Preliminaries

In this week's lab you'll use Praat to calculate the fundamental frequency of vowels and sonorants, examine the spectra of fricatives and vowels, identify vowel formants and plot an F1-F2 vowel space, and measure voice onset time in oral plosives (stops).

Before the lab, you should watch the videos in module 2 on consonant and vowel acoustics, vowel space, and voice onset time.

Goals

At the end of this lab you should be able to:

- Identify the cycle of a complex periodic wave and calculate its fundamental frequency
- Adjust the spectrogram and formant settings to improve performance of the formant tracking algorithm and ease of identifying speech sounds visually.
- Examine and compare the spectrum of various speech sounds
- Identify vowel formants in the spectrogram (and spectrum) and measure their values
- Plot and interpret an F1-F2 vowel space based on the values you measured
- Segment a recording of speech based on the visual appearance of the waveform and spectrogram
- Align transcriptions to the segmentations you have created
- Measure the duration of various acoustic events, including voice onset time

Resources

As always, your tutor can help with any questions that you have.

If you need a refresher on how to use any of the basic Praat functionalities, refer to the lab from module 1 (Praat Basics).

You may also benefit from the following videos from David Ogden:

- Praat 4: Getting help with formants and F0
- Praat: Finding Formants
- Praat 13: Calculating VOT

Materials

- `speechproc_phonlab1.wav`
- the recording of your own voice from Lab 1 (or a recreation/new recording of it)

- `speechproc_phonlab2_rvowels.wav` (a recording of Rebekka producing English vowels in an /h_d/ environment
- `speechproc_phonlab2_rvot.wav` (a recording of Rebekka producing English /p t k/ in word initial and intervocalic positions)
- new recordings as you find them necessary (in particular, a recording of your vowels in a language that you speak, but maybe you'll want to record other things as well)

Tasks

- Calculate the fundamental frequency of the (first) vowel in *last* and *picture* in `speechproc_phonlab1.wav`. If you have time, do the same with your own recording and compare your F0s to those of a classmate.
- Adjust the spectrogram settings and compare the vowel spectra in broad and narrow band spectrograms.
- Compare the spectral envelopes of the fricative portions of *picture* and *last*. If you have time, compare the provided audio to your own fricatives.
- Measure F1 and F2 for the 14 vowels in Rebekka's variety of English. Plot the values that you measured to create a visualization of Rebekka's vowel space. If you have time, record yourself reading the same words (provided below) and plot your own vowel space.
- Measure the voice onset time for the speech sounds /p t k/ in Rebekka's speech. If you have time, record yourself reading the same items, and compare your VOT to Rebekka's.
- **BONUS:** look up the vowels in a language that you speak other than English, and make a list of words containing each vowel. Create a vowel space plot for this language as well. Compare this to your English vowel space.
- **BONUS:** look up the stop consonants in a language other than English that you speak, and record yourself saying each consonant in word initial and intervocalic position (e.g. "pa, apa"). Measure your VOT in this language and compare to your VOT in English.

Follow the instructions or feel free to work out the tasks on your own.

Contents

TIP: for each of the following tasks, you might find it easier to create a TextGrid, segment the relevant interval, and label it so that you can easily come back to it later.

1 Fundamental frequency

Materials

For this exercise use the file `speechproc_phonlab1.wav`.

1.1 Calculate F0 from the waveform

Calculate the fundamental frequency of the vowels in *last* and *picture*.

TIP: since speech is not perfectly periodic, it's usually a good idea to calculate F0 over a number of cycles rather than a single cycle.

1. (a) What is the duration of the first 5 complete oscillations in the vowel?

   (b) Divide the duration you measured in 1a by 5 to give the average period (duration) of a single vibration cycle.

   (c) Now that you know the period of a single cycle, work out the frequency (number of cycles per second) at this part of the vowel.

2. Repeat the measurements in 1 for the vowel in *picture*.

3. Repeat the measurements in 1-2 for your own speech. Compare your measurements with your classmates – how similar or different are your F0s?

1.2 Narrowband spectrogram and F0

The default spectrogram settings in Praat create what is known as a **broad-** or **wideband spectrogram**. The broadband spectrogram has high resolution in the time domain, and low resolution in the frequency domain. This will prove to be very useful for measuring vowel formants, but makes it difficult to see the harmonic structure, which can also tell us about the fundamental frequency. A narrow band spectrogram on the other hand has high resolution in the frequency domain and low resolution in the time domain. This makes viewing the harmonic structure easier.

Adjust the spectrogram settings from broad to narrow like this:

- In the `SoundEditor` window, click on the `Spectrum` menu
- Select `Spectrogram settings...`
- Change the window length from 0.005 s to 0.05 s
- Click 'OK' or 'Apply'.

You should now see a pattern of horizontal bands where before you could see vertical pulses. In a periodic sound such as a vowel, this narrowband view of the spectrogram shows the **harmonic structure**. The lowest harmonic of a periodic wave is the same as the fundamental frequency.

- Click on the lowest harmonic in the spectrogram to measure its frequency.
- Now open the `Spectrum` menu and select `View spectral slice`.
- From the Objects list, select the spectrum object you have just created and click on 'View & edit'.
- Notice that there are very clearly defined peaks at regular intervals along the frequency range.
- Click on the midline of the lowest peak (furthest to the left). This should be roughly equaly to the value that you measured from the spectrogram – **why is that?**

> To change the view back to a broad band spectrogram, go back to `Spectrogram settings...` and click on the button labeled 'Standards'. Click 'OK'.

1.3 Praat's pitch tracker

Of course Praat also provides a "pitch" tracker that will automatically calculate the F0 for you. To use this functionality click on the `Pitch` menu at the top of the Sound Editor window, then select 'Show pitch'. A blue line should appear superimposed on the spectrogram. If you click on the blue pitch track at the same point in time as before, you should be able to read the F0 value on the right side of the spectrogram viewer. If all has gone well, this should be very close to the values you have calculated and measured before.

2 Fricative spectra

For this section use the file `speechproc_phonlab1.wav`.

We saw above how the spectrum can provide information about the fundamental frequency in periodic speech sounds. However, it can also provide information about filtered aperiodic noise such as frication. There are two intervals of oral frication in the provided audio. Identify these intervals, then extract a spectral slice from the midpoint of each interval.

Compare the spectra of each of these fricatives to the spectra of the vowels you were looking at in 1.2, above. How do the fricative spectra compare to those of the vowels?

How do the fricative spectra compare to each other?

3 Vowel Space

TIP: Be sure to reset your spectrogram settings to the defaults before working through this section.

Materials

For this exercise, you'll use the file `speechproc_phonlab2_rvowels.wav`, and perhaps a recording of your own vowels in a language of your choosing.

Here is the list of words in the recording:

- Heed
- Hid
- Head
- Had
- Hod
- Hawed
- Hud
- Hood
- Who'd
- Heard
- Hide
- How'd
- Hayed
- Hoed

Before you begin the tasks below: add a Point tier to your TextGrid and call it 'vowel'. Use this tier to indicate the point that your vowel formant data was taken from. Label the point with the word that the vowel came from.

3.1 Formants in the spectrum: Visual estimates

For each vowel:

- Click on the point you have labeled for measurement in your TextGrid.
- Select 'Spectrum' from the menu at the top of the Editor window.
- Then click 'View Spectral slice'.
- From the Sound Editor window, select the spectral slice you have just created, then click on 'View & Edit'.

> Try looking at the spectral slice from the broad and narrow band spectrograms of the same point side by side. How are they similar and how are they different?

3.2 Praat's formant tracker

- In the Sound editor window, under 'Formants', tick 'Show formants'.
- Under 'Spectrogram', tick 'Show spectrogram'.

Now the formants are displayed as red dots on the spectrogram. The bottom row of red dots represents the detected F1, the one above it the detected F2. You may notice that the formants do not stay at precisely the same frequency throughout the entire duration of the vowel. For this exercise, try to report formant values **at or near the midpoint** of the vowel duration.

> You may need to adjust the Formant settings to improve the performance of the formant tracking algorithm.
>
> Open the Formant menu, then select "Formant settings..." Adjust the values of the Formant ceiling and the number of formants until the formant tracks align smoothly and continuously with frequency regions of high amplitude in the spectrogram.
>
> You can also reset the formant settings by clicking on the Standards button in the Formant Settings window.

1. Click on the point where you have placed the label for a given vowel.
2. From the menu at the top of the window, select 'Formants', then 'Formant listing'. This gives you precise values of the formants at the specified time point, as calculated by Praat's algorithm.

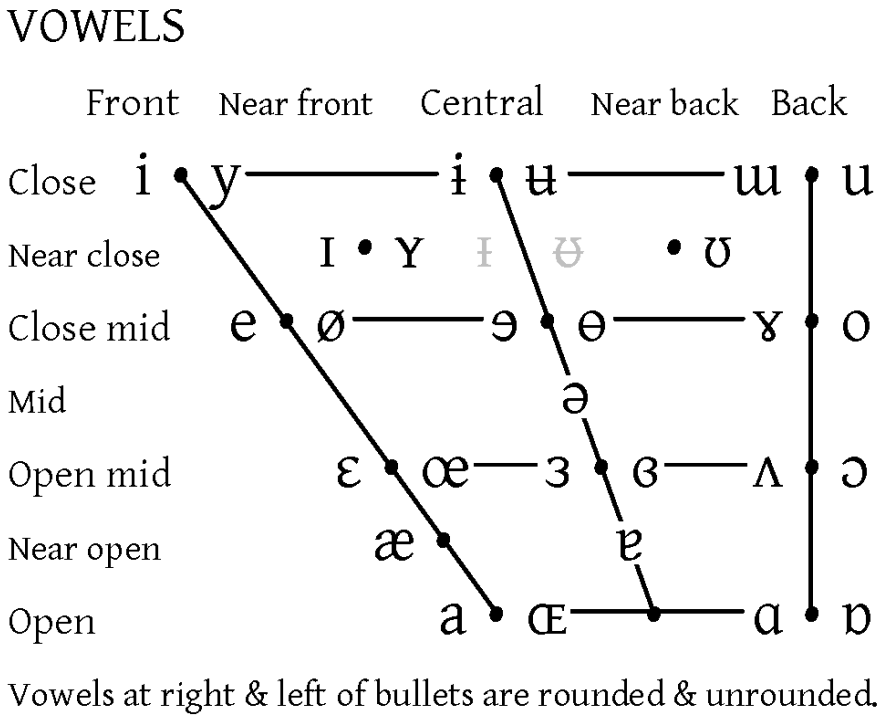

Figure 1: Vowels of the International Phonetic Alphabet

3.3 Plot the F1-F2 vowel space

Now you have the exact F1 and F2 values for midpoint of each of the 14 vowels in the recording. **Create a vowel space plot with these values by plotting F1 on the y-axis and F2 on the x-axis.** You can create this plot using any method you choose: pen & paper, Excel, Matlab, R, or this handy online plotting tool: Online Chart Tool. If you use this tool, be sure to choose an XY graph. Label each point with the word that it came from.

Once you have plotted the various vowels using word labels, compare the vowel space to the IPA vowel quadrilateral in Figure 1. Consider which IPA symbols would be the most appropriate for transcribing them.

4 Voice onset time

For this exercise, use the file `speechproc_phonlab2_rvot.wav`.

This file contains a recording of Rebekka saying the voiced and voiceless stops /p t k b d g/ in word initial and intervocalic positions. Measure the voice onset time of the *intervocalic* stops.

For this task, you may find it helpful to create a new interval Tier in your TextGrid. Label it 'VOT' and annotate the stop consonants as follows:

- Insert a boundary at the start of the release burst.
- Add a boundary at the start of the periodic vibrations of the following vowel.
- Label the interval between the release burst and the vowel with the stop symbol (p t k b d g) followed by a 'b'. So, for the /p/ release, the interval will be labeled 'pb', the /b/ release will be labeled 'bb', etc.
- Add a boundary at the end of periodic structure in the vowel that precedes the release burst.
- Label the interval with the stop symbol + 'c' ('pc', 'tc', etc)
- If present, add a boundary at the start of periodic vibration prior to the stop release.
- Label the interval between the start of this periodic vibration (voicing) and the stop release as the stop + v ('pv', 'bv', etc)

Keeping in mind that voice onset time is measured relative to the release burst of the stop, use the intervals that you have created to measure and report the voice onset time for each of the stops presented here.

- Are all of the intervals present for each of the tokens?
- Is there a reason to use the intervocalic tokens for this task?
- If you have recorded your own voice, do you have similar or different VOTs to the recording?
- Is your VOT the same or different for English and another language that you speak?