NASALS AND NASALIZATION IN HINDI

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ABSTRACT

We assert that common diachronic phonological variation (sound change) arises from synchronic phonetic variation. To provide support for this view we sought evidence in Modern Hindi for the phonetic "seeds" of two sound changes posited in the history of Hindi and many other Indo-Aryan languages.

The first is the posited introduction of a nasal consonant between a nasal vowel and a following voiced stop (but *not* a following voiceless stop), e.g., Skt *čandra* "moon" > Old Hindi *čã:da* > Mod. Hindi [čãnd] (but cf. Skt *danta* "tooth" > Old Hindi *dã:ta* > Mod. Hindi [dãt]). Physiological and acoustic recordings of speakers of Hindi and of French showed that when pronouncing a sequence of a distinctively nasal vowel followed by a voiced stop in the next word, the voiced stop was often prenasalized. How such a nasal can be carved out of a voiced stop (but not a voiceless stop) can be explained by phonetic principles.

The second is so-called "spontaneous nasalization", i.e., the emergence of distinctively nasal vowels in words lacking an etymological nasal. E.g., Hindi [sãp] < Skt (Sanskrit) *sarpa*, "snake". Ohala and Amador (1981) hypothesized that high airflow segments such as voiceless fricatives or voiceless aspirated stops require a larger-than-normal glottal opening which may be partially assimilated by adjacent vowels (though still voiced). This slightly open glottis during voicing creates acoustic effects which mimic nasalization (without being physiologically nasal), e.g., increased bandwidth of the first formant. We tested this hypothesis by creating .3 sec long vowels by iterating single periods from the VC junctions in [sas] as well as from the oral vowels in [kat] and [lal] and asking listeners to judge the degree of nasalization. Although [sas] is demonstrably as oral as [lal], listeners judged the vowel made from the period adjacent to [s] to be more nasal than those from [lal].

Thus, phonetically-explainable variation has been shown in these cases to parallel sound change.

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INTRODUCTION

In this paper we pursue phonetic explanations for two somewhat puzzling patterns in the development of Modern Hindi (MH) from Middle Indo-Aryan (MIA). That phonetic explanations are possible is suggested by the fact that similar patterns or tendencies may be found in other completely different languages: in general, the only thing common to diverse languages is the physical apparatus for speech production and perception.

EPENTHETIC NASALS

The first pattern we consider involves apparent epenthetic nasals. MH words such as [dãt][1] "tooth vs [čãnd] "moon" present an interesting asymmetry in their phonological history: in their development from MIA to Old Hindi (OH) and then to New IA both were subject to cluster simplification with compensatory lengthening and nasalization of the preceding vowel (Beames 1872, Misra 1967). Thus: Skt *danta* > MIA *danta* > OH *dã:ta* > MH [dãt]; Skt *čandra* > MIA *čanda* > OH *čã:da* > MH [čãnd]. In the latter case the nasal consonant present in Sanskrit but then subsequently lost, re-appears in MH. Is it plausible that a nasal be re-introduced only before a voiced stop or should we re-think the historical derivation of such words? The primary evidence that the nasal was indeed lost by the time of OH is the fact of compensatory lengthening of the vowel which in numerous other instances correlates with simplification of medial consonant clusters or geminates, e.g., Skt *hasti* "elephant" > Prakrit *hatt^{h}i* > MH [hat^{h}i]; Skt *sarpa* "snake" > Prakrit *sappa* > MH [sãp]. Our aim is to marshall phonetic evidence in support of the scenario that a nasal consonant (N) could have been re-introduced preferentially between a nasalized vowel ($\tilde{V}$) and a voiced stop (D).

In previous papers (Ohala & Ohala 1991, in press) we attempted to show that a sequence of $\tilde{V}$ + D is often manifested phonetically as the sequence [$\tilde{V}^N$D], i.e., with a epenthetic nasal consonant homorganic to the stop. The stop, in other words, is prenasalized. Such an epenthetic nasal either fails to appear or is much shorter in duration in $\tilde{V}$ + T sequences. The evidence for this came primarily from traces of nasal pressure (via a nasal "olive") recorded during cross-word sequences in both MH and French of $\tilde{V}$ + D on the one hand versus $\tilde{V}$ + T sequences on the other. For example, in the French utterance "dit 'saint' bel enfant" the phrase /sã bɛl/ was realized phonetically as [sã^{m}bɛl] with a nasal segment on the order of 70 msec. This contrasts with the utterance "dit

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[1] The transcription of modern words is in IPA with the following exceptions: [a] = IPA [ɑ], [t, d] are dental, [č] = IPA [tʃ]; [a] in MH is a phonologically long vowel although is not explicitly marked for length. Transcriptions for earlier forms are the conventional transliterations based on orthography.

'saint' pour moi" where the sequence /sã puʁ/ showed an intrusive nasal only 30 msec in duration. In the Hindi utterance /ap jəhã dekʰo/ 'you see here', the sequence /ã d/ was realized phonetically as [ãⁿd] with an epenthetic nasal about 60 msec in duration. In contrast, in the utterance /ap jəhã tako/ 'you glance here', the sequence /ã t/ showed only a 30 msec intrusive nasal.

We argued that since the phonetic manifestations of the constituent words of the crucial sequences in these sentences do not show a nasal consonant, the nasals that do appear must be a purely phonetic event, a transitional element between the Ṽ and the following stop. We offered the following reasons as to why a voiced stop but not a voiceless one could tolerate a nasal onset (Ohala & Ohala, in press):

> ... among the auditory cues for a voiced stop there must be a spectral and amplitude discontinuity with respect to neighboring sonorants (if any), low amplitude voicing during its closure, and termination in a burst; these requirements are still met even with velic leakage during the first part of the stop as long as the velic valve is closed just before the release and pressure is allowed to build up behind the closure. However, voiceless stops have less tolerance for such leakage because any nasal sound -- voiced or voiceless -- would undercut either their stop or their voiceless character.

We also cited similar patterns in other languages, both phonetic and phonological, as regards voiced stops' tolerance of a nasal onset (Yanagihara & Hyde 1966; Suen & Beddoes 1974; Roberts & Babcock 1975; Paradis 1988/89; Kawasaki 1981). Since then additional such evidence has come to our attention (Duez 1991, Aguilar Cuevas et al. 1991).

We posit that unintended, non-distinctive contextual phonetic variation can become intended and distinctive if subject to reinterpretation by listeners. This presumably is the mechanism underlying what Jakobson refers to as "phonologization". The plausibility of such a scenario underlying this type of sound change is reinforced by numerous laboratory studies (J. Ohala 1981, 1989).

Some question might remain, however, as to whether the epenthetic nasal that appears in word sandhi might differ from those appearing in internal sandhi in the development of MH words like [čãnd] < OH *čã:da*. In the present study, therefore, we sought to demonstrate that the epenthetic nasal could appear within a word.

Method

To show the emergence of a nasal onset to a voiced stop within a word it is not possible to look for it in existing words where its presence seems rather to have a phonological, i.e., distinctive, function. We therefore looked for it in made-up words. We borrowed a word-blending technique used previously by Treiman (1983, 1986) and Derwing and Nearey (1991). We asked 5 male Hindi speakers to combine the CV of words like [pãč] "five" and the final -C of words like [sud] "proper name" to form the non-existing *[pãd]. The subjects, who were non-linguists, were trained in this task by first presenting them with models of word blending which did not involve nasal vowels and then testing them on similar examples. The list of words to be so manipulated was presented orthographically via the traditional Devanagari script. The list was sometimes read twice, time and the subject's patience permitting. A variety of final -C's were included in the corpus, both voiced and voiceless. All but two of the CV-C blends yielded nonsense words with the exception of two of the blends involving final voiceless -C's.

We were interested in determining whether there was any acoustic evidence of an epenthetic nasal, i.e., a nasal onset to the voiced stop. Naturally, this would be a relatively brief phonetic event with potentially tenuous acoustic correlates. We therefore adopted the following criteria for the identification of such intrusive nasals. First, in order to say that a nasal consonant was present there should (a) be visual evidence in a spectrographic display of the utterance of the usual acoustic correlates of a nasal: a discontinuity in the amplitude and the spectrum of the signal (vis-a-vis the preceding vowel), and (b) be auditory evidence of the nasal consonant when the utterance is heard with the final stop release gated out. It is important to listen to a gated portion of the utterance since even phonetically trained ears have been known to "add" or subtract details to the percept of the speech signal by integrating elements from larger contexts. Second, in order to say that the nasal was intrusive and not phonological, it should be brief, i.e., shorter than a phonologically distinctive nasal consonant. Using the same speakers, we recorded instances of full nasals in words like [čãnd] and found that such full (phonological) nasals typically had durations on the order of 90 - 100 msec (cf. also M. Ohala 1983).

Results

As mentioned, the acoustic speech signal is often ambiguous regarding presence or absence of a nasal onset to a voiced stop, especially as the transition between nasal to oral state is a gradual, not abrupt, one. Thus for many of the tokens recorded and analyzed we could not say definitively whether a nasal onset occurred or not. Also in some other tokens we found what would seem to be a full nasal by virtue of their relatively long duration (c. 100 msec). These almost invariably were found on the second reading of the list. Such a full nasal could arise either due to a phonological rule, i.e., a regular process operating on an underlying form, or due to a misreading of the orthographic representation.

Nevertheless both acoustic and auditory analysis revealed some tokens by some of the speakers which had nasal onsets to the voiced stops (but never voiceless stops) which met our criteria for epenthetic nasals. They had the acoustic characteristics of nasals, they sounded like nasals, and they had durations on the order of 50 - 60 msec.

Discussion

We conclude that nasal onsets to voiced stops preceded by nasal segments (in this case a nasal vowel) is a phonetically common process for the reasons given above and that these may appear both across and within word boundaries. Such a transitional nasal may become a full nasal via phonologization, i.e., reinterpretation of predictable contextual phonetic variation as distinctive.

SPONTANEOUS NASALIZATION

The second sound pattern considered is what Grierson (1922) called 'spontaneous nasalization', i.e., the emergence of distinctive nasalization on a vowel when there was no historical antecedent to it. This is illustrated by comparing the origins of the two MH words [dā̃t] "tooth" and [sā̃p] "snake". The former derives from Skt *danta* which contained a post-vocalic nasal (subsequently lost with concomitant lengthening and nasalization of the vowel); the latter derives from Skt. *sarpa* which did not originally have any nasal segment. Similar patterns are evident in the development of nasal segments in other languages (J. Ohala 1975, 1983; Matisoff 1975). Bloch (1920, 1965) speculated that long vowels were especially susceptible to spontaneous nasalization and, in fact, there is recent experimental evidence supporting this (Whalen & Beddor 1989). Additionally, M. Ohala (1975, 1983) found that at least for IA such nasalization seemed to be associated with adjacent fricatives and aspirated consonants and as suggested by J. Ohala (1975, 1980, 1983) there is a plausible phonetic reason for this:

(a) High airflow segments like voiceless fricatives and aspirated stops require for their production a greater-than-normal glottal opening (vis-a-vis comparable voiceless segments like voiceless unaspirated stops).

(b) This greater-than-normal glottal opening may spread via assimilation to the margins of adjacent vowels, even though these vowels may remain completely voiced.

(c) This slightly open glottis creates acoustic effects due to some coupling between the oral and the sub-glottal cavities that mimic the effects of coupling of the oral and nasal cavities, i.e., lowered amplitude and increased bandwidth of formant one.

(d) Vowels that sound nasal to listeners, even though they are not physiologically nasal, can be reinterpreted and produced as nasal, thus precipitating a sound change.

Points (a), (b), and (c) are well established in the phonetic literature (see references in J. Ohala 1975, 1983). Ohala and Amador (1981, summarized in J. Ohala 1983) tested point (d) by conducting a speech perception experiment. In brief, they showed that portions of oral vowels immediately adjacent to voiceless fricatives in English and Spanish are perceived by phonetically-trained listeners to be as nasal as comparable vowel fragments adjacent to nasal consonants (and thus phonetically nasalized). The vowel stimuli they presented to listeners were made by taking single periods from vowels adjacent to the consonants and copying or iterating them until an isolated steady-state vowel of approximately 500 msec was made.

We attempted to extend the perceptual evidence to vowel samples made from the speech of a Hindi speaker.

Method

We followed the method of Ohala and Amador. Using *C-Speech*, a speech processing software package, we obtained single tokens of digitized samples of words spoken by a male Hindi speaker and isolated the last or second-to-last identifiable vowel period from the words [kat] "to spin", [kam] "work", [sãs] "breath", and [sas] "mother-in-law". We also took one period from the middle of the word [lal] "red". We then iterated these periods until we had steady-state vowels approximately 300 msec long. The amplitude was ramped at onset and offset to eliminate annoying transients. Three samples each of these five vowels, for a total of 15 vowel tokens were randomized and presented to listeners with the instructions that they were to judge the degree of nasalization of each token on a 5-point scale (by marking an answer sheet provided), ignoring any variations in loudness, pitch, or vowel quality. The hypotheses being tested were that (a) the token made from [sas] would be perceived as more nasal than those from [kat] and [lal] and (b) would be judged as nasal as those from [kam] and [sãs].

The stimulus tape was presented to the listeners in their homes or places of work. They heard the speech samples monaurally via earphones over a high quality portable tape recorder at a comfortable level of loudness. Unfortunately the ambient noise conditions were often far from ideal. They were first allowed to hear the whole tape without making any judgments and then heard the tape a second time during which they gave their judgments.

The first group of subjects we tested were all in Delhi, India. Ten were linguistically naive native speakers of Hindi and 13 were linguistically trained but not professional phoneticians (speakers of various Indian languages having distinctively nasal vowels). It was clear from their responses (e.g., high variability in a given listener's judgments of the same stimulus) as well as their verbal comments that they were unable to ignore variations in pitch, loudness, and vowel quality in order to focus on degree of nasalization. We will not discuss their data further.

Next we recruited 5 subjects (attending the Pan-Asiatic Linguistics Symposium in Bangkok) who were phonetically-trained linguists, native speakers of either English, Danish, or French).

Results

Subjects varied in their treatment of the 5-pt. scale, some didn't use the full scale and others, though using the full scale, concentrated their answers towards one end or the other. Therefore, after averaging the three judgments per subject per token, we normalized all such averages by converting them to z-scores, i.e.,

$$z_{ij} = (x_{ij} - M_j)/s_j,$$

where z_{ij} is the normalized score for the i^{th} response of the j^{th} subject, x_{ij} is the original judgment, M_j and s_j are mean and standard deviation, respectively, of the averaged judgments of the j^{th} subject.

The results obtained from the 5 phonetically trained subjects are presented graphically in Figure 1. Although the degree of nasalization of the vowel period taken from [sas] was not judged to be as great as that from [kam] and [sãs] (thus differing somewhat from the results of Ohala & Amador for English and Spanish vowels), it was judged to be more nasal than the oral vowels in [kat] and [lal]. A one-way analysis of variance on the between-token variation was significant ($F(4,20) = 4.32$, $p < .05$); statistical tests on the difference in means of those token pairs of interest revealed that only the difference between [sas] and [lal] was significant. (The difference between [sãs] and [lal] was significant, of course, but this was *not* crucial to our hypotheses.) This provides partial support for hypothesis (a), above, as well as hypothesis (b). However, the sample size was small and we are not confident that the lack of a significant difference in the perceived nasalization of the tokens from [sas] vs. [sãs] and [kam] would persist in a larger sample. Though sounding somewhat nasal, the token from [sas] may be less nasal than vowels that are physiologically nasal. Nevertheless, we consider these results to

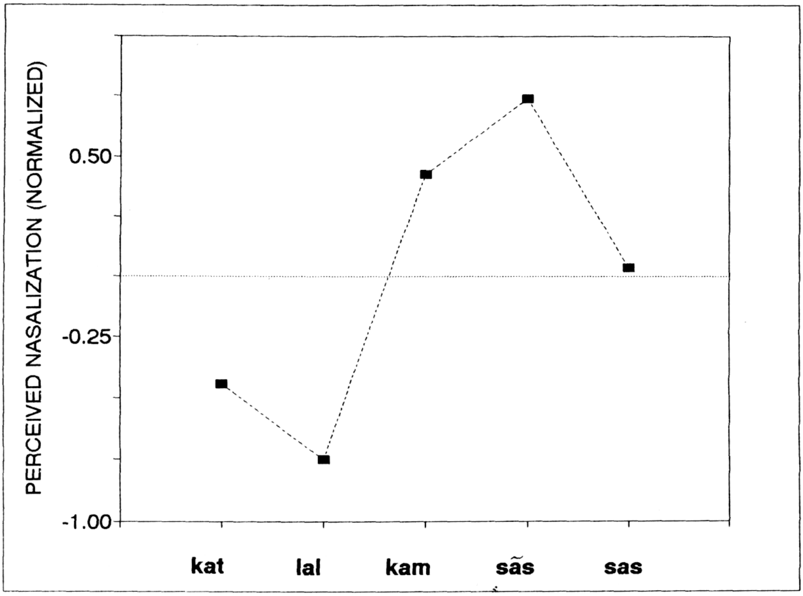

Figure 1. Normalized judgments of perceived vowel nasality (vertical axis) of single periods isolated and then iterated from the tokens indicated (horizontal axis); subjects were 5 phonetically-trained listeners.

be promising partial support for the general hypothesis that the margins of vowels adjacent of high airflow consonants may sound nasal.

GENERAL DISCUSSION

Although this paper was concerned with two specific problems in the historical phonology of Hindi, we believe the results have wider implications. First, as suggested earlier, the same sound patterns can be found in other languages and presumably the same phonetic explanations apply in them. Second, we think these explorations provide further examples of how sound change -- its initiation, if not its subsequent spread -- can be studied in the laboratory.

The first step in our attempt to explain certain sound changes has been to search the phonetic record in order to find synchronic variation which parallels the diachronic pattern and then, if possible, identify the phonetic causes of the variation. But although such phonetically-caused variation is similar to these sound changes, it is not *equivalent* to sound change. Listeners normally factor out or "correct" familiar, contextually predictable, distortions, just as -- in the visual domain -- we "correct" for color distortions of ambient light. A white paper still appears to us "white" under greenish fluorescent light. So, too, a vowel distorted by adjacent consonants sounds undistorted assuming the listener has made the connection between the conditioning environment and the conditioned perturbation. Experimental phonetic evidence supports this (J. Ohala 1989, 1991). This is why even though the vowel margins adjacent to high airflow segments might mimic the effects of nasalization, they wouldn't necessarily always sound nasal in connected speech. If, however, the context conditioning the perturbation is removed, as was done in our listening test, or is otherwise ignored by the listener, then the perturbations can be interpreted at face value. In this way sound change -- essentially a misapprehension by the listener-- can arise.

This account contrasts markedly with other popular accounts of sound change which are essentially teleological, i.e., claims that pronunciation changes to make speech easier to produce, easier to perceive, easier to compute or to learn, or that it changes to accommodate changing communication needs. According to the account we follow here sound change is an innocent mistake by the listener: an error in decoding the intentions of the speaker. It is thus similar to errors made by scribes in copying texts and is no more purposeful than their errors and does not result in any improvement in the form of language.

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REFERENCES

Aguilar Cuevas, L. et al. 1991. Analysis of Spanish sequence "de" in content words and in function words in continuous speech. Paper presented at ESCA [European Speech Communication Association] Workshop on Phonetics and Phonology of Speaking Styles: Reduction and elaboration in speech communication, Universitat Autònoma de Barcelona, Spain. 30 Sept -2 Oct 1991.

Beames, J. 1872. *A comparative grammar of the Modern Aryan languages of India: to wit, Hindi, Panjabi, Sindhi, Gujarati, Marathi, Oriya, and Bangali.* Vol. 1: *On sounds.* London: Trübner.

Bloch, J. 1920. *La formation de la langue marathe.* Paris, E. Champion.

Bloch, Jules. 1965. *Indo-Aryan. From the Vedas to modern times.* Paris: Librairie d'Amerique et d'Orient Adrien-Maisonneuve.

Derwing, B. L. & Nearey, T. M. 1991. The 'vowel-stickiness' phenomenon: Three sources of experimental evidence. *Proceedings of the 12th International Conference on Phonetic Sciences, Aix-en-Provence.* 3.210-213.

Duez, D. 1991. Relationships between production and perception in French dental stops in spontaneous speech. Paper presented at Symposium on Current Phonetic Research Paradigms: Implications for Speech Motor Control. Stockholm University, 13-16 Aug 1991.

Grierson, Sir George. 1922. Spontaneous nasalization in the Indo-Aryan languages. *Journal of the Royal Asiatic Society of Great Britain.* July. 381-388.

Kawasaki, H. 1986. Phonetic explanation for phonological universals: The case of distinctive vowel nasalization. In J. J. Ohala & J. J. Jaeger (eds.), *Experimental Phonology.* Orlando, FL: Academic Press. 81-103.

Matisoff, James A. 1975. Rhinoglottophilia: the mysterious connection between nasality and glottality,. In C. A. Ferguson, L. M. Hyman, & J. J. Ohala (eds.), *Nasalfest: Papers from a symposium on nasals and nasalization.* Stanford: Language Universals Project. 265-287.

Misra, B. G. 1967. *Historical phonology of Modern Standard Hindi:*

Proto-Indo-European to the present. Doctoral Diss., Cornell Univ.

Ohala, J. J. 1975. Phonetic explanations for nasal sound patterns. In: C. A. Ferguson, L. M. Hyman, & J. J. Ohala (eds.), *Nasalfest: Papers from a symposium on nasals and nasalization*. Stanford: Language Universals Project. 289-316.

Ohala, J. J. 1980. The application of phonological universals in speech pathology. In: N. J. Lass (ed.), *Speech and language. Advances in basic research and practice*. Vol. 3. New York: Academic Press. 75-97.

Ohala, J. J. 1981. The listener as a source of sound change. In C. S. Masek, R. A. Hendrick, & M. F. Miller (eds.), *Papers from the Parasession on Language and Behavior*. Chicago: CLS. 178-203.

Ohala, J. J. 1983. The phonological end justifies any means. In S. Hattori & K. Inoue. (eds.) *Proceedings of the XIIIth Int. Congr. of Linguists, Tokyo, 29 Aug.-4 Sept. 1982*. Tokyo [Distributed by Sanseido Shoten.] 232- 243.

Ohala, J. J. 1989. Sound change is drawn from a pool of synchronic variation. L. E. Breivik & E. H. Jahr (eds.), *Language Change: Contributions to the study of its causes*. [Series: *Trends in Linguistics, Studies and Monographs* No. 43]. Berlin: Mouton de Gruyter. 173-198.

Ohala, J. J. 1991. What's cognitive, what's not, in sound change. L.A.U.D. [Universität Duisburg Gesamthochschule] Paper A 297.

Ohala, J. J. & Amador, M. 1981. Spontaneous nasalization. *J. Acous. Soc. Am.* 68.S54-S55.

Ohala, M. 1975. Nasals and nasalization in Hindi. In: C. A. Ferguson, L. M. Hyman, & J. J. Ohala (eds.), *Nasalfest. Papers from a symposium on nasals and nasalization*. Stanford Language Universals Project. 317-332.

Ohala, M. 1983. Aspects of *Hindi Phonology*. Delhi: Motilal Banarsidass.

Ohala, M. & Ohala, J. J. 1991. Epenthetic nasals in the historical phonology of Hindi. *Proceedings of the XIIth International Congress of Phonetic Sciences, Aix-en-Provence, 19-24 Aug 1991*. Vol. 3, pp. 126-129.

Ohala, M. & Ohala, J. In press. Nasal epenthesis in Hindi.

Phonetica.

Paradis, C. 1988-1989. On constraints and repair strategies. *The Linguistic Review* 6.71-97.

Roberts, E. W. & W. R. Babcock. 1975. Parametric relationships in English CVNC and CVC monosyllables. *Language & Speech* 18.83-95

Suen, C-Y. and Beddoes, M. P. 1974. The silent interval of stop consonants. *Language & Speech* 17.126-134.

Treiman, R. 1983. The structure of spoken syllables: evidence from novel word games. *Cognition* 15.49.74.

Treiman, R. 1986. The division between onsets and rimes in English syllables. *Journal of Memory & Language* 25.476-491.

Whalen, D. H. & Beddor, P. S. 1989. Connections between nasality and vowel duration and height: elucidation of the Eastern Algonquian intrusive nasal. *Language* 65.457-486.

Yanagihara, N. & C. Hyde. 1966. An aerodynamic study of the articulatory mechanism in the production of bilabial stop consonants. *Studia Phonologica* 4.70-80.