Lecture 2 (1 November 2012)

Please note that you have to hand in all assignments to receive full grades. Hand in at the latest on Monday night.

Assignment 3: read Hayward chapter 2.

3a. Page 21. After you have read the text about “Slinkys” in §2.2, try to imagine what they look like. Then visit **slinky.org** to see whether you were right. Then study the eight “physics experiments”. Make sure you understand the difference between a longitudinal wave and a transverse wave. Sound is which of the two?

3b. Page 22. In Figure 2.1, the fork goes through the rest position at time points 1, 3, and 5. The caption seems to relate that position to “not sounding”. Does this mean that there is no sound at time points 1, 3, and 5?

3c. Page 23. A sine curve. Many tuning forks vibrate at a frequency of 440 Hz, i.e. 440 full vibrations per second (Fig. 2.1 shows one full vibration). You can create such a sine wave in Praat by going to **Create Sound from formula...** in the **New** menu and typing

```
0.3 * sin (2*pi*440*x)
```

for the **Formula**. In this formula, *x* means the time, and 0.3 is the amplitude, as you can see when you click **Edit**. Play the sound to make sure that it really represents the well-known fork tuned at the note ‘A’.

In the Sound window, select one full vibration and choose **Draw selected sound...** from the **File** menu. The sound appears in the **Picture** window, from where you copy it into your Word file (**Copy to clipboard** from the **File** menu). Compute its duration (which is also the *period* of the original 440-Hz sound) by subtracting the starting time from the end time. How could you have predicted this duration from the knowledge that there are 440 vibrations per second (try §2.2.4 if you don’t succeed)?

3d. Page 23. *Rarefaction* is a funny word. It does not only occur in vibration, where it alternates with *compression* hundreds of times per second. I am fairly sure that for producing sounds like [p t k] you use a slow compression (caused by expiration activity) to provide the energy needed for obtaining a release burst. Do you know of any exotic speech sounds that use for obtaining the burst a slow rarefaction instead? Look on page 264 for ideas and check with Ladefoged or so if you are not sure.

3e. Page 27/28. What is the wavelength of a 440-Hz sine wave in air?

Section 2.3 is nice for discussing, because it relates to linguistics.

3f. You have already seen how to create a sine wave in Praat (assignment 4c: frequency 440 Hz, top amplitude 0.3 Pascal). To add to that sound a second harmonic (see §2.4) with a top amplitude of 0.1 Pascal, you could choose **Formula...** from the **Modify** menu and type

```
self + 0.1 * sin (2*pi*880*x)
```

Now re-create Hayward’s example sound on page 31 by starting with **Create Sound from formula...**, then applying **Formula...**. Show me two periods of the sound, just as in the figure (the term *period* is explained in §2.4.1, in case you don’t know it yet). You may have to play around with the amplitudes a bit to get exactly the same shape. Don’t throw away the sound yet, because you will need it for a following assignment.

3g. By doing **To Spectrum...** and **Draw...**, you should be able to create a picture similar to that in figure 2.9.

3h. Something is wrong with Figure 2.12b. What is wrong? Show me that you can do it better than Hayward.

3i. Pronounce an /s/ and draw its spectrum. It should look like Figure 2.15.

Decibels, octaves, and the spectra of periodic and noisy sounds are nice concepts to be graded about during class.

Assignment 4: standard deviations.

Question: Do you think that the results of measuring the averages prove that /i/ is pronounced a bit longer than /ɪ/ in Dutch? Certainly the *average* measured /i/ (i.e. averaged across 1 token of each of 8 speakers) was a bit longer than the *average* measured /ɪ/, but that might be a coincidence. What do you think **(4a)**?

And what do you think about the difference between /i/ and /a/ in Dutch? Will the latter be reliably longer, and why do you think that **(4b)**?

The difference between the averages does not tell us much.

Suppose, for instance, that the mean duration of /ɪ/ was 150 ms, and that the 8 values were 143, 145, 147, 149, 151, 153, 155, and 157 ms. Also, suppose that the mean duration of /i/ was 170 ms, and the 8 values were 163, 165, 167, 169, 171, 173, 175, and 177 ms. Even if those 16 values had been measured for 16 different speakers (i.e. the 8 /i/ tokens were from different speakers than the 8 /ɪ/ tokens), we would probably think that the total non-overlap between the two measured distributions indicates that Dutch /i/ is indeed longer than Dutch /ɪ/.

But now suppose that the 8 values for /ɪ/ were 80, 100, 120, 140, 160, 180, 200, and 220 ms. By eye, you can compute that the average is again 150 ms. And suppose that the values for /i/ were 100, 120, 140, 160, 180, 200, 220, and 240 ms, with again an (obvious?) average of 170 ms. If those 16 values had been measured for 16 different speakers, we would probably not consider the difference between the distributions large enough to conclude that Dutch /i/ is indeed longer than Dutch /ɪ/.

So our judgment about the reliability of the conclusion that Dutch /i/ is longer than Dutch /ɪ/ will depend on the spreading and overlap of the two distributions of duration values, as well as on the number of speakers (if all the values of 80, 100, and so on occur repeatedly in the same proportions for 1600 speakers instead of 16 speakers, we will probably conclude that /i/ is about 20 ms longer than /ɪ/).

There exists measures for the spreading of a measured distribution. For the values 143, 145, 147, 149, 151, 153, 155, and 157 ms, you can easily see (i.e. by eye) that the average distance from a value to the mean (i.e. 150 ms) is 4 ms. In other words, the distances from the values to the mean are |143–150| = 7, |145–150| = 5, |147–150| = 3, |149–150| = 1, |151–150| = 1, |153–150| = 3, |155–150| = 5, and |157–150| = 7, and the average of 7, 5, 3, 1, 1, 3, 5, and 7 is 4 (by eye). [Those pipes indicate 'absolute value' and turn negative numbers into positive numbers]

But statisticians use a slightly more sophisticated measure, namely the *standard deviation*. To compute it, you take the squares of those distances: 49, 25, 9, 1, 1, 9, 25, and 49. Then you could compute the average of those squared values, i.e. the sum (49+25+9+1+1+9+25+49 = 168), divided by 8, which is 21 ms^2. Except that statisticians don't do it that way: they divide by one less, i.e. by 7! This gives 168/7 = 24 ms^2. This is called the *observed variance*. To get the standard deviation, you take its square root, e.g. by typing `sqrt(24)` into the Calculator (don't bother about doing *this* by hand). The result is 4.90 ms, a bit greater than the naive average distance measure computed above.

Question 4c: how many of the eight values of the example fall within one standard deviation from the mean? What percentage is that?

For large experiments approximately 68% of the measured values tend to fall within one standard deviation from the mean. This 68% is a number that all statisticians know, because it provides a check on whether you have computed everything right.

So why did we divide by 7 instead of 8, i.e. always one less than the number of measurements? Consider the 'limiting case' in which there is only a single measurement. The mean would be equal to that one value, so that the only distance from the values to the mean is 0, so that the root-mean-square of the distances would have been 0. Zero is not a good estimate of the spreading if you have just one measurement; actually, with just one measurement you cannot say anything about the spreading. Therefore, we compute `sqrt(0/(1-1))`, and that is *undefined* (try it in the Calculator).

Question 4d: given that the standard deviation of 143, 145, 147, 149, 151, 153, 155, and 157 ms is 4.90 ms, what will the standard deviation of 80, 100, 120, 140, 160, 180, 200, and 220 ms be? Show that the answer can be given without doing any real computation.

Task 4e. Compute the standard deviation of the duration for /ɪ/ by hand: make a column for the eight values, then make a column for the eight differences with the mean (i.e. subtract the mean from each measurement value), then make a column for the eight squares, then sum the eight squares, then divide the result by 7, then take the square root. Show in your Word file how you did it.

Task 4f. Compute the standard deviation of the duration for /i/ by typing a formula into the **Calculator** (Ctrl-U) in PRAAT, and copy this formula into your Word file. The formula would be something like:

```
sqrt (((140.4-147.1)^2+(154.0-147.1)^2+...)/7)
```

The "`^2`" means "to the second power", i.e. it computes a square.

Task 4g. Compute the standard deviation for /aː/ by extending your existing PRAAT script that you used for computing the mean, and copy this into your Word file (the "#" at the beginning of some lines means that those lines are 'comments'):

```
duration [1] = 134.2
duration [2] = 123.5
duration [3] = 139.1
numberOfSpeakers = 3
# Compute the mean.
sum = 0.0
for speaker from 1 to numberOfSpeakers
   sum += duration [speaker]
endfor
average = sum / numberOfSpeakers
# Compute the standard deviation.
sumOfSquares = 0.0
for speaker from 1 to numberOfSpeakers
   sumOfSquares += (duration [speaker] - average) ^ 2
endfor
stdev = sqrt (sumOfSquares / (numberOfSpeakers - 1))
# Report the results.
echo The average duration is 'average:2' ms,
... and its standard deviation is 'stdev:2' ms.
```

You can use the three dots at the beginning of a line (as in the last line here) to break up a long line into parts.

Task 4h. So now you have three different ways of computing the standard deviation. Please tell us for each vowel how many measured durations are within one standard deviation (σ) from the mean (μ). In order to see this clearly, you may have to compute $\mu-\sigma$ and $\mu+\sigma$ for each vowel. Next, compute for each vowel what percentage of the values lies between $\mu-\sigma$ and $\mu+\sigma$ (by dividing the number by 8). Are these percentages close to the famous number of 68%?