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LINGUISTIC PHONETICS IN THE UCLA PHONETICS LAB*

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ABSTRACT

Faculty and students in the UCLA Phonetics Laboratory are linguists who want to describe the segmental and suprasegmental phonetic properties of languages, to relate these phonetic descriptions to phonological properties, and to explore the broader theoretical relation of phonetics to phonology. This presentation will survey some of our recent projects. Work on basic phonetic description of languages includes extensive study of aspects of Korean, and cross-language studies of intonation. Many projects in addition to the studies on intonation are concerned with speech prosody: for example, prosodic phrasing and segmental articulation, and prosody and voice quality. We also try to relate production and perception: for example, the optical phonetics and visual perception of prosody, and benefits of childhood overhearing of a language on later phonetic production.

INTRODUCTION

It is a great privilege to be given the opportunity to showcase some of the work from our laboratory at the Sound to Sense conference. I cannot represent all of linguistics phonetics, let alone all of phonetics and phonology, but from many recent studies in our lab, I've chosen a few to present briefly, grouped somewhat arbitrarily into three larger topics. Our general focus can be said to be documentation of segments and prosody from a variety of languages, and describing the behavior of a language's sounds as part of a linguistic system. My topics here will be language description, prosody, and production-perception.

LANGUAGE DESCRIPTION

Archives of recordings

We are a phonetics lab within a linguistics department, and so description of languages is important to us. I will first mention the valuable continuing work by [Peter and Jenny Ladefoged](#) in making samples from the lab's collections of audio recordings of many languages, materials taken from a variety of student and faculty research projects, available on the web (at <http://www.phonetics.ucla.edu>). Peter has noted that this site gets about 100 hits a day from all over the world. He currently has NSF funding for a continuation of this archiving project (a brief news notice about it can be found on the departmental website, at <http://www.linguistics.ucla.edu/general/newslet4.htm#PhoneticDataArchive>).

Korean

Quite a lot of descriptive work on Korean is done in our lab, due primarily to the presence of [Sun-Ah Jun](#). Some of this work will be mentioned in later sections.

* Written version of presentation at the Sound to Sense conference at MIT, June 2004.

Intonation

Also due to Sun-Ah Jun, work on intonation, especially ToBI-style analysis of intonation, is a focus in the lab. The name ToBI stands for tones and break indices, referring to the two kinds of elements in this system of analysis. It's worth noting that the first ToBI system, for American English (Silverman et al., 1992), was developed in part at MIT due to the efforts of several people attending the Sound To Sense conference, and that the prior work that informed the substance of ToBI systems also originated at MIT – the tone part of ToBI from Janet Pierrehumbert's Linguistics dissertation (Pierrehumbert, 1980), and the break index part in the Speech Group (e.g. Price et al., 1991). An edited book that is about to appear, *Prosodic Typology: The Phonology of Intonation and Phrasing* (Jun, 2004), presents and compares ToBI analyses of 14 languages (see <http://www.oup.co.uk/isbn/0-19-924963-6>). Several languages have been described at UCLA, including Seoul, Chonnam, and Kyungsang Korean, French, Greek, Argentinian Spanish, and Farsi. In addition to language description, studies of intonation also treat its applications to clinical populations, to sentence processing, and to second language learning. These are growing research areas in the field and in our lab.

Phonation

Another kind of language description concerns phonation, specifically the phonetic correlates of phonologically contrastive phonation types (voice qualities) in languages: voice qualities such as modal, breathy, and creaky, as in the Zapotec languages of Oaxaca, Mexico. Work on non-modal phonation in our lab goes back to Peter Ladefoged and Ian Maddieson, and is an interest we share with the voice laboratory in the UCLA medical school. Our quantitative study of voice was jump-started by Peter's visit some 20-plus years ago to the MIT Speech Group, where he learned about a new acoustic measure of phonation type, H1-H2.

First, examples from a language in which isolation forms show the phonation contrast quite well: San Lucas Quiavini Zapotec, in Figure 1. These are three words that differ in their phonation, as part of the phonology of the language. (To hear these examples, please go to slide 5 in the original [Powerpoint presentation](#) available on-line.)

Next, Figure 2 gives examples from the Zapotec language (Santa Ana del Valle Zapotec) that Christina Esposito is studying. (To hear these examples, please go to slide 6 in the [Powerpoint presentation](#).) The figure also gives averages of an acoustic measure (H1-A3, due to Klatt) for a corpus of words for one of her three speakers, from Esposito (2003a, 2003b). The acoustic measure shows, as expected, that in breathy voice the fundamental dominates over the higher frequencies, while in creaky voice the higher frequencies are stronger.

Now at first it was not entirely clear that this language really had these contrasts, and it turns out that there was an interesting reason for that confusion. Figure 3 shows the same acoustic measure for the same items as in the previous figure, but now divided out by different ranges of fundamental frequency. The contrast is clear only at lower f_0 s, as on the right of Figure 3; when f_0 is high, as on the left, the contrasts are almost merged and are very hard to hear. And in this language, isolation or citation forms, like focused forms in initial position in sentences, have a high f_0 . So just in the kinds of forms a fieldworker might elicit, the contrast is not apparent, and knowledge of the intonational system is crucial to understanding the phonation system. This observation leads to our next major topic.

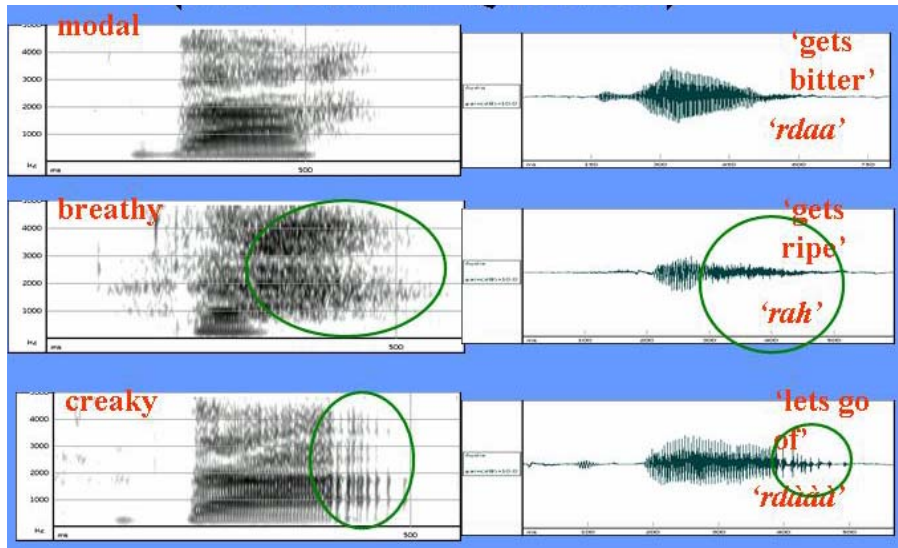


Figure 1. Spectrograms and waveforms of three words of San Lucas Quiavini Zapotec contrasting in phonation type. The circles point out the regions of non-modal phonation. Prepared by Melissa Epstein using recordings made by Matthew Gordon of UC Santa Barbara.

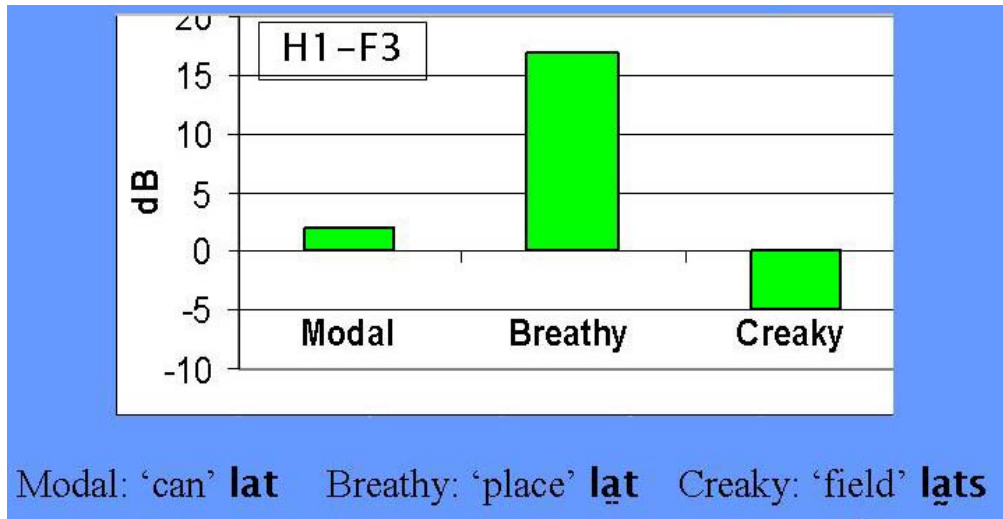


Figure 2. Mean spectral tilt measure (amplitude of the fundamental minus the amplitude of the highest harmonic in the third formant) for three phonation types produced by a male speaker of Santa Ana del Valle Zapotec, and example of a minimal triplet. Prepared by Christina Esposito.

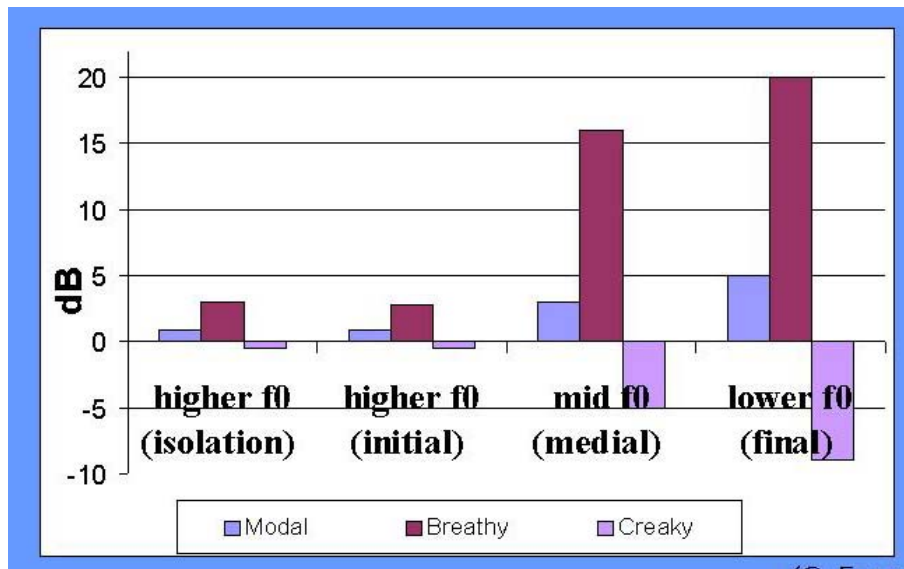


Figure 3. Same data as in Figure 2, but divided by fundamental frequency range, which varies with position in utterance. Prepared by Christina Esposito.

PROSODY

By *prosody* I mean the organization of speech into a hierarchy of units or domains (the grouping function of prosody) in which some units are more prominent than others (the prominence-marking function of prosody, where prominence includes what is called accent, or phrasal stress).

Prosody and voice quality

Intonation is part of prosody, and we have already seen an effect of intonational f0 on phonation contrast in Santa Ana del Valle Zapotec. Another effect of prosody on voice quality, related to interests in the MIT speech group, is non-contrastive phonation varying with intonation. That is, even in a language like English, non-modal phonations (breathy, creaky) occur, but governed by prosody rather than the lexicon. Furthermore, there is also phonation variation within modal voice quality (laxer, tenser phonation), similarly governed by prosody. Both of these kinds of voice quality variation as a function of position and accent have been studied by Melissa Epstein (2002, 2003).

Consider first the occurrence of non-modal phonation at different locations in English sentences. Non-modal phonation was defined as glottal cycles which could not be fit with the LF model (Fant et al., 1985). Figure 4 gives Epstein's finding for three speakers: phrase-final Low boundary tones have more non-modal phonation than High tones. That is not a surprising result, but perhaps surprising is that it is the *phonological Low tone*, that is, a phrase-final low f0, not the low f0 per se, that matters. The evidence that low f0 is not itself the determining factor, seen in Figure 5, is that Low tones associated with accent are generally modal, even with a low f0. It is unaccented words, not accented words, that have more non-modal phonation. So, the phonation variation is linked to the phonological system of prosody, not just to f0.

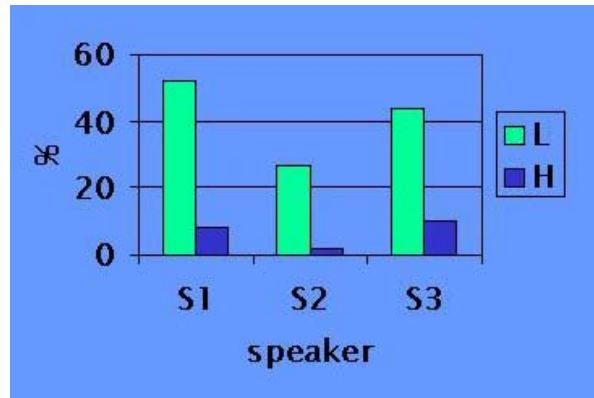


Figure 4. Percent of test syllables with non-modal phonation for Low vs. High boundary tones, for three speakers of American English in Epstein's study.

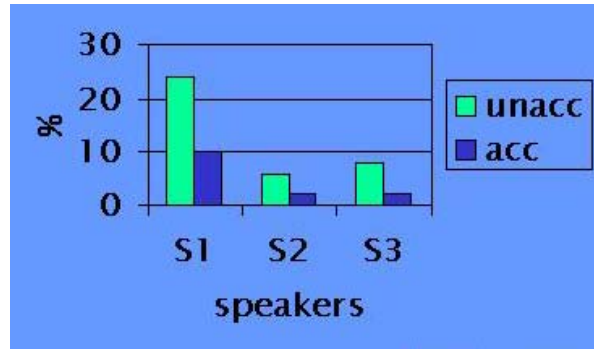


Figure 5. Percent of syllables with non-modal phonation when pitch-accented vs. unaccented, for three speakers of American English in Epstein's study.

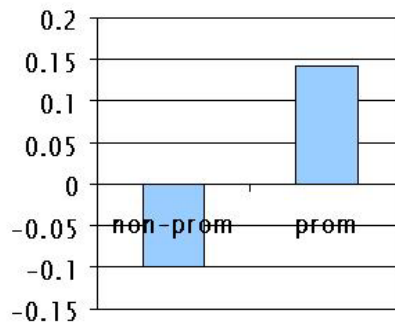


Figure 6. Mean values of Excitation Energy, normalized for each speaker, for prominent (accented) vs. non-prominent syllables. Higher value indicates tenser phonation. Prepared by Melissa Epstein.

With respect to variation within modal phonation, Epstein found the values of the parameters of the LF model for individual glottal cycles, normalized for each speaker relative to a baseline value. She compared these values for prominent vs. non-prominent words, and for phrase-initial prominent vs. phrase-final prominent words. The result, shown in Figure 6 for the LF model parameter Excitation Energy, was that prominent words have a tenser voice quality. Further analysis showed that this held especially for phrase-initial prominent words.

Phrasing and articulation

Prosody does not affect only phonation; a major focus in our lab is its effect on segmental properties. That is, how each segment's phonological properties are realized phonetically depends in part on the segment's position in prosodic structure. An idea from traditional historical phonetics concerned with understanding historical sound changes is strengthening, that is, the idea that some positions are stronger than others, and segments in those positions are stronger. That is they show articulatory strengthening, or more extreme articulations. Now, it seems that these stronger positions can be derived from a prosodic hierarchy; for example, initial in a prosodic domain is a strong position. The prosodic hierarchy is a proposal from phonology that has turned out to have important consequences for phonetics. (See Shattuck-Hufnagel & Turk, 1996 for a review.) Here in Figure 7 is part of a prosodic hierarchy, which shows smaller units grouped into larger ones, or, viewed from the top down, how a larger unit like the Utterance is composed of one or more Intonational Phrases. Our interest is the articulation of segments that are in stronger positions within such a structure. The beginning of a major phrase, for example, is a stronger position than the beginning of a word inside a phrase.

We have mostly looked at articulatory strengthening using electropalatography; for example, comparing maximum total tongue-palate contact of segments across prosodic positions, e.g. in different initial positions. We have studied four languages: English (e.g. Fougeron & Keating 1997), Korean (Cho & Keating 2001; Kim 2001, 2003), French (Fougeron 1998, 2001), and Taiwanese (Keating et al. 2003). Electropalatography uses an acrylic false palate embedded with small contact electrodes (Figure 8); when the tongue touches the pseudo-palate, the contact pattern is recorded to a computer.

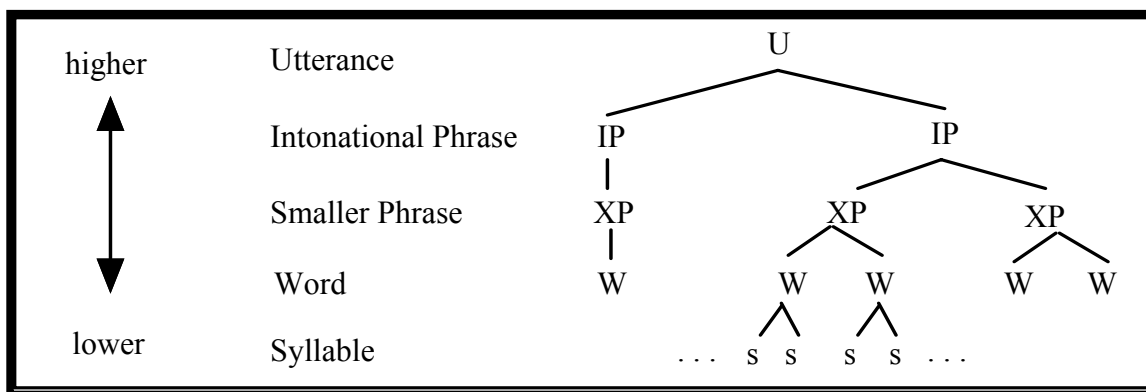


Figure 7. Partial prosodic hierarchy (some domains omitted), from Keating et al. (2003). The smaller phrase is labeled XP because it varies across languages. From Keating et al. (2003).

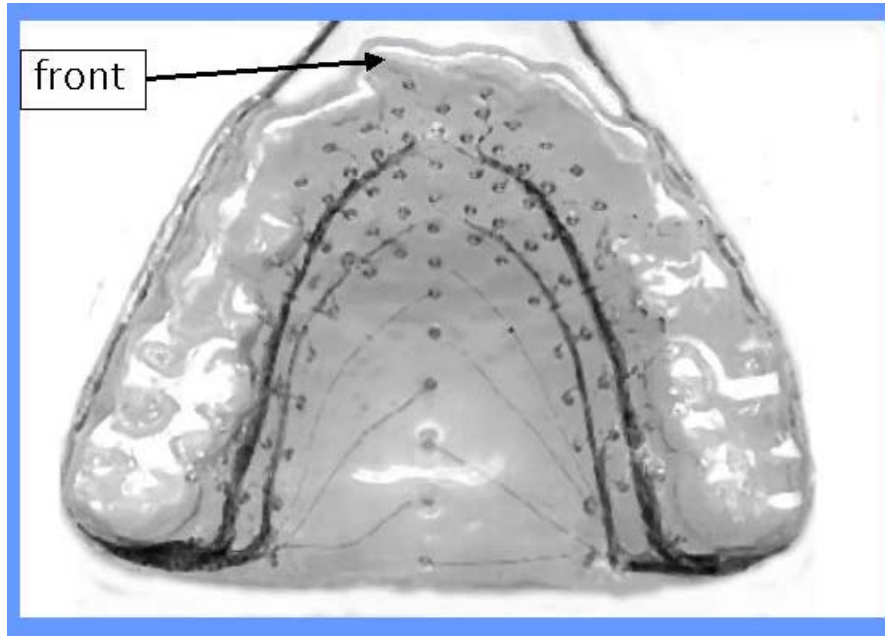


Figure 8. Custom electrode layout on the pseudo-palate for the Kay Elemetrics Palatometer. The 96 gold electrodes are the dots seen on the palate.

Figure 9 is a sample frame of contact, for an /n/; it shows tongue contact all around the edge of the palate, especially the sides of the tongue with the inner surfaces of the teeth. Figure 10 presents a set of such frames, showing the maximum contact for French /n/s taken from the beginnings of five successively smaller prosodic domains, with less contact in the weaker positions. (To hear two of these examples, please go to slide 19 in the [Powerpoint presentation](#).)

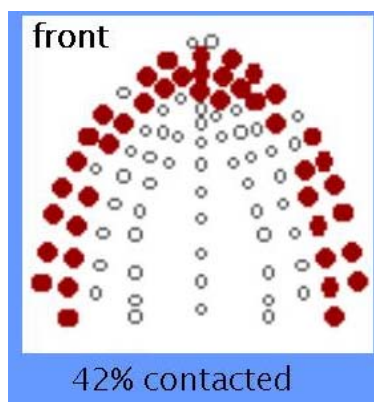


Figure 9. Sample frame of contact, for Korean word-initial /n/. Circles are electrodes, filled ones are contacted.

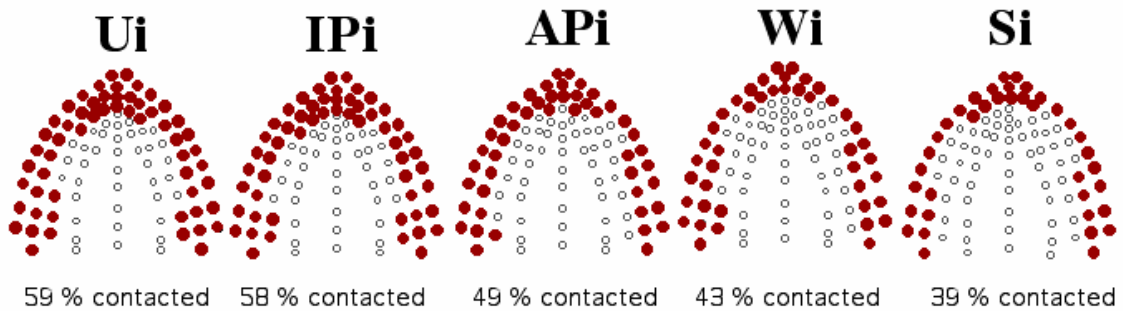


Figure 10. A set of sample data frames of EPG data showing the maximum contact for French /n/ at the beginnings of five successively smaller prosodic domains. After Keating et al. (2003).

Figure 11 (next page) shows, for Korean, what the overall results from such studies can show : in this case (Cho & Keating 2001), four stops of Korean (tense, aspirated, lax, and nasal) in four prosodic positions (Utterance-initial, Intonational Phrase-initial, Accentual Phrase-initial, and Word-initial), with less and less total contact for consonants in weaker positions. In contrast to the overall contact measure shown in Figure 11, Figure 12 gives more detailed measurements of fricative channels (Kim 2001, 2003); these measurements show another aspect of articulatory strengthening – more contact can lead to smaller channels in stronger positions.

All of these studies show that articulation does indeed vary with prosodic position; this leads to a view of speech production planning which I've been thinking about with Stefanie Shattuck-Hufnagel (Keating & Shattuck-Hufnagel, 2002). In this bigger picture, each phonetic segment, with its features, is a terminal node in a big prosodic tree. Each segment has a position in the tree relative to the domains and prominences of the utterance. Crucially, the pronunciation of each feature depends in part on this prosodic position; you don't know how to pronounce a feature until you know where it is in the tree.

To summarize this section of the paper, prosody is a crucial aspect of speech, including phonation and segmental articulation, and much of our work is organized around understanding those connections.

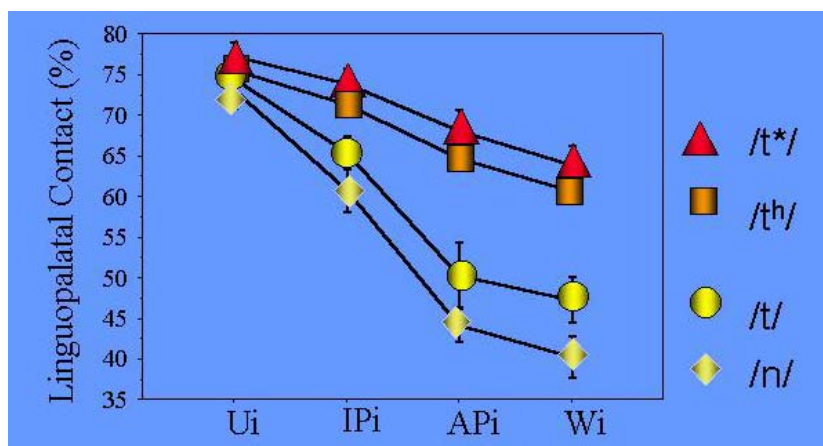


Figure 11. Mean maximum EPG contact for four Korean consonants in four prosodic positions, averaged for three speakers. Prepared by Taehong Cho.

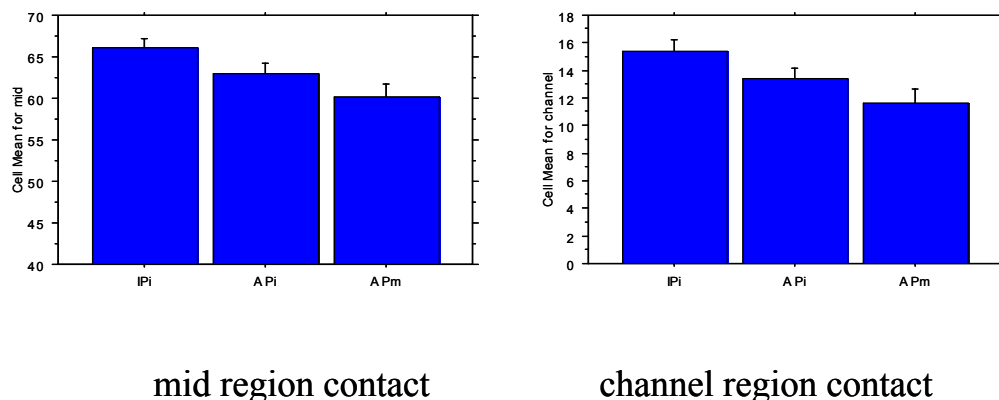


Figure 12. EPG contact in two subregions of the palate for Korean /s/ in three prosodic positions. Prepared by Sahyang Kim.

COARTICULATION

Much of our work in the 1980s on phonetic implementation was concerned with coarticulation, and here are two ways in which it has figured in our more recent work.

Initial strengthening

First, the relation of coarticulation to domain-initial strengthening has been studied by Cho (2002, 2004). Coarticulation refers to interactions between neighboring segments, generally due to articulatory overlap; we can ask how prosodic strengthening affects overlap and thus coarticulation. In particular, does a strong segment resist its neighbors? Cho looked at vowel-to-vowel coarticulation between [i] and [a] across [b] and three different prosodic boundaries, as in the set of configurations shown in Figure 13; each vowel was accented, or not. To study tongue position variation, he used electromagnetic articulography, a technique that the MIT

speech group has done so much to develop (Perkell et al., 1992). At UCLA we use the Carstens Articulograph AG-100, which shares with the MIT system the basic property that receiver coils are glued to articulators, and their positions are tracked within an electromagnetic field set up around the head. In Cho's study the interest was the two coils on the tongue body, T2 and T3 in Figure 14.

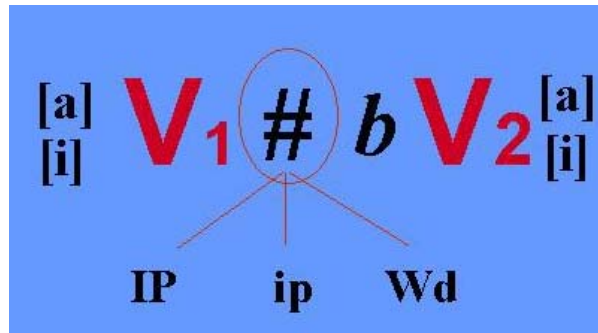


Figure 13. Design of test sequences in Cho (2002), with two test vowels across one of three prosodic boundaries. Prepared by Taehong Cho.

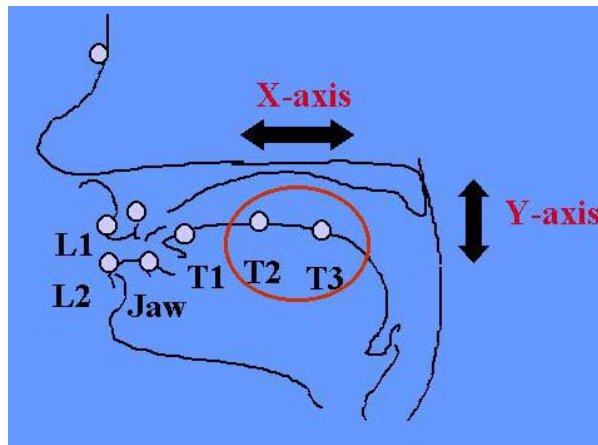


Figure 14. Locations of EMA receiver coils, including the two on the tongue body studied for vowel articulations, in Cho (2002). Prepared by Taehong Cho.

Here we will look at the result for just one case, the effect of V1 [i] on V2 [a]. There is less effect of V1 on V2 across a larger prosodic boundary. Figure 15 shows that [a] is more like [i] when they are separated by only a Word boundary, and it is least like [i] when they are separated by an Intonational Phrase boundary. Thus, resistance to coarticulatory influences is another aspect of domain-initial strengthening; stronger segments do resist contextual segmental influence.

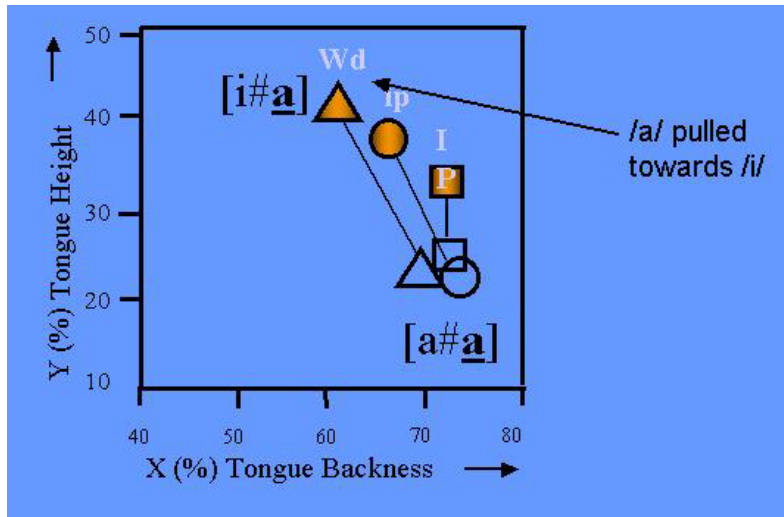


Figure 15. Effect of V1 [i] on V2 [a] as a function of prosodic boundary in Cho (2002). Prepared by Taehong Cho.

Lexicon

Several studies in the lab have been concerned with lexical effects on speech production (Billerey-Mosier 2002, Jones 2002). Rebecca Brown Scarborough has considered lexical effects on coarticulation (Brown 2002; Scarborough 2004). The notion of a lexical neighborhood (Luce, 1986, that is, the other words that are similar to a given word, and compete with it, is an important development in psycholinguistics, and one which affects how a given word is pronounced. Figure 16 is Scarborough's illustration of two different neighborhoods, one sparse and the other dense.

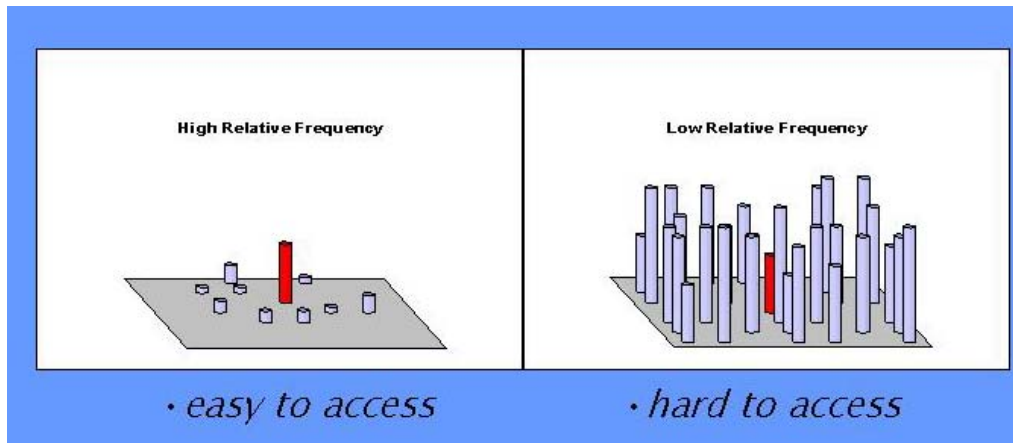


Figure 16. Lexical competitors of a target word (red column) in a sparse neighborhood (left) vs. in a dense neighborhood (right). Bar height indicates frequency of occurrence; absolute frequency of the target word (the red bars) is the same in the two cases. Prepared by Rebecca Scarborough.

The question of interest here is: Are words from dense lexical neighborhoods, with many lexical competitors, produced with more or less coarticulation than other words? Scarborough (2004) has looked at production of two kinds of coarticulation in two directions, but here I present an earlier partial result, for nasal coarticulation in CVN words (Brown 2002). She compared the nasalization of vowels before nasal consonants in words from sparse (“easy”) vs. dense (“hard”) neighborhoods. Some sample words from the corpus are given in Table 1. The acoustic measure of nasalization she used, A1-P0, is one developed in the MIT Speech Group (Chen 1996). The result, shown in Figure 17, was more nasal coarticulation in “hard” words. That is, just as phonetic details are modulated by prosody, so too are they modulated by a word’s lexical status.

Table 1. Sample words in the CVN corpus. Easy words have fewer/less frequent competitors; hard words have more/more frequent competitors, as in Figure 16.

| HARD | EASY |
|------|--------|
| bun | sponge |
| fend | drum |
| gum | blonde |

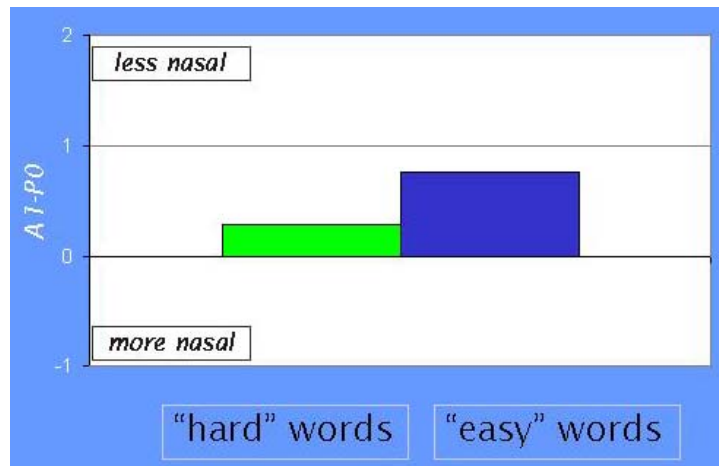


Figure 17. Amount of nasalization in the vowels of hard vs. easy CVN words. Prepared by Rebecca Scarborough.

PRODUCTION AND PERCEPTION

Finally, I will present some of our work on perception as it relates to production.

Optical prosody

Our work on optical phonetics has been part of a project with UCLA Electrical Engineering and the House Ear Institute. One of our questions has been what aspects of production are

important to visual perceivers, including with respect to prosody. Consider the optical signal available for the visual perception of phrasal stress-accent: the extents, durations, and velocities of movements of the lips, chin, head, and eyebrows are all potentially visible. Thus in a production-perception comparison, we can ask which of the optical correlates of stress-accent account for its visual intelligibility, to the extent that it is indeed intelligible.

Our study (Keating et al., 2003 and in preparation) first looked at the *production* of stress-accent by three speakers. Table 2 illustrates the kind of utterance studied, and what is meant by phrasal stress-accent here. Each sentence contained three proper names, one of which could be stressed. The three speakers read these sentences while being videotaped, and while the movements of 20 reflectors attached to the face were tracked. A sample frame of video, showing the locations of the reflectors, is shown in Figure 18; these markers were tracked by infrared cameras. The 11 measurements listed in Figure 18 were made from the indicated subset of the markers. (For more details about the methods in this and related studies in the project, see Jiang et al., 2002.)

Table 2. Sample sentences in the phrasal stress-accent corpus. Underlined words are test words; speakers were instructed to accent words in all-caps.

| |
|--|
| So <u>TOMMY</u> gave <u>Timmy</u> a song from <u>Debby</u> . |
| So <u>Tommy</u> gave <u>TIMMY</u> a song from <u>Debby</u> . |
| So <u>Tommy</u> gave <u>Timmy</u> a song from <u>DEBBY</u> . |
| So <u>Tommy</u> gave <u>Timmy</u> a song from <u>Debby</u> . |

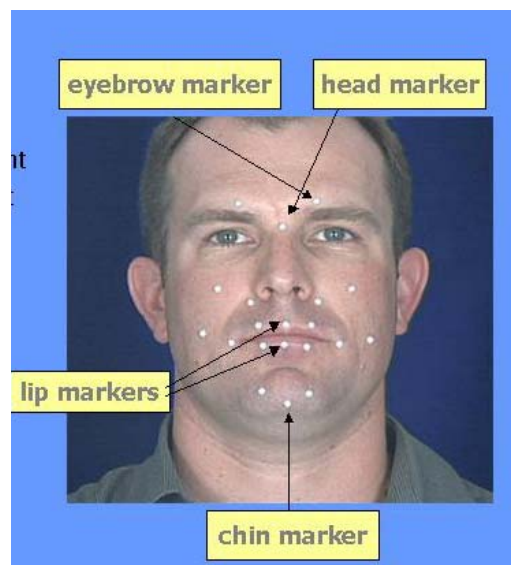


Figure 18. Sample video frame showing facepoint marker locations.

Table 3. Measurements taken from facial markers.

| |
|---------------------------------|
| Left eyebrow displacement |
| Head displacement |
| Interlip maximum distance |
| Interlip opening displacement |
| Interlip closing displacement |
| Lower lip opening peak velocity |
| Lower lip closing peak velocity |
| Chin opening displacement |
| Chin opening peak velocity |
| Chin closing displacement |
| Chin closing peak velocity |

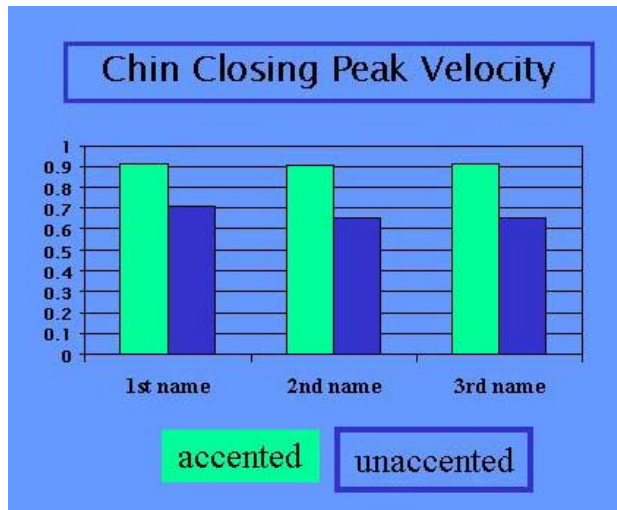


Figure 19. Sample correlate of phrasal stress: chin closing peak velocity for stress-accented vs unaccented syllables in three positions in test sentences.

This production study showed that all 11 measures varied depending on the phrasal stress-accent. For example, Figure 19 shows the differences in maximum closing velocity of the chin marker, for accented vs. unaccented vowels in names in all three positions: the chin rises more quickly in a stress-accented vowel. The chin and eyebrow measures were affected by stress-accent most consistently across speakers.

We then looked at the *perception* of these phrasal stress-accents. We took videos of sentences from the production study, and played them, without sound, to perceivers. They saw, along with

the video clip, a written sentence, and their task was to indicate which name in the sentence, if any, had received a stress. Figure 20 shows the results. All three speakers were intelligible above chance, and all 16 perceivers performed above chance. But crucially, performance was far from perfect, which allows us to examine what aspects of the signal, of the 11 potentially available cues that we have identified, the perceivers seem to be using.

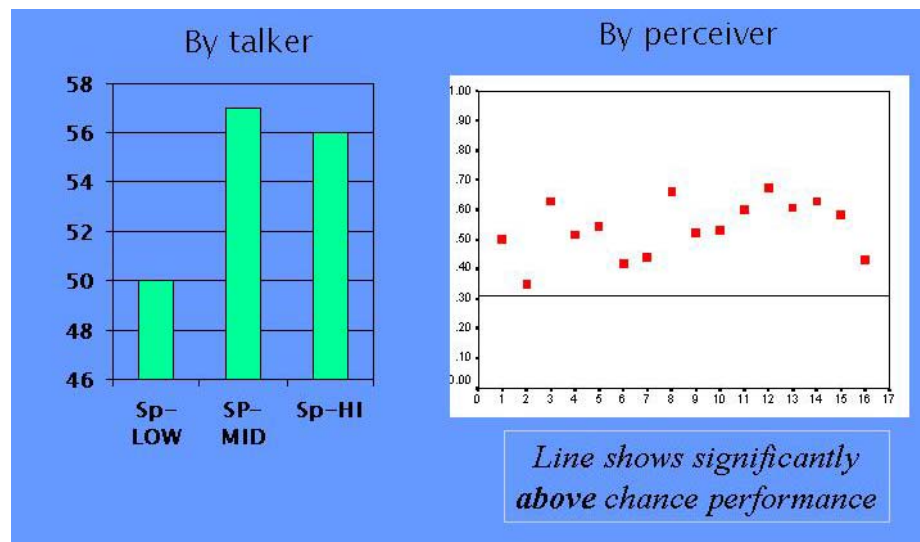


Figure 20. Percent correct visual perception of phrasal stress, by talker (3) and by perceiver (16). Chance is 50 percent.

Correlation analysis, and partial correlations, show that the chin opening measures (chin opening displacement and peak velocity) are most related to visual perception performance. These production measures account for the most variance in perception. Other measures, such as chin closing measures, lip measures, head movements, or eyebrow movements, are not as well correlated, even though we know that some of them vary as much in production. This kind of study tells us which aspects of the optical speech signal seem to be most informative to perceivers, and this kind of information could be useful for face synthesis applications.

Heritage language ability

Finally, a rather different topic concerns the relation of production and perception abilities within individuals, from work by Sun-Ah Jun and Terry Au with students, e.g. Oh et al. (2003). A common linguistic background in cities like Los Angeles is that of children who give up their heritage language in favor of English. Their project included a study of adults learning Korean in college classes; they compared four groups of adults: a control group of lifelong native speakers, a group who spoke only in early childhood no later than age 7, a group who overheard but did not speak, and a control group with no childhood exposure to the language. Here I give their results on these adults' production of VOT in Korean denti-alveolar stops. As seen in Figure 21, the childhood-only speakers were essentially like the native speakers, while the childhood overhearers were essentially like the no-Korean group. The same result held of overall foreign accent ratings for the speakers. That is, if you spoke Korean for even a while as

a child, you will have good pronunciation as an adult, but if you did not speak it as a child, merely having overheard it is no immediate help in your later pronunciation.

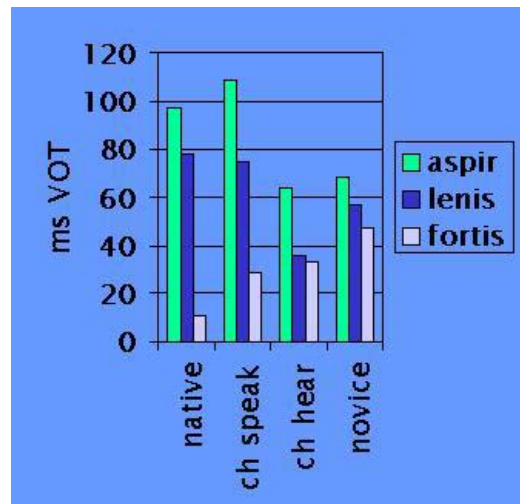


Figure 21. Mean production of VOT for Korean denti-alveolar stops, by lifelong native speakers, childhood-only speakers, overhearers, and never-exposed speakers.

However, looking at adult *perception* of Korean VOT, as seen in Figure 22 (next page), again the childhood-only speakers were as good as native speakers, but the childhood overhearers were also as good as native speakers. That is, even just overhearing from childhood is enough to give a later perceptual advantage, without any speaking experience. Furthermore, in a parallel Spanish study that also looked at later performance in a language classroom (Knightly et al., 2003), they found that childhood overhearing without speaking does give an advantage in later learning of pronunciation. In the long run, the project should help us to understand what advantages may remain in later life from early exposure to a heritage language.

CONCLUSION

In this paper I have tried to give a taste of what some linguistic phoneticians in the UCLA Phonetics Lab are interested in today. We invite you to visit [our lab's website](#), which has information about other projects as well. We believe that a linguistic phonetics program, especially one with outstanding colleagues in phonology, as at UCLA, is a great place to be interested in speech.

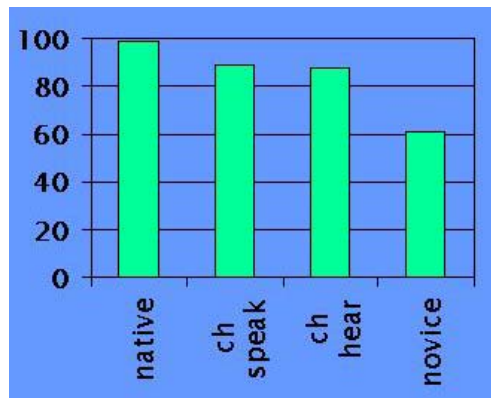


Figure 22. Percent correct perception of VOT for Korean stops, by same four groups of speakers as in Figure 21.

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