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Quantity and Laryngeal Contrasts in Norwegian

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Abstract

This paper reports on the results of an investigation of the fortis-lenis contrast in stops and the complementary quantity contrast in Norwegian and compares these same contrasts in two dialects of Swedish. The data show that in initial position one series of stops has consistently long-lag Voice Onset Time (VOT) and this series is also voiceless in post-vocalic position, often with some preaspiration. The other series can be produced with either prevoicing or short-lag VOT in initial position and is almost always fully voiced in post-vocalic position. These results support the claim that both phonological features [voice] and [spread glottis] are active in Norwegian. The quantity contrast (VC: vs. V:C) was robust for all speakers, but the durational difference between the two quantity patterns was greater for females than for males. Overall the durational difference between the two quantity types in Norwegian was found to be similar to that in Central Standard Swedish, but not as great as in Fenno-Swedish.

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1. Introduction

In this paper we report on the results of an experiment focusing on stops in utterance-initial, intervocalic and utterance-final positions in the Trøndelag dialect (Mid-Norway), henceforth Tr-Norwegian. We investigated the fortis-lenis contrast and the complementary quantity contrast and compare these to two dialects of Swedish, Central Standard Swedish (henceforth CS Swedish) and Fenno-Swedish, a variety of Swedish spoken in Finland, also known as Finland Swedish.

Norwegian is known to have a two-way laryngeal contrast in stops, but, beyond that, there has been little discussion in the literature about the nature of that contrast, especially the nature of the lenis series. It is, of course, well-known that in some Germanic languages the stop contrast is between stops with long-lag Voice Onset Time (VOT), or aspiration, and stops with short-lag VOT in utterance-initial position (e.g. German and English), whereas in others (e.g. Dutch and Yiddish) the stop contrast is between stops with short-lag VOT or no aspiration and stops with negative VOT or prevoicing, in utterance-initial position (Iverson & Salmons, 1995; Keating, 1984; Lisker & Abramson, 1964). Ringen & Suomi (2012) have recently shown that Fenno-Swedish is another Germanic language like Dutch and Yiddish with a contrast between stops with short-lag VOT and negative VOT.

Recently, many phoneticians and phonologists have argued that for some languages the feature of laryngeal contrast is [spread glottis], henceforth [sg] (either [+sg] vs. [-sg] or privative [sg] vs. [∅]), not [voice], as has been traditionally assumed (Keating, 1984; Kingston & Diehl 1994, among others). According to the traditional view, both *true voice languages* such as Russian and Hungarian and *aspirating languages* such as English and German have a contrast between stops specified as [voice] and stops with no laryngeal specification (assuming privative features, as we do for the following discussion). According to the non-traditional view, the stop contrast in true voice languages is also between stops with the feature [voice] and stops with no laryngeal specification, but in aspirating languages the contrast is between stops specified as [sg] and stops with no laryngeal specification. The non-traditional view is supported by diachronic, synchronic and experimental evidence as well as evidence from child language acquisition (Beckman, Jessen & Ringen, 2013; Harris, 1994; Honeybone, 2005; Iverson & Salmons, 1995; Jessen, 1996, 1998; Jessen & Ringen, 2002; Kager et al., 2007 and Rice, 1994).

The implementation of the fortis-lenis contrast in utterance-initial position, by both prevoicing and aspiration, sets CS Swedish apart from other Germanic languages like German or English (with aspiration and no prevoicing) on the one hand, and Dutch, Yiddish and

Fenno-Swedish (with prevoicing and little or no aspiration) on the other. Helgason & Ringen (2008), Beckman, Helgason, McMurray & Ringen (2011) suggest that in CS Swedish the laryngeal contrast is between stops that are specified as [voice] and stops that are specified as [sg]; the stop contrast is *overspecified*. Specifically, a two-way laryngeal contrast can be represented with a single laryngeal feature (e.g., either [voice] or [sg]): One series is specified for the feature, the other is not specified for that feature. Hence, a two-way laryngeal contrast using two laryngeal features can be said to be overspecified. One of the main motivations for this study was to determine what the nature of the laryngeal stop contrast in Tr-Norwegian is, whether it is like the closely related CS Swedish in that it has both aspiration (pre and post) and prevoicing, whether it is like Fenno-Swedish with only prevoicing and no aspiration, or whether it is like other Germanic languages with aspiration and no prevoicing. We also wanted to investigate whether there are differences in the speech of males and females with respect to amount of (pre)voicing, preaspiration, and voicing during closure as has been reported in other studies (Helgason, Stölten & Engstrand, 2003; Karlsson, Zetterholm & Sullivan, 2004; Helgason & Ringen, 2008).

Most studies of voicing and aspiration have focused on utterance-initial stops. We investigated not only utterance-initial stops, but also intervocalic and final stops. These are important for the issue of what phonological features are active in a language. It has been claimed by advocates of the non-traditional view of laryngeal features that voicing of intervocalic stops in (some) aspirating languages is the result of *passive voicing* in a voiced environment, not from an *active voicing* which occurs in a true voice language (Iverson & Salmons, 1995; Jessen, 1996, 1998; Jessen & Ringen, 2002). As pointed out by Beckman et al. (2013), this means that there should be differences in the amount of closure voicing in the medial (and final) stops in aspirating and true voice languages.

Detailed phonetic information about the nature of the contrast in Norwegian – whether lenis[2] stops are prevoiced, whether fortis stops are (pre-)aspirated – is rather scarce. Vanvik (1972) analyzed the speech of a single speaker of Norwegian, reporting that the contrast in utterance-initial stops is between prevoiced and aspirated stops. Halvorsen (1998) investigated timing relations in fortis and lenis stops in spoken Norwegian. The production portion of her study reports mainly VOT values for stops in initial, medial and final position. Unfortunately, a number of issues were not investigated in her study: closure duration was measured for fortis but not for lenis stops. Positive VOT values are reported for lenis stops in

[2] For the sake of clarity the labels *fortis* and *lenis* are used for the two contrasting sets of stops without implying anything about the phonetic or phonological nature of the contrast.

intervocalic position, but no data on voicing during stop closure are given. Kristoffersen (2000:74) describes the phonetic realization of the fortis – lenis contrast in Norwegian as between an aspirated set and a voiced set. According to him, the voiced stops occur partially or fully (pre)voiced in onsets and are fully voiced intervocalically. Kristoffersen cites Endresen (1985: 94-96) who states that lenis stops are partially voiced (i.e., with voicing starting late in the closure) in utterance-initial position. Similarly, Hovdhaugen (1971: 161) specifies these stops as *half-voiced* (our translation). Thus, these authors' descriptions seem to imply that Norwegian lenis stops in utterance-initial position always show prevoicing, though to varying degrees. Their impressionistic observations are at odds with Halvorsen (1998), who found occurrences of both prevoicing and voice lag in lenis stops in utterance-initial position. Only intervocalic stops were investigated in van Dommelen & Ringen (2007).

In addition to our results for the laryngeal contrast in stops in Norwegian, in this paper we present information about the quantity contrast in Norwegian. There is little information in the phonetics literature about the Norwegian quantity contrast and whether it differs from the quantity contrast in the closely related varieties of Swedish. Most varieties of Norwegian are reported to allow only one of two quantity patterns in stressed syllables (cf., e.g., Kristoffersen 2000, 116-120): a short vowel in a stressed syllable must be followed by a long consonant (or by two qualitatively different consonants) and a long vowel in a stressed syllable must be followed by a short consonant. As a result, stressed syllables in Norwegian have a complementary durational relationship between the vowel and the following consonant. Kristoffersen states that an "exceptionless surface generalization is that a stressed syllable must be heavy" (p. 116). Since the phonetic realization of the voicing contrast in intervocalic and final position can be expected to be affected by quantity, it was necessary to consider quantity as well as voicing and aspiration. Thus, in this paper, in addition to our results for the laryngeal contrast in stops in Norwegian, we present information about the relationship between the Norwegian fortis/lenis contrast and the quantity contrast. Apart from shedding new light on the quantity contrast in Norwegian more generally, our results allow comparison with the phonetic manifestation of quantity in CS Swedish and Fenno-Swedish (Helgason et al., 2013).

2. Method

2.1. Speech material and recordings

The speech material used for this study consisted of a list of 25 words with an initial stop (16 lenis and 9 fortis), 19 words with an intervocalic stop (10 lenis and 9 fortis), and 15 words with a final stop (12 lenis and 3 fortis). In addition, some speakers realized canonically disyllabic words (e.g., *lade* [ˈlaːdə] ‘(to) load’) with apocope of the schwa, thus rendering them as monosyllables with a final lenis stop. In the analysis, these tokens were added to the corresponding 12 test words with a canonical final lenis stop. In all three positions (initial, medial and final) places of articulation represented were bilabial, alveolar and velar. The numbers of tokens within the three different categories varied. A number of words contained target consonants in more than one position (e.g., *pute* [ˈpʉːtə] ‘pillow’ with an initial as well as a medial stop). The target words contained both short and long vowels, however, without any systematic variation. In total, 43 different target words were used.

The 43 target words occurred together with 18 distracters. This list of 61 words was read twice with different randomized orders. Recordings took place in the sound-treated studio of the Department of Language and Communication Studies at NTNU using high-quality equipment. The microphone signals were high-pass filtered with a cut-off frequency of 50 Hz, digitized with a sampling frequency of 44.1 kHz and a 16-bit quantization, and stored on hard disk for further processing. Subjects read single test words from a computer screen. Presentation pace of the words was set by one of the experimenters sitting in a control room. The word list is given in the Appendix.

2.2. Subjects

Eleven subjects aged between 21 and 37 years were recruited to serve as speakers. Five of them were males, six females. All subjects had grown up in the Trøndelag region. Two speakers (one male, one female) were not purely monolingual, but spoke 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. More importantly, this impression was confirmed by the instrumental analysis of the recordings. Therefore, they were included in the investigation. All subjects were paid for their participation.

2.3. Measurements and statistical treatment

Measurements of segment durations were performed using Praat (Boersma & Weenink, 2009). While Norwegian fortis stops in initial position usually are produced with relatively strong aspiration, stops in intervocalic position have less postaspiration. In the measurements, postaspiration was defined as the duration of 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. In utterance-final position, the end of a stop's aspiration is much harder to define. For all practical purposes the onset of normal expiration was used as a criterion. As a rule, this segmentation point was determined by a relatively abrupt decrease in spectral energy. It can be expected that, due to both measurement uncertainty and differences in speaker behavior, aspiration duration for final stops will vary more than for non-final stops.

In utterance-initial lenis stops, prevoicing was measured as the interval between the onset of voicing and the onset of the stop release (cf. Fig. 1). Voice lag was measured as the interval between the onset of the release and the start of regular phonation for the following vowel. In intervocalic and utterance-final lenis stops, voicing was measured as the interval between the end of the preceding vowel (determined by a steep fall in signal amplitude and formant intensity) and the cessation of periodicity within the stop closure.

In almost all words containing a fortis stop in intervocalic position, a certain degree of preaspiration was observed. Preaspiration precedes stop closure and manifests itself as a period of breathy vowel quality followed by (often voiceless) friction produced at the glottis. Following the convention used by Helgason & Ringen (2008), "preaspiration" was defined as any period of breathy voicing plus following friction (cf. Fig. 1).

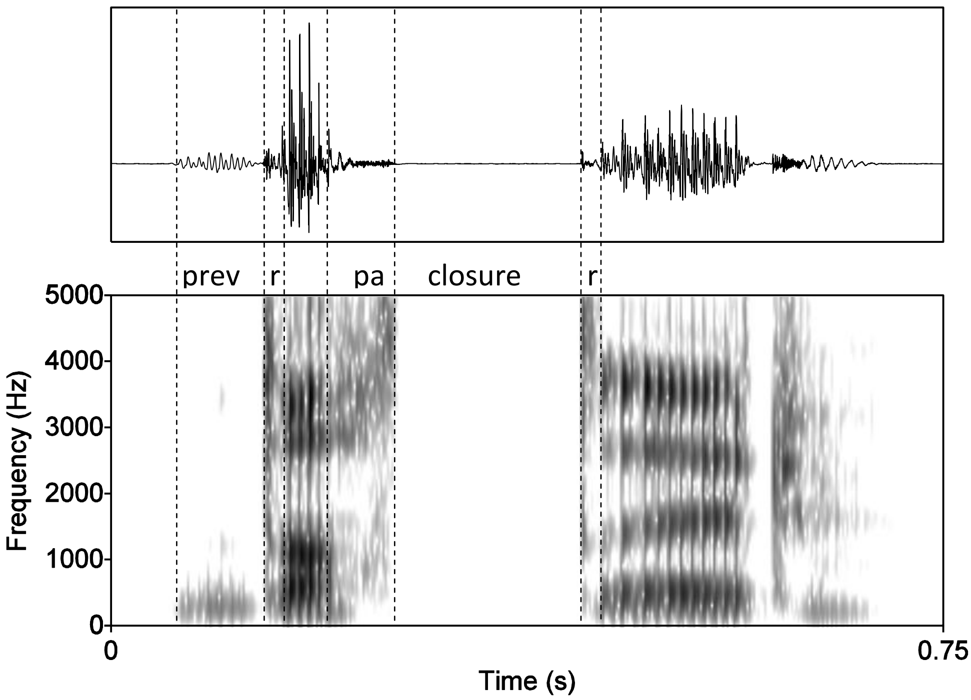

Figure 1
Waveform and spectrogram of the word 'datter' (daughter) produced by a male speaker. Relevant segments are indicated. prev= prevoicing; r= release; pa = preaspiration.

All data were statistically analyzed using the R program's package lme4 (R Core Team, 2012) to calculate Linear Mixed Effects Models (LMEM; Barr et al., 2013; see also Baayen, 2008). Each analysis started by defining a null model and subsequently, to assess the significance of single factors and interactions, likelihood ratio tests were performed comparing the null model with a model without the factor under scrutiny. As a rule, only statistically significant (α = 0.05) results are reported. For further details, see design specifications in section 3.

3. Results

3.1. Utterance-initial lenis and fortis stops

Measurement results for lenis and fortis stops in utterance-initial position are presented in Table 1. As can be seen, VOT distributions are different for the two types of stops. While fortis stops were consistently produced with relatively long voice lag (mean VOT = +52 ms), the VOT distribution for lenis stops is bimodal: 37 % of the lenis stops had prevoicing (mean -75 ms), whereas 63 % were produced with voice lag (mean +17 ms). Figure 2 shows that there was considerable between-subject variation in the production of lenis stops. One subject prevoiced almost 90 % of her initial lenis stops whereas two subjects produced only about 10 % of such stops with prevoicing. Subject PH (male) had no prevoicing at all. Females prevoiced more frequently than males (43 % vs. 30 %) and their prevoicing was longer (-81 ms vs. -64 ms). Also, the amount of postaspiration in fortis stops was somewhat longer for females than for males (+55 ms vs. +48 ms). To investigate these effects, LMEM analyses were carried out with stop type (fortis; lenis) and speaker sex as fixed factors with by-subject random intercept and slope for stop type and by-item random intercept and slope for speaker sex. Place of articulation was not included because its effect can be expected to be different for voice lead and voice lag values. (It is included in further analyses, see below.) Comparison of the full model with a model without stop type revealed that this factor was significant

Table 1. Utterance-initial lenis and fortis stops. Voicing lead (-VOT) and lag (+VOT) in ms and frequency of occurrence (n and in %). sd = standard deviation.

	lenis									fortis		
	total n	-VOT	sd	n	(%)	+VOT	sd	n	(%)	n	+VOT	sd
Females	192	-81	38	82	43	16	7	110	57	108	55	20
Males	160	-64	27	48	30	17	7	112	70	90	48	14
Pooled	352	-75	35	130	37	17	7	222	63	198	52	18

($\chi^2(1)= 19.5$; $p < 0.001$). However, neither the factor speaker sex nor its interaction with stop type reached statistical significance.

In view of the bimodal distribution of VOT values for the lenis stops, two further LMEM analyses were performed. First, the lag values for lenis stops (17 ms) were compared with those for fortis stops (52 ms). LMEMs included stop type (fortis; lenis), place of articulation (bilabial, alveolar, velar) and speaker sex as fixed factors with by-subject random intercepts and slopes for the two fixed factors and by-item random intercept and slope for speaker sex. Whereas the effect of stop type was significant ($\chi^2(1)= 26.4$; $p < 0.001$), this was not the case for place of articulation. There were no other significant effects. Second, a separate analysis of the prevoiced lenis stops was run including place of articulation and speaker sex as fixed factors with by-item random intercept and slope for speaker sex and by-subject random intercept and slope for place of articulation. The analysis revealed that voice lead in bilabials was somewhat longer than in alveolar and velar stops (-80 ms vs. -72 ms and -73 ms, respectively). Presumably due to the relatively small number of observations, however, this effect did not reach statistical significance. Also, the factor speaker sex did not reach significance.

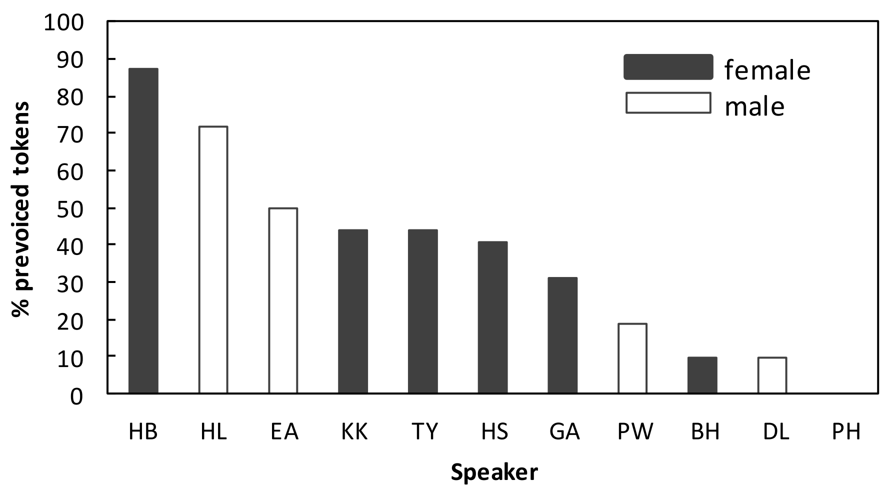

Figure 2
Percentage of initial lenis stop tokens produced with prevoicing ranked for individual speakers.

3.2. Intervocalic and utterance-final lenis and fortis stops

In this section, different aspects of stops in intervocalic and utterance-final position are investigated. Section 3.2.1 focuses on the issue of temporal organization of VC dyads (vowel, closure, and release[3] duration). The next section deals with the production of voicing during the closure of lenis stops. Finally, in section 3.2.3 results for preaspiration in fortis stops are reported.

3.2.1. Quantity

Statistical evaluation using LMEM included the fixed factors stop type (fortis, lenis), stop length (short, long), stop position (intervocalic, utterance-final) and speaker sex with by-subject random slopes and intercepts for the first three factors and by-item slope and intercept for speaker sex. Investigating voicing (section 3.2.2) and preaspiration (section 3.2.3), the factor stop type was omitted from the analyses since these parameters are only relevant for one of the two stop types lenis/fortis each.

Mean vowel, closure and stop release durations pooled across male and female speakers are presented in Figure 3. Statistical analysis revealed that long vowels were reliably longer than short ones (mean difference: 88 ms; $\chi^2(1)= 42.4$; $p < 0.001$), longer in final vs. intervocalic position (mean difference: 27 ms; $\chi^2(1)= 19.1$; $p < 0.001$) and longer before lenis than fortis stop (mean difference: 23 ms; $\chi^2(1)= 29.2$; $p < 0.001$). While speaker sex had no significant effect, there was a significant speaker sex by stop length interaction ($\chi^2(1)= 4.96$; $p = 0.026$). This interaction is because males had shorter long vowels than females, while their short vowels showed the opposite tendency (see Tables 2-5). The only other significant interaction was between stop length and type, caused by the generally larger long vs. short vowel duration difference before lenis vs. fortis stop ($\chi^2(1)= 14.7$; $p < 0.001$).

Somewhat different results were obtained for closure duration. Short stops had reliably shorter closure durations than long ones (on average 57 ms; $\chi^2(1)= 22.1$; $p < 0.001$) and fortis stops were longer than their lenis counterparts (27 ms; $\chi^2(1)= 25.3$; $p < 0.001$). There was, however, no significant effect of stop position. The same was true for the factor speaker sex. As can be seen from Figure 3b, stop position affected both fortis and lenis closure durations in short but not in long stops. This observation is supported by the significant interaction of this factor with stop length ($\chi^2(1)= 13.1$; $p < 0.001$). There were no other significant interactions.

[3] In the following, we will use the term *release* to denote mere stop release as well as stop release followed by aspiration.

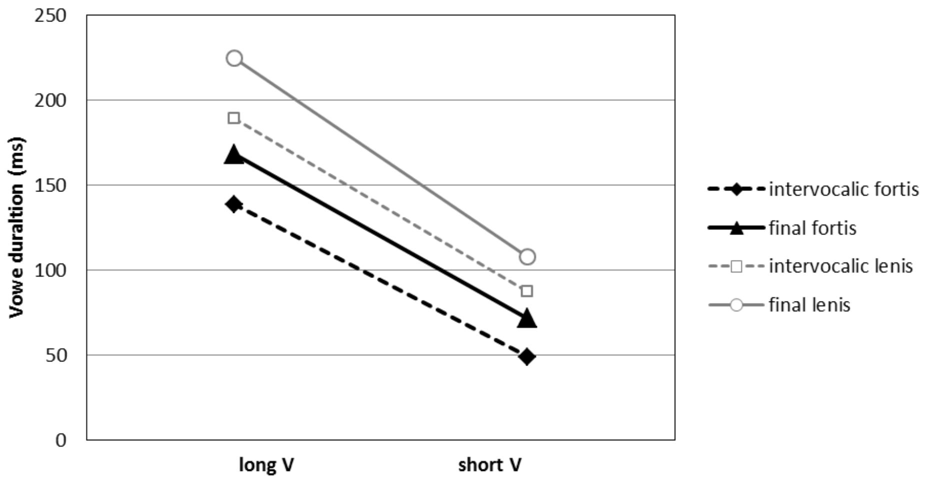

Figure 3a

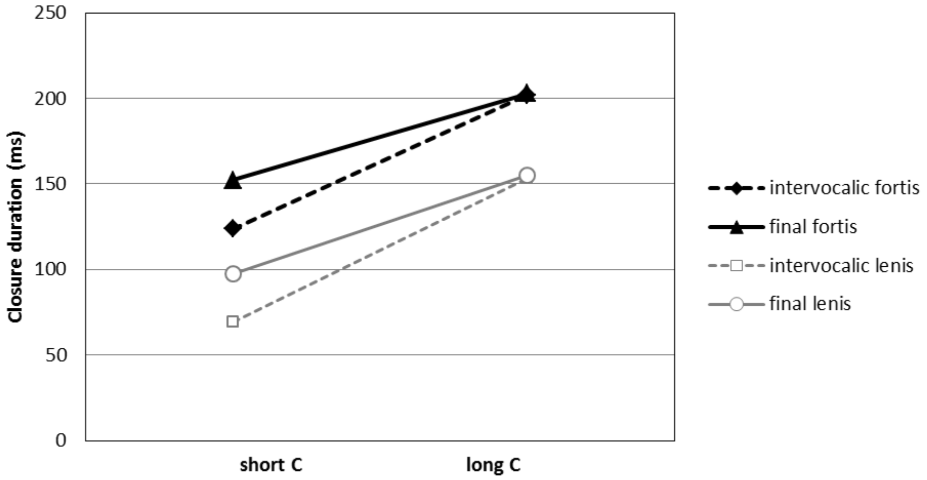

Figure 3b

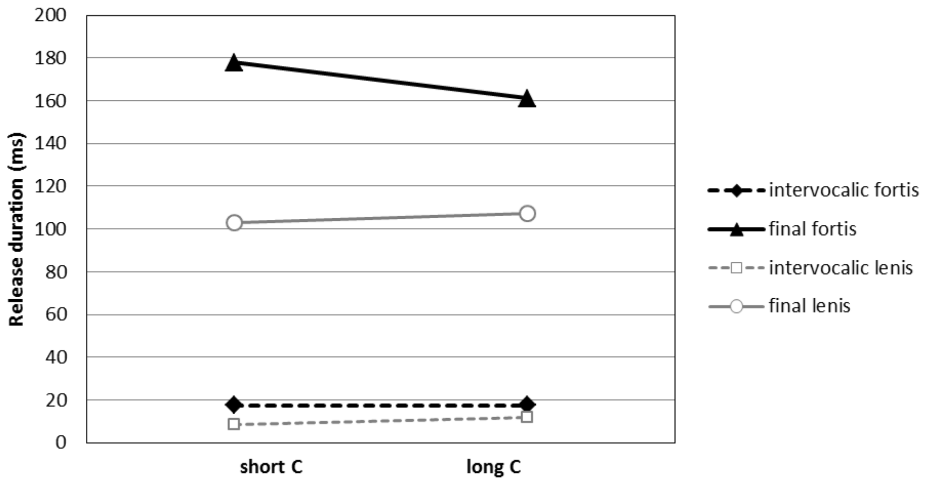

Figure 3c

Figure 3
Vowel (3a), closure (3b) and stop release (3c) durations in ms in tokens containing short and long stops (C) in intervocalic and utterance-final position.

The general picture for stop release duration differed from the effects observed for vowel and closure duration (cf. Fig. 3c). Short and long stops had similar release durations (59 ms and 65 ms; non-significantly different). As there was no significant interaction between stop length and stop position, this appeared to be true for both intervocalic and final stops. In contrast, release duration was much longer for final than intervocalic stops (119 ms vs. 14 ms; $\chi^2(1)= 29.0$; $p < 0.001$). Release durations were similar for fortis and lenis stops in intervocalic position (17 ms vs. 10 ms) but substantially different in utterance-final position (173 ms vs. 106 ms). This is underpinned by the significant stop type by stop position interaction ($\chi^2(1)= 39.1$; $p < 0.001$). Neither the effect of speaker sex nor the interactions of this factor with stop type, stop length and stop position reached significance.

Table 2. Intervocalic lenis stops. Vowel (V), stop closure (C) and release (Rel) duration in ms; amount of stop voicing (Voice) in ms and in %. sd = standard deviation.

		n	V	sd	C	sd	Voice (%)	sd (%)	Rel	sd
Short C	Females	47	204	37	76	20	73 (97)	21 (11)	8	7
	Males	36	169	27	61	18	61 (100)	18 (0)	9	9
	Pooled	83	189	37	69	21	68 (98)	20 (8)	9	8
Long C	Females	69	84	14	174	56	140 (86)	40 (22)	10	5
	Males	56	91	17	128	27	121 (95)	24 (11)	14	15
	Pooled	125	87	16	153	51	131 (90)	35 (19)	12	11
Overall		208	128	56	120	58	106 (93)	43 (16)	10	10

Table 3. Intervocalic fortis stops. Vowel (V), stop closure (C), preaspiration (PrA = breathy vowel + frication) and release (Rel) duration in ms. sd = standard deviation.

		n	V	sd	PrA	sd	C	sd	Rel	sd
Short C	Females	69	146	31	47	27	137	35	16	5
	Males	50	128	23	34	15	105	22	20	7
	Pooled	119	139	29	42	23	124	34	17	6
Long C	Females	36	47	11	43	21	231	65	17	5
	Males	26	53	7	37	10	162	40	19	6
	Pooled	62	49	10	41	18	202	65	18	5
Overall		181	108	49	41	21	151	60	17	6

Table 4. Utterance-final lenis stops. Vowel (V), stop closure (C) and release (Rel) duration in ms; amount of stop voicing (voice) in ms and in %. sd = standard deviation.

		n	V	sd	C	sd	voice (%)	sd (%)	Rel	sd
Short C	Females	48	233	56	99	26	88 (89)	27 (14)	122	57
	Males	44	215	36	96	23	85 (89)	22 (15)	82	29
	Pooled	92	225	48	98	24	86 (89)	24 (15)	103	49
Long C	Females	96	106	20	160	40	132 (86)	33 (21)	119	43
	Males	83	110	25	149	26	123 (84)	28 (18)	93	31
	Pooled	179	108	22	155	34	128 (85)	31 (19)	107	40
Overall		271	147	65	135	41	114 (86)	35 (18)	106	43

Table 5. Final fortis stops. Vowel (V), stop closure (C), preaspiration (PrA = breathy vowel + frication) and release (Rel) duration in ms. sd = standard deviation.

		n	V	sd	PrA	sd	C	sd	Rel	sd
Short C	Females	25	175	46	33	27	155	36	211	76
	Males	20	159	27	21	14	148	20	139	45
	Pooled	45	168	39	27	23	152	30	178	73
Long C	Females	11	67	16	35	20	211	47	174	84
	Males	10	77	19	26	17	194	34	146	45
	Pooled	21	72	18	31	19	203	41	161	68
Overall		66	137	56	28	22	168	41	173	71

3.2.2. Voicing

In evaluating voicing production during stop closure, the amount of voicing is expressed as percent of total closure duration. In this way, variation of voicing duration due to experimental conditions (short vs. long stop, intervocalic vs. utterance-final position) as well as unsystematic factors like varying speech rate are eliminated, thus enabling comparisons across all conditions. Inspection of the data revealed that most lenis stops in intervocalic and final position were fully voiced or almost fully voiced. For these positions mean percentages of voicing during the closure were 93 % (range: 20 % – 100 %; median: 100 %) and 86 % (range: 14 % – 100 %; median: 93 %), respectively (cf. Tables 2 and 4). Statistical analysis revealed that the effect of stop position was statistically significant ($\chi^2(1)= 4.68$; $p = 0.031$). Further, stop length affected voicing similarly (short vs. long stop: 94 % vs. 87 % voiced, respectively; $\chi^2(1)= 16.1$; $p < 0.001$), while the stop position by length interaction did not reach significance. Pooled across all conditions, male and female speakers had very similar amounts of voicing (91 % and 88 %, respectively; non-significantly different). The difference in voicing for short vs. long stops was somewhat larger for female than for male speakers (93 % - 86 % = 7 % vs. 94 % - 89 % = 5 %), but the stop length by speaker sex interaction did not reach statistical significance.

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. To explore the issue of voicing production during consonantal closure in more detail, the correlation between voicing (expressed in percent of closure duration) and closure duration was calculated. A Pearson product-moment correlation analysis indicated that across all lenis stops in intervocalic position the proportion of voicing decreased with increasingly longer closure duration ($r = -0.632$; n = 208; $p < 0.001$). For the category of short intervocalic stops only a weak correlation was found ($r = -0.226$; n = 83; $p = 0.040$). This can be explained by the high proportion of fully voiced closures in short stops (94 % vs. 66 % in long stops), which therefore reduced the variation of relative voicing duration. For the long intervocalic stops, however, the correlation between stop closure duration and amount of voicing was much stronger ($r = -0.714$; n = 125; $p < 0.001$). Generally weaker correlations were found for stops in utterance-final position: for short stops $r = -0.217$ (n = 92; $p = 0.038$), for long stops $r = -0.529$ (n = 179; $p < 0.001$). These weaker correlations cannot be due to frequent occurrence of fully voiced closures in utterance-final position, since only 53 % of the short stops and 41 % of their long counterparts were completely voiced (recall that 94% of the short intervocalic stops were fully voiced). In any event, our data seem to indicate that with longer closure durations aerodynamic factors constrain the relative amount of stop voicing to some extent.

3.2.3. Preaspiration

There was a moderate amount of preaspiration in intervocalic as well as utterance-final fortis stops (pooled across both sexes and long and short consonants 41 ms and 28 ms, respectively; cf. Tables 3 and 5). Probably due to relatively large scatter in the data, the effect of position failed to reach statistical significance (cf. standard deviations of around 20 ms; $\chi^2(1)= 3.31$; $p = 0.069$). In spite of the differences between the mean values for female vs. male speakers (intervocalic stops: 46 ms vs. 35 ms; utterance-final stops: 33 ms vs. 23 ms), the factor sex did not reach statistical significance. Closer inspection of the data showed that the larger average values for the females are mainly due to long preaspiration for one female (intervocalic: 83 ms; utterance-final: 71 ms). Removing the data for this speaker resulted in much more similar average values for females vs. males: 38 ms vs. 35 ms for intervocalic stops and 26 ms vs. 23 ms for utterance-final stops.

4. Discussion

4.1. Utterance-initial lenis and fortis stops

4.1.1. Utterance-initial lenis stops

The results for prevoicing of lenis stops in utterance-initial position for Norwegian reported by Halvorsen (1998) are similar to those of our subjects. Seven out of her nine subjects produced lenis stops with varying degrees of voicing lead and voicing lag as did ten of our eleven subjects. Two of her subjects had essentially only voicing lead and one of our subjects had voicing lead in almost 90 % of her lenis stops. Among the subjects showing bimodal distributions, three of Halvorsen's subjects had the same dialectal background as our speakers (Trøndelag dialect), two had a Bergen dialect and two an Eastern Norwegian dialect. Pooled across all nine of Halvorsen's speakers the mean voicing lead value was -94 ms, somewhat larger than the value for our subjects of -75 ms, possibly due to speaking rate differences between the two groups of subjects or differences in the measurement techniques. Still more similar are the mean voicing lag values for the lenis stops in the two investigations (Halvorsen: 14 ms; present: 17 ms). Thus, given these empirical results, the traditional description of Norwegian lenis stops in initial position as consistently prevoiced (Hovdhaugen, 1971; Endresen, 1985; Kristoffersen, 2000; Vanvik, 1972) is not supported by our results. It might be that that the earlier claims are not accurate, that a change is underway, or both. Since most of the previous claims about prevoicing were not based on acoustic analysis, we cannot say whether they are accurate, but we do suggest that if they are, a change is occurring and that there is an increasing tendency for Norwegian speakers to have less prevoicing.

With a clearly bimodal distribution of VOT values for lenis stops, Norwegian obviously differs from closely related CS Swedish, the variety spoken in Stockholm, and Fenno-Swedish, the variety of Swedish spoken in Finland. For CS Swedish, Helgason & Ringen (2008) report that their six subjects exhibited robust prevoicing in utterance-initial lenis stops (mean -88 ms) with 93 % of the tokens exhibiting more than 10 ms of prevoicing. Ringen & Suomi (2012) report that their twelve Fenno-Swedish speaking subjects exhibited prevoicing in utterance-initial lenis stops (mean -80 ms) in 87 % of the tokens. The amount of prevoicing in utterance-initial lenis stops produced by our subjects is also less than reported for Dutch van Alphen & Smits (2004): 75 % of their subjects' utterance-initial lenis tokens exhibited prevoicing compared to 37 % of ours. Although this percentage is lower than the percentages of lenis stops with prevoicing in utterance-initial position in CS Swedish, Fenno-Swedish, and Dutch, it is also very different from those reported for (GB) English speakers by Docherty (1992): only 7 % of Docherty's five subjects' tokens of initial lenis stops exhibited prevoicing, with one subject responsible for almost all of the prevoiced tokens.

The profile of Docherty's speakers is similar to that reported by Jessen (1998) for German. Only one subject was responsible for almost all of the prevoiced tokens in both cases. Similarly, only a few lenis stops were produced with prevoicing by the four American English speakers in Kessinger & Blumstein (1997).

In contrast to the studies of English speakers in Docherty's and Kessinger & Blumstein's studies, most of the ten speakers of American English in Flege (1982) showed prevoicing. Prevoicing was observed in stops occurring in minimal pairs (56 %) and even more often in non-minimal pairs (61 %). There are several reasons that these figures are probably not representative of American English speakers' prevoicing, however. First, one of the speakers, who was bilingual in Spanish and English, was one of four speakers who typically produced only prevoiced stops. Flege suggests the fact that this speaker prevoiced stops in English is "consistent with the observation that Spanish-English bilinguals prevoice in English (where it is optional) just as they do in Spanish (where it is linguistically required; Williams 1977)…" Second, half of the subjects had training in phonetics and there were only two test words recorded: *pay* and *bay*. Even for subjects not trained in phonetics, the object of the experiment would most likely have been clear and subjects may well have exaggerated the difference between *pay* and *bay*, both when asked to produce minimal pairs and when asked to repeat *bay* ten times (the so-called "non-minimal pairs"), and then to repeat *pay* ten times. And finally, the only stops in Flege's study were bilabial, whereas, in the other studies, other places of articulation are reported. Since the number of tokens with prevoicing is often greater for bilabials than for other places of articulation, the fact that there were only bilabials in Flege's study may have contributed to the higher percentage of stops with prevoicing in his study. For further discussion of methodological problems with studies of voicing, see Kharlamov (2012).

4.1.2. *Utterance-initial fortis stops*

The traditional description of Norwegian fortis stops as being aspirated is supported by our study as well as by that of Halvorsen (1998) where strong aspiration in utterance-initial fortis stops was found (mean VOT values of +52 ms and +65 ms, respectively).

The reported voicing lag value for utterance-initial fortis stops in CS Swedish (Helgason & Ringen, 2008) was +64 ms, similar to the value for Norwegian in our study. In contrast, the voicing lag value of +36 ms for utterance-initial fortis stops in Fenno-Swedish (Ringen & Suomi, 2012) is different from both CS Swedish and Norwegian.

4.2. Intervocalic and utterance-final lenis and fortis stops

4.2.1. *Quantity*

Following Helgason, Ringen & Suomi (2013) we estimate the degree of the durational separation between the two quantity types by considering comparable word types for each quantity. First consider how much the proportion of the vowel in the VC-sequence (V/(V+C)[4], henceforth referred to as V %; see Table 6) differs between V:C with a lenis stop and VC: with a lenis stop, in intervocalic position. From Table 6 we can see that, pooled across females and males, the durational separation is 35 percentage points (pps). The separation between V:C with a fortis stop and VC: with a fortis stop in intervocalic position is 28 pps. Corresponding values for CS Swedish given by Helgason, Ringen & Suomi (2013) are slightly lower (32 pps and 23 pps, respectively). For utterance-final lenis stops, the values

Table 6. Proportion of vowel (V%) in VC structures (V/[V+C]) for different consonant positions and quantity types. Diff.: degree of durational separation between VC: and V:C (as percentage points). NB For fortis stops, vowel duration includes preaspiration.

		Intervocalic			Utterance-final		
		V:C	VC:	Diff.	V:C	VC:	Diff.
Lenis	Females	73	34	39	70	40	30
	Males	74	42	32	69	42	27
	Pooled	73	38	35	69	41	28
Fortis	Females	59	29	30	57	33	24
	Males	61	37	24	55	35	20
	Pooled	60	32	28	56	34	22

[4] To allow comparison with data for Swedish presented in Helgason et al. (2013), for fortis stops vowel duration includes preaspiration.

for Norwegian are higher than the corresponding ones for CS Swedish (Norwegian: 28 pps vs. CS Swedish: 18 pps), while the values for utterance-final fortis stops are similar (22 pps vs. 21 pps). So, in general our Norwegian subjects' separation between the two quantity types is similar to what has been found for the CS Swedish subjects with the exception of utterance-final lenis stops. In all cases, however, Fenno-Swedish has a greater separation between the two quantity types than do either CS or Tr-Norwegian (Helgason et al., 2013). On average, Fenno-Swedish exceeds CS by approximately 13 pps and Tr-Norwegian by 9 pps for all conditions except long vowel followed by an intervocalic fortis stop (see next paragraph).

In Fenno-Swedish, Helgason et al. (2013) report that speakers split into two distinct subgroups in their production of disyllabic words with a long vowel and an intervocalic (short) fortis stop (i.e. words with a structure like *baka*). This is unlike Tr-Norwegian and CS Swedish, where all speakers behave uniformly. One group of Fenno-Swedish speakers has a V% of 71 %, the other has a V% of 50 %. In CS Swedish, the V% is 55 % in this word type, in Tr-Norwegian it is 60 %.

4.2.2. Voicing

In Tr-Norwegian, intervocalic short lenis stops pattern with intervocalic lenis stops in languages such as CS Swedish, Fenno-Swedish, Serbian, Russian and Hungarian, languages which have been argued to have an active [voice]. In intervocalic position, we found that short lenis stops were characterized by almost full voicing (94 % of the short lenis stops were fully voiced, mean voicing 98% of closure). Long lenis stops were somewhat less fully voiced (66 % of the long lenis stops were fully voiced), similar to the reports for CS Swedish where short intervocalic short lenis stops were almost all completely voiced and where intervocalic long lenis stops were voiced for more than 50 % of the closure for all subjects and for over 75 % of the closure for all but two subjects (Helgason & Ringen, 2008). In Fenno-Swedish, 80 % of the short intervocalic lenis stops were fully voiced as compared to 52 % of the corresponding long stops (Ringen & Suomi, 2012). Sokolović-Perović (2012) reports that 95.2 % of the Serbian (short) intervocalic (word-initial, sentence-medial) lenis stops in her study were fully voiced. In one recent study of Russian, 97.5 % intervocalic lenis stops were pronounced with voicing during the entire closure (Ringen & Kulikov, 2012). Similarly, Gósy & Ringen (2009) report that in a study of Hungarian speakers in Budapest, 95.5 % of all the intervocalic lenis stops were fully voiced. In contrast, the voicing in intervocalic lenis short stops in these languages is quite different from the voicing reported for German and English, which is often classified as *passive voicing*, meaning that it does not result from an active voicing gesture on the part of the speaker, but rather from the voicing of adjacent segments. Only 62.5 % of the intervocalic German (short) stops in Jessen's (1998) study were voiced for more than 90 % of the closure (Beckman et al. 2013), and Docherty (1992) reports that in medial position (word-initial before a voiced sound as in *Say **b**ags instead*) his subjects produced almost all lenis stops with "interrupted medial voicing" (page 119f), that is, most are not fully voiced. Hence, the voicing in intervocalic lenis stops in Tr-Norwegian is more like the voicing of intervocalic lenis stops in true voice languages than in aspirating languages.

In Tr-Norwegian, final lenis stops pattern with final lenis stops in true voice languages with no word-final devoicing, such as CS Swedish, Hungarian, and Serbian. Gósy & Ringen (2009) found that in Hungarian the word-final lenis stops had robust voicing, similar to what Helgason & Ringen (2008) found in Swedish. Ringen & Suomi (2012) found that the mean percentage of closure that was voiced in final lenis stops in Fenno-Swedish was 73 %. Soković-Perović reports that in Serbian, utterance final lenis stops were voiced for an average of 62 % of the closure. For Norwegian we found that the mean voicing of final lenis stops was 86 % of closure.

4.2.3. Preaspiration

With respect to the realization of intervocalic and prepausal fortis stops, our results for Tr-Norwegian are similar to those reported for CS Swedish by Helgason & Ringen (2008) who measured a mean preaspiration duration of 44 ms, which is very close to the present study's value of 41 ms of preaspiration in intervocalic fortis stops. Fenno-Swedish, in contrast, is reported to have no preaspiration (Ringen & Suomi, 2012).

4.3. Feature(s) of contrast

Earlier descriptions of Norwegian (based on impressionistic observations) are similar to the description of CS Swedish reported by Helgason & Ringen (2008). We suggest that Tr-Norwegian may be undergoing a change. If earlier descriptions are accurate, it is changing from a language in which, like Swedish, the stop contrast is between stops that are specified as [voice] and stops that are specified as [sg] to a language like English and German in which the contrast is between stops specified with [sg] and stops with no specification. If, on the other hand, prevoicing and robust intervocalic and final voicing in lenis stops is new, it is becoming more like CS Swedish, that is, it is changing from a language like English and German to one like CS Swedish.

The development in Fenno-Swedish gives a clue about the changes that have occurred in Tr-Norwegian. The Swedish speaking ancestors of Fenno-Swedish speakers first settled in Finland about eight hundred years ago. Ringen & Suomi (2012) suggest that Fenno-Swedish developed from a variety of Swedish that is like CS Swedish in its laryngeal characteristics, with both prevoicing and aspiration. They argue that the fact that Fenno-Swedish lacks aspirated stops, but has (pre)voiced stops, is the result of influence of Finnish (which lacks aspirated stops as well as voiced stops). It would be difficult to understand how Fenno-Swedish could have developed *voiced stops* through contact with a language that *lacks* voiced stops. Assuming that Ringen & Suomi (2012) are right that the variety of Swedish spoken by the Swedish settlers in Finland over eight hundred years ago had both prevoicing and aspiration, as is found in present-day CS Swedish, it is not unreasonable to assume that the closely related Tr-Norwegian also exhibited a similar stop system at an earlier time and there is more phonetic variation today than was found earlier.

We have seen that Tr-Norwegian utterance-initial stops are not as robustly voiced as they are in Fenno-Swedish and Swedish, but there is substantially more prevoicing than is found in German and English, which we take as one indication that the lenis stops are specified as [voice] in Tr-Norwegian. Since the fortis stops exhibit the same aspiration as in CS Swedish, there is little question that the fortis stops are specified as [sg].

The behavior of the lenis stops in intervocalic and final positions in Tr-Norwegian is a second indication that they are specified as [voice]: their behavior is similar to intervocalic and word-final stops in CS Swedish and Fenno-Swedish where it has been argued that lenis stops are specified as [voice]. In these positions, we found robust voicing, similar to what has been found in Fenno-Swedish and CS Swedish as well as in true voice languages where it is clear that the lenis stops are specified as [voice] (see section 4.2.2). In all three languages, the percentage of the closure that was voiced in long, lenis stops was less than for short, lenis stops. This is because the production of voicing during stop closure is constrained by aerodynamic factors.

Based on the fact that Tr-Norwegian lenis stops exhibit substantially more prevoicing than has typically been found in aspirating languages and also exhibit robust intervocalic and final voicing, similar to that found in true voice languages, we suggest that the stop contrast in Tr-Norwegian, like CS Swedish, involves both [voice] and [sg]. This means that the implementation of the feature [voice] with vocal fold vibration is not required in Tr-Norwegian as strictly as it is in CS Swedish in all positions. This is similar to the implementation of [sg] as preaspiration in CS Swedish (and Norwegian), which occurs very frequently, but not for all speakers (see Helgason, 2002 for discussion).

Helgason (2002) suggests that phonetic variation, such as we have found in initial lenis stops in Tr-Norwegian can lead to phonological change. The subjects we recorded have voicing to varying degrees in their utterance-initial lenis stops. This variation may lead to a situation in which the next generations of speakers, like our speakers, exhibit variation in the amount of prevoicing, but with less and less prevoicing until a generation of speakers no longer exhibits any prevoicing of utterance-initial stops and phonological reanalysis has occurred. As Helgason notes, this scenario does not require that any specific speakers reanalyze stops. Rather, as the amount of (pre)voicing decreases from generation to generation, there is a point at which there is no evidence for the next generation to have a [voice] feature for lenis stops at all.

Some studies of VOT have found little variation in subjects' productions (Ringen & Kulikov, 2012 for Russian; Helgason & Ringen, 2008 for Swedish). Scobbie (2006) suggests that this may be because subjects are routinely selected from a relatively homogenous group (colleagues and university students) and not chosen to maximize individual differences. Nonetheless, our subjects, like Scobbie's and those of Ringen & Suomi (2012) exhibit variation in VOT. The subjects that Scobbie discusses had lived on the Shetland Islands all of their lives and all were speakers of English. However, their parents were from different locations: they were natives of the Shetland Islands, from Scotland or from England. According to Scobbie, the traditional Shetland Islands dialect has prevoiced lenis stops and short-lag fortis stops, whereas the other English varieties have prevoiced or short–lag VOT lenis stops and long-lag fortis stops. Scobbie calls these *incompatible* VOT systems because the short-lag VOT is ambiguous as to whether it cues fortis or lenis stops.

We suggest that some of the Shetland Island speakers in the study reported by Scobbie, (i.e. those with prevoiced lenis stops and short lag fortis stops), have a contrast between stops specified as [voice] and stops with no laryngeal specification, others (i.e. those with short-lag lenis stops and long-lag fortis stops) have a contrast between stops specified with [sg] and stops with no laryngeal specification, and still others (i.e. those with prevoiced lenis stops and long-lag fortis stops) have, like (at least) some of our Norwegian speakers and the CS speakers of Helgason & Ringen (2008), a contrast between stops specified with [voice] and stops specified with [sg]. Some of the Shetland Island speakers with prevoiced lenis stops and short-lag fortis stops also had some lenis stops with short lag VOT, meaning that, for these speakers, some of the fortis and lenis stops fall within the short-lag VOT range. Some of

Ringen & Suomi's (2012) Fenno-Swedish speakers (all of whom were bilingual in Finnish, a different type of "mixed" VOT community) also had some overlap between the lenis and fortis stops, with some of the lenis stops within the short-lag range as the fortis stops.

At first glance, the variability in VOT across speakers in Scobbie (2006) and in Ringen & Suomi (2012) would seem to pose a significant problem for listeners. It does not appear that any single VOT boundary will work for distinguishing lenis stops from the fortis stops for all speakers. However, there are a number of empirical studies that suggest that listeners compute phonetic boundaries that are specific to speaker characteristics like gender (Johnson, Strand, & D'Imperio, 1999; Strand, 1999), and that they can learn speaker specific category boundaries fairly quickly for cues like VOT (Allen & Miller, 2004; Munson, 2011). While some have argued that such speaker-contingent speech perception can only be accommodated in exemplar models (Nygaard, Sommers, & Pisoni, 1994), more recent accounts like C-CuRE (Cole, Linebaugh, Munson, & McMurray, 2010; McMurray, Cole & Munson, 2011; McMurray & Jongman, 2011) suggest a much simpler alternative: listeners simply react to cues like VOT relative to their expectations about the range of VOTs that a speaker produces (see also Jacewicz, Fox & Lyle, 2009).

Crucially, this means that listeners actively identify the speaker and then use this to help interpret phonetic cues like VOT, but using much simpler categorization metrics and without the high memory load and complexity of an exemplar model. No matter what categorization model one adopts, however, it is clear that one does not need to assume a fixed VOT boundary that applies to all speakers – there is a wealth of both empirical and theoretical support for the idea that listeners are much more flexible and adjust their boundaries based on who is talking.

4.4. *Speaker sex*

4.4.1. Voicing

In general, there was a tendency for female speakers to have more frequent and longer prevoicing in initial stops. Previous investigators have reported divergent sex-specific prevoicing results in (utterance-)initial stops. Longer prevoicing in female productions was also found for the Umeå dialect of Swedish (Karlsson, Zetterholm & Sullivan, 2004), in Hungarian (Gósy & Ringen, 2009) and in Serbian (Soković-Perović, 2012). But many other studies of languages in which substantial numbers of speakers prevoice initial stops have found that males have significantly longer and/or more frequent prevoicing than females: CS Swedish (Helgason & Ringen, 2008), Dutch (van Alphen & Smits, 2004), Russian (Ringen &

Kulikov, 2012). It might be that our female subjects are speaking more slowly than the males. Therefore, we measured the duration of the words with initial lenis stop presented in Table 1 and correlated VOT with speech rate calculated as number of phones/s. For cases with voicing lead, Pearson's product moment correlation coefficient was r = -0.176 (n = 130). Although the result is just significant (p = 0.045) it is of crucial importance that the amount of explained variance (r^2) is only 3.1%. For cases with voicing lag, the amount of explained variance is even smaller (0.02%; r = 0.014, n = 222; p = 0.838). These results suggest that speech rate can be ruled out as a factor contributing to sex-specific behavior. As in other cases where women use longer and more frequent prevoicing than men, it is unclear what explains the tendency in our data. One possibility is that this is a case of female speakers tending to produce more clear speech than males (see also section 4.4.3).

4.4.2. Preaspiration

With respect to preaspiration, no significant sex-specific differences were observed in the present study. This outcome is in line with the absence of speaker sex effects for subjects from the same dialect region in van Dommelen (1999). It should be noted that these results were found for younger speakers. Older female speakers of Norwegian in van Dommelen (2000) produced longer preaspiration than did older males, whereas there was no effect of sex for younger speakers. Helgason, Stölten & Engstrand (2003) found that older female speakers of Northern Swedish display significantly longer preaspirations than older males. For younger speakers, the effect was in the same direction but much weaker. Stronger manifestation of preaspiration in female speakers has been attributed to anatomical differences between the female and the male larynx (cf. Fant, Kruckenberg & Nord, 1991; Titze, 1989). The above-mentioned observations, possibly indicating sociophonetic changes, suggest that biological differences represent only one of the relevant factors in the production of preaspiration. Apart from speaker sex, speaker age was a relevant factor in the studies mentioned above. Older speakers, particularly females, produced usually longer preaspiration durations than younger ones. That this result was not due to the physiology of the aging larynx is suggested by observations of higher frequency of preaspiration in *younger* speakers than older speakers of Newcastle English (Docherty et al., 2006). Note, however, that preaspiration duration is not reported in that study.

Table 7. Average duration (in ms) of vowel + consonant for different word types. sd = standard deviation. NB For fortis stops, vowel duration includes preaspiration.

Qty / Stop type/Position /	Females			Males		
	n	V+C	sd	n	V+C	sd
V:C / lenis / intervocalic	47	280	54	36	230	37
V:C / lenis / final	48	332	66	44	311	35
V:C / fortis / intervocalic	69	331	67	50	267	36
V:C / fortis / final	25	364	55	20	328	38
VC: / lenis / intervocalic	69	259	57	56	219	33
VC: / lenis / final	96	266	44	83	258	32
VC: / fortis / intervocalic	36	321	71	26	252	39
VC: / fortis / final	11	312	51	10	297	54

4.4.3. Durations

In section 3.2.1 we did not find any effect of speaker sex on vowel and consonant duration. There was, however, a significant interaction of speaker sex with stop length. To further investigate the influence of this factor, we start by looking into possible sex-specific speaking rate differences. Table 7 gives the average duration of vowel + consonant (in ms) for the different word types considered. We see that this duration is consistently greater for females than for males. This could reflect slower speaking rate on the part of females. However let us examine the degree of the durational separation between the two quantity types for females and males. As noted by Helgason et al. (2013) absolute durations should not be used for quantity comparisons. For languages that have complementary length such as Norwegian, comparisons of V and C durations provide a better indicator of quantity (cf. Pind 1986 for Icelandic and Bannert 1979 for Swedish). Therefore, when comparing our female speakers with our male speakers, we present our data in terms of V % (see Table 6). Note that this measure of duration is, essentially, normalized for speaking rate. Also, recall that sex-specific speaking rate could be ruled out as a factor in the production of prevoicing (section 4.4.1).

Consider how much the V % differs between the two quantity types, V:C with a lenis stop and VC: with a lenis stop in intervocalic position. From Table 6 we can see that for women the durational separation is 39 percentage points. In contrast, this separation in males is 32 pps. For lenis stop in utterance-final position as well as fortis stop in intervocalic and utterance-final position similar, although somewhat smaller, female-male differences are found (30 pps vs. 27 pps, 30 pps vs. 24 pps, and 24 pps vs. 20 pps, respectively). Thus the durational separation between the two quantity contrasts is consistently greater in females than in males. These differences cannot be attributed to different speaking rates, suggesting that female speakers tended to produce more clear speech than did males.

4.5. *Conclusions*

We have found that the laryngeal contrast in Tr-Norwegian is similar to that of CS Swedish and Fenno-Swedish in some respects and different in others. In both CS Swedish and Fenno-Swedish, there is robust prevoicing of utterance-initial stops whereas in Tr-Norwegian we find a bi-modal distribution: some subjects prevoice the majority of their utterance-initial stops and others have short-lag VOT for the majority of their utterance-initial lenis stops. Intervocalic and final lenis stops are more similar to those of CS Swedish and Fenno-Swedish in that most stops in these positions are fully voiced. This is similar to what is found in true voice languages such as Russian and Serbian, and contrasts with what is found in aspirating languages such as German. Fortis stops were found to be similar to CS Swedish in that they have long-lag VOT in utterance-initial position and are often preaspirated in post-vocalic position. The Tr-Norwegian fortis stops are different from those found in Fenno-Swedish, where no aspiration, either pre- or post- is found.

The complementary quantity contrast in Tr-Norwegian is similar to that found in both CS Swedish and Fenno-Swedish. The durational differences between the two quantity types are greater in Tr-Norwegian than in CS Swedish, but less than in Fenno-Swedish.

We suggest that the robust post-vocalic voicing of lenis stops and the variation in prevoicing found in utterance-initial lenis stops, coupled with the aspiration of utterance-initial fortis stops and the variation in preaspiration of post-vocalic fortis stops is best analyzed as a contrast between stops that are specified as [voice] or [sg], i.e., that the contrast is overspecified as has also been suggested for CS Swedish. The fact that there is variation in prevoicing of utterance-initial lenis stops and variation in preaspiration of post-vocalic fortis stops can be viewed in the same way: voicing of initial stops specified as [voice] and preaspiration of postvocalic [sg] stops is permitted, but not required in Tr-Norwegian.

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Appendix
Wordlist

Utterance-initial lenis and fortis stops

bad	('bath')	padde	('toad')
bredt	('broad')	pakke	('parcel')
brukt	('used')	pute	('pillow')
bygd	('built')	tak	('roof')
dam	('pond')	taket	('roof [the]')
data	('data')	tapt	('lost')
datter	('daughter')	kake	('cake')
David	(*first name*)	kappe	('cloak')
Davidsen	(*second name*)	katt	('cat')
dobbel	('double')		
dyne	('blanket')		
gape	('[to] yawn')		
gate	('street')		
gløgg	('smart')		
grov	('coarse' [adj.])		
grovt	('coarse' [adv.])		

Intervocalic lenis and fortis stops

fabel	('fable')	gape	('[to] yawn')
lade	('[to] load')	gate	('street')
spade	('spade')	data	('data')
hage	('garden')	pute	('pillow')
labben	('paw [the]')	kake	('cake')
dobbel	('double')	taket	('roof [the]')
nebbet	('beak [the]')	kappe	('cloak')
padde	('toad')	datter	('daughter')
leddet	('joint [the]')	pakke	('parcel')
legge	('[to] lay')		

Utterance-final lenis and fortis stops

stab	('staff')	skap	('cupboard')
bad	('bath')	katt	('cat')
lad(e)	('[to] load')	tak	('roof')
spad(e)	('spade')		
lag	('layer')		
hag(e)	('garden')		
labb	('paw')		
nebb	('beak')		
kladd	('draft')		
padd(e)	('toad')		
sydd	('sewn')		
ledd	('joint')		
treg	('slow')		
gløgg	('smart')		
stygg	('ugly')		
trygg	('secure')		
legg(e)	('[to] lay')		

(e): Disyllabic words pronounced as monosyllables by some of the speakers