PHONETIC DIMENSIONS OF SEGMENTAL STRENGTH

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ABSTRACT

Natural Phonology (NatPhon) has been the first explanatory model of sound structure which assigned the central role to functional phonetic principles such as articulatory effort and perceptual distinctiveness. These conflicting principles have been operationalised in a procedural model consisting of weakening processes (minimizing articulatory effort) and strengthening processes (maximizing perceptual distintiveness). Whereas the weakening processes have been mostly categorical in nature, the formalization of the phonological strengthening has been a parenial problem for the procedural models of phonology.

In this contribution I will argue that all dimensions of segmental strengthening are controlled by phonetics, and that articulatory, acoustic and auditory constraints on speech should be carefully studied to provide a detailed account of strengthening.

Keywords: Phonetics/Phonology interface, phonetic strength.

1. INTRODUCTION

Much recent work in phonology ([17], [6], [7], [2], [12]) shares with Natural Phonology (cf. [4], [5]) an assumption about a pivotal role that a conflict between effort and distinctiveness plays in explaining sound systems. In NatPhon the conflict has been expressed by an interaction of two types of constraints: the lenition (weakening) constraints; and the fortition (strengthening) constraints. The constraint interaction was subject to simultaneous ordering but included mechanisms of constraint limitation and constraint suppression. Like in recent Optimality Theory dominated approaches to phonology, and unlike the then dominant SPE approaches [13], the processes were operating on output forms.

The interactions of functionally motivated constraints have been much more highly formalized in the OT-dominated approaches to phonology. The proviso of constraint violability and constraint dominance has tightened some of the loose ends of the model of process interaction that NatPhon has never convincingly solved. Unlike the classical OT models, NatPhon has always been critical of strict constraint interaction, however, has never been able to present a plausible alternative (cf. [7] for a formal model of weighted constraints which appears to be most similar in spirit to NatPhon).

All functional models, however, face a common problem that the opposite sides of the functional conflict (weakening vs. strengthening) are expressed by processes of a very different nature. Whereas the weakening processes are often context dependent categorical (phonological) changes, the strengthening processes are inherently scalar and much less context dependent.

In a gestural model of segmental strength Dogil and Luschützky [3] have proposed some anthropophonetically constant parameters defining the possible range of underlying representations. The parameters are gesturally based, where gesture is an articulatory phonetic execution of an underlying representation of a phonological segment. A strengthening or weakening process may change the execution of a gesture. If this change is motivated by the gestural composition of the neighboring sounds, we can classify these processes as weakening processes, since they represent a deviation from the execution of the underlying gesture (cf. [3:29ff]. In the strengthening processes it is the underlying gesture that is ultimately going to be changed, and we cannot assign this change in a similar relativistic way by reference to the gestural composition of the segmental (or suprasegmental) neighbourhood. Strengthening is panchronic in nature and, to use Luschützky´s [16] insightful terminology, fullfils an evolutive (vs. adaptive) role in the forming a sound system.

In section 4 I will return to the gestural model of articulatory strengthening. In the sections following immediately I will sketch a model of segmental strength which operates with scalar values of acoustic and auditory phonetics.

2. ACOUSTIC STRENGTH

Sound systems in human languages emerge and prevail due to basic, non-linear relations between articulatory, acoustic and auditory mappings underlying human speech. Stevens [20: 3] observed that "there appear to be ranges of the articulatory parameter for which there is very little change in the acoustic parameter and other ranges where the acoustic parameter is more sensitive to changes in articulation." These non-linearities are captured in the quantal theory of speech [20,21], which defines ranges of articulatory-acoustic relations where the variation of the articulatory parameter over a range of values (for example abduction of the vocal folds) causes a change of state in the acoustic pattern (for example a change from aperiodic to periodic signals). It is argued that the regions of acoustic stability (eg. periodic / aperiodic signals) are exploited by languages. From a panchronic perspective, languages tend to develop phonological systems the sounds of which target such regions of stability in the articulation to acoustic mapping. The panchronic strengthening from the point of view of the acoustic theory of speech production [9] would lead to sound systems where all sounds concentrate in the centers of the areas of acoustic stability as defined and predicted by the quantal theory. As Johnson has succinctly put it "..the natural non-linearity in the mapping from articulation and acoustic output leads to natural classes of speech sounds" [9: 83].

3. AUDITORY STRENGTHENING

It can be argued that speakers not only have quite complex knowledge about the quantal acoustic effects of their own articulatory gestures, but that they also possess fairly precise control over the auditory/perceptual consequences of these gestures. Kingston and Diehl [11] review persuasive experimental results which show that "..speakers…use listener-oriented phonetic knowledge when they adapt their articulatory behaviour to ensure sufficient auditory distinctiveness of phonological contrasts." [11: 440]. This formulation of perceptual enhancement is very similar to the standard definition of strengthening processes in NatPhon ([5: 30], however, in Kingston/Diehl seminal paper they are formulated in phonetic, rather than functional/semiotic terms.

Auditory strengthening (auditory enhancement) in phonetics is understood not as an abstract dissimilation operation but rather as a highly attenuated and controlled assignment of phonetic properties which allow the listener a better perception of intended contrast. Kinston and Diehl [11] discuss at length such listener-oriented enhancement of voicing contrast (e.g. low F1 cue). Similarly the tenuous contrast among hissing and hushing sibilants (e.g. Polish [s, ʃ, ç]) is auditorily strengthened by adding lip rounding to the sibilant with the lowest noise frequency (the [ʃ]). At the same time the sibilant with the highest noise frequency (the [s]) is strengthened by the articulatory action of the tip of the tongue which closes off the lower incisors cavity. Note that neither rounding of [ʃ] nor articulating the [s] with the tip of tongue in the lower incisors cavity are essential (or even necessary) parts of the articulatory score of a sibilant. However, the speakers of Slavic languages appear to have a very clear knowledge about the auditory consequences of these gestures on the perception of the sibilant contrast (cf. [23]. As an example of Polish sibilants shows the speakers can apply such listener-oriented enhancement not just to one member of the contrast, but they use a network of mutual enhancement relations to make the perception of tenuous contrasts as easy as possible.

4. ARTICULATORY STRENGTHENING

It is generally assumed in phonology (including NatPhon) that the relative articulatory strength is just the reciprocal term for the relative sonority, and that the strength scale (obstruents → nasals → approximants → vowels) is the mirror image of the sonority scale. The strengthening process involves the increase in the constriction of the oral tract caused by the articulatory gesture, and the weakening is identical to sonorization. The consideration of context free strengthening and weakening processes motivated by the movements along this abstract strength/sonority scale immediately shows that there must be much more going on here than a wholesale change in the stricture control (cf. [3: 25-29] for a discussion of deductive theories of sound change based on sonority and segmental strength). The stipulated incompatibility of sonority and strength within a single sound category cannot be maintained either – the laryngeals [h, ʔ] have a low degree of sonority and a low degree of consonantal strength. Their low degree of sonority is evidenced by the

fact that they occupy the weakest positions within the syllable, and their low degree of strength is evidenced by the fact that they are almost entirely irresistant to coarticulation [10], [22].

Articulatorily strong segments are more resistant to coarticulation, however, as seminal phonetic studies of coarticulatory resistance show [1],[18], speakers implement much more fine detail into their articulatory gestures to "strengthen" them and thus to increase their coarticulatory resistance than is presupposed by a uni-dimentional strength/sonority scale. For example, Recanens´ [19] articulatory model of lingual corticulation identifies the degree of tongue dorsum elevation as the main factor in their articulatory strength (i.e. their level of coarticulatory resistance) - "..palatals ought to allow lesser coarticulation than labials, dentals and alveolars because they are constrained for larger vocal-tract regions" [19: 99].

The fine tuning of articulatory strength is controlled by detailed phonetic knowledge that speakers have about the consequences of individual articulatory gestures used in speech. This knowledge is by no means restricted to the lingual gesture.

Dogil and Luschützky [3] have postulated a system of gestural strengthening, that attempts to achieve exactly this fine tuning of phonetic knowledge. They claim that speakers have control over at least four cardinal articulatory gestures (the velo-pharyngeal gesture, the initiatory gesture, the phonatory gesture and the articulatory stricture gesture). They have further argued that the phonetic control that speakers have over these gestures is characterized by a high degree of independence. Hence speaker may strengthen one gesture but not necessarily the others in order to increase the prominence (or raise the level of coarticulatory resistance) of the underlying segment.

The velopharyngeal gesture is bipolar and segments in most languages are specified as either oral or nasal. The strengthening of the gesture is the activation of both of its poles. This leads to the production of half-nasal sounds including prenasalized obstruents, postnasalized stops and nasalized obstruents. Half-nasalization of stops is a clear strengthening process, leading to the resolution of the stop-voicing dilemma. The opening of the velar port during the formation of a stop helps to maintain higher transglottal flow indispensable for voicing.

The initiation gesture, which generates the airflow that powers speech production, can be accomplished by three separate organs (pulmonic initiation, glottalic initiation, velaric initiation). Moreover, the initiation may be accomplished by two distinct aerodynamic procedures (rarefaction or compression of air). Due to this complexity many possibilities for strengthening are available and are actually utilized in the diachronic development of sound systems ([3:33-36]. Experimental phonetic evidence on coarticulatory behaviour shows that ejectives, implosives and particularly the clicks are to be considered stronger than the pulmonically initiated sounds. Velaric and glottalic initiation gestures allow for much less coarticulatory effects than the pulmonic gestures do [14], [15], [8].

The gesture of phonation may be considered as bipolar if spreading and constriction of the vocal folds are considered as the major two subgestures controlling phonation. The combination of the action of these polar gestures leads to quantal phonatory areas characterized by voicelessness, aspiration, voicing, breathy voicing, creaky voicing and glottal occlusion. The strength relations within this gesture are fairly complex, however, there is convincing experimental and diachronic evidence for aspiration to be a strengthening process in respect to phonation. Also several independent sound laws of Indo-European languages show that breathy-voiced sounds are to be considered stronger than their voiced, voiceless and aspirated counterparts [3].

The articulatory gestures, which is defined by as a movement or posture of an articulator that interrupts or modifies the air-flow in such a way as to give rise to a specific type of sound, is multi-dimentional and its strength can be varied along at least three of the following parameters:

- Degree of stricture (stops, fricatives, approximants, vowels)
- Completeness of stricture (stops, laterals, rhotics)
- Gestural condensation (affricates and diphthongs)

Sounds with highest degree of stricture are stronger than the ones with lower degree of stricture. This is evidence in their coarticulatory resistance as well as in their bahaviour in general sound laws.

The more complete stricture also implies higher segmental strength. It is hypothesized by the model that laterals allow less coarticulatory effects than rhotics. The phonotactic asymmetry of lateral-rhotic clusters (*lr-* initial clusters and *–rl* final clusters cross linguistically) also appears to support a general view that rhotics are weaker than laterals.

The strength relations of the parameter of gestural condensation which accounts for contour segments like affricates, diththongs and multiply articulated stops are not well investigated, but they seem to be determined by their primary articulation [3:41ff].

5. CONCLUSION

In this contribution I have argued that strengthening processes, which NatPhon as well as other functional phonological models considers to be an opposite pole to the weakening processes, have to be accounted for by very different methods than the categorical rules or constraints of phonology. I have argued that strengthening ultimately changes the underlying representation of a segment, that it increases the segments coarticulatory resistance and that it can be accounted for only by controlled acoustic, auditory and articulatory phonetic knowledge. The listener-oriented knowledge accounts for many auditorily based strengthening processes which are systematically (and in no sense automatically [11]) chosen to enhance contrast. The speaker-oriented strengthening has to be accounted for by the application of detailed phonetic knowledge of strength relations within fairly independent articulatory gestures. Last, but not least, the explanatory models of natural non-linearities in the mapping from articulation and acoustic output predict natural classes of speech sounds [21].

We are still at the beginning of the process of discovering the fine structure of these relations, but we have valid experimental paradigms (e.g. coarticulatory resistance) and well formalised phonetic theories (e.g. quantal theory of speech) that make a research program of understanding the basic conflict between fortitions and lenitions in language and speech as fascinating as it has been when first proposed by Natural Phonology.

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