Lecture 2-6: Plosives and Nasals

Overview

1. **Acoustic Cues:** when listeners interpret a speech signal, they look for aspects of the spectro-temporal pattern that indicate which particular phonetic and phonological components were produced by the speaker. In terms of vowels, we have seen that the identity of the vowel is indicated (or **cued**) by the formant frequencies. For fricatives, we have seen that the frequency of the main spectral peak and the bandwidth of that peak increase as the place of constriction moves further forward in the mouth. For diphthongs and approximants, we have seen that their identity is indicated by both the frequencies and the shapes of formant movements. In general the manner of obstruents is indicated by rapid formant transitions in the vowel regions leading up to and following the articulation of the obstruent, particularly the first formant transition. The place of obstruents is also indicated in these formant transitions, particularly the shape of the second and third formant transitions. Since transitions change in shape a great deal according to the identity of the vowel, we introduced the notion of **locus frequency** to independently characterise the transition shape for a given consonant. All of these indicators: formant frequencies, spectral peaks, transitions, locus frequencies are called **acoustic cues** to phonetic identity.
2. **Plosives:** the articulation of a plosive requires a closing articulation phase, an obstruction phase (stop gap), a release phase, an optional aspiration phase, and an opening articulation phase, see figure 2-6.1. These phases have characteristic acoustic cues associated with them. The **manner** cues for plosives include the presence of the silent region in the stop gap, the rapid formant transitions and particularly a low locus frequency for F1, sudden energy change, release burst and aspiration. The **place** cues for plosives include the centre frequency (i.e. main spectral peak) of the turbulence occurring at the release (the **burst**), and the locus frequency for the second and third formant transitions. The burst centre frequency cue turns out to be processed *relative* to the frequency of the vowel F2 (as shown by the **pi-ka-pu** experiment, see figure 2-6.2).

Place	Burst Centre Frequency	F2 Locus Frequency	F3 Locus Frequency
Bilabial	Lower than vowel F2	Low	Low
Alveolar	Higher than vowel F2	Mid	High
Velar	Close to vowel F2	High	Mid

   The **voicing** cues for plosives include the voice onset time, the presence of aspiration, the presence of an audible F1 transition, the intensity of the burst and the duration of the preceding vowel. There are notable differences in cues to voicing across languages: some do not use aspiration, others have a three-way contrast, see figure 2-6.3.
3. **Nasals**: nasal consonants involve a lowering of the soft-palate (velum) which links in the nasal cavities as additional acoustic resonators. The **manner** cues for nasals include the presence of a low-frequency resonance due to the nasal cavity, and the rapid fall and rise in energy as the nasal is made and released. The **place** cues to nasals mostly arise from the second and third formant transitions, as for plosives, see figure 2-6.4. In addition, the spectral shape of the nasal itself varies slightly with the place of the obstruction in the vocal

tract. This seems to be due to the size of the cavity trapped *behind* the obstruction which modifies the filter characteristic of the branched tube. The **nasalisation** of vowels is cued by the presence of a low-frequency resonance and an increase in formant damping.

4. **Redundant coding of phonetic features**: when the voice or manner or place of a consonant changes, we observe many changes in the spectrographic picture. Comparing a voiced plosive with a voiceless plosive reveals many acoustic differences. This multiplicity or **redundancy** of cues makes the contrast easier to perceive and the interpretation more robust in poor listening conditions.

Readings

At least one from:

- Hewlett & Beck, An introduction to the science of phonetics, Chapter 7: Further exploration of speech complexity, pp82-102. *Description of stop production and measurement.*
- Johnson, Acoustic & Auditory Phonetics (1^{st} edition), Chapter 7: Stops and affricates. *Rather basic description.*

Learning Activities

You can help yourself understand and remember this week's teaching by doing the following activities before next week:

1. Construct a table with columns labelled voice, place and manner, and with rows labelled vowels, diphthongs, approximants, fricatives, nasals and plosives. In each box make suggestions for acoustic cues that a listener might use to help identify sounds of that category.
2. Research the term Voice Onset Time on the web. Find out how it varies across languages. Find out how have people used VOT to explore our understanding of speech perception.
3. Write an explanation of why redundancy of information coding makes for more robust communication systems. Be sure to illustrate your argument with non speech examples.

If you are unsure about any of these, make sure you ask questions in the lab or in tutorial.

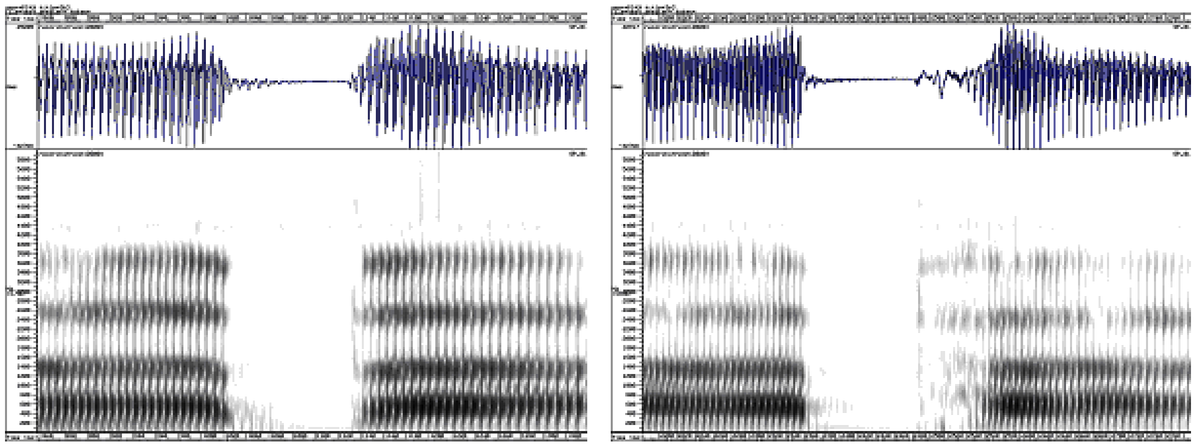
Reflections

You can improve your learning by reflecting on your understanding. Here are some suggestions for questions related to this week's teaching.

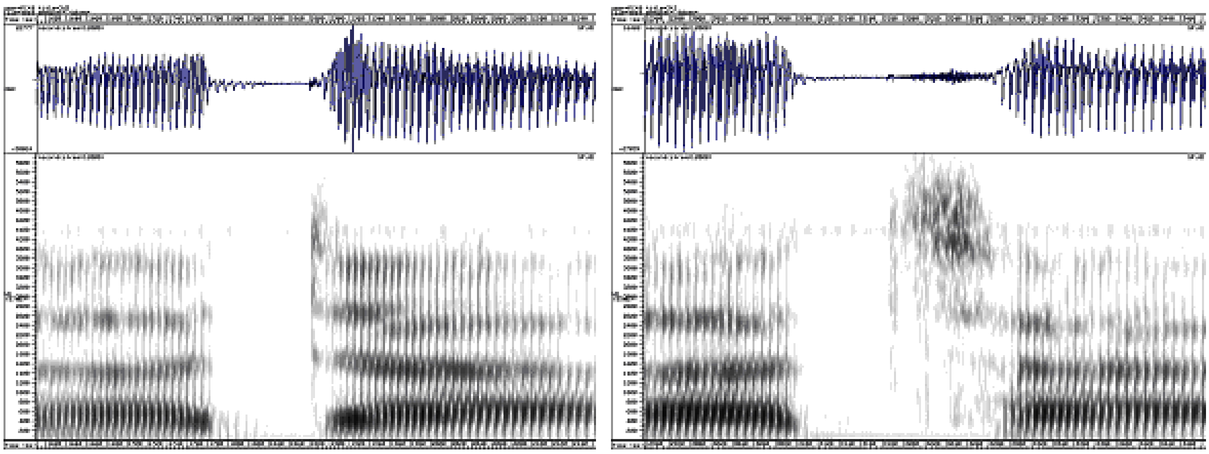
1. What differences are there between syllable-initial and syllable-final plosives?
2. Why does the burst centre frequency for /k/ vary with vowel context?
3. What happens when two plosives are adjacent, e.g. in "goodbye" or "bookcase"?
4. What happens to nasals when you have a cold? What happens for speakers with a 'cleft palate'?
5. Think of some more examples where one phonological unit can be produced as a family of sounds (even for one speaker)
6. Think of some more examples of one sound being perceived as different phonological units (depending on the context in which it arises).
7. In general, why are some words easier to recognise than others?
8. In general, why are some speakers easier to understand than others?

Figure 2-6.1 Spectrograms of Plosives

Bilabial: /b/, /p/



Alveolar: /d/, /t/



Velar: /g/, /k/

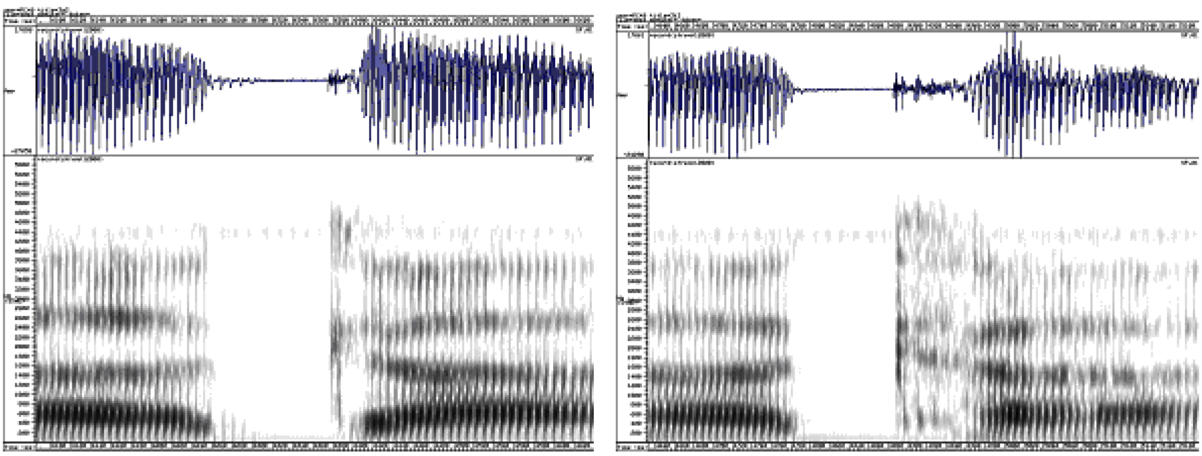
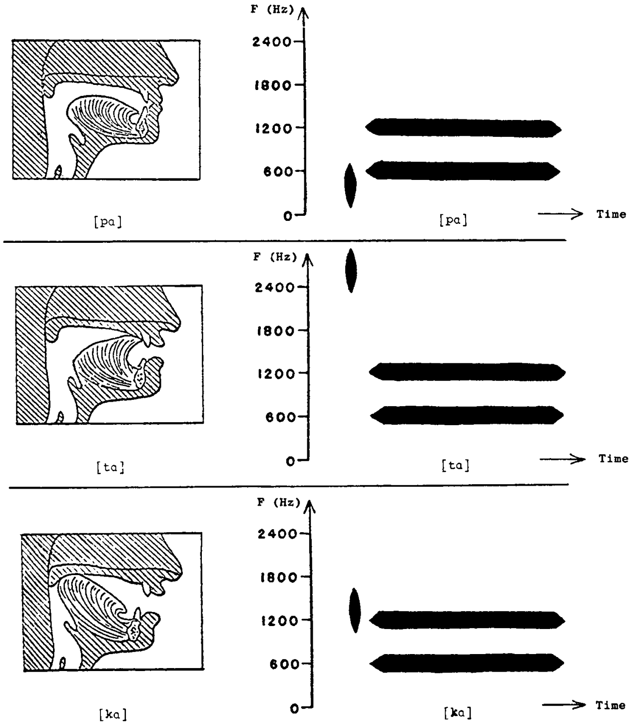


Figure 2-6.2 Pi-ka-pu Experiment

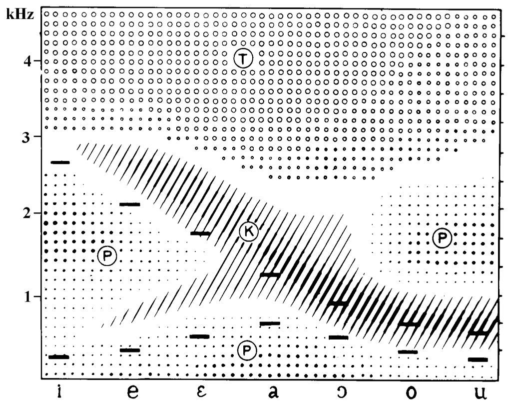
Cooper, Delattre, Liberman, Borst & Gerstman, "Some experiments on the perception of synthetic speech sounds", JASA 24 (1952) 597.

Stimuli:



Synthetic stimuli with bursts of different centre frequencies before different vowels. There were no formant transitions.

Perception Results:



Low frequency bursts heard as /p/, high frequency bursts heard as /t/, bursts close to vowel F2 heard as /k/.

Mid burst can be either /p/ or /k/ depending on vowel context

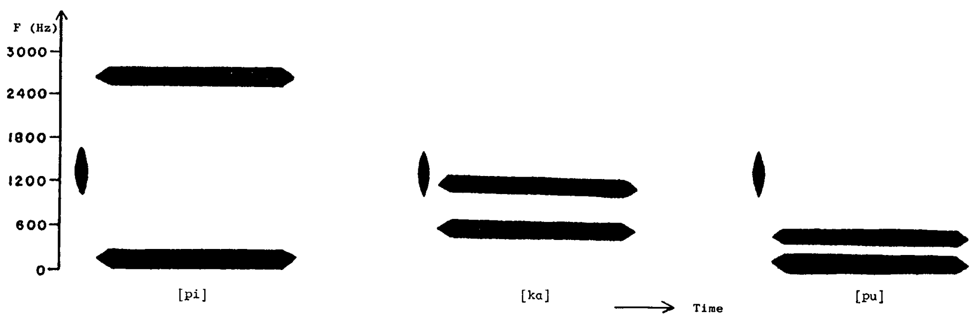
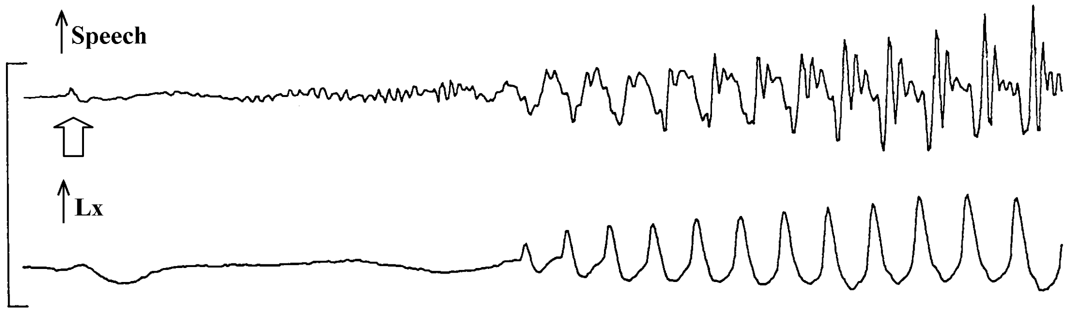
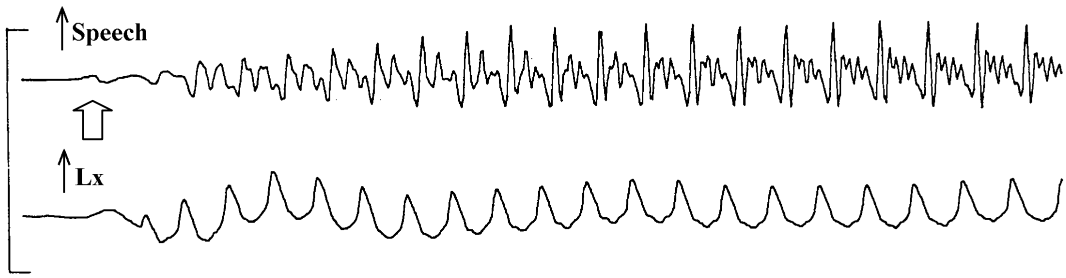


Figure 2-6.3 Voice Onset Time Differences Across Languages

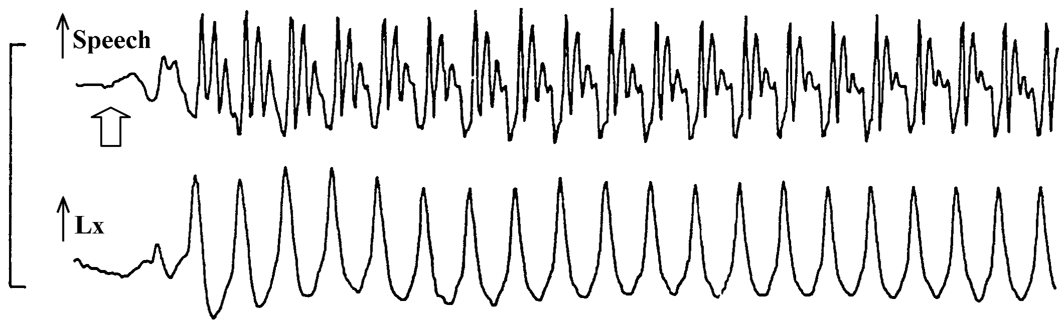
English /p/: long VOT and aspiration



English /b/: short VOT no aspiration



French /p/: short VOT no aspiration



French /b/: negative VOT no aspiration

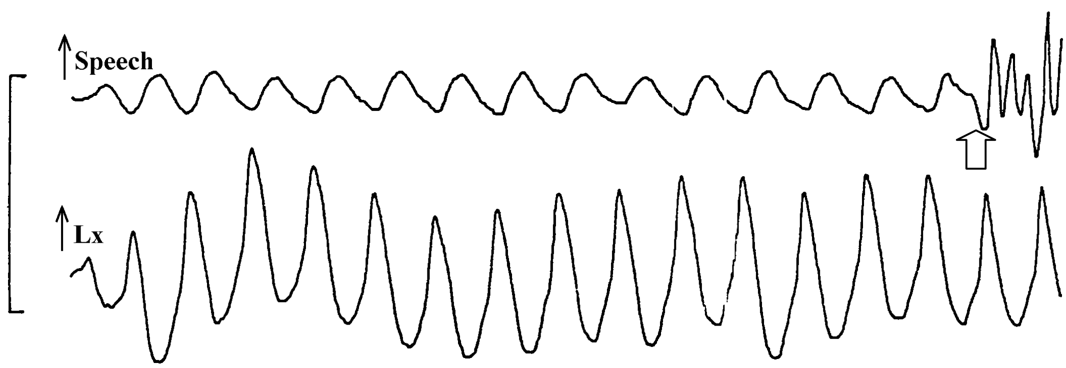
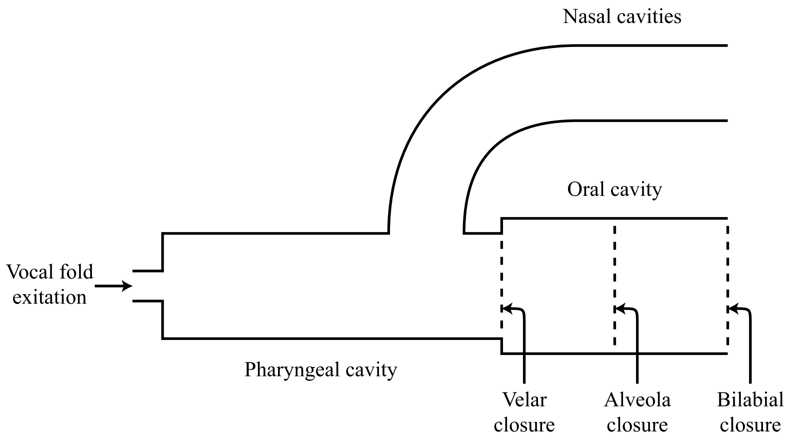


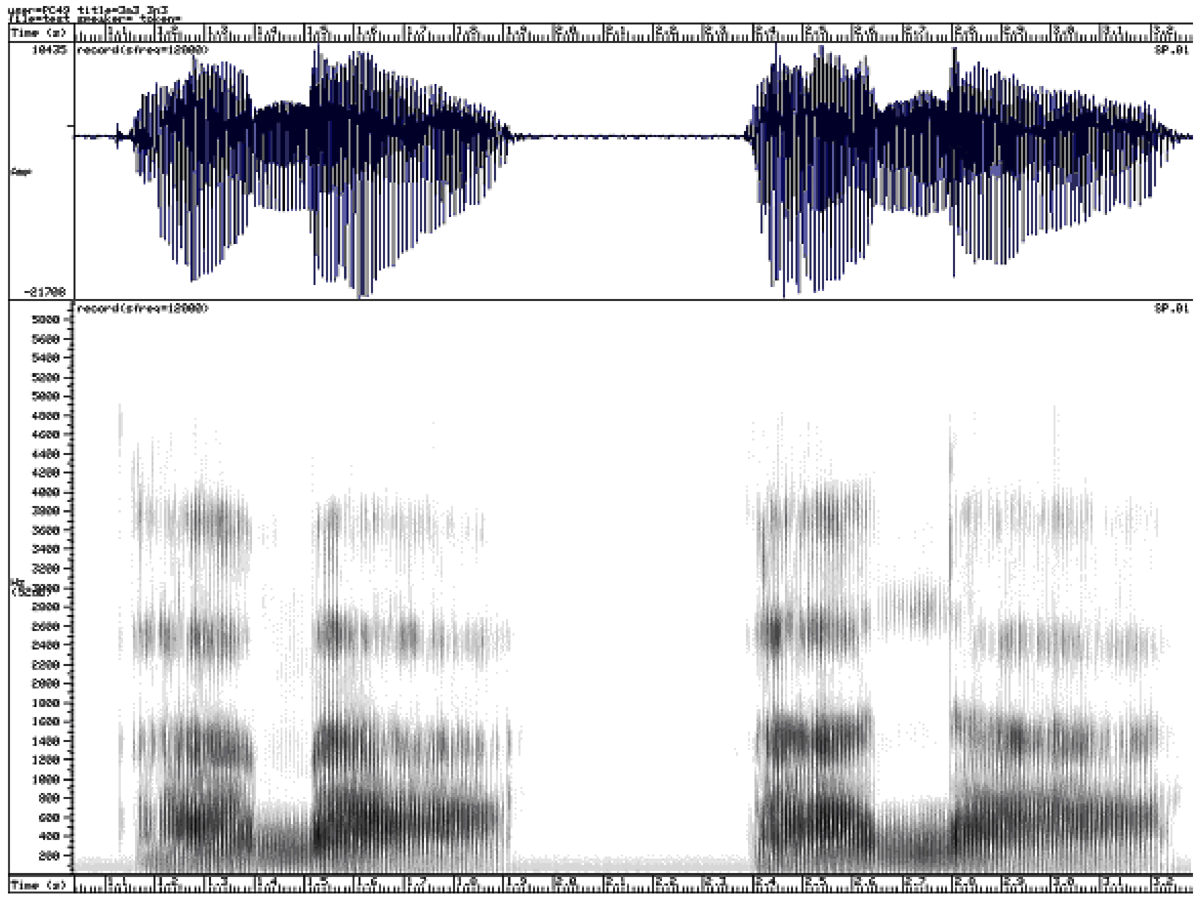
Figure 2-6.4 Nasal Consonants

Tube Model for Nasal Consonants



Oral cavity forms side chamber of cavity, of different size depending on place of obstruction.

Spectrograms of Nasals /m/ and /n/



Lab 2-6: Voice Onset Time Measurements

Introduction
In plosive-vowel productions, speakers can control the interval between the release of a stop at the point of obstruction and the onset of periodic vibration in the larynx (this is called voice onset time or VOT). By keeping the vocal folds approximated and tensed, it is possible for vibration to occur rapidly and automatically as a consequence of the drop in pressure in the supra-glottal cavity. By keeping the vocal folds slightly apart, however, it is possible for turbulence to arise at the glottis just after the release: this is called 'aspiration'. At some time interval after the plosive release, the speaker can then adjust the vocal folds to switch from turbulence into periodic vibration.

In this experiment you will investigate how VOT varies between the six English plosives [b,d,g,p,t,k] in your own speech.

Scientific Objectives
- to investigate differences in VOT between voiced and voiceless plosives
- to investigate differences in VOT between bilabial, alveolar and velar voiced plosives

Learning Objectives
- to understand how voice onset time is measured and how it varies across English plosives.
- to confirm the form of spectrographic cues to plosive place and voicing
- to appreciate the components of a scientific experiment in phonetics, including data capture, measurement, analysis and interpretation.
- to become more familiar with the use of the laboratory computers for numerical investigations and statistical analysis.

Apparatus
You will use the laboratory computers to (i) acquire and measure your recordings of /ɑbɑ/, /ɑdɑ/, /ɑgɑ/, /ɑpɑ/, /ɑtɑ/ and /ɑkɑ/; (ii) perform statistical tests on the differences in VOT.

Method
You should work in groups of three or four at a PC with laryngograph input. The SFS software can be used to record both speech pressure and Lx signals and to display them on the screen (http://www.phon.ucl.ac.uk/resource/sfs/). You will be able to display the start of each plosive in turn and measure the duration between the stop burst and the start of the first full Lx voicing cycle.

Once you have collected all the measurements from all the speakers in your group, the SPSS statistics program will be started for you. To perform the statistical tests, enter your data into columns using the data editor as shown overleaf.

That is, variable 'Voice' contains '0' for all unvoiced measurements, and '1' for all voiced measurements. Variable 'Place' contains '1' for voiced bilabials, '2' for voiced alveolars, and '3' for voiced velars. The unvoiced sounds do not have entries in the 'Place' variable. Variable 'VOT' contains the voice onset time measurements in milliseconds.

Voice	Place	VOT
1	1	10
0		45
1	2	15
0		90
1	3	20

Observations

1. Print out wide band spectrograms from **one** member of the group. Locate the main acoustic cues to place and voicing that differentiate the six plosives.
2. Measure the interval between burst and onset of voicing for each of your group's productions of [p], [b], [t], [d], [k] and [g]. Plot a scatter graph of VOT for each plosive as you go along.
3. Enter your data into SPSS, as shown in the Method.
4. Use SPSS to test the following null hypothesis at a significance level of 0.05:
   "VOT does not vary between voiced and voiceless plosives"
   Choose an appropriate test and write down your interpretation of the test and the result.
5. Use SPSS to test the following null hypothesis at a significance level of 0.05:
   "VOT of voiced plosives does not vary according to place"
   Choose and appropriate test and write down your interpretation of the test and the result.

Concluding Remarks

To what extent do you think listeners make use of VOT differences in choosing between voiced and unvoiced plosives? To what extent do you think VOT affects their choice of place?

Outline another experiment that you might use to confirm your hypotheses.

Examination Questions

These are questions from past exam papers. You may like to write outline answers to these, or to discuss them in tutorial.

1. Explain the acoustic and articulatory differences between the VCV sequences /utu/ and /idi/. Use sketches to demonstrate the spectrographic patterns for both. [2003/4]
2. Explain what is meant by Voice Onset Time (VOT) and how it is used in different languages to differentiate words. Describe how VOT can be measured in the laboratory and what statistical test might be used to demonstrate that VOT varies across consonantal voice and consonantal place. [2005/6]
3. Sketch a stylised spectrogram for a generic vowel-plosive-vowel sound, linking the spectral changes to their articulatory causes. Describe how your picture would vary for plosives of different places of articulation and of different voicing. [2007/8]