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Articulatory phonology and Sukuma “aspirated nasals”*

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1. Articulatory phonology

A common way of viewing the phonological component of a grammar is to regard it as producing, through a set of operations or derivations, a final representation that consists of a set of categorial elements (such as features) and a network of relationships between them. This representation serves as the input to rules of phonetic implementation that express a mapping between the categorial elements and the realm of phonetic properties that are gradient rather than categorial in their nature. Rules of ‘phonetic implementation’ deal with these gradient phenomena, in particular with all details of timing. In a series of papers in the last several years, Browman and Goldstein (1986, 1989, 1991) have put forward a challenge to this view. Stated very tersely, they propose that the basic elements of phonology are articulatory gestures and their relative timing with respect to each other. The gestures are abstractions but they are individually specified in ways that contain information about their magnitude and duration, and their relative timing is explicit. In this way, much that is more usually treated as part of the domain of phonetic implementation is incorporated into the phonology. Browman and Goldstein suggest that the standard view makes the wrong distinction between categorial and gradient processes; many apparently categorial processes in phonology are the result of processes that are actually gradient. We will illustrate this point briefly with an example based on one used by Browman and Goldstein (1989).

Figure 1 (a) shows the movement trajectory over time of a sensor attached to the lower lip during an utterance of the nonsense word /abə/. In this particular utterance the lower lip reached closure against the upper lip at the moment shown by the intersection of the trajectory with the horizontal line labeled ‘closure’ (upward movement continues beyond this point because the lips compress). The acoustic duration of the closure for /b/ is the interval that the trajectory remains above the line where closure occurs. Now, the time course and shape of the lip movement trajectory can remain identical to that observed in Figure 1 (a) but have a lesser magnitude, as in 1 (b), resulting in a considerably shorter closure duration. If the magnitude of the lip movement is again reduced, as shown in 1 (c), then closure will not be achieved and the sound produced will be a bilabial fricative or approximant. Although the differences between 1 (a) and 1 (b) and between 1 (b) and 1 (c) both involve similar changes in the magnitude of a movement, because of the acoustic consequences it would be customary to regard the difference between (a) and (b) (shortening of closure duration) as a matter of phonetic variability, but to regard the difference between (b) and (c) (variation between /b/ and /β/) as a phonological process involving a change of features. However, from the articulatory point of view, shortening a closure and fricating it result from steps along the same continuum, a phonological continuum of lenition.

In this example, the timing of the articulatory gestures themselves doesn’t undergo any change from 1 (a) to 1 (c), although there are consequences for the acoustic durations. In fact, Browman & Goldstein argue that acoustic durations can often give a misleading impression of the articulatory organization of an utterance (see especially Browman & Goldstein 1991).

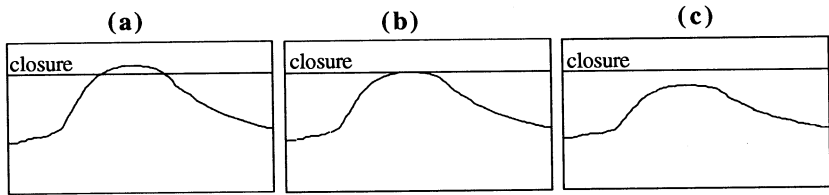


Figure 1. Trajectory of lower lip movement over time: (a) as measured in [abə], and (b), (c) modified in amplitude of the labial closing movement.

An actual articulatory trajectory such as that shown in 1 (a) is the result of the combined action of several underlying controlling gestures that are active over specified time intervals and are coordinated in time with each other in a particular way. Browman and Goldstein suggest a 'box' notation to represent the activation intervals and the relative phasing of these underlying gestures. A simplified representation of the English word 'palm' in this notation is shown in Figure 2. The activation intervals of gestures in four major 'control channels' are shown by the small boxes. (The generation of articulator movement trajectories from these abstract gestures will not be discussed here). The word includes labial closure gestures at the beginning and end, with the final one coinciding with velic opening. Between these two gestures the tongue body forms a low back constriction. Note that the default position of the glottis is assumed to be that for voicing; an active gesture is required to devoice. This devoicing gesture extends throughout the initial labial gesture and into the beginning of the tongue body gesture for the vowel. The aspiration of the initial consonant is thus modeled not as an attribute of the stop or the vowel, but as resulting from the particular timing of the gestures in the phonological representation. In what follows, we will use the insights provided by Browman and Goldstein's articulatory perspective to examine an important phonological feature of the Bantu language Sukuma.

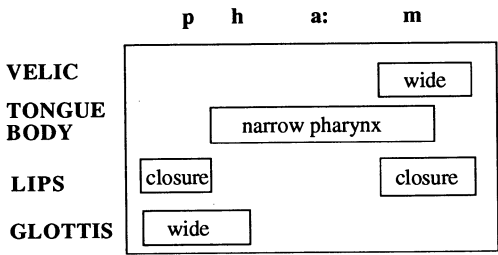


Figure 2. Articulatory notation for the major phonological components in "palm".

2. Sukuma aspirated nasals

Sukuma is among those Eastern Bantu languages in which original voiceless prenasalised stops (including those resulting from the class 9/10 nasal prefix) have become what are here called

“aspirated nasals” (Kerremans 1980). We will describe the phonetic nature of these “aspirated nasals” and compare them with the more recently derived voiceless prenasalized segments which occur in Sukuma. These result from syncope of class 1 and 3 prefixes and other cases of syncope. The objectives are to better understand the diachronic process by which these sounds originated and to provide insights into their appropriate phonological description.

The sounds in question will be written using a digraph of a nasal symbol and ‘h’. There are stops and nasals at four places of articulation in Sukuma, namely, bilabial, alveolar, palatal and velar, and correspondingly there are four aspirated nasals. The great majority of occurrences of the aspirated nasals derive from earlier voiceless prenasalized stops. Some of these were stem-internal, as in the stems of nouns like /muunhɔ/ “person”, /ndunhɔ/ “ladle” and /giighi/ “owl”, or the stems of verbs like /kubɔɔmha/ “to freeze”, /kuiinha/ “to give” /konuunha/ “to feel”, and /konuughɔ/ “to smell”. A very large number of the original voiceless prenasalized stops arise from prefixation of the class 9/10 marker, a nasal, to noun stems that had original voiceless initial stops. Examples are /mhala/ “gazelle”, /nhaawa/ “spotted hyena”, /ɲhɔɔji/ “detective” and /ɲhɔɔɔ/ “sheep”. Thus, /mhala/ derives from class 9 prefix /N/ + stem /*-pala/ and so on. The place of the nasal is determined by the historic underlying stop, in the way that place usually is in the case of nasals before stops.

For a proportion of these nouns in class 9 or 10, a range of different prefixes with CV-structure may occur and in this case the original consonant can still be recovered. For example, diminutives with /ka-/ (singular, class 12) and /w-/ (class 13, plural) and augmentatives with /li-/ (singular, class 5) and /ma-/ (class 6, plural) can be formed with some nouns. So, in addition to /mhala/ “gazelle”, we also find /kapala/ “little gazelle”, /wɔpala/ “little gazelles”, /lipala/ “big gazelle”, and /mapala/ “big gazelles” with the historic stem-initial consonant. In addition, there are a number of forms with a singular in class 11 (/lɔ-/) which form their plural in class 10. Examples include /lukoba/ “thunder” with plural /ɲhɔba/ and /lɔkumɔ/ “reputation” with plural /ɲhɔba/. Adjectival forms and other nominal modifiers that take a concordial prefix determined by the class of the noun also show this alternation between aspirated nasals in class 9 or 10 and a voiceless stop when other prefixes occur; for example, compare the class 9/10 adjectival forms in /mhala mhaagga/ “living gazelle” and /mhala nhaale/ “small gazelle” with the class 1 forms /muunha mpaagga/ “living girl” and /muunha ntaale/ “small girl”.

The final source of aspirated nasals are verbal derivatives and other roots in class 1 or class 3 with stem-initial /-h/. The underlying shape of the prefix for these classes can be taken as /mu-/, but this surfaces in relatively few forms. If the stem begins with a stop, the vowel in the prefix is usually syncopated, and the nasal assimilates to the place of articulation of the stop which remains a stop. The class 1 adjectival cases cited above illustrate this process with adjectival stems beginning with /-p-/ and /-t-/. Both voiced and voiceless prenasalized stops are derived in this way. Some examples among class 1 nouns are /ntɛmi/ “chief” (plural /batɛmi/), /ɲkɛ/ “wife” (plural /bakɛ/), and /ɲgɔɔsa/ “man” (plural /bagɔɔsa/), and among class 3 nouns /mpini/ “hip” (plural /mipini/), /nti/ “tree” (plural /miti/), /ndunhɔ/ “wooden spoon” (plural /midunhɔ/), and /ɲgɔɔɲgɔ/ “back” (plural /migɔɔɲgɔ/). However, when the initial consonant of the stem is /-h/ the same syncope takes place, creating a bilabial aspirated nasal, as in /mhayɔ/ “word” (pl. /mihayɔ/), formed from the verb stem /-hay-/ “speak,” infinitive /kohaya/.

Now that we have described the occurrence of aspirated nasals, we may inquire more closely into what kind of sounds they are. Batibo (1967 [1986]), a speaker of the northern (kemunasukuma) dialect, classifies them as voiceless nasals, but notes that they are pronounced with accompanying "strong," "very strong" or "very noticeable" aspiration. In his pioneering work on Sukuma tone, Richardson (1959) transcribed the corresponding sounds, as pronounced in the eastern, kemunakeeya, dialect as voiceless nasals followed by [h], i.e. [ɲh] etc. Since 'aspiration' is a rather ambiguous term, and since voiceless nasals more commonly arise from perseveration of voicelessness from a preceding voiceless segment rather than from anticipation of a following voiceless consonant, analysis of the phonetic nature of these consonants can provide significant new information of general phonetic interest, as well as serving as a basis for a phonological interpretation.

3. Phonetic investigation

Audio recordings were made of wordlists containing aspirated nasals and prenasalized stops and fricatives spoken by a native speaker of Sukuma. The speaker was Herman Batibo, who very graciously consented to take part in this experiment while he was a visiting scholar at UCLA. He also generously compiled the wordlist used. For a subset of this wordlist, simultaneous records of nasal air-flow, oral air-flow and intra-oral air pressure were also obtained. In the experimental setup used, the air flowing from the mouth is collected in a shaped mask which fits quite closely around the mouth. A thin tube inside the mask is passed between the lips so that the air pressure inside the mouth can be sensed. Another tube with a wide termination is fitted inside one nostril to record when air is passing through the nasal airway. A microphone inside the mask also records a (degraded) audio signal. These four channels are digitized directly onto a computer; the audio signal at 11 kHz, and the three channels of aerodynamic data at 480 Hz. This setup is described more fully in Ladefoged (1990).

The resulting traces look like that in Figure 3, which shows a record of the word /mpanga/. The top trace is the radiated pressure wave (the audio signal recorded within the oral mask). The enclosed space of the mask distorts the sound, making this audio signal unsatisfactory for acoustic analysis. However, the audio signal is helpful in segmenting the sound and in determining such matters as the onset and offset of phonation. Acoustic analysis is made from other recordings. The second trace is the oral flow. Since the lips are closed at the beginning of this word, there is no oral airflow. Flow starts at the release of the labial closure, at about the 150 ms time-point in the signal, and very rapidly reaches its maximum. There is considerable flow for a period of about 50 ms before the first clear signs of vocal cord vibration are apparent in the flow record, in the form of fluctuations around the baseline of the trace. That is, there is a period of voiceless aspiration after the release. Study of other tokens of the same type indicates that there is always a period of strong aspiration, but that vocal cord vibration may start soon after the oral release. In these cases the period of aspiration can be described as breathy voiced.

The third trace shows intraoral pressure at a point behind the lips. The lips are closed at the onset of this word and the pressure transducer records the pressure fluctuations in the oral cavity due to the vibration of the vocal cords during the nasal. Note that baseline pressure increases during the nasal and reaches a plateau during the hold of the voiceless stop. Naturally, when the oral occlusion is released there is a rapid drop in the pressure in the intraoral cavity. Since the remainder of this word is produced with the lips open, there is little further pressure variation that is sensed at the location being monitored in this experiment. The final trace is the nasal flow

channel. Since this is monitored by a tube in one nostril only, there is more impedance to flow through that nostril than through the other one. For this reason, this signal appears more sensitive to the pressure fluctuations resulting from voicing than to net airflow volume. It serves very well to monitor the coupling of the nasal passage to the oral tract, since these pressure fluctuations are isolated from the air in the nasal passage when the velum is raised and the velopharyngeal port consequently is closed. We can thus detect when the nasal passage is closed and the fully oral stop /p/ begins. In this token this is shortly before vocal cord vibration ceases, as pressure fluctuations can still be seen in the intraoral pressure trace after the nasal airflow trace has become flat.

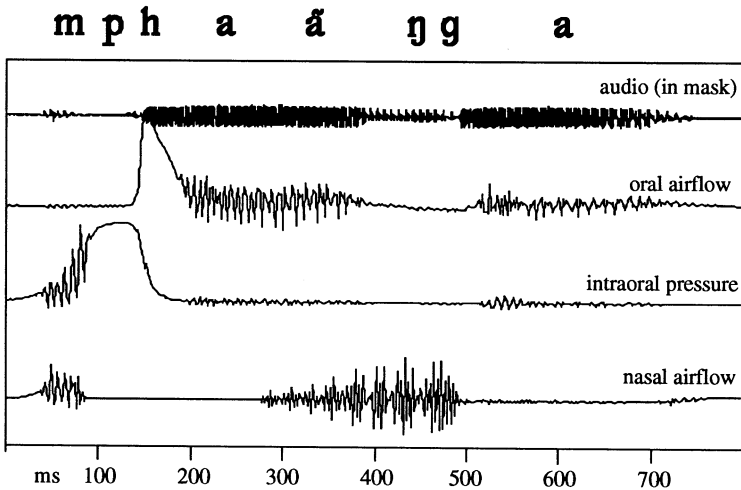


Figure 3. Aerodynamic record of an utterance of the word /mpaŋga/ "living (cl.3)".

Note that there is a second prenasalized stop in this word and that nasal coupling is initiated well in advance of the nasal component of this stop. The onset of nasalization occurs before the 300 ms time-point, about midway through the vowel, whereas the onset of the oral closure for the nasal, detectable by the cessation of oral flow and the reduction of amplitude in the audio signal, occurs at about the 400 ms point. The oral closure for this voiced prenasalized stop is about 125 ms long, but, as can be judged from the interval between the offset of nasal flow and the onset of oral flow for the following vowel, only a very brief portion is an oral stop. A phonetic transcription of the word, marking aspiration and vowel nasalization, is aligned approximately with the appropriate portions of the signal.

Now let us look at a word with an aspirated nasal in initial position. A record of the word /mhala/ "gazelle" is shown in Figure 4. The record shows that an aspirated nasal consists of an initial plain nasal portion with modal phonation, up to about the 130 ms time-point. This is followed by an interval during which both intraoral pressure and nasal flow rise, indicating for this interval both continued oral closure and nasal coupling. Since the vocal cords continue to vibrate

during this period, it seems unlikely that this pattern is achieved simply by opening the glottis wider. It seems probable that the production of this sequence also involves an increase in subglottal pressure. However, to simplify matters we will describe the situation as if just a glottal adjustment was involved. When the oral closure at the lips is released, shortly before the 200 ms time-point, a period of high oral air-flow follows which overlaps with the onset of the following vowel; that is, there is aspiration. Note the similarity in the relationship between the oral flow and the intraoral pressure to that observed with the voiceless prenasalized stop in Figure 3, once allowance is made for the fact of continuing coupling to the nasal passage.

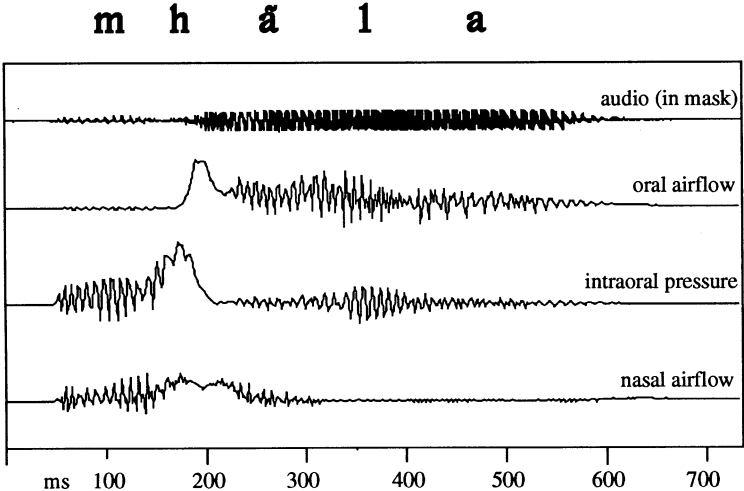


Figure 4. Aerodynamic record of an utterance of the word /mha1a/ "gazelle".

Note that nasal flow continues through much of the following vowel, but ceases (just after the 300 ms timepoint) before the following oral consonant is initiated (at about 350 ms). From examination of other tokens we can generalize that a vowel after an aspirated nasal is partly or weakly nasalized if an oral consonant follows and quite strongly nasalized throughout if another nasal consonant follows. The same pattern holds for the spread of nasalization from plain nasals, as may be seen in the word /namhala/ "with a gazelle" in Figure 5. Here we see nasal coupling from the onset of the word right through to the middle of the vowel before the /l/, where it dies out. In this token, the magnitude of the increase in oral airflow at the release of oral closure for the non-initial aspirated nasal is considerably less than that seen in the initial position in Figure 4. The post-release aspiration portion has relatively strong nasal airflow, and the audio signal indicates that this portion is relatively noisy. From examination of all traces in this figure, the aspiration portion appears to be almost completely voiceless.

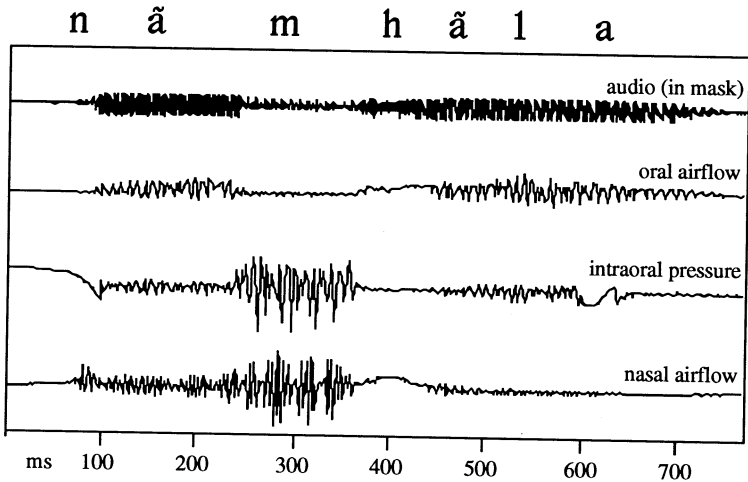


Figure 5. Aerodynamic record of an utterance of the word /*namhala*/ "gazelle (+ comitative prefix)".

Variation in amount of voicing in aspirated nasals is typical. Figure 6 shows waveforms of two tokens of the word /*mhala*/ recorded with no facemask. The first is the more frequent type, with vocal cord vibration throughout the aspiration portion and significant acoustical noisiness superimposed on the voicing for a short time. In the second, vocal cord vibration ceases at about the time of oral release, and the aspiration portion is entirely voiceless. In this case the voiced portion of the following vowel is truncated, resulting in almost identical durations of the interval from oral release for [m] to the onset of oral constriction for /l/ in the two tokens. When the values of glottal opening, pulmonic pressure and other variables fall within particular ranges, voicing will cease, but devoicing does not appear to be a planned part of the articulation of aspirated nasals.

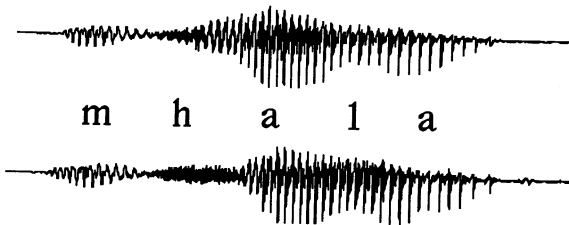


Figure 6. Waveforms of two utterances of /*mhala*/ "gazelle".

4. Discussion

Our phonetic observations indicate that the use of the term “aspirated nasal” to describe the type of sounds involved in Sukuma appropriately captures a similarity between these sounds and the derived prenasalized voiceless aspirated stops in Sukuma as well to other aspirated sounds in other languages. However, contrary to earlier descriptions, the nasal portion of aspirated nasals is not voiceless. In fact the aspiration portion is itself usually voiced, and the voiced nasal portion is usually two to three times longer than it is in the prenasalized voiceless aspirated stops. That means that when comparing, say, /mp/ and /mh/, the duration of the total oral closure is similar. Moreover the glottal gesture involved in producing the accompanying aspiration in both these sounds is timed in a similar way in relation to the release of the oral closure.

These phonetic characteristics also suggest that the diachronic development of aspirated nasals did not involve any stage in which the nasal portion became devoiced, as has sometimes been proposed (Kerremans 1980, Hinnebusch & Huffman, ms). If it is assumed that the original voiceless prenasalized stops from which they derive were aspirated, the diachronic process can be well characterized in gestural terms. It can be modeled as the extension of active duration of the velic opening gesture while the relative timing of the oral gesture and glottal spreading gesture remain undisturbed. Vocal cord vibration now typically persists during the entire complex, since impedance to transglottal airflow is low due to the escape of air through the nasal passage. We assume that cessation of voicing in /mp/ results passively because transglottal airflow cannot be sustained while both oral and nasal escape of air is prevented.

Using a notation like that in Figure 1, the initial CV of a word like /mpanga/ would be represented as in Figure 7 (a), while the initial CV of /mhala/ would be represented as in 7 (b). All components in the two representations are the same, apart from the longer activation interval for the velic gesture in 7 (b). The diachronic change of */mpala/ to /mhala/ involves simply this timing rearrangement among elements already present.

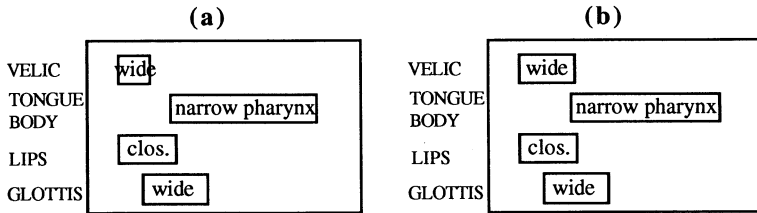


Figure 7. Articulatory notation for (a) the initial CV /mpa./ as in /mpanga/ or */mpala/ and (b) the initial CV /mha./ as in /mhala/.

The synchronic derivation of /mhala/ from /-pala/ and a nasal ‘prefix’ is simply the addition of the velic gesture, timed as in 7 (b), to a structure which is identical to 7 (b) except for the absence of that gesture (cf. “palm” in Figure 2). A more conventional phonological description would perhaps posit a floating nasal prefix, which docks to a root node specified for the place, manner and laryngeal features characterizing an initial stop. This operation would change the stop to a nasal (assuming stops and nasals share manner features) and provide for the place of the nasal,

as sketched in Figure 8. However, note that this account requires several additional statements of 'phonetic implementation' before it would fully characterize the aspirated nasals. Modal voicing must be assigned to the onset of the nasal portion and the realization of the laryngeal feature [spread glottis] extended to the onset of the following vowel. In the articulatory phonology model, these properties are built into the phonological representation itself.

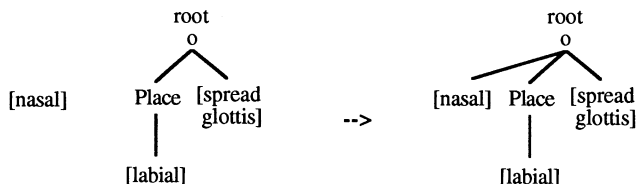


Figure 8. Sketch of a 'nasal docking' account of the derivation of aspirated nasals.

By focussing attention on the productive control of speech, an articulatory phonology perspective can draw our attention to regularities that might escape notice in other paradigms (cf Steriade 1991). It still draws a distinction between phonological and phonetic processes: in the Sukuma examples discussed, the extent of devoicing and the extent that nasality spreads from nasal consonants into adjoining vowels are not phonologically significant. But recognizing the relative temporal constancy between major articulatory components can be seen to simplify both diachronic and synchronic accounts of the interesting and comparatively rare phenomenon of aspirated nasals in this language.

Footnote

* The present text is closer to that presented at the 22nd Annual Conference on African Linguistics in Nairobi, July 1991, rather than to the earlier version actually presented at the Berkeley Linguistics Society conference.

References

- Batibo, Herman. 1976 [1985]. *Le kesukuma: langue bantu de Tanzanie: Phonologie et morphologie*. Editions Recherche sur les Civilisations, A.D.P.F., Paris.
- Browman, Cathe and Louis M. Goldstein. 1986. Towards an articulatory phonology. *Phonology* 3: 219-252.
- Browman, Cathe and Louis M. Goldstein. 1989. Articulatory gestures as phonological units. *Phonology* 6: 201-251.
- Browman, Cathe and Louis M. Goldstein. 1991. Tiers in articulatory phonology, with some implications for casual speech. In *Papers in Laboratory Phonology I* (ed. J. Kingston & M. Beckman). Cambridge University Press, Cambridge.
- Hinnebusch, Thomas and Marie Huffman. Nasal-devoicing, aspiration and nasal-loss in North-East Coast Bantu. Ms. University of California, Los Angeles.

- Huffman, Marie. 1990. *Implementation of Nasal: Timing and Articulatory Landmarks* (UCLA Working Papers in Linguistics 75). University of California, Los Angeles.
- Kerremans, R. 1980. "Nasale suivie de consonne sourde en proto-bantou." *Africana Linguistica* 8:159-198.
- Ladefoged, Peter. 1990. Computerized phonetic fieldwork. In *Proceedings of the Third Australian International Conference on Speech Science and Technology* (ed. R. Seidl). Australian Speech Science and Technology Association, Canberra.
- Richardson, Irvine. 1959. *The Role of Tone in the Structure of Sukuma*. School of Oriental and African Studies, London.
- Steriade, Donca. 1991. Commentary on Browman and Goldstein 'Tiers in articulatory phonology, with some implications for casual speech'. In *Papers in Laboratory Phonology I* (ed. J. Kingston & M. Beckman). Cambridge University Press, Cambridge.