The Phonetics-Phonology Interface: Comments on Clements & Osu, Solé, Frota, and Chitoran et al.

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Research in how phonology relates to phonetics has followed diverse lines, and the papers in this section illustrate three of the different paths that have been taken. The contributions of Solé and of Chitoran and her colleagues follow a classic route, showing how many phonological phenomena can be better understood by attributing them to phonetic causes, and studying those causes with sophisticated methods and equipment. Frota follows a research tradition associated with Pierrehumbert and her colleagues: the pitch movements of an intonational system – varying, gradient, and often hard to come to grips with – can be brought into an orderly pattern by tying them to an intonational phonology, which provides the structural basis on which the raw pitch data can be understood, as well as relating the pitch contours to other structural entities like syllables, stress, and boundaries. Broadly, we can see Solé and Chitoran et al.'s papers as attempts to use phonetics to illuminate phonology, and Frota's paper as an attempt to use phonology to illuminate phonetics.

Clements and Osu's paper follows a long-standing phonological tradition from Jakobson and Trubetzkoy through Chomsky and Halle and much of Clements's own earlier work. The guiding idea, as I interpret it, is that it is possible for the theorist to examine the chaotically diverse world of phonetic phenomena and extract from it a fairly small set of truly essential phonetic features; the ones that play a role in phonological structure. Clements and Osu show, I think, the right way to pursue this program: with full attention to phonetic detail, and careful consideration of rival hypotheses.

As the papers are all clear and defend their positions well, I have little to add to what they have to say. However, Chitoran, Gold-

stein and Byrd's paper (hereafter CGB) on Georgian harmonic clusters raises a couple of questions that are worth pursuing further.

To review: a harmonic cluster in Georgian can be defined as one that requires agreement in laryngeal features. The phonological question at hand is to explain, on a phonetic basis, why only certain clusters in Georgian are harmonic. CGB's explanation ultimately hinges on patterns of articulatory overlap and the distribution of acoustic cues that are found in various overlap configurations.

To start, I will compare CGB's paper with Chitoran's earlier treatment (1998) of the harmonic clusters. Chitoran sought to use acoustic measurements to determine whether these clusters are actually "complex segments"; i.e. single segments with two simultaneous places of articulation. Her evidence suggested a negative answer; in particular, she observed salient **release bursts** in the middle of these clusters. Chitoran interpreted these bursts as evidence for fully-nonoverlapped articulation: "simultaneity of closure ... can be eliminated from the list of properties characterizing harmonic clusters" (p. 140).[1]

Electromagnetic articulography, however, appears to indicate otherwise: in the experiments for CGB, the authors found that the harmonic clusters do indeed have extensive articulatory overlap. What, then, are we to make of the medial release bursts?[2]

CGB have a nice answer for this: they note that it is possible to release a stop and produce a burst even while another stop is being articulated. All that is necessary is that the released stop have a fronter place of articulation than the "covering" stop (otherwise, the acoustic consequences of the release would be confined within a closed vocal tract).

Applying this idea to the harmonic clusters, the prediction is that they should occur only in front-to-back sequences, and this turns out to be true. Thus, CGB's idea not only solves a phonetic mystery, but it also provides a phonetic explanation for phonological patterning. Here is the explanation laid out all in one place:

- Languages favor overlapped consonant sequences, for reasons of speed and efficiency (CGB, sections 1 and 5.1).

- However, overlap is avoided when cues for consonant place would be obscured (CGB 1).
- A major cue for place of articulation occurs at consonant release (CGB 2.1).
- Release is totally inaudible when a consonant is overlapped by a fronter closure, but is moderately audible when it is overlapped by a backer closure (CGB 2.2).
- Georgian accordingly assigns a greater degree of overlap to front-to-back clusters, where doing so does not radically damage perceptibility of place (CGB 2.2).
- Heterogeneous laryngeal specifications can be executed more easily if sufficient time is available to them; i.e. in non-overlapped clusters (CGB 5.3).
- Thus, Georgian requires front-to-back clusters, which are heavily overlapped, to be harmonic (CGB 5.3).

This elegant account shows that phonetic explanation in phonology can involve quite nontrivial chains of reasoning. I think it is likely to be correct in its outlines. However, two important mysteries remain.

First, while it is true that all heavily overlapped clusters in Georgian are front-to-back, it is *not* true that all front-to-back clusters are heavily overlapped. As CGB's experiment showed (see Tables III and IV), **labial-coronal** sequences receive *non*-overlapped articulation. Moreover, this anomaly is reflected at the phonological level: the harmonic clusters of Georgian do not include labial-coronal sequences (CGB, section 3.1).

Another mystery involves differences in **intensity** between the bursts produced under various situations of articulatory overlap. Chitoran's (1998) acoustic study includes a spectrographic comparison between the true harmonic cluster of [**dg**oma] 'standing' (her Fig. 3) and the "accidental" /d#g/ cluster that arises from word concatenation in [sa**d g**ip'ovo] 'where do I find you?' (Fig. 6). In [dgoma], the burst of [d] is quite robust; whereas in [sad gip'ovo], the burst is (as Chitoran puts it) "quite weak, not clearly visible on the spectrogram." This is despite the fact that /dg/ is a front-to-back cluster; i.e. the /d/ burst is not obscured by the /g/ closure.

Puzzled by this difference, I checked spectrographically for bursts in several tokens of front-to-back clusters in my own (American English) speech, making sure I pronounced them with articulatory overlap. I found that the bursts I produced for the fronter consonant were like those in Georgian [sad gip'ovo]: acoustically present, but very weak. Henderson & Repp (1982) studied overlap bursts in a systematic experiment, and most of the bursts they found were also weak – so weak that experimental subjects did hardly better than chance in trying to detect them.

In contrast, the burst found in Georgian harmonic clusters (as distinguished from "accidental" clusters like [sa**d** **g**ip'ovo]), is apparently rather strong, indeed, it is strong enough to serve as the principal cue for a phonological contrast (/dg/ vs. /g/). I conjecture, then, that there must something about harmonic clusters per se, going beyond a simple consonant release, that gives special prominence to the C1 burst.

A clue for what this might be is given in CGB, section 2.2. Discussing the idea of a release generated in overlap conditions, the authors note: "if ... the second consonant has a place of articulation more posterior than that of the first, then at least some acoustic information will be generated on release of C1 (even if it does not generate the substantial release burst associated with venting a high-pressure chamber to the atmosphere)." The lack of high pressure in the chamber formed between two simultaneous articulations explains why the bursts in [sa**d** **g**ip'ovo], and in English, are so weak. But we also need an explanation for why the bursts in harmonic clusters are so strong.

I conjecture, then, that harmonic clusters actually *do* involve "venting a high-pressure chamber to the atmosphere." My guess is that Georgian achieves this with an **egressive velaric** airstream mechanism; i.e. the opposite of what happens in clicks.[3] A slight pressure buildup is effected between the front (labial/coronal) and back (dorsal) closures, probably through forward and upward motion of the tongue dorsum, and the release of this pressure gives rise to a more robust burst at the front closure than would otherwise occur. The egressive velaric mechanism permits a strong burst for both members of a cluster, even under conditions of heavy overlap.

At the level of phonetic introspection, I find it rather easy to produce strong bursts for [d] and [b] in syllables like [dga] or [bga] by using an egressive velaric airstream mechanism. Of course, it is an empirical question whether Georgian speakers do the same thing in speaking their language.

If correct, my hypothesis would explain the other mystery noted above, namely the absence of labial-coronal harmonic clusters. Specifically, the *ingressive* velaric airstream mechanism, as used in click languages, is known to be limited to labial-dorsal and coronal-dorsal combinations (cf. CGB 5.1), and does not occur for labial-coronal sequences (indeed, this is why the mechanism is called "velaric," and why phonetic taxonomies do not include an "alveolic" airstream mechanism). All else being equal, we would expect the counterpart egressive mechanism to be limited to dorsal combinations. Introspectively, I find that it is far easier to produce acoustically robust egressive releases in coronal-dorsal and labial-dorsal combinations than in the labial-coronal combination. Lastly, since it is impossible to produce a velaric egressive consonant without front-to-back order and heavy articulatory overlap, all of CGB's reasoning about overlap and its phonological consequences would carry over under this theory.

My conjecture could be tested by making oral pressure measurements. If the anticipated inter-closure pressure build-up does not occur, then some other explanation for the robust bursts of Georgian harmonic clusters, and for why labial-coronal clusters are not harmonic, will have to be found.

Notes

1 Chitoran was not alone in holding this opinion. Robins & Waterson (1952) transcribed the harmonic cluster in *dgoma* 'stand' with a superscript schwa ([d^{ə}goma]), indicating that they perceived a fully non-overlapped pronunciation.

2 A crucial assumption here, which seems plausible but for which I have no data, is that the consultants for the two experiments did not differ in how they pronounced the harmonic clusters. In other words, a single speaker measured both articulatorily and acoustically would be shown to produce release bursts under conditions of heavy overlap.

3 According to Catford (1977), there are four airstream mechanisms found in ordinary languages: egressive pulmonic, egressive glottalic, ingressive glottalic, and ingressive velaric. He notes the existence of bilabial egressive velaric stops used (a) as gestural sounds by French speakers; (b) in Damin, the ritual language of the Lardil (Australia). If I am correct about Georgian it would count as the first observed instance of egressive velaric sounds in ordinary language.

References

Catford, J. C.
1977 *Fundamental Problems in Phonetics*. Edinburgh: Edinburgh University Press.

Chitoran, I.
1998 Georgian harmonic clusters: phonetic cues to phonological representation. *Phonology*, **15**, 121–41.

Henderson, J. B. & Repp, B. H.
1982 Is a stop consonant released when followed by another stop consonant? *Phonetica*, **39**, 71–82.

Robins, R. H. & Waterson, N.
1952 Notes on the phonetics of the Georgian word. *Bulletin of the School of Oriental and African Studies*, **14**, 54–72.