LOW LEVEL PHONETIC IMPLEMENTATION RULES: EVIDENCE FROM SINDHI

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Abstract. The traditional notions of segmental phonetic representation and rule systems formulated in terms of discrete operations have paid little attention to the processes of "phonetic implementation" as opposed to "physiological implementaion". This paper argues that some details of speech, such as timing and cordination of articulatory gestures, have language-specific conditioning, and therefore should fall within the sope of phonology. Evidence will be provided from implosives in Sindhi and other languages in support of the premise, and the status of low level phonetic implementational phenomena in phonological theory will be discussed.

1. INTRODUCTION

Chomsky & Halle (1968) and Goldsmith (1980) characterize sound contrasts on the phonological level in terms of binary feature values. They consider each feature to be both a component at the phonological level and a single physical scale. Recently, Ladefoged (1981) and Lindau and Ladefoged (1983) have shown that relating a feature to a single physical scale often constitutes an oversimplified view of feature correlates.

Sounds of one language may differ from those of another because of the phonetic value of the segments along the same continuum. To take an example, the linguistic specification that distinguishes between [p] and [b] in English is that they are [-voice] and [+voice] respectively. The articulatory instruction that accompanies the feature [+voice] is "vibrate the vocal folds". In order to implement this instruction, a number of articulatory instructions have to be performed, such as keeping the vocal folds sufficiently lax, reducing the distance between the vocal folds, keeping the airflow through the glottis powerful enough to cause vibration, and maintaining the difference between the subglottal and supraglottal air pressure by lowering the larynx, allowing air to escape through a small velic opening, and/or expanding the walls of the phyarnx. "Vibrate the vocal folds", however, is the primary instruction that is associated with the linguistic feature [+voice], and the rest of the articulatory gestures are ways of implementing this instruction. Speakers of different language backgrounds choose different combinations of parameters for the implementation of voicing in stops. The phonetic implementation of these differences is as much important as those in the sound patterns. In order to illustrate this point, I will discuss some phonetic differences between implosives in Sindhi and few other languages.

Implosives have been traditionally characterized as glottalic ingressive sounds produced by lowering the vibrating glottis (Catford, 1939; Pike, 1943). Lindau (1984, p. 152) notes that Hausa implosives are produced with aperiodic, inefficiently closing vocal cord vibrations and that there is considerable speaker to speaker variation between implosives in languages, and that languages may differ in the way that they maintain distinction between implosives and the corresponding plosives. Ladeofged (1964, p.6) noted that his Igbo implosives only produced negative

pressures 8% of the time. Ladefoged (1971, pp. 25-26) therefore observes: " Although these sounds may be called implosives, in ordinary conversational utterances air seldom flows into the mouth when the stop closure is released."

In this connection, Painter (1978, p. 254) observes: ." Despite Ladefoged's caveat (1964, p.6) that his Igbo implosives only produced negative pressures 8% of the time... my physiological data for Ga, Sindhi and Yoruba show negative pressures most of the time." More recently, Nihalani (1986) has shown that there exist natural languages like Sindhi (spoken in India and Pakistan) and Kalabari (spoken in Nigeria) in which implosives do involve an ingressive air flow in addition to the downward displacement of the vibrating glottis. The quantitative measurements of the air flow dynamics run counter to Ladefoged's assumption that there are no real implosives.

Ladefoged (p. c.) has commented that Nihalani's findings are based on his own speech (one single speaker), and that the aerodynamic data are collected from citation forms. Ladefoged has valid criticism in that we should always use large enough sample to base our generalizations. It is obviously crucial to any study of this sort to have as many speakers as practicable, in order to increase the possibility of making meaningful language-specific generalisations.

The purpose of this study was to expand the data on pressure-flow dynamics from much larger number of informants in order to explore aerodynamic characteristics of implosives in Sindhi and also to determine whether these articulatory strategies are consistent within a language or vary only according to speaker-specific idiosyncracies.

2. TEST MATERIALS

Data on the intraoral pressure and oral air flow were collected from 3 speakers (1 male and 2 females, based in Los Angeles). A minimal pair representing the bilabial implosive sound positioned syllable-initially was selected. The language informants were requested to utter words in a carrier phrase: "hi: ɓaru

3. INSTRUMENTATION

The language informant speaks into a specially constructed mouthpiece pressed against the face, which takes the oral air flow through calibrated resistance so that a pressure transducer provides a signal that is directly proportional to the rate of air flow. If one can find a language informant who is willing to tolerate a nasal catheter, then it is possible to record the pressure build up behind stop closures anywhere in the vocal tract. Alternatively, a simple way of obtaining supraglottal air pressure and air flow data on just bilabial sounds was used by inserting a small tube between the lips.

All these parameters were digitized along with the audio signal from a microphone at the rate of 11000 samples/sec. Figure 1 is an example of the aerodynamic data recorded in the Phonetics Lab, UCLA. The top channel records the audio-signal, the middle channel represents oral air flow and the bottom channel represents intraoral air pressure.

4. RESULTS

Figure 1 gives the aerodynamic record of the word [ɓaru] 'child'. The closure phase in the articulation of the implosive sound is characterized by a straight line Q-C (channel 2) indicating absence of air flow in either direction through the mouth. The large periodic fluctuations in the delimited segment R-S on the the pressure tracing (channel 3) reflect the vibrations of the vocal cords. A mid-line was drawn through these ripples by hand. The maximum pressure was measured on the mid-line. The measurements of the Psupra were made at the point of release of closure. Table 1 presents the Peak Psupra values of the syllable-initial implosives/explosives.

Table 1. Peak Measurements of Supraglottal air pressure in cm H2O.

	b	ɓ	Difference
HW	7.5	-2	5

SS	6.5	-5	1.5

In the production of the implosive [ɓ], the vocal folds are brought together before the larynx is lowered. Vocal folds remain fairly tightly together throughout the articulation so that air will not pass through the glottis in such large volume as to destroy the negative pressure necessary for an implosive. Lowering of the larynx obviously enlarges the supraglottal cavity behind the oral closure which results in generating negative pressure inside the mouth. Since the larynx lowers only after the vocal folds are constricted, the lips brought together and velopharyngeal port closed, the rarefaction process in the expanding supraglottal cavities is not affected so much so that the air is sucked in when the outer closure is released. These results are typical of other female speaker as well.

Another interesting feature was noted consistently in the speech of both speakers. Implosives are produced with a relatively short closure duration. Table 2 presents the duration of voicing in both 'implosives' and 'explosives.

Table 2. Duration of voicing in ms.

	b	ɓ	Difference
HW	14	10	4
SS	12.5	9	3.5

Note that the voicing of implosives ranges between 70% to 72% of the corresponding explosives.

The third speaker, however, produced implosives with a voiceless beginning of the closure. The closure displays highly aperiodic vibration, whereas the voiced plosive [b] in the speech of the third speaker has periodic voicing vibrations during the closure phase. So the voicelessness or aperiodicity in the case of third speaker may serve to keep the implosives apart from the voiced plosive. However, the spectrograms made from the independent recording of the same speaker clearly indicate presence of vocal fold activity throughout the period of closure in the articulation of implosives. I don't know how to resolve this anomaly.

5. DISCUSSION

The aerodynamic records show in the case of 2 out of 3 speakers that the movement of the larynx occurs while the vocal cords are vibrating. This downward movement of the vibrating glottis enlarges the supraglottal cavity behind the closure. These vibrations are maintained by a small amount of lung air which is not of sufficient volume to destroy the partial vacuum caused by the downward laryngeal movement and thus prevent the occurrence of suction pressure. The negative pressure ranging between -2 cmH2O to -5 cmH2O was generated in the mouth. On separation of the articulators, the airflow was found to be ingressive. Thus the quantitative measurements, on the whole, confirm the results reported earlier by Nihalani (1986).

6. THEORETICAL ISSUES

The preceding discussion makes it clear that Sindhi implosives show negative pressure most of the time in contrast to the implosives observed by Ladefoged in which negative pressure was produced only 8% of the time. The first question that comes up is: Should the linguistic characterization of implosives be based on negative pressure/suction, with the greater degree of downward displacement of the larynx being a physiological consequence of the need to maintain the pressure difference for suction, OR should the linguistic characterization specify (as Ladefoged implies) the greater displacement of the larynx?

Suppose we took the position that the linguistic instruction that is assoicated with the production of implosives is "lower the larynx". Voiced explosives and the implosives would then be linguistically distinguished from each other in that the instruction to lower the larynx is implementational in the former (the larynx is lowered in order to keep the vocal folds vibrating), while it is phonological in the latter. This distinction in the phonological function of

the articulatory gesture of 'larynx lowering' is parallel to that of 'velum lowering'. In the production of nasal sounds, the instruction to lower the velum is phonological in that it is assoicated with the feature [+nasal], while in the production of voiced plosives in Sindhi the lowering of the velum is only a means of implementing the vibration of the vocal folds (Nihalani 1975).

The distinction between the implosives in Hausa, on the one hand, and Sindhi, on the other, in "not having" and "having" ingressive airflow would then be a difference in the implementation of the instruction to lower the larynx. In Hausa, the oral closure is released only when the supraglottal air pressure is neutralized with the ambient pressure, while in Sindhi the oral closure is released when the supraglottal air pressure is less than that of the atmospheric pressure. As a result, there is an ingressive airflow in Sindhi but not in Hausa.

An alternative would be to hold that the relevant phonological feature of implosives is [+suction], which is associated with the instruction "create an ingressive air flow". The lowering of the larynx would then be a procedure for the implementation of this instruction. That this instruction is not actually realized in languages like Hausa would then be analogous to the fact that the phonological instruction to vibrate the vocal folds fails to apply prepausally and postpausally during the closure period of voiced stops in languages like English.

An interesting theoretical issue that arises from the study of implosives in Sindhi is the status of implementation phenomena in phonological theory. There has been a growing body of literature in phonetics and phonology during recent years arguing that some details of speech, such as timing and coordination of articulatory gestures, have language-specific conditioning, and theorefore they fall within the scope of phonology (Ladefoged, 1980,1985; Liberman,1983; Port, Al-Ani and Maeda, 1980; Port and Mitleb, 1983; Mohanan, 1986; Cohn, 1990; Huffman, 1990). These processes of "phonetic implementation" as opposed to "physiological implementation" pose a challenge to the traditional notions of segmental phonetic representation and rule systems formulated in terms of discrete operations, and are therefore or profound interest.

Until recently, a widely accepted view, following Chomsky & Halle was that phonetic implementation was universal and this was discussed explicitly in terms of coarticulation. Phonetic implementation or the physical realization of the abstract patterns represented by the phonology was assumed to be mechanical. As a consequence, a phonological output was assumed to have a unique physical realization. It was also assumed that phonetic differences occurred cross-linguistically. Within this framework, the distinction between phonetics and phonology appeared clear-cut. Phonology involved language-specific rules, whereas phonetics was the universal mechanical realization of the phonology. Since the mapping was thought to be universal, little attention was paid to the phonetic implementation of phonological representation from a linguistic point of view. However, the more phoneticians looked for cross-language phonetic generalisations, the more exceptions they found to possible universal phonetic generalisations. Many phonetic processess that were assumed to be mechanical and to follow automatically from physiological factors, on clearer examination, turned out to demonstrate significant differences between languages. Differences of each language therefore will have to be described in terms of language-specific low level rules of "phonetic implementation", and these must form part of the phonological description of natural languages. Thus an understanding of the mapping processes from discrete, categorial and timelesss phonological units to continuous articulatory and acoustic quantitative physical manifestations is a real central issue in the general understanding of phonology, and is the important goal of linguistic phonetics.