LING 576 Acoustic Phonetics
Spring 2009
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Topic number 1: Acoustic Phonetics Overview
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Reading:
Borden, Gloria J., Katherine S. Harris & Lawrence J. Raphael. 1994. Speech science primer: Physiology, acoustics, and perception of speech. Baltimore: Williams & Wilkins. Read Chapter 1.
Denes, P.B. & Pinson, E.N. 1993. The speech chain. 2nd edition. New York: W.H. Freeman. Read Chapter 1.

1. Basic definitions

Acoustics is the study of sound.

Acoustic phonetics is the study of speech sound waves, generally using electronic instruments.

2. Technology

Early acoustic phonetic work largely involved a dedicated (and very expensive) device called a sound spectrograph.

Today, most acoustic phonetic analysis is done using speech analysis software on a personal computer.

Examples of speech analysis software:

- SIL Speech Analyzer (http://www.sil.org/computing/speechtools/download.htm)
- PRAAT (http://www.fon.hum.uva.nl/praat/)
- University College London Speech Filing System (http://www.phon.ucl.ac.uk/resource/sfs/)
- SIL WinCECIL program (obsolete)

Additional software packages are listed on George Dillon's University of Washington faculty web page (http://faculty.washington.edu/dillon/PhonResources/).

The effective use of speech analysis software requires the availability of good quality sound recordings, generally in the form of .wav files.

Some other electronic instruments relevant to speech analysis:

- Electroglottograph (see the Glottal Enterprises web page at http://www.glottal.com/Products%20and%20Services/electroglottograph.html)

An electroglottograph measures larynx position and patterns of vocal fold vibration. (What is this useful for?)

- Instruments for measuring oral and nasal airflow

Some devices of this sort are also produced by Glottal Enterprises.

- Electropalatograph

"An electropalatograph (also termed palatometer) is an instrument that records the timing and location of tongue contact with the hard palate during continuous speech. The technique requires the speaker to wear an artificial palate that is moulded to fit the roof of the mouth. Tongue-palate contact is recorded by a number of silver or gold contacts located on the lingual surface of the artificial palate (also termed pseudopalate)."

-- From the Articulate Instruments web site (http://www.articulateinstruments.com/electropalatograph.htm), accessed on 12/23/06.

- Digital video recorders
- Magnetic Resonance Imaging (MRI) (cf. Tiede 1996)
- Ultrasound (cf. Gick 2002)

Use of MRI and ultrasound have supplanted x-ray cinematography (cf. Ladefoged et. al. 1972, Painter 1973), due to the health risks associated with the latter.

What these instruments have in common:

- They investigate *articulatory*, rather than acoustic properties.
- They tend, for the most part, to be very expensive.

"More recently, the increased availablility [sic] and lower price of portable and PC-based ultrasound units, digital video recording equipment, and image analysis software have brought ultrasound within financial reach of many linguistic phonetics labs (used ultrasound units may also be available)."

-- Gick (pre-publication version, p.2)

This does *not* mean that such equipment (especially ultrasound) is something an individual linguist can necessarily afford!

In general, acoustic speech analysis provides less direct information about articulatory events than the instruments listed above. In some cases, this leads to conclusions about articulatory behavior that are less certain.

This disadvantage is offset however by several advantages of acoustic analysis:

- Low cost (often free)
- Portability
- Durability

For these reasons, acoustic analysis is by far the most common form of instrumental phonetic investigation.

It is also important to note that use of articulatory instruments and acoustic analysis are not mutually exclusive. Rather, use of instruments such as those listed above typically proceeds hand-in-hand with acoustic analysis.

3. Purposes of acoustic analysis

Broadly speaking, there are two different primary reasons why a linguist would carry out acoustic analysis on a language:

- As an aid to phonetic and phonological analysis of a language(s) whose phonological system is not yet fully understood.
- To better understand the acoustic correlate(s) of some phonological, articulatory, or perceptual feature in a language(s) whose phonological system is already understood.

Investigations of the latter type sometimes involve a comparison of corresponding acoustic properties in several different languages, to see how a particular phonological feature is manifested acoustically (with possible inferences about articulation).

In still other cases of the latter type, the speech of different individual speakers of the same language is compared to investigate dialectal and/or sociolinguistic differences, or effects of pathology.

(Real or hypothetical) examples of acoustic investigations of the first type?

Published examples are not especially easy to find. (Why?)

(Real or hypothetical) examples of acoustic investigations of the second type?

Published examples are easy to come by.

One interesting recent example: Everett (2008).

In this course, we will be concerned primarily with the first of the two purposes listed above, though we may look at some investigations of the second type as well.

It is important to realize that the fundamental principles of acoustics involved are the same in either case.

It is also very important to keep in mind that investigations of the first type greatly depend on the existence of studies of the second type. (Why?)

4. The usefulness of acoustic analysis for linguistic fieldwork

Acoustic analysis is of interest to the field linguist largely because of its value in helping to establish the phonetic identity of sounds.

Articulatory events have acoustic consequences. From the acoustic record of an utterance, it is possible to make inferences about the articulatory nature of the sounds it contains.

Two ways this happens:

- Particular types of sounds have characteristic acoustic "signatures."

It is often possible to make reliable inferences about both the place and manner of articulation of a sound from its acoustic characteristics.

Note however that in many of the cases where this can be done easily and reliably, the differences will also be plainly audible to a linguist with good training and experience.

Acoustic (or other kinds of instrumental) analysis is not a substitute for one's ears!

Nevertheless, there are cases where one can learn more from the acoustic record than from one's ears alone, or in which acoustic analysis can be helpful in confirming or disconfirming a hypothesis.

"The use of all these techniques furnished a great deal of information. I do not know of any previous attempt to use data provided by palatograms, linguagrams, casts of the mouth, photographs of the lips and spectrograms all of the same utterances, supplemented by tracings of cine-radiology films and pressure and flow recordings of similar utterances of the same word. But

although instrumental techniques were used extensively in the course of this study, I would like to stress that an equally important part of the work consisted of simply observing and imitating informants. As a result of an experimental approach I was often able to select the most appropriate out of a number of conflicting hypotheses about the way in which a particular sound was made; and occasionally instrumental data revealed a new articulatory possibility which I had not thought of before. Nevertheless I am still sure that 'instrumental phonetics is, strictly speaking, not phonetics at all. It is only a help...The final arbiter in all phonetic questions is the trained ear of the practical phonetician.' (Sweet, 1911). For those of us who are not as skilled as Sweet, instrumental phonetics may be a very powerful aid and of great use in providing objective records on the basis of which we may verify or amend our subjective impressions. But even the most extensive array of instruments can never be a substitute for the linguist's accurate observation and imitation of an informant."

--Ladefoged (1968:xvi)

- There are many cases where the magnitude of an acoustic property is directly dependent on the magnitude of some articulatory event and/or the value of some phonological feature. This can be extremely useful in comparing sounds within the same or different utterances.

Example: The measured value of a vowel's fundamental frequency is proportional to tone height (i.e., it is generally higher for high tones than for non-high tones in comparable contexts).

Of these two ways of making inferences from acoustic records, the second (comparison of two sounds) is often the more useful. However, doing this effectively often requires some sophistication (for example to control for possible contextual effects), careful planning, and patience.

5. Some limitations of acoustic analysis

In a field linguist's ideal "dream" scenario, inferring the phonetic identity of sounds from their acoustic record would be simple and straightforward:

- Every acoustic feature would correspond transparently to a particular articulatory event, and vice-versa.
- The mapping of acoustic features to perceptual properties would also be one-to-one. Among other things, there would be no perceptually (and hence linguistically) irrelevant features in the acoustic record to complicate the analysis.
- Acoustic measurements made on the same sound as pronounced by different speakers of the same language would consistently yield similar values.

- Transitions between phonetic categories (e.g., between high and mid vowels or high and low tones) would correspond to fixed and well-defined values of the corresponding acoustic features, making it possible to easily infer the category a sound belonged to from the appropriate acoustic measurement.

Uninformed discussion of acoustic speech analysis has sometimes given the impression that something like this ideal world exists.

Occasionally, this simple picture has even been reinforced by features of speech analysis software.

Unfortunately, things are much more complicated in the real world.

Some of the complications:

- The mapping of acoustic properties to articulatory events is not strictly one-to-one. Sometimes, there is more than one articulatory gesture that is capable of causing a given acoustic outcome.
- Not all acoustic features are perceptually relevant; some are apparently factored out automatically in the process of speech perception.

Why is this important?

"As far as speech perception research is concerned, it is not inconceivable that the sound spectrograph has had an overall detrimental influence over the last 40 years by emphasizing aspects of speech spectra that are probably not direct perceptual cues (and in some cases may not even be resolved by the ear)."

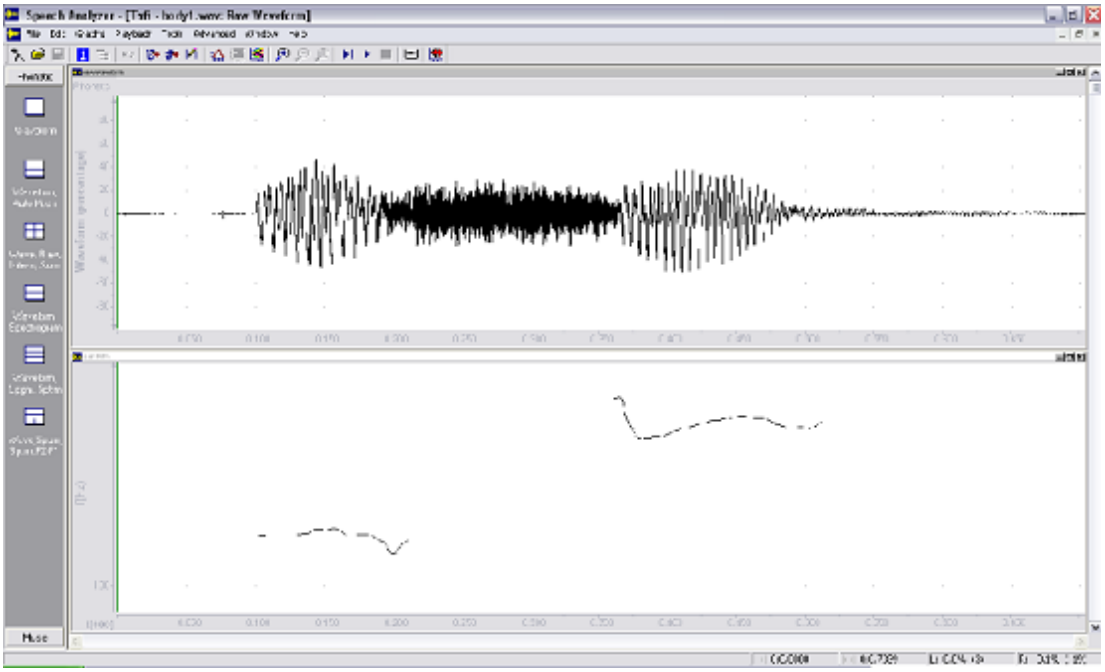
-- Dennis Klatt

- Acoustic measurements made on a particular sound can vary greatly among individual speakers of the same language.
- The linguistic interpretation of many acoustic properties is *relative.*

In such cases, it is difficult or impossible to make valid inferences about the phonetic category of a sound simply by measuring its value of the relevant acoustic property.

For example, while it is true that higher tone values correlate (all else being equal) with higher fundamental frequency (an acoustic property), there is no absolute fundamental frequency threshold between high and non-high tones. Hence, it is not generally possible to tell what the tone of a vowel is simply by measuring its fundamental frequency.

A specific example: What can (and cannot) be inferred about the tone values of syllables in the utterance whose waveform and fundamental frequency displays are shown below?



These difficulties do not mean that acoustic analysis is either impossible or a waste of time.

They do mean that:

- Acoustic speech analysis is not a trivial matter.
- Effective acoustic speech analysis requires a lot of background knowledge of acoustic phonetic theory.
- In the absence of this knowledge, it's very easy to draw wrong conclusions from overly simplistic use of speech analysis software.

However, with good background knowledge, patience, and experience, acoustic speech analysis can be tremendously helpful in carrying out phonetic and phonological fieldwork.

References

Everett, Caleb. 2008. Locus equation analysis as a tool for linguistic fieldwork. Language Documentation & Conservation 2(2):185-211. http://scholarspace.manoa.hawaii.edu/handle/10125/4351

Gick, Bryan. 2002. The use of ultrasound for linguistic phonetic fieldwork. Journal of the International Phonetic Association 32:113-121. (Prepublication version available at http://linguistlist.org/emeld/school/readingroom/Gick_JIPA_Ultrasound.pdf.)

Ladefoged, Peter. 1964. A phonetic study of West African languages. 2nd edition. Cambridge: Cambridge University Press.

Ladefoged, Peter, Joseph DeClerk, Mona Lindau, and G. Papçun. 1972. An auditory-motor theory of vowel production. UCLA Working Papers in Phonetics 22:48-75.

Painter, Colin. 1973. Cineradiographic data on the feature 'covered' in Twi vowel harmony. Phonetica 28:97-120.

Tiede, M.K. 1996. An MRI-based study of pharyngeal volume contrasts in Akan and English. Journal of Phonetics 24:399-421.