Intervocalic fortis and lenis stops in a Norwegian dialect

Wim A. van Dommelen[1] & Catherine Ringen[2]
[1]Department of Language and Communication Studies, NTNU, Trondheim
[2]Department of Linguistics, University of Iowa

Abstract

This study looks into the realization of intervocalic fortis and lenis stop consonants produced by a group of subjects from the Trøndelag region in Norway. The speech material consisted of isolated words containing fortis and lenis stops occurring after phonologically long and short vowels. Three different places of articulation were included: bilabial, alveolar and velar.

The results of acoustic measurements show that the fortis stops are characterized by long durations, voicelessness and often some degree of preaspiration. The lenis stops have shorter durations and are often fully voiced. For the male speakers a somewhat larger degree of voicing was found than for the females. The relative amount of voicing was found to be inversely proportional to closure duration.

Introduction

Relatively little is known about the production of intervocalic fortis and lenis stops in Norwegian. In a study by van Dommelen (1999) the word pair /la:kə/ - /la:gə/ was investigated. A group of 24 subjects with different dialectal backgrounds served as speakers. Five subjects spoke dialects that are traditionally regarded to have preaspiration in fortis stops. It was shown, however, that also the other speakers often produced some form of preaspiration. Pooled across the whole group of speakers, 81 % of the closure duration was voiced. The relative amount of voicing was dependent on dialectal background, the values being 51 % for the "preaspiration" group and 91 % for the remaining speakers.

A more comprehensive study of Norwegian stops is the work done by Halvorsen (1998). She investigated fortis and lenis stops produced by speakers from three different dialect backgrounds spoken in Eastern Norway, Bergen and Trøndelag. The stops occurred in initial and intervocalic position. As to the intervocalic stops, Halvorsen remarks that in general the voicing of /b, d, g/ tapered off in the closure and ceased shortly before the release (p. 76-77). Such realizations were registered as having zero lead and her study does not report the amount of voicing in the consonantal closure. In addition, closure durations for intervocalic /p, t, k/ are given but not for /b, d, g/. Therefore, the present investigation was performed to shed more light on the realization of Norwegian stops.

Method

Speech material

The speech material for the present investigation consisted of 19 isolated disyllabic words. The test words contained intervocalic fortis *vs* lenis stops following a long *vs* short vowel. The places of articulation represented were bilabial (2 fortis, 4 lenis stops), alveolar (4 fortis, 4 lenis) and velar (3 fortis, 2 lenis). Vowel quality was not varied systematically. The words occurred in a list of in total 61 items in randomized order.

Subjects and recordings

Eleven subjects aged between 21 and 37 years were recruited to serve as speakers. Five of them were males, six females. All subjects had their dialect background from the Trøndelag region. Two speakers (one male, one female) were not purely monolingual but had English and Finnish, respectively, as a second language. According to impressionistic observation their pronunciation did not deviate from the dialect represented by the other speakers. Therefore, it was decided not to exclude them from the investigation. All subjects were paid for their participation.

Recordings took place in a sound-treated studio using a Milab LSR 1000 microphone. The microphone signal was recorded directly onto hard disk with 16 bit quantization and a sampling frequency of 44.1 kHz. Test words were presented one by one on a computer screen placed in front of the subject. In this way, all renditions were separated by pauses and list reading effects were avoided. The list of 61 words was read twice with different randomizations.

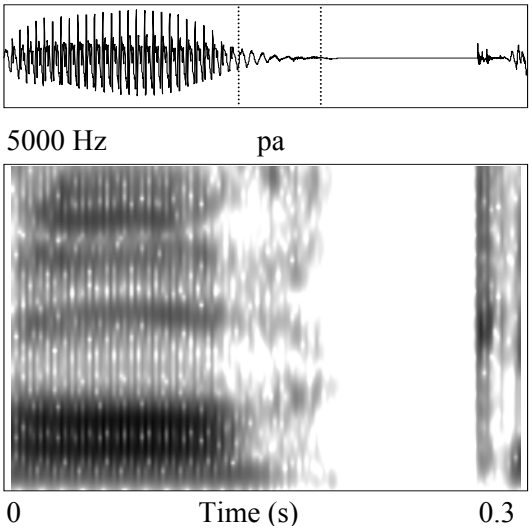

Figure 1. Vowel and intervocalic stop in "kake" produced by a female speaker. Preaspiration (pa) is indicated by dotted lines

Analysis

Measurements of segment durations were performed using the Praat program (Boersma & Weenink, 2006). In almost all words containing a fortis stop a manifestation of preaspiration could be observed. A preaspiration phase is usually characterized by a portion of breathy vowel quality that is followed by (often voiceless) friction. Accordingly, the following segment durations were measured: the preconsonantal vowel, the breathy part of the vowel, the friction, the consonantal closure and the postaspiration. In line with the convention chosen by Helgason (2002), "preaspiration" was defined as any period of breathy voicing plus following friction. Postapiration was defined as the stop release plus any period of friction. The criterion for the end of this period was the start of regular phonation for the following vowel.

Segments measured in words with an intervocalic lenis stop were the preconsonantal vowel, the voicing during the consonantal closure, the closure itself and the release burst. The criterion for the end of the release burst was the disappearance of friction noise.

Results

In the description of the results we will first look into two aspects of the stops, closure duration and voicing. Subsequently, the realization of pre- and postaspiration will be discussed followed by a presentation of the results for the preconsonantal vowel in its relation to the fortis *vs* lenis stops.

Closure duration and voicing

Evaluation of the measurement data showed that phonetic voicing is an important factor in the distinction of the intervocalic stops investigated here. The typical realization of a fortis stop involves some form for preaspiration (i.e., breathy voiced vowel portion followed by friction noise), a completely voiceless closure phase and an aspirated release (Fig. 1). In contrast to the relatively long closure of a fortis stop the closure phase of a lenis stop is shorter and characterized by the presence of phonetic voicing.

Table 1. Closure durations of fortis and lenis stops. Short= following /V:/, long= following /V/. Means and standard deviations in ms

		mean	sd	n
fortis	short	123	35	119
	long	202	65	62
	pooled	150	61	181
lenis	short	69	21	83
	long	153	51	125
	pooled	120	58	208

As can be seen from Table 1, pooled across all conditions and speakers the fortis stop closures were on average 30 ms longer than their lenis counterparts (150 ms vs 120 ms). Though relatively small, the difference is statistically significant ($t(387)= 4.991$; $p< 0.001$).

More conspicuous is the difference in voicing during the closure. On average, the lenis stops were almost fully voiced (approximately 93 % of the closure duration; Table 2). Thus it appears that the speakers made virtually optimal use of the voicing parameter to distinguish between the fortis and lenis stop categories.

Table 2. Amount of voicing in % in lenis stops. Short= following /V:/, long= following /V/

	gender	mean	sd	n
short	male	100.0	0.0	36
	female	97.0	11.1	47
	pooled	98.3	8.4	83
long	male	95.4	10.9	56
	female	85.7	22.2	69
	pooled	90.1	18.6	125
	overall	93.3	15.9	207

During the production of a voiced stop consonant, the transglottal air pressure difference will decrease gradually. As a consequence, voicing will cease when the closure phase exceeds a maximum duration. Through the inclusion of phonologically long and short vowels in the present speech material we could investigate whether there is a connection between stop closure duration and the relative amount of voicing in the stop. The data showed that this is indeed the case. Closure duration of a lenis stop following a long vowel appeared to be substantially shorter than following a short vowel (69 ms *vs* 153 ms; Table 1). Fully voiced closures were observed in 78 out of 83 short stops (corresponding to 94 %) as against 82 out of 125 (66 %) in long stops. Accordingly, the relative amount of voicing during the consonantal closure was significantly larger in the former than in the latter (Table 2: 98.3 % *vs* 90.1 %; $t(205)= 3.755$; $p< 0.001$).

Table 3. Correlation between closure duration and amount of voicing in % in lenis stops

Stop	r	p	n
short	-0.214	0.052	83
long	-0.714	<0.001	125
all	-0.626	<0.001	207

Further, the data revealed an effect of speaker gender on closure voicing in that the male subjects had somewhat stronger voicing than the females (97.2 % *vs* 90.3 %), but the effect of stop duration on relative voicing was found for both groups. An ANOVA showed that both gender and stop duration affected voicing ($F(1, 204)= 8.935$; $p< 0.001$ and $F(1, 204)= 13.852$; $p< 0.001$, respectively), while the interaction between these two factors did not reach significance ($F(1, 204)= 2.504$; $p= 0.115$).

To explore the production of voicing during the consonantal closure in more detail, the correlation between voicing and stop duration was calculated. The results of these calculations are presented in Table 3. The negative correlation coefficient of $r= -0.626$ across all lenis stops indicates that the proportion of voicing decreases with increasingly longer closure duration. For the category of short stops only a marginally significant correlation was found. This can be explained by the high proportion of fully voiced closures (94 %; see above), which therefore reduces the variation of the variable of relative voicing duration. For the long stops, however, a highly significant correlation ($r= -0.714$) was found. Taken together, the correlation data suggest that the production of voicing during stop closure is to a certain extent constrained by aerodynamic factors.

Pre- and postaspiration

In the production of fortis stops, preaspiration appeared to be one of the constituent parameters. Averaged across all speakers and voiceless stops preaspiration (i.e., breathy voiced vowel portion plus friction) was measured to have a duration of 41 ms. The duration of preaspiration turned out to be dependent on speaker gender, average values for the female speakers being larger than for the males (46 ms *vs* 35 ms). Contrary to the gender factor, vowel quantity did not affect preaspiration duration, being 41 ms on average after both long and short vowels. Further, preaspiration varied with place of articulation. Longest durations were observed for alveolar stops (45 ms), being slightly longer than for velars (42 ms), whereas bilabials had shortest preaspirations (32 ms). According to an ANOVA with gender, vowel quantity and place of articulation as factors the effect of gender was statistically significant ($F(1, 169)= 8.566$; $p= 0.004$). The same was true for place of articulation ($F(1, 169)= 6.597$; $p= 0.002$).

The measurements on postaspiration in fortis stops showed the following results. Pooled across all speakers and conditions, mean postaspiration duration amounted to 18 ms. This value is not so much larger than the one measured for the release of the lenis stops (10 ms). According to a t-test the difference is significant ($t(363)= 8.526$; $p< 0.001$). In congruence with previous results for other languages, place of articulation had a systematic influence on the duration of postaspiration.

Shortest durations were measured for bilabials (13 ms), somewhat longer durations for alveolars (17 ms) whereas velar stops had longest postaspiration (21 ms). The release bursts of the lenis stops showed the same duration pattern of bilabial (7 ms) < alveolar (11 ms) < velar (20 ms). An ANOVA with place of articulation and voicing status (fortis/lenis) as factors showed that both factors are significant ($F(2, 359)= 31.415$; $p< 0.001$ and $F(1, 359)= 19.379$; $p< 0.001$) with a significant interaction ($F(2, 359)= 3.248$; $p= 0.040$).

Preconsonantal vowel duration

Table 4 presents durations of the preconsonantal vowel in the test words. With a mean of 159 ms long vowels were approximately twice as long as short vowels. The influence of a following fortis *vs* lenis stop is much weaker for long vowels (188/139 = 1.35). For short vowels the corresponding ratio amounts to 87/49= 1.78. According to an ANOVA with vowel length and voicing status (fortis/lenis) of the stop both factors are statistically significant ($F(1, 386)= 1277.417$; $p< 0.001$ and $F(1, 386)= 267.056$; $p< 0.001$) with a significant interaction ($F(1, 386)= 4.373$; $p= 0.037$).

Table 4. Vowel durations in words containing fortis and lenis stops. Mean and standard deviation in ms

vowel	stop	mean	sd	n
long	fortis	139	29	120
	lenis	188	36	82
	pooled	159	40	202
short	fortis	49	10	62
	lenis	87	16	126
	pooled	75	23	188

Discussion

The group of speakers in the present investigation have been shown to be fairly homogeneous with respect to the realization of the fortis/lenis contrast in intervocalic stops. Fortis stops were reliably longer than their lenis counterparts and were preceded by shorter vowels. The voicing parameter substantially contributed to the distinction in that fortis stops lacked voicing while lenis stops were often fully voiced. For initial /b, d, g/ in Norwegian, Halvorsen (1998) found a bimodal distribution of voice onset time (voicing lead/lag) that was largely independent of speaker dialect. Unfortunately, her study does not answer the question of voicing distribution in the stops in intervocalic position.

Previous studies have gone into the question of which mechanisms lie behind consistent temporal differences as found for voiceless *vs* voiced consonants. Kluender, Diehl and Wright (1988) postulated general auditory contrast effects between segments of different duration. However, Fowler (1992) provided convincing evidence that this explanation is unlikely. It seems more probable that the physiologically oriented model proposed by Slis (1970) at least offers a partial explanation.

The longer preaspiration durations measured for the females compared to the males may be explainable by physiological factors (Fant, Kruckenberg and Nord, 1991). Further, it might be speculated that the generally smaller amount of voicing for the female speakers is caused by smaller dimensions of their vocal tracts, giving rise to earlier equalization of transglottal air pressure difference. The present gender effect on stop voicing is in line with Jessen and Ringen (2002) who found that women, but not men, showed failure to voice intervocalic velar stops in German.

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