VELAR AND GLOTTAL ACTIVITY IN A SPEAKER OF ICELANDIC

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ABSTRACT

The realization of Icelandic preaspirated plosives and voiceless nasals is examined, particularly the timing and extent of the devoicing gesture and of velar excursion. The segmental status of preaspiration is discussed and it is suggested that the voiceless nasals can be quite simply regarded as "ordinary" nasals coarticulated with a following preaspirated plosive.

INTRODUCTION

In this paper we examine an aspect of Icelandic that is particularly interesting from the point of view of interarticulatory timing - the realisation of the preaspirated plosives and voiceless nasals (henceforth abbreviated to HC and NH). These sounds have also been of central interest in the phonological analysis of Icelandic.
They are both subject to considerable restrictions on where they can occur in the word: HC occurs only after short vowel medially or finally ("seppi", "löpp") and in combination with other consonants only before /l/ and /n/ ("epli"). NH is subject to dialectal variation but in southern Icelandic occurs principally before /p, t, k/ following short vowel, i.e in the position in which HC also occurs.
The emergence of these two groups of sounds has also been linked diachronically /8/ through a shift in the timing of the devoicing gesture on the plosive. Synchronic analyses have varied, however. Pétursson /7/, in a phonemic description, analyzes preaspiration as the phoneme /h/ based on his phonetic investigations; and based on the existence of minimal pairs such as "dempi" vs. "dembi" ([tempi] vs. [tempi]) assumes the existence of separate voiceless and voiced nasal phonemes. There is thus no apparent relationship between these two groups of sounds. In other analyses /1/ this relationship is preserved, preaspiration being introduced by rule as an auto-segment, and modifying the adjacent nasal if one is present.
The questions just briefly touched on provided the motivation for examining these sounds in as homogeneous an environment as possible. This also gave the opportunity to return to a question raised in our earlier /4/ investigation of German where varying oral articulations in word-pairs such as "fette" vs. "feste" seemed to be combined with a constantly timed glottal gesture when viewed from the onset of the preceding vowel.

SUBJECT, MATERIAL AND METHOD

A male speaker of Southern Icelandic acted as subject. Based on the considerations outlined above the speech material was chosen to permit contrast of preaspirated plosives, unaspirated plosives, voiceless nasal plus plosive and voiced nasal plus plosive. This led to the following list of 10 words, the sounds of interest all being in medial, post-stress position.

"hitti"	preaspirated
"hiti"	unaspirated
"henti"	voiceless nasal
"hendi"	voiced nasal
"seppi"	preaspirated
"sepi"	unaspirated
"dempi"	voiceless nasal
"dembi"	voiced nasal
"hetta"	preaspirated
"sempinn"	voiceless nasal

This list was subjected to six different randomizations, the words being embedded in the sentence frame:
"ég segi ..... þá"
The following procedure was followed for the recordings: Glottal activity was assessed by the transillumination technique and velar activity by Künzel's photoelectric method /5/. For obvious technical reasons velar and glottal activity had to be recorded separately. Precautions were taken to ensure that both recordings were spoken at roughly the same rate. A third recording of oral air-pressure will not be discussed further here; however, it enabled the audio-signal measurements to be based on 18 tokens per word (3 recordings x 6) rather than 6 tokens per word as in the case of the physiological signals.

RESULTS

The results will be presented in three sections: first, the temporal measurements made on the speech signal (summarized in Table 1); and then the results for glottal and velar activity.
Figure 1 shows ensemble averages for glottograph and velograph signals and audio envelope for eight of the ten words. Note that the velar and glottal signals were not, of course, recorded simultaneously. The audio envelope represents an average over both recordings.

Segment Durations

The words will be treated as consisting of a maximum of three basic segments (cf. Table 1):

1. the vowel preceding the consonantal group,
2. the nasal or preaspiration section,
3. the occlusion phase of the plosive.

Vowel length divided the material into two groups, one group consisting only of "sepi" and "hiti", in which the (diphthongized) vowel was 120-140 ms in length (segment 2 being completely lacking here, of course) and a second group containing all other words, in which the length of the vowel was roughly 60-85 ms. As far as segment 2 is concerned, the length of preaspiration was clearly shorter than that of the nasals:
50-70 ms vs. 110-150 ms. Within the nasals the voiceless sounds tended to be longer than the voiced counterparts.
The length of the plosive occlusion tended to counterbalance the length of segment 2 with much shorter plosives following the nasals than in the preaspirated or unaspirated conditions:
ca. 80 ms vs. ca. 120-140 ms.
The relative lengths of preaspiration and the plosive occlusion are comparable to those in /3/ and /10/, while in /7/ the preaspiration was sometimes as long as the following occlusion. Clearly this did not occur here. Nonetheless, there seems to be a feeling in the literature that preaspiration is so long that it cannot be a mirror-image of postaspiration but rather is an independent segment. We believe this argument has been over-valued (but see discussion).
The fact that occlusions for preaspirated and unaspirated plosives are not reliably distinguishable in length also agrees with /3/.

Table 1

Main segment durations averaged over all three recordings (n = 18).

	vowel		nasal or preasp.		occlusion	
	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
hitti	75	9.0	51	12.5	146	20.7
hiti	142	14.5	---	---	134	16.4
henti	63	10.4	141	13.5	92	11.2
hendi	63	6.0	115	11.7	92	12.7
seppi	59	5.7	76	10.0	123	14.9
sepi	125	14.4	---	---	134	16.1
dempi	68	4.4	143	10.5	87	15.3
dembi	86	5.2	108	12.2	79	20.8
hetta	70	7.2	67	8.4	136	15.9
sempinn	62	4.5	130	10.6	83	15.1

Glottal Activity

Fig. 1 shows that the amplitude of the devoicing gesture for HC and NH was very large, being greater even than for the pre-vocalic fricatives (e.g. /s/ in "seppi"). This agrees with /10/ while Löfqvist /6/ generally noted rather smaller glottal openings for HC. The unaspirated plosives (e.g. "sepi") had a clear devoicing gesture but of restricted amplitude while for the plosives following the voiced nasals no evidence of glottal opening could be seen. Pre-vocalic /h/ (e.g. "hitti") also had a devoicing gesture, of course, but also of restricted amplitude so that, in view of the unconstricted vocal tract in these sounds, they were often not completely voiceless.
The above remarks refer to aspects of the glottal gesture that are so prominent as to be unaffected by non-linearities in the glottographic signal. Any differences in glottal activity between HC and NH are clearly more subtle, however. In the nasals the glottal gesture, particularly the adductory phase, coincides with a period of fast velar movement, so that reliable differences in maximum glottal opening and maximum opening and closing speed cannot be assumed.
The timing of glottal activity can be approached with more confidence, however. There are some clear differences, but also some interesting similarities between HC and NH. Firstly, it should come as no surprise that the interval from peak glottal opening (PGO) to formation of the occlusion for the plosive is completely different for the HC and NH sounds. The data for all 18 tokens of HC and NH gives:

$\bar{x}$ = 85.4 ms; sd = 13.5 ms for the nasals
$\bar{x}$ = 10.4 ms; sd = 8.6 ms for the preaspirates

This is a natural consequence of the broad similarity in the glottal gesture and the different structuring of the oral articulation exemplified in Table 1.
Regarding similarities in timing the first point to be made is that there is no difference in the overall duration of the gesture as estimated by the interval from instant of maximum opening speed to instant of maximum closing speed.
Support for the hypothesis developed on the basis of the earlier German material was also found; while it unfortunately proved impossible to measure the beginning of glottal abduction reliably, nonetheless the interval from vowel onset to the moment of maximal abduction velocity, and from vowel onset to PGO were not significantly different in the two classes of sounds.

Velar Activity

Regarding the nasals as a group it has already been pointed out that the voiceless nasals as measured from the audio signal were clearly longer than the voiced counterparts. This result was highly significant. There was, however, no reciprocal adjustment in the length of the following plosive, nor differences in the length of the preceding vowel. This replicates results previously presented by Pétursson /9/ quite closely, although he did find some reciprocal adjustment in the length of the plosive.
Regarding the velar gesture itself there were no significant differences in maximum raising or lowering speed or in overall excursion. Taking the length of the interval between the positions of maximum lowering and raising speed as a measure of the length of the velar gesture the values for "dempi" were significantly greater than those for "dembi" in a straight t-test. For "henti"/"hendi" this comparison would be meaningless because of the considerable anticipatory coarticulation (see Fig. 1).
A further motivation for examining velar activity in these groups of sounds was that in his cineradiographic recordings Pétursson /7/ had observed slight velar lowering in the preaspirates as well as in pre-vocalic /h/ and interpreted this as additional evidence for regarding preaspiration phonemically as /h/. We were unable to replicate this finding in our material; the pairs "seppi"/"sepi" and "hitti"/"hiti" clearly do not differ in velar activity (See Fig. 1). In both of these pairs the velum is lower in the vowels than in the adjacent occlusives, but this simply reflects the well-known differences in intrinsic velar height for these sounds /2/. In pre-vocalic /h/ (e.g "hitti", "henti") the velum can clearly take on a high or low position depending on the surrounding sounds. In fact, this dependence on the environment seems so complete that one could doubt whether /h/ has any intrinsic height specification at all.

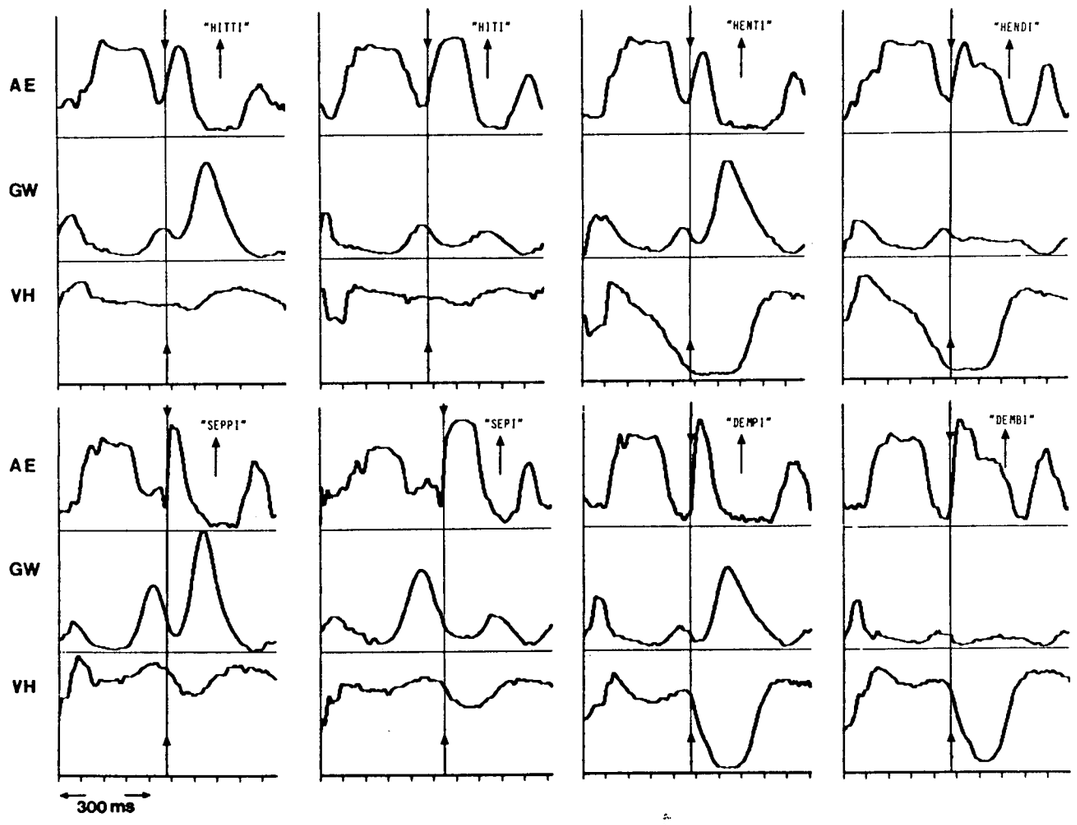

Fig.1 Averaged audio envelopes (AE), transillumination (GW), and velograph signals (VH), lined-up at onset of arrowed vowel.

DISCUSSION

The first question to consider here is the segmental status of preaspiration. Since we were unable to reproduce Pétursson's observations of velar behaviour in the preaspirates the main point is how much weight should be attached to comparisons of the length of preaspiration and other kinds of segment. In our material HC seems to be behaving like a single consonant since 1) preaspiration was shorter than the nasal segments in the nasal-plosive clusters, 2) the occlusion for preaspirated and unaspirated plosives is the same length, 3) plosive occlusions in the nasal-plosive clusters are much shorter than in the simple preaspirated or unaspirated plosives, 4) the shortening effect on the plosive of introducing a preceding nasal is virtually identical in the hypothetical preaspirated case and in the unaspirated case.

There is still perhaps an extremely cogent reason for retaining the segmental status of preaspiration; as Árnason points out /1/, words with preaspiration are given contrastive stress by lengthening the preaspiration phase, which in this respect behaves completely independently of the following plosive. It would be interesting to examine this phenomenon glottographically.

Turning to the glottal activity one could argue that the similarities for HC and NH suggest that two voiceless segments are present in both cases. However one might equally well point to the great difference between pre-vocalic and putative pre-consonantal /h/.

Thus this kind of argument does not get us very far, the same being true to a lesser extent for the segment-length arguments.

I believe that it is more fruitful to consider the aerodynamic and physiological constraints within which the language's contrasts must be produced.

Thus it is, for example, by no means clear that preaspiration and postaspiration of equal length are equally perceptually prominent, the one being superimposed on a closing, and the other on an opening movement of the vocal tract. Moreover, reliable devoicing with an unconstricted vocal tract, as at the beginning of the preaspiration phase, requires a large-amplitude glottal opening. This may explain why preaspiration does tend to be longer than postaspiration and perhaps also a less common phenomenon. Yet the fact that they are not perfect mirror-images of each other clearly need not mean that fundamentally different types of segment are involved.

The question of perceptibility may, as Pétursson has pointed out /9/, also explain why voiceless nasals are longer than voiced ones: these voiceless segments must be distinguishable from the quite large number of other voiceless segments that Icelandic can allow in this position.

We thus believe that up to this point there are no compelling reasons for regarding preaspiration as a separate segment, whether analyzed as an /h/ phoneme or as an auto-segment that has moved from the plosive where it originated.

This opens the way for viewing the existence of the voiceless nasals from the point of view of the speech motor system as a simple coarticulatory phenomenon. We would suggest that the voicelessness of the nasals is essentially a mirror-image of the voicelessness of the /l/ segment in English "plea". It was shown here that, as in the earlier German example, HC and NH share a very similar glottal gesture, but with reorganisation of the supra-glottal articulation. We would hypothesize that pairs such as "plea" and "pea" in English also superimpose a constant glottal gesture on reorganised oral articulation. While we believe that our results allow a coherent description of these sounds from a motor-speech perspective the restricted nature of the material examined naturally leaves a number of questions unanswered. In particular it would be desirable to include a more comprehensive range of voiced and voiceless continuants plus plosive in the description and to examine the realization of these sounds under contrastive stress.

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