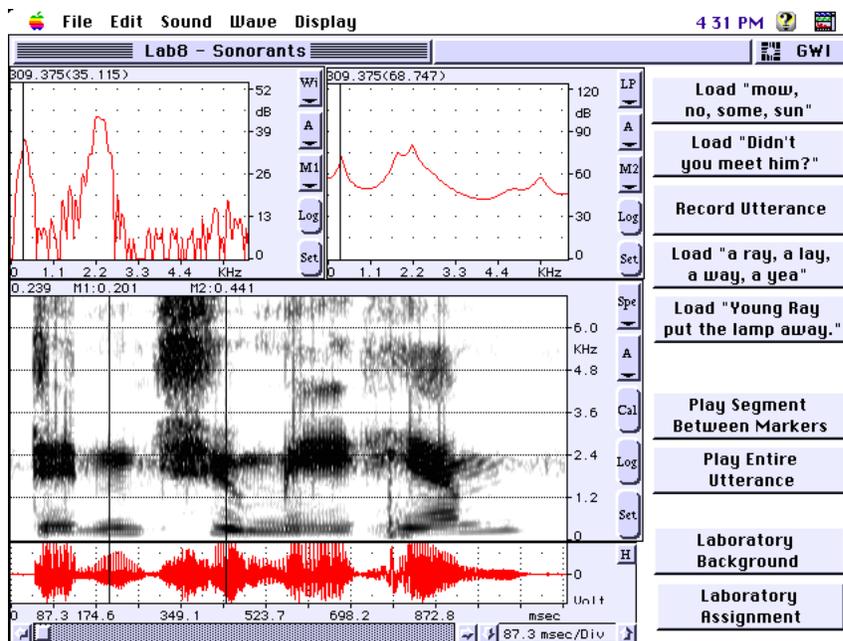
Ohde, R. N., & Sharf, D. J. (1992). *Phonetic analysis of normal and abnormal speech* (pp. 76-96). New York: Merrill.

Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 395-412). San Diego: Singular Publishing Group.

Lab 8: SONORANTS

Purpose:

The purpose of this lab is to learn some techniques to analyze spectral characteristics of sonorants (nasals and approximants) consonants.



Background Information:

Sonorant consonants include nasal and approximant phonemes. These consonants are produced through manipulation of vocal tract resonance. The acoustic elements most frequently examined relates to sonorant production are F_2 and F_3 and formant transitions.

Approximants can be divided into liquids (/r/ & /l/) and glides (/w/ & /j/) which are also called semivowels. The production of approximants involves greater vocal tract constriction than used in vowel productions. Approximants are also produced with movements similar to diphthong productions; however, these movements are greater as well as quicker than those of diphthongs. Although these movements and the resultant formant transitions are quicker than those in diphthongs, the transitions are slower than those of other consonants.

Nasal consonants are produced with closure of the oral cavity with sound radiating through the nasal cavity. The acoustic feature which results from the closed oral cavity and the radiation of sound through the nasal cavity is the nasal murmur. Nasal murmurs are associated with distinct regions of energy similar to the formant patterns of sustained vowels. However, along with these formants, nasals also possess antiformants which are areas of greatly reduced energy. These antiformants are the result of the divided passages of the vocal tract which "trap" energy in the resonance system (vocal tract). Antiformants can be described in a manner similar to formants by measuring their center (peak) frequencies and/or their bandwidths.

The nasal murmur has a low (approximately 300 Hz) nasal formant which has an amplitude comparable to vowel formants; however, they have less overall energy across their spectrum. That is, nasal murmurs have a number of much weaker resonances at higher frequencies.

Another acoustic characteristic of nasals is the clear distinction between an adjacent vowel and the nasal production which reflects the relatively quick onset of oral closure associated with this type of production. This distinction is tied largely to F_2 transitions.

SoundScope “Sonorant” Instrument

This instrument, like the previous lab’s instrument, provides you with four displays: two snapshot displays (a data plot representing a single point in time), an analysis display, and a waveform display. The intent of this instrument is to enable you to analyze the spectral (formant) characteristics of approximant and nasal consonants using a wideband FFT, LPC, and spectrogram. As with previous lab instruments, you again have buttons to input or record utterances as well as analyzing and playing back these elements of speech.

Exercises:

Activity 1. Input Trace 1 by clicking on the *Load “mow, no, some, sun”* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A]** Using marker movements (M1 & M2) determine the duration of each word in this utterance. **[B] Identify** the two nasal productions in the initial and the two nasal in the word final position and the formant bands of each. **[C] Measure** peak F_1 and F_2 for each of the four nasal productions by moving marker M1 to the durational midpoint of each of these phonemes. **[D] Record** these values. **[E] Note** any antiresonances (areas of greatly reduced energy) associated with these productions. **[F] Examine** the F_2 transitions between the nasal to vowel productions (two CV) and the vowel to nasal (two VC). How are these four formant transitions similar and/or different?

Activity 2. Input Trace 2 by clicking on the *Load “Didn’t you meet him?”* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A] Identify** the nasal productions and the formant bands of each in this utterance. **[B] Measure** peak F_1 and F_2 for each of the three nasal productions by moving marker M1 to the durational midpoint of each of these phonemes. **[C] Record** these values. **[D] Note** any antiresonances (areas of greatly reduced energy) associated with these productions. **[E] Examine** the F_2 transitions associated with these nasal productions.

Activity 3. Input Trace 3 by clicking on the *Load “a ray, a lay, a way, a yea”* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen).

This adjusts the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display's analysis filter to a wideband setting (300 Hz for males; 450 or 600 Hz for females). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A] Identify** each phoneme in this utterance (each approximant is located between vowels). **[B] Measure** the peak F_1 , F_2 , and F_3 for each of the four approximant productions by moving marker M1 to the durational midpoint of each of these phonemes. **[D] Record** these values. **[E] Note** the presence (or absence) of high frequency energy (above F_3) in each of these approximant productions. **[F] Compare** the productions of /r/ and /l/ and the productions of /w/ and /j/. What appears to be the salient characteristics that distinguish these consonants from one another?

Activity 4. Input Trace 4 by clicking on the *Load "Young Ray put the lamp away"* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display's analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A] Identify** the nasal and approximant consonant productions on this spectrogram. **[B] Measure** the peak F_1 , F_2 , and F_3 for each of the sonorant productions by moving marker M1 to the durational midpoint of each of these phonemes. **[D] Record** these values. **[E] Compare** these values to the same type of sonorant analyzed previously in this lab. Are your measures similar by phoneme type? **[F] Examine** the formant transitions of these productions.

Optional Activity. Record one of the utterances that you have previously analyzed ("mow, no, some, sun," or "Didn't you meet him?" or "a ray, a lay, a way, a yea" or "Young Ray put the lamp away."). Using procedures similar to the corresponding activity for the utterance you have chosen, **compare** your nasal and/or approximant productions to those of the adult male productions already completed.

Read More About It:

Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp. 365-375). Boston: Little, Brown.

Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 129-136). San Diego: Singular Publishing Group.

Ohde, R. N., & Sharf, D. J. (1992). *Phonetic analysis of normal and abnormal speech* (pp. 55-93). New York: Merrill.

Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 413-424). San Diego: Singular Publishing Group.

Lab 9: FRICATIVES

Purpose:

The purpose of this lab is to explore the acoustic features of fricative consonants.

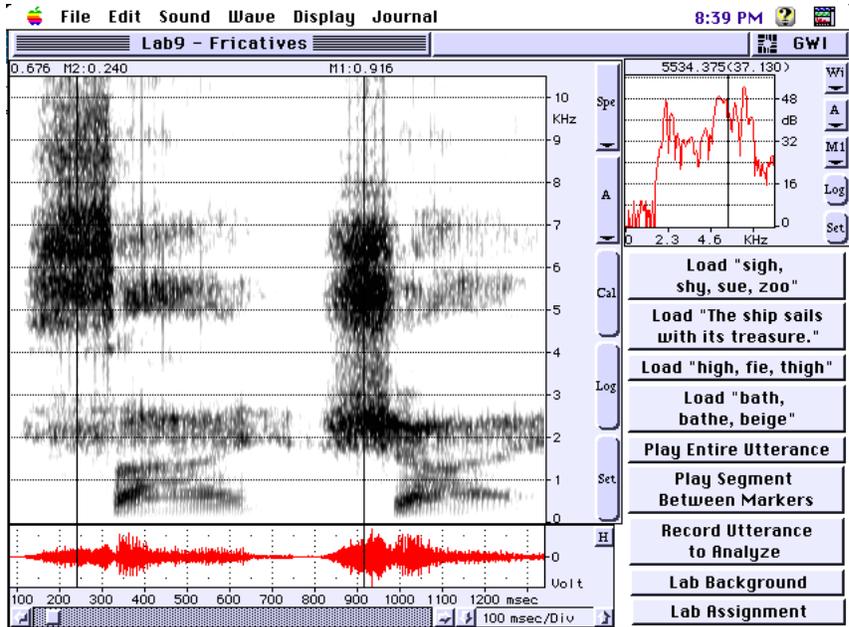
Background Information:

Fricatives are produced by a formation of a narrow constriction somewhere in the vocal tract. As air is forced through this constriction during fricative production it becomes turbulent. This turbulence results in the generation of turbulent noise. Fricatives have relatively long durations of aperiodic energy (noise). It is this lengthy interval of noise that distinguishes fricatives as a distinctive sound class.

Fricatives can be further classified as either sibilants (sometimes called stridents) and nonsibilants (also called non-stridents). For sibilant productions, airflow is directed by the tongue so that it passes between the teeth. The mechanism for sibilant production results in a very distinctive fricative noise. Nonsibilant productions are made by either placing the tongue tip between the teeth or by bringing the lower lip into light contact with the upper teeth. Nonsibilants are weak in overall energy and possess a fairly flat or diffuse spectrum. Sibilant fricatives have a much greater noise energy, especially at the higher frequencies, than nonsibilants.

Although spectrograms may be used for the analysis of the spectral characteristics of fricatives, an FFT is the preferred tool for this type of analysis. The analysis of these spectral characteristics may involve the frequency region of the primary (most intense) noise energy. The salient spectral properties of fricatives are classified based on articulatory placement and include:

- + Labiodental - low-energy, diffuse spectrum
- + Linguadental - low-energy, diffuse spectrum, overall spectral flatness
- + Lingualalveolar - intense noise with energy in the high frequencies
(above the F_4 average of the speaker's vowels)
- + Linguapalatal - intense noise with most energy in the mid to high frequencies
(above the F_3 average of the speaker's vowels)
- + Glottal - low-energy, diffuse noise



Transitions occur between fricatives to vowel productions as they do for all consonants. Articulatory changes associated with the transitions from fricatives to vowels result in “bends” (transitions) in formant patterns. As with sonorants, the formant transitions are suggestive of the place of consonant articulation.

SoundScope “Oscilloscope” Instrument

This instrument provides you with three displays: one snapshot (wideband FFT) display (a data plot representing amplitude by frequency at single point in time), an analysis (wideband spectrogram) display, and a waveform display. Notice that the spectrogram range is from 0 to 11 kHz which enables the display of the high frequency noise associated with fricative productions. The intent of this instrument is to enable you to examine the spectral characteristics of fricatives employing wideband FFT and spectrogram analyses. As with previous lab instruments, you again have buttons to input or record utterances as well as analyzing and playing back these elements of speech.

Exercises:

Activity 1. Input Trace 1 by clicking on the *Load “sign, shy, sue, zoo”* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A]** Using marker movements (M1 & M2) determine the duration of each word in this utterance. **[B] Identify** the four sibilants in this utterance. **[C] Examine** the spectral signature (the frequency region of the primary [most intense] noise energy) of each sibilant production. Do this by moving marker M1 to the durational midpoint of each of these phonemes and examining the corresponding FFT (snapshot display). **[D] Examine** the spectral characteristics or signatures of each of these four sibilants. **[E] Adjust** the time scale, using the *horizontal scale adjust control*, so only the first two words of the utterance (sigh & shy) are displayed in the waveform display. You may need to use the *horizontal scroll control* to position the desired portion of the utterance in this display. **Create** another spectrogram by clicking on the *Cal (Calculate)* button. This should give you a better view of the spectral characteristics of these two sibilants. **[F]** Again, **examine** the spectral signature (the frequency region of the primary [most intense] noise energy) of each sibilant production. Do this by moving marker M1 to the durational midpoint of each of these phonemes and examining the corresponding FFT (snapshot display). **[G] Describe** the spectral differences of these two sibilants. What is the range of the primary noise energy of each? **[H] Repeat** steps [E] and [F] this time **examining** and **describing** the characteristics of the /s/ and /z/ phonemes. **[I]** What conclusions can you draw based on your analysis of these four sibilants?

Activity 2. Input Trace 2 by clicking on the *Load “The ship sails full of treasure”* button. **Press** the *auto horizontal scale adjust button* to adjust the time scale to

include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display's analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button which is also on the right hand side of the main analysis display window. **[A] Identify** the four sibilants and two nonsibilants in this utterance. **[B] Adjust** the time scale, using the *horizontal scale adjust control*, so only the two words containing the phonemes of interest in the utterance are displayed in the waveform display. You may need to use the *horizontal scroll control* to position the desired portion of the utterance in this display. **Create** additional spectrograms by clicking on the *Cal (Calculate)* button. This should give you a better view of the spectral characteristics of the fricatives being analyzed. **[C]** Again, **examine** the spectral signature (the frequency region of the primary [most intense] noise energy) of each sibilant production. Do this by moving marker M1 to the durational midpoint of each of these phonemes and examining the corresponding FFT (snapshot display). **[D] Repeat** as necessary until all fricative productions in this utterance are analyzed. **[E] Describe** the spectral differences of these fricatives. What is the range of the primary noise energy of each? **[F]** What differences did you find between the sibilant and nonsibilant fricative productions?

Activity 3. Input Trace 3 by clicking on the *Load "high, fie, thigh"* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display's analysis filter to a wideband. **Create** a spectrogram by clicking on the *Cal (Calculate)* button. **[A] Identify** each nonsibilant production in this utterance. **[B] Examine** the spectral signature (the frequency region of the primary [most intense] noise energy) of each nonsibilant production. Do this by moving marker M1 to the durational midpoint of each of these phonemes and examining the corresponding FFT (snapshot display). **[C] Examine** the spectral characteristics or signatures of each of these four sibilants. **[D] Describe** and **compare** the spectral differences of these three nonsibilants. What is the range of the primary noise energy of each? **[E] Compare** your spectral descriptions of these nonsibilant to the sibilants obtained in Activity 1. What conclusions can you draw based on your analysis of these sibilants and nonsibilants?

Activity 4. Input Trace 4 by clicking on the *Load "bath, bathe, beige"* button. **Press** the *auto horizontal scale adjust button* (top right side of the screen) to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button and **set** this display's analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button. **[A] Identify** each nonsibilant production in this utterance. **[B] Examine** the spectral signature (the frequency region of the primary [most intense] noise energy) of each nonsibilant production. Do this by moving marker M1 to the durational midpoint of each of these phonemes and examining the corresponding FFT (snapshot display). **[C] Examine** the spectral characteristics or signatures of each of these three sibilants. **[D] Describe** and **compare** the spectral

differences of these three nonsibilants. [E] What is the range of the primary noise energy of each? [F] What are the acoustic and/or spectral differences associated with voice versus unvoiced productions? [G] **Compare** your spectral descriptions of these nonsibilant to the sibilants obtained in the previous lab Activities. [H] What conclusions can you draw, based on your analysis, of these nonsibilants?

Optional Activity. **Record** one of the utterances that you have previously analyzed (“*sigh, shy, sue, zoo,*” or “*The ship sails full of treasure*” or “*high, fie, thigh*” or “*bath, bathe, beige*”). Using procedures similar to the corresponding activity for the utterance you have chosen, **Compare** your sibilant and nonsibilant productions to those of the adult male productions already completed.

Read More About It:

Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp. 366-369). Boston: Little, Brown.

Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 121-129). San Diego: Singular Publishing Group.

Ohde, R. N., & Sharf, D. J. (1992). *Phonetic analysis of normal and abnormal speech* (pp. 190-207). New York: Merrill.

Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 425-436). San Diego: Singular Publishing Group.

Lab 10: PLOSIVES & AFFRICATES

Purpose:

The purpose of this lab is to explore the acoustic features of plosive and affricate consonants.

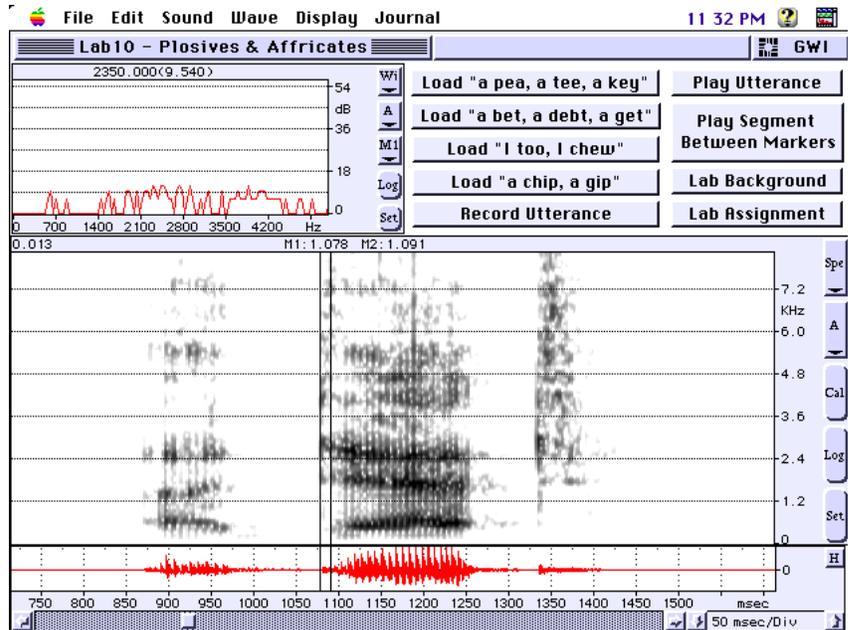
Background Information:

Plosives, which are also known as stops, and affricates are consonants produced by an articulatory occlusion producing a momentary blockage of the vocal tract. This occlusion results in a temporary period void of acoustic energy. When the blockage of the vocal tract is released in the production of these consonants, there is an acoustic release burst.

Along with the features of silence and the release burst, the acoustic signatures of aspiration and transitions can also be examined for plosive productions. These acoustic features are somewhat dependent upon the position of the plosive in the syllable being uttered. Syllable-initial plosives yield the acoustic cues of silence, burst, aspiration (voiceless stops only) and transitions to the following vowel in this temporal order. Plosives in the syllable-final position usually have the acoustic feature sequence of transition, silence, burst (if it's released) and aspiration (is optional and only possible if the plosive is released). Plosives in the syllable-medial position often have similar acoustic characteristics as syllable-initial productions with a second transition from the initial vowel to the silence of the stop. The acoustic feature sequence of the medial position plosive is transition, silence, burst, aspiration, and transition.

For syllable-initial stops, a primary acoustic cue of voicing is voice onset time (VOT). VOT is defined as the interval between the release burst and the onset of voicing of the vowel. A VOT of 0 msec is the result of the stop release and voice onset being simultaneous. For a negative VOT, which is called prevoicing or voicing lead, voicing onset precedes the stop release. Short term voicing lag is used to refer to positive VOT values which are the result of voicing slightly lagging the articulatory release.

Affricate consonants are produced when the vocal tract occlusion and subsequent burst is released into frication rather than into a vocalic segment as in plosive productions. Therefore, affricates have an acoustic feature sequence of silence, release burst, and frication. Affricates are analyzed by examining essentially both phases of its production



pattern. That is, we examine the stop gap (silence) and release burst which relates to the acoustic features similar to plosives. We can also analyze the aperiodic noise energy associated with the frication aspect of this type of production.

SoundScope “Oscilloscope” Instrument

This instrument, which is similar to that of Lab 9, provides you with three displays: a wideband FFT (snapshot) display (a data plot representing a single point in time), an analysis (wideband spectrogram) display, and a waveform display. The intent of this instrument is to enable you to identify and possibly measure stop gaps, release bursts, voice onsets and VOT of stops and affricates as well as the frication associated with affricate productions. These types of analyses can best be made using wideband spectrograms. The FFT snapshot display may be helpful in examining the frication associated with the production of affricates. As with previous lab instruments, you again have buttons to input or record utterances as well as analyzing and playing back these elements of speech.

Exercises:

Activity 1. Input Trace 1 by clicking on the *Load “a pea, a tee, a key”* button. Press the *auto horizontal scale adjust* button (top right side of the screen). This adjusts the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button. **[A] Identify** each phoneme of this utterance. **[B] Identify** the release burst of each of the stop consonant productions and the onset of voicing for the vowels following each release burst. **[C] Adjust** the time scale, using the *horizontal scale adjust control*, so only the first two words of the utterance (a pea) are displayed in the waveform display. You may need to use the *horizontal scroll control* to position the desired portion of the utterance in this display. **Create** another spectrogram by clicking on the *Cal (Calculate)* button. This should give you a better view of the spectral characteristics of this VCV production. **[D] Measure** the voice onset time (VOT) by moving marker *M1* to the onset of the release burst of the /p/ and marker *M2* to the onset of the voicing for the following vowel /i/. **[E] Record** the VOT (the durational difference between M1 & M2 displayed above the analysis display on the left hand side. **[F] Scroll**, using the *horizontal scroll control*, so only the next two words of the utterance (a tee) are displayed in the waveform display. **Create** another spectrogram by clicking on the *Cal (Calculate)* button. This should give you a good view of the spectral characteristics of this second VCV production. **[G] Repeat** steps [D] and [E] **measuring** and **recording** the VOT for this production. **[H] Scroll**, using the *horizontal scroll control*, so only the last two words of the utterance (a key) are displayed in the waveform display. **Create** another spectrogram by clicking on the *Cal (Calculate)* button. **[I] Repeat** steps [D] and [E] **measuring** and **recording** the VOT for this production. **[J] Compare** the VOT measures of /pi/, /ti/, & /ki/.

Activity 2. Input Trace 2 by clicking on the *Load “a bet, a debt, a get”* button. Press the *auto horizontal scale adjust button* (top right side of the screen). This adjusts the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button on the right side of the main analysis display window. **Set** this display’s analysis filter to 300 Hz (wideband). **Create** a spectrogram by clicking on the *Cal (Calculate)* button. **[A] Identify** each phoneme of this utterance. **[B] Identify** the release burst of each of the stop consonant productions and the onset of voicing for the vowels following each release burst. **[C] Adjust** the time scale, using the *horizontal scale adjust control*, so only the first two words of the utterance (a bet) are displayed in the waveform display. You may need to use the *horizontal scroll control* to position the desired portion of the utterance in this display. **Create** another spectrogram by clicking on the *Cal (Calculate)* button. This should give you a better view of the spectral characteristics of this VCV production. **[D] Measure** the voice onset time (VOT) by moving marker *M1* to the onset of the release burst of the /b/ and marker *M2* to the onset of the voicing for the following vowel /ɜ/. **[E] Record** the VOT. **[F] Scroll**, using the *horizontal scroll control*, so only the next two words of the utterance (a debt) are displayed in the waveform display. **Create** another spectrogram. **[G] Repeat** steps [D] and [E] **measuring** and **recording** the VOT for this production. **[H] Scroll**, using the *horizontal scroll control*, so only the last two words of the utterance (a get) are displayed in the waveform display. **Create** another spectrogram by clicking on the *Cal (Calculate)* button. **[I] Repeat** steps [D] and [E] **measuring** and **recording** the VOT for this production. **[J] Compare** the VOT measures of these three words. **[K] Compare** the VOT values associated with the voiced and unvoiced stops. Which are shorter in duration? Why?

Activity 3. Input Trace 3 by clicking on the *Load “I too, I chew”* button. **Press** the *auto horizontal scale adjust button* to adjust the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button to **Set** this display’s analysis filter to 300 Hz (wideband). **Create** a spectrogram. **[A] Identify** each phoneme of this utterance. **[B] Identify** the release burst of both the stop and the affricate consonant productions, the frication of this release (in the affricate production), and the onset of voicing for the vowels following each release burst. **[C] Adjust** the time scale, using the *horizontal scale adjust control*, so only the first two words of the utterance (I too) are displayed in the waveform display. You may need to use the *horizontal scroll control* to position the desired portion of the utterance in this display. **Create** another spectrogram by clicking on the *Cal (Calculate)* button. This should give you a better view of the spectral characteristics of this VCV production. **[D] Measure** the voice onset time (VOT) by moving marker *M1* to the onset of the release burst of the /t/ and marker *M2* to the onset of the voicing for the following vowel /u/. **[E] Record** the VOT. **[F] Scroll**, using the *horizontal scroll control*, so only the next two words of the utterance (I chew) are displayed in the waveform display. **Create** another spectrogram. **[G] Repeat** steps [D] and [E] **measuring** and **recording** the VOT for this production. **[H] Position** marker *M1* at the durational midpoint of the release burst frication of this affricate production and **examine** the

spectral characteristics (signature) of this high frequency energy.

[I] Compare the VOT measures of these two word pairs. **[J] Compare** the VOT values associated with the stop and the affricate. Which are shorter in duration? Why?

Activity 4. Input Trace 4 by clicking on the *Load “a chip, a gip”* button. **Press** the *auto horizontal scale adjust button* to adjust the time scale to include the entire utterance in the waveform display. **Click** on the *Set (Set-up)* button to **Set** this display’s analysis filter to 300 Hz (wideband). **Create** a spectrogram. **[A] Identify** each phoneme of this utterance. **[B] Identify** the release burst of each affricate production, the frication of this release, and the onset of voicing for the vowels following each release burst. **[C] Adjust** the time scale, using the *horizontal scale adjust control*, so only the first two words of the utterance (a chip) are displayed in the waveform display. You may need to use the *horizontal scroll control* to position the desired portion of the utterance in this display. **Create** another spectrogram by clicking on the *Cal (Calculate)* button. This should give you a better view of the spectral characteristics of this VCV production. **[D] Measure** the voice onset time (VOT) by moving marker *M1* to the onset of the release burst of the /t/ and marker *M2* to the onset of the voicing for the following vowel /u/. **[E] Record** the VOT. **[F] Position** marker *M1* at the durational midpoint of the release burst frication of this affricate production and **examine** the spectral characteristics (signature) of this high frequency energy. **[G] Scroll**, using the *horizontal scroll control*, so only the next two words of the utterance (a gip) are displayed in the waveform display. **Create** another spectrogram. **[G] Repeat** steps [D], [E], and [F] **measuring** and **recording** the VOTs for these productions and a **description** of the spectral characteristics (signature) of their high frequency energy. **[H] Compare** the VOT measures of these two words pairs. **[I] Compare** the spectral characteristics of the high frequency energy associated to the frication of their release bursts. How do these signatures differ?

Optional Activity. Record one of the utterances that you have previously analyzed (“a pea, a tea, a key,” or “a bet, a debt, a get?” or “I too, I chew” or “a chip, a jip”). Using procedures similar to the corresponding activity for the utterance you have chosen, **Compare** your stop and/or affricate productions to those of the adult male productions already completed.

Read More About It:

Baken, R. J. (1987). *Clinical measurement of speech and voice* (pp. 369-379). Boston: Little, Brown.

Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech* (pp. 105-121; 129-130). San Diego: Singular Publishing Group.

Ohde, R. N., & Sharf, D. J. (1992). *Phonetic analysis of normal and abnormal speech*

(pp. 55-93). New York: Merrill.

Orlikoff, R. F., & Baken, R. J. (1993). *Clinical speech and voice measurement: Laboratory exercises* (pp. 437-454). San Diego: Singular Publishing Group.