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Syllable reduction and articulation rates in Danish, Norwegian and Swedish

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This investigation compares articulation rates of phonological and phonetic syllables in Norwegian, Swedish and Danish to investigate differences in degrees of syllable deletion (reduction) among these three languages. For the investigation two sets of data are used: one consisting of recorded speech from radio news and another consisting of sentences read aloud. The results of the comparative investigation show that in both data sets Danish exhibits a much larger degree of syllable reduction in speech than Norwegian and Swedish. The finding that certain syllable deletion processes take place in Danish but not in Norwegian and Swedish is viewed as typological. The results indicate that Danish words are shorter than their Norwegian and Swedish counterparts. This could be a contributing factor to problems that arise in inter-Scandinavian communication.

Keywords articulation rate, Danish, Norwegian, Swedish, syllable deletion, syllable reduction

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1. INTRODUCTION

Typological differences between the North Germanic languages Norwegian, Swedish and Danish have been described to a large extent in previous literature (e.g. in Bandle et al. 2005). There are, however, some linguistic features that have not yet been studied in depth or of which comparative investigations are lacking. The degree to which syllables and phonemes are reduced in speech is one such feature. This article reports a comparative investigation of reduction and speed of articulation in the three most widely spoken Scandinavian languages. Through a descriptive investigation of differences in speech tempo in Norwegian, Swedish and Danish our study aims to portray fundamental differences in the phonetic realisations of the three languages.

1.1 Linguistic similarities between Norwegian, Swedish and Danish

The three North Germanic languages spoken in mainland Scandinavia (here used to refer to Norway, Sweden and Denmark only) are typologically closely related:

they share a great proportion of their lexis. They are mutually intelligible to a large extent (Maurud 1976; Delsing & Lundin Åkesson 2005). Historical events that we will not go into details of in this article have led to a situation where Norwegian and Danish are especially closely related at the lexical level. A review of descriptive literature of differences between the Scandinavian national varieties indicates that both morpho-syntactic as well as phonological differences between the three varieties can be substantial (see Lundeby 1969; Landmark 1970; Fjeldstad & Hervold 1989; Fjeldstad & Cramer 1992; Cramer & Kirkegaard 1993; Mårtenson & Fjeldstad 1993; Braunmüller 1998; Christensen 2007; Teleman 2008).

The accounts cited above indicate that the highest number of morpho-syntactic differences is identified between Norwegian and the other two varieties. The acknowledged differences between the language pairs generally comprise minor discrepancies in word order (particularly involving a negator or an infinitival marker), or the morphological marking of definiteness. Another example mentioned often is the placement of the particle in phrasal verb constructions. In Danish the particle must occur after the object while it comes before the object in Swedish and can occur in either place in Norwegian.

Typological differences among the three varieties found in the phonology are somewhat larger. Major differences occur especially between Danish and the other two languages. Swedish and Norwegian share a number of phonological traits. For instance, both languages make use of two lexical tonal accents that can distinguish minimal pairs. Also, if we compare the vowel system of Standard Swedish (e.g. Leinonen 2010) with that of the Norwegian variety spoken around the capital Oslo (e.g. Kristoffersen 2000), a variety often referred to as Standard Norwegian (Røyneland 2005), we find very similar inventories. Both languages have nine distinctive long vowels and nine distinctive short vowels. The Danish phoneme inventory, however, is often described consisting of MORE contrastive vowels than Swedish and Norwegian, with 12 distinctive long vowels and 13 distinctive short vowels (e.g. Basbøll 2005:50). In addition to differences in the phoneme inventory, Danish has another feature that is different from anything found in Swedish and Norwegian, namely *stød*, which has been analysed as a realisation of creaky voice or laryngealisation by Grønnum (1998:179) and Basbøll (2005:83).

The languages in question, Norwegian, Swedish and Danish, are among the languages that have been referred to as stress-timed languages. The syllable-timed or stress-timed distinction is not a dichotomy, but rather a continuum. The 'syllable-timed' end of the continuum can be described as speech where all syllables have the same duration. 'Stress-timed', on the other hand, can be described as speech where the time duration between the stressed syllables is equal. Germanic languages are generally described at the 'stress-timed' end of the continuum (e.g. Ladefoged 1975). This implies that the languages employ some degree of reduction in fluent

speech to achieve relatively similar durations between major stress groups in the utterance.

Reduction is one of the features of Danish that has received some attention in previous studies (see below), though arguably all the Scandinavian North Germanic varieties exhibit some reduction in speech. East Norwegian as well as most Swedish varieties show an assimilation process, for instance, by which rhotics with succeeding alveolar consonants /d l n s t/ change into retroflex sounds /d ʎ ŋ ʂ t/. Schwa-deletion and syllabification of /n/ can occur word-finally in all three languages, for instance, in the pronunciation of Danish *våben*, Swedish *vapen* and Norwegian *våpen* ‘weapon’.

Interestingly, reduction-related processes like assimilation, schwa-reduction and lenition have received particular attention in work on spoken Danish, possibly due to the link between the processes and problems in speech development and speech perception. Bleses et al. (2008) suggest that the large number of reduction and assimilation processes in Danish causes or boosts the delay in vocabulary development in Danish infants and children compared to that of their peers from ten European countries and from the US and Mexico. They point out that schwa-deletion and the vocalisation of consonants result in long vocalic stretches, making the Danish sound structure unclear with weak, or even no, cues for word and syllable boundaries. Grønnum (2007) gives numerous examples of phonetic reduction taken from the Danish Phonetically Annotated Spontaneous Speech (DanPASS) corpus. She notes how the phrase *behøver ikke* ‘does not need to’, /be.ˈhø:v.ø.e.gə/ in its phonological form, is reduced in fluent speech to single syllable [bɛg]. Similarly the phrase *kan jo ikke* ‘cannot’ is pronounced [ˈkʰa.jo.eg] in its full form, but reduced to [kɛg] in fluent speech. Notably, four or even five phonological syllables in the two examples are reduced to one single phonetic syllable.

Descriptions of equally dramatic reduction processes have not been found for Norwegian and Swedish in the literature. However, when considering the examples above, a large degree of reduction processes can also be seen in Norwegian and Swedish. The Norwegian phrase *behøver ikke* ‘does not need to’ can be reduced from its canonical form /bø.hø:v.ø.ri.kə/ to [bæk.kə], from five to two syllables. In Swedish, the same applies where *behöver inte* ‘does not need to’ has five canonical syllables in phonological form /bø.hø:v.ø.rin.tə/ but can be reduced to bisyllabic [bœn.tə] in fluent speech.

There are a number of articulatory processes that fall in the category of what is referred to as ‘reduction’. Articulatory weakening in the production of vowels is particularly referred to as reduction in phonetic literature. Laver (1994:157) lists shortening, pitch-lowering, centralisation and lowering of intensity as vowel-reduction processes. These form, along with syllable re-organisation processes, the compression, or reduction of syllables in fluent speech. The elision or lenition of consonants can also be viewed as reduction processes. This investigation is, however, not concerned with reduction processes on phoneme level, but considers instead

the extent of deletion of syllables in spoken Norwegian, Swedish and Danish. By conducting a comparative investigation of the numbers of phonological and phonetic syllables produced per time unit in the three Scandinavian languages, we investigate whether the syllable reduction processes are indeed more extreme in Danish as opposed to in Norwegian and Swedish, as indicated by the previous literature described above.

To facilitate a measurement of speech reduction, the current study therefore compares the number of canonical (or phonological) syllables in six data sets of natural speech from Norway, Sweden and Denmark with the number of phonetic syllables produced in the same data. The phonetic syllables are measured automatically by the computer counting the number of voiced intensity peaks in the speech signal. The difference between the two counts (phonological and phonetic) is a measure of the degree of reduction that occurs in the three languages.

By counting the number of syllables produced in natural speech we also measure the articulation rates at which the languages are spoken. This gives us further opportunity to compare the three languages on a phonetic level. Our study is, thus, two-fold. Its main aim is to give an account of the typological differences of syllable reduction among Norwegian, Swedish and Danish while it also presents results that can be used for a comparative investigation of differences on a purely phonetic level, i.e. in speech tempos, between the languages.

1.2 Previous research of tempo and reduction in speech

Reduction and the tempo at which speech is produced go hand in hand. To increase the rate of our speech, our articulatory processes become less precise and some phonological content can be deleted or shortened in duration. Likewise, the more reduction that takes place in the production of an utterance, the shorter the time must be to produce it. In this paper, we compare the tempos at which Norwegian, Swedish and Danish are spoken.

Studies of the tempo at which speech is produced are generally concerned either with SPEECH RATE or ARTICULATION RATE. Speech rate is defined as the number of items (words, syllables, phonemes, etc.) produced during a specific time period. This means that pauses in speech are considered part of the signal and taken into the measurement. Articulation rate, on the other hand, is a measure of the amount of articulatory activity within a time frame, i.e. the number of speech items per time unit after silent intervals have been removed from the signal. This study is concerned with articulation rate and reports a study of speech where silent intervals longer than 150 ms have been removed. Previous studies of articulation rates disagree on the exact measure of what constitutes a meaningful pause and what does not. Campione & Véronis (2002) claim for their study of pauses in German, Italian, English, French and Spanish that pauses shorter than 200 ms are difficult to discriminate from occlusives

but that some brief pauses can be as short as 60 ms. In the current study we follow Tsao & Weismer's (1997) suggestion, setting a cut-off point at 150 ms for pauses. This duration was chosen based on their claim that 150 ms is longer than the typical stop closure interval, yet probably the lowest threshold of what constitutes a meaningful pause (Tsao & Weismer 1997:861). As the aim of our comparative investigation is to put side-by-side amounts of articulatory activity per time period in three different linguistic varieties, pauses are excluded from the speech signal to ensure that the data sets from the different languages are as comparable as possible for this purpose.

Some previous studies have been conducted to investigate tempo of speech (either speech rates or articulation rates) cross-linguistically, many of which have concluded that tempos do not differ substantially across languages. Osser & Peng (1964) compared the number of phonemes produced per minute by native speakers of American English and native speakers of Japanese, but found no significant cross-linguistic difference in speech rate. Neither did Kowal, Wiese & O'Connell (1983), who re-evaluated findings from earlier studies based on spontaneous speech in English, German, French, Spanish and Finnish. Den Os (1988) conducted a comparative study on Italian and Dutch speech rate. She analysed the tempo of reading aloud by native speakers of Italian and Dutch but did not find a significant difference when syllables per second were compared across languages. When phonemes produced per second were compared, however, articulation rate in Italian turned out to be significantly slower than in Dutch. This might have to do with the fact that Dutch has more complex consonant clusters than Italian, and that the Dutch syllable can thus be said to generally consist of more phonemes.

What the studies above have in common is that they investigate tempo in fluent speech in languages that are not mutually intelligible, or even very closely related. Another approach to investigating speech or articulation rates is to compare rates produced in varieties that are very closely related, i.e. in regional varieties of the same language or in languages that are mutually intelligible. By comparing syllable reduction and articulation rates in such varieties one can minimise the possibility that differences found between languages stem from different phonotactics or lexical structure in the languages.

A number of studies exist where variation in tempo between different regional varieties of the same language HAS been investigated. Verhoeven, De Pauw & Kloots (2004) compared articulation rates in Belgian and Netherlandic Dutch and found that Netherlandic Dutch varieties are articulated at a significantly higher rate than Belgian Dutch ones. Robb, Maclagan & Chen (2004) also attest variation in English between varieties spoken in Christchurch (New Zealand) and those spoken in Connecticut (American English) and conclude that New Zealand English is spoken at a higher rate than American English. Robb et al. (2004) relate their findings back to reduction processes and suggest that because New Zealand English has a high degree of vowel

raising, vowels tend to be shorter in New Zealand English than in American English, which again has an effect on articulation rates in the two varieties.

Although no comparison has ever been made of the tempos at which the three North Germanic Scandinavian languages are spoken, some previous work has been done to look into speech rates in the respective languages. There is just one quantitative study of speech AND articulation rates in Norwegian (Almberg 2000). Almberg (2000) reports tempo in the pronunciation of 60 informants from three regions of Norway. The data used in the study consist of read-aloud strings of numbers in addition to announcements of telephone numbers that the informants knew by heart. Almberg (2000) concludes that there is a significant correlation between articulation rates and utterance length in his data: longer utterances are produced at higher articulation rates. This finding is not new, and is most likely universally true (Fonagy & Magdics 1960). The mean articulation rates in Almberg's (2000:66) Norwegian corpus vary between 3.6 and 4.4 syllables per second depending on the utterance length. The study reports no regional differences found in speech tempo in Norwegian. Importantly for the current investigation, Almberg (2000) does not consider the amount of syllable reduction that occurs in fluent speech in his data.

Jande (2003) considers the effect of reduction and speed on perceived naturalness of synthesised Swedish speech. Jande (2003) concludes that reduced speech sounds more natural than canonical speech when the speed of the speech is fast (at medium or high speech rates). The reduction measured in Jande's (2003) work consists of vowel or syllable deletion processes mainly, but the author gives no information about the degree of reduction that occurs in natural Swedish speech as opposed to Danish or Norwegian. Another study has looked at articulation rates in Swedish (Hansson 2002). The study is primarily concerned with rate differences between words within the prosodic phrase and concludes that reduction in speech happens throughout the prosodic phrase and that Swedish shows some signs of phrase-final lengthening. Hansson (2002) makes no claims about variation (or consistency) in articulation rates across speakers or regions, however.

No previous investigation has reported empirical results on speech or articulation rates in Danish. As mentioned in the previous section, however, a number of studies have covered speech reduction in Danish. We hypothesise here that a large degree of reduction in speech also means that Danish is produced at a high articulation rate. As previous research has presented evidence that a higher speech rate reduces our ability to successfully perceive speech (e.g. Vaughan & Letowski 1997; Gordon-Salant, Fitzgibbons & Friedman 2007; Jones, Berry & Stevens 2007), a higher amount of reduction processes (or a subsequent higher rate of articulation) in Danish could be one contributory factor to why spoken Danish is generally viewed as a language difficult to understand by other Scandinavians (see Delsing & Lundin Åkesson 2005).

2. METHOD

2.1 *Material and speakers*

The aim of the current investigation is to conduct a comparative investigation of syllable reduction across Norwegian, Swedish and Danish. For the investigation, equivalent types of data from the three national speech communities should be analysed. Our investigation focuses on standard-like speech in the three countries using data consisting of short sentences with cognate words read aloud as well as radio news broadcasts read by professional news readers. Both types of data were recorded in a highly controlled setting and so our findings will not necessarily reflect reduction and articulation rates found in less formal speech. An advantage of using these data is, however, that they are highly comparable across speaker communities.

The radio news broadcasts data set was compiled of recordings made by the three previously state-owned nationwide radio stations in Norway (NRK), Sweden (SR) and Denmark (DR). The Norwegian recordings used were originally aired on the station P1, the Swedish recordings on stations P1 and P3, and the Danish recordings on stations P1 and P4. A total of 26 minutes of fluent speech was used for the analysis. The lengths of the recordings vary between 21.43 and 44.85 seconds. The data were produced by 55 informants, distributed evenly across nations and genders save an additional male Danish speaker, as illustrated in Table 1.

	Males	Females
Norway	9	9
Sweden	9	9
Denmark	10	9
Total	28	27

Table 1. Nationality and gender of the speakers in the radio news data set.

The news broadcasts were all aired in spring 2010 and had been recorded with speakers who use a standard accent. This means that the Swedish and Danish broadcasters spoke their respective codified standard varieties while the Norwegian informants all spoke a variety that used Bokmål features with an East Norwegian accent.

The second data set used for this investigation consisted of 16 read-aloud sentences produced by nine male speakers, three from each of the countries' capital cities, Oslo, Stockholm and Copenhagen. This second data set was added to the investigation to compare the larger corpus of radio news broadcasts consisting of different lexical contents to data consisting of the same lexical (and morphological) contents (the read sentences). The sentences recorded by the nine speakers for this

control set all consisted of cognate words with the same number of canonical syllables in all three languages. The speakers who recorded the sentences all use varieties similar to the speakers who produced the data in the radio news broadcast corpus: Standard Swedish, Standard Danish and an urban East Norwegian variety based on Bokmål. The speakers were all students in their twenties.

The sentences recorded for the second data set were ‘semantically unpredictable sentences’ (henceforth SUSs) generated by the method developed by Benoît, Grice & Hazan (1996). These sentences are generally used in sentence intelligibility experiments, but are also ideal for analyses of speech production. The SUSs are syntactically correct but consist of phrases with concepts that are not likely to be semantically related with each other (see Gooskens et al. 2010 for a more detailed description of the material). It was hypothesised that reading these sentences would be equally difficult in all three languages and that articulation rates could not be influenced by lexical combinations that might be more frequent in one language than in another. The SUS can be automatically generated using basic syntactic structures and a number of lexicons containing the most frequently occurring short words in each language. The syntactic structures are simple and the sentence length does not exceed seven words. An example of a SUS is given in (1).

- (1) a. Et folk deler et job som går. Danish
 b. Et folk deler en jobb som går. Norwegian
 c. Ett folk delar ett jobb som går. Swedish
 a people shares a job that walks

The sentences developed for the current experiment consist of Danish–Norwegian–Swedish cognate words only and vary in length having from six to ten phonological syllables (either six or seven words). All sentences read by the informants can be found in the appendix.

2.2 Measurements

Previous investigations have mainly measured articulation rate as the number of syllables produced per second (e.g. Kowal et al. 1983; Den Os 1988; Almborg 2000; Verhoeven et al. 2004). Because the primary goal of the current study is to investigate syllable reduction, we measure articulation rate in the same way here. We measure both phonetic syllables (actually produced) as well as phonological syllables (canonical syllables) to make a measurement of the degree of reduction that takes place in the languages.

All sound recordings analysed in this investigation were transcribed in Praat (Boersma & Weenink 2008). Any pauses in the speech signal with durations of more than 150 ms were removed. The length of the recordings was established for each individual speaker, and canonical, or phonological, syllables were counted based

on orthography. This count was checked against descriptions of the phonological syllables in the three languages (Grønnum 1998 for Danish; Kristoffersen 2000 for Norwegian; Elert 1997 for Swedish). The number of syllables was subsequently divided by utterance duration to calculate articulation rate of PHONOLOGICAL syllables.

To calculate degree of reduction, and articulation rate of PHONETIC syllables, the number of syllables actually produced in the three languages was determined automatically using a Praat script developed by De Jong & Wempe (2009). This script counts the number of intensity peaks (with drops in intensity of 2 dB immediately before and after the peak) in the speech signal that have voicing (where F0 can be measured). To obtain individual phonetic articulation rates per speaker, the number of syllables produced by every speaker is simply divided by the duration of the analysed sample for this speaker. One advantage of an automated measure of syllables is that a comparable measurement can be made for all three languages without human interference. Human knowledge of phonology and underlying syllable structure could influence a researcher's ability to objectively identify phonetic syllables in a speech signal. The disadvantage of the script lies in the same matter, however, it can count somewhat differently from that which a human does. De Jong & Wempe (2009) found that automatic and human syllable detection correlate highly ($.71 < r < .88$), but that they are not completely congruent processes. It remains unclear, however, whether the algorithm detects too few syllables, or whether humans detect too many under the influence of their phonological or orthographic knowledge. Importantly for our study, the discrepancy between human and automatic syllable detection would be the same across all languages measured as long as the same parameters are used for the measurement.

Examples of how the automated analysis deals with specific phonetic details in Norwegian, Swedish and Danish are shown in Figures 1–3, portraying the output of the automated analysis in Praat for three speakers producing the SUS 'A free earth answers a friend' taken from our data set of read sentences. We see that the automated phonetic syllable count finds five syllables for the Danish speaker, seven syllables for the Norwegian speaker and seven syllables for the Swedish speaker.

Particularly relevant to the current study is the treatment of *stød* (see Section 1.1.1. above) in Danish by the automated count. One worry is that the laryngeal activity occurring with *stød* could interfere with the automated measure of voiced intensity peaks in the signal. In Danish the words *fri* 'free' and *jord* 'earth' have *stød*. The occurrence of *stød* in the sentence in Figure 1 has no bearing on the syllable count for Danish, however. The analysis counts three phonetic syllables for the three nucleus vowels produced in the first half of the sentence *en fri jord* 'a free earth'.

The automated count finds seven phonetic syllables in both the Norwegian as well as the Swedish recording (see Figure 2 and Figure 3). From an auditory analysis, it is clear that the two speakers in the recordings use a particularly careful pronunciation

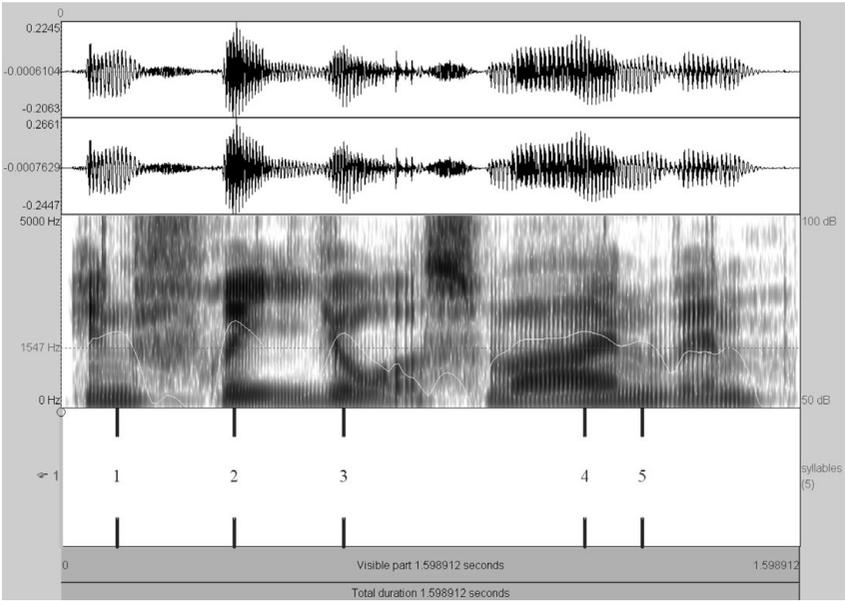


Figure 1. Screen shot of oscillogram, spectrogram and phonetic syllable tier for *En fri jord svarer en ven* (Danish).

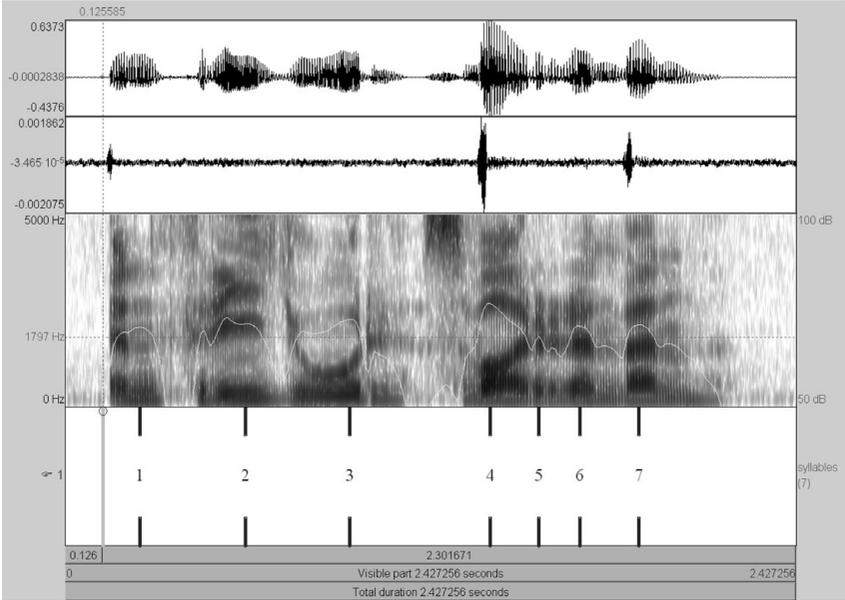


Figure 2. Screen shot of oscillogram, spectrogram and phonetic syllable tier for *En fri jord svarer en venn* (Norwegian).

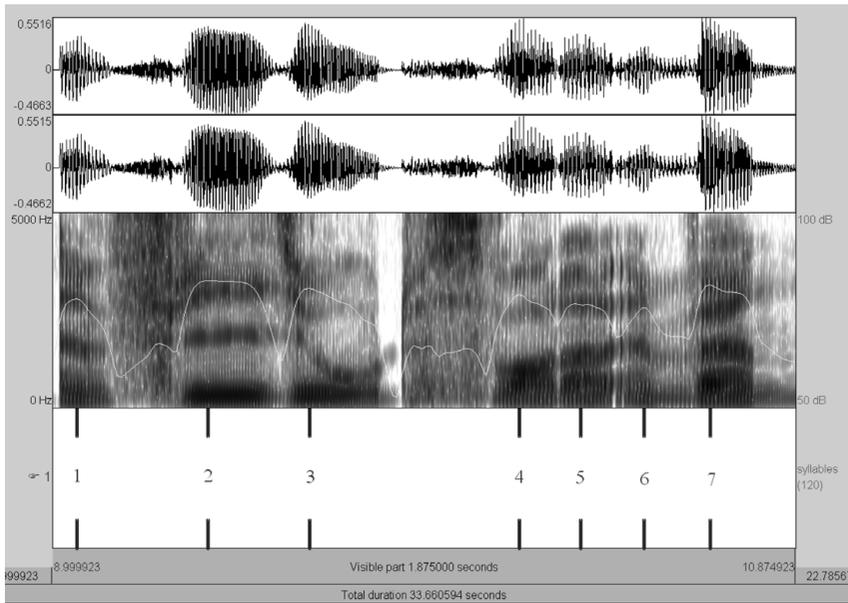


Figure 3. Screen shot of oscillogram, spectrogram and phonetic syllable tier for *En fri jord svarar en vän* (Swedish).

of the second half of the illustration sentence. All canonical syllables are produced in *svarer en venn/svarar en vän* ‘answers a friend’ by both the Norwegian as well as the Swedish speaker. The Norwegian produces [svɑ:.rø.røn.vɛn] and the Swedish [svɑ:.rø.røn.vɛn]. Comparatively, the automated analysis finds only two phonetic syllables in this part of the utterance as spoken by the Danish speaker (Figure 1). In addition, through an auditory analysis, the authors counted only two phonetic syllables in this part of the Danish speaker’s utterance and thus transcribed his utterance: [svɑ:n.vɛn].

The examples illustrated by Figures 1–3 show findings in line with de Jong & Wempe’s (2009) claim that an automated syllable count correlates highly with a human count. In our opinion, both approaches to syllable counting have their strengths and weaknesses. A manual approach is error-prone due to the researcher’s phonological knowledge that might interfere with the count, whilst an automated analysis could presumably be influenced by changes in voice quality where intensity becomes lower, or the F0 becomes weaker. With a large set of recordings an automated count of syllables is clearly preferable, and since this current study aims to investigate reduction in a fairly large data set we opt for an automated phonetic syllable count for our analysis.

	Utterance length (seconds)	Phonological syllables produced	Articulation rates (syllables per second)
Norwegian	502.64	2701	5.37
Swedish	500.44	2676	5.35
Danish	570.27	3543	6.21

Table 2. Articulation rate of phonological syllables in the radio news broadcast data.

	Utterance length (seconds)	Phonological syllables produced	Articulation rates (syllables per second)
Norwegian	94.07	362	3.85
Swedish	105.76	357	3.38
Danish	78.78	372	4.72

Table 3. Articulation rate of phonological syllables in the SUS data.

3. RESULTS

3.1 Phonological syllables

Table 2 shows the overall measurements in the radio news broadcast data set along with the mean number of phonological syllables produced per second in each recording. Table 3 shows the same measurements in the read SUS data.

Firstly, the two tables show that the mean articulation rates of phonological syllables are rather different in the two types of recordings. A faster syllable rate was produced in the radio news broadcasts than in the reading of sentences. This is in line with earlier findings by Fonagy & Magdics (1960) and Almborg (2000), who reported that long utterances are produced at higher speed than short utterances. Our read sentences consisted of no more than seven words, while utterances in the news broadcast data could consist of up to 32 words. Furthermore, the SUS are semantically anomalous and this could also be a possible factor slowing speakers down. The pattern found in the two types of recordings is the same, however. The Danish speakers have a significantly higher articulation rate than the other Scandinavian speakers in both types of data sets.

In a one-way ANOVA on the radio news broadcast data set with speakers' individual means of phonological syllables produced per second, the difference is highly significant ($F(2,52) = 22.563, p < .001$). A Tukey post-hoc test reveals that only the difference between Danish and the two other languages is significant; the difference between Norwegian and Swedish is not. In a one-way ANOVA on the SUS data set with the nine speakers' individual means of phonological syllables produced per second, the differences between the languages are also significant $p < .05$ ($F(2,6) = 9.334$). The post-hoc indicates, however, that only the difference between Swedish and Danish is significant in this data set. Norwegian lies in between

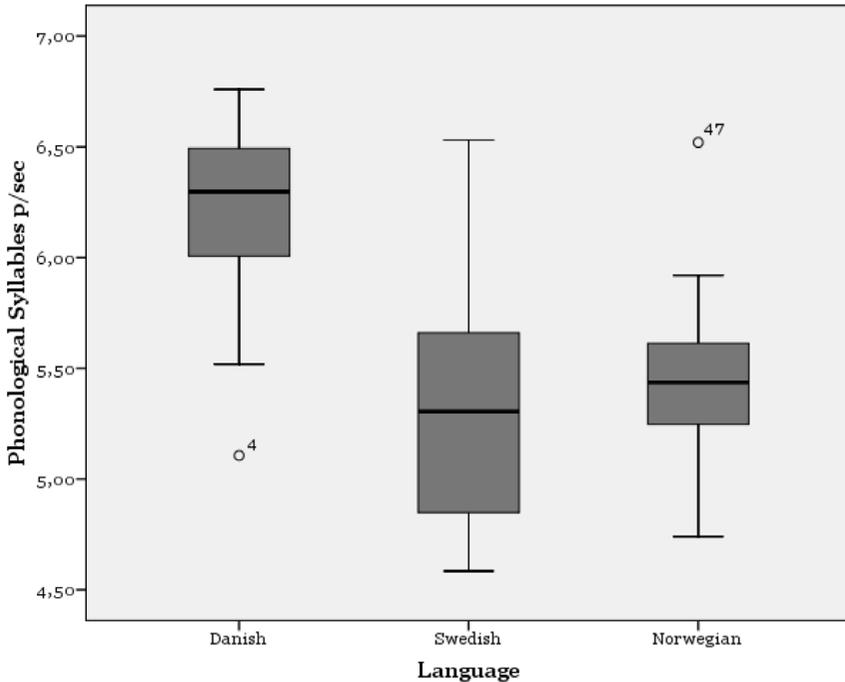


Figure 4. Box plot of articulation rates of phonological syllables in the news broadcast data by language.

and is neither significantly different from Swedish nor Danish. Figure 4 shows a box plot illustrating the ranges in articulation rates for the three language groups in the news broadcast data. The line in the middle of the boxes is the median speech rate while the boxes represent the middle two quartiles. As is visible from Figure 4, the Danish and Norwegian speakers have less variation in articulation rates than the Swedish speakers. The variation in Swedish speakers could be due to social background or age differences in the sample, but this is of less relevance for the typological description in the current article.¹

3.2 Phonetic syllables

Tables 4 and 5 show the measurements of phonetic syllables as produced by the automated analysis with the Praat script.

We tested whether articulation rates of phonetic syllables differed across the three groups of speakers in the two corpora (news readers and SUS): this turned out not to be the case. A one-way ANOVA of speakers' mean articulation rates of phonetic syllables showed no significant differences between Norwegian, Swedish and Danish rates, neither for the news corpus, nor for the SUS corpus.

	Utterance length (seconds)	Phonetic syllables measured	Articulation rates (syllables per second)
Norwegian	502.64	2215	4.41
Swedish	500.44	2242	4.48
Danish	570.27	2498	4.38

Table 4. Articulation rate of phonetic syllables in the radio news broadcast data.

	Utterance length (seconds)	Phonetic syllables measured	Articulation rates (syllables per second)
Norwegian	94.07	373	3.97
Swedish	105.76	370	3.50
Danish	78.78	309	3.92

Table 5. Articulation rate of phonetic syllables in the SUS data.

3.3 Reduction

With a count of phonological and phonetic syllables produced per time unit in all three languages, the extent of reduction in every speaker group was calculated. The articulation rates of phonological and phonetic syllables are compared in Figure 5. The figure makes clear that the difference between the number of phonological and phonetic syllables is larger in the news corpus than in the SUS corpus. Furthermore, Figure 5 indicates that it is in the Danish language group that the difference between the number of phonological and phonetic syllables is the largest.

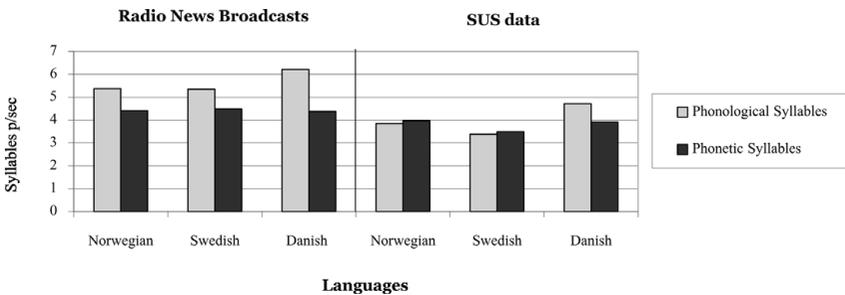


Figure 5. Differences (reduction) in articulation rates of phonological and phonetic syllables in the two data sets.

Within every language group the difference between the number of phonological and phonetic syllables counted in the radio news broadcasts is significant. This was tested with paired samples *t*-tests of speakers' mean articulation rates of phonological versus phonetic syllables (Danish $t(18) = -16.184$, $p < .001$; Swedish: $t(17) = -5.302$, $p < .001$; Norwegian: $t(17) = -9.174$, $p < .001$). In paired samples *t*-tests

of speakers' mean articulation rates for the SUS data, only Danish has a significant difference between phonological and phonetic syllables $t(2) = -9.442, p < .03$.

To calculate whether the difference between phonological and phonetic syllables is larger for the Danish speakers than for the Norwegian and Swedish speakers in the radio news broadcasts, the reduction ratio was calculated in the radio news broadcast data by subtracting the number of phonetic syllables by the number of phonological syllables counted per speaker. A one-way ANOVA was subsequently conducted on these individual differential scores with language as a factor in the analysis. The outcome shows that the differences between the number of phonological and phonetic syllables counted is indeed significantly larger for the Danish speakers (mean 1.8) than for the Norwegian speakers (mean 1) and Swedish speakers (mean 0.9): ($F(2,52) = 15.793, p \leq .001$). A post-hoc Tukey test shows that the difference between Swedish and Norwegian is not significant, and that Danish has significantly more reduction than both Swedish and Norwegian.

4. DISCUSSION

4.1 Syllable reduction in Norwegian, Swedish and Danish

The results presented above show that all three Scandinavian varieties have a degree of reduction in speech, but that the largest amount of syllable reduction occurs can be found in the Danish data. In the comparison of the articulation rates of phonological and phonetic syllables made in the current investigation, the ratio of the number of phonetic syllables per phonological syllables is by far the largest for Danish speakers. This difference can be seen as a measurement of the elision of syllables that occurs in fluent speech. Previous literature has indicated that the reduction of syllables is a particularly noticeable feature in spoken Danish. The current investigation can substantiate this claim with data that shows that the amount of syllable reduction that occurs in Danish is indeed larger than that which occurs in Swedish and Norwegian.

In the radio news broadcasts the number of phonological syllables differs significantly from the number of syllables actually produced, i.e. phonetic syllables. This is the case for all three speaker groups and indicates that syllable reduction happens to some degree in fluent speech in all the varieties in question. This is not surprising, but makes the findings from the SUS data more interesting: the automated count of phonetic syllables shows that there are no real differences between the number of phonetic and phonological syllables in the Swedish and Norwegian SUS data. Sentence reading is a rather formal task (as opposed to speaking freely or speaking with notes) where a large deal of attention is paid to speech. It thus seems that in Norwegian and Swedish most, if not all, phonological syllables are realised in such speech situations. This is not the case for Danish, however. The results from the

SUS data indicate that in Danish there is a large degree of syllable reduction even in careful speech styles.

Our results thus indicate a substantial typological difference between the three Scandinavian languages: Danish words are produced as shorter than Norwegian and Swedish words. There is no *a priori* reason to believe the number of underlying syllables should be different for Danish than for Norwegian and Swedish. Indeed, Grønnum (1998) defines the Danish phonological syllable as built around the canonical nucleus vowel (or in some cases a sonorant consonant), which is also the case for the Norwegian (Kristoffersen 2000) and Swedish syllable (Elert 1997). Grønnum (1998:211) indicates that Danish speakers are able to identify the correct number of canonical syllables in words, and there seem to be no grounds for claiming that this is different for Swedish or Norwegian speakers. It could be that the large-scale reduction of syllables in spoken Danish has repercussions for the canonical representations of these syllables over time. Reduction processes such as APOCOPE, SYNCOPE or HAPLOLOGY result in syllables disappearing from the canonical syllables and words. McMahon (1994) uses the haplogy example *Eng-la-lond* from Old English undergoing loss of the medial syllable and resulting in today's canonical *England*. It could be that we are witnessing Danish undergoing a severe sound change where reduction processes, even in the formal speech styles investigated here, happen on a large scale. More research is needed to investigate which types of syllables become elided in Danish and whether stylistic constraints on such reduction exist at all.

4.2 Articulation speed in Norwegian, Swedish and Danish

By investigating the number of syllables produced per time unit in a corpus of free speech in Danish, Norwegian and Swedish, we have also measured articulation rates in the three languages. Some of the results presented above could indicate that Danish speakers actually talk faster than Norwegians and Swedes do, but this would be a too simplistic rendition of our findings. What we have found is, rather, that in fluent Standard Danish speech a lot more phonological information is transferred per time unit than in fluent standard-like Norwegian and in fluent Standard Swedish. The Danish news broadcasters produce almost an entire phonological syllable (.84 and .86 syllable to Norwegian and Swedish, respectively) more per second than their other Scandinavian peers on average. This indicates that more semantic information is also transferred per time unit. The fact that this difference is also found in the controlled SUS-corpus, where all words that were analysed had the same number of canonical syllables, indicates that word length differences in the news corpus have had no bearings on the results.

On the other hand, if one simply measures the amount of syllables actually produced in fluent speech without taking into consideration the content of the speech

signal, there are no differences between Danes, Swedes and Norwegians in their articulation rates. The automated analysis of voiced intensity peaks in the recordings of the three languages shows no significant difference in the number of phonetic syllables produced per time unit by speakers of different nationalities. Phonetically speaking, therefore, Danish is not spoken faster than Norwegian and Swedish in our data.

To conclude, one might put forward another measure of speed in speech: communication rate. If one were to use a measure of the amount of phonological content which was transferred per time unit to determine speed, our data indicate that Danes communicate the fastest in Scandinavia and that this happens through large-scale syllable elision.

4.3 Comparison of our findings with previous studies

To give an indication of whether the differences reported above are indeed constant and reflections of typological traits of Danish and Norwegian and Swedish, it is useful to compare our findings with those of previous studies. Almberg (2000) found articulation rates between 3.6 and 4.4 phonetic syllables per second depending on utterance length in his Norwegian data of realised strings of numbers. This rate is comparable to that found for Norwegian in the current study. The mean number of phonetic syllables measured for our study is 3.97 and 4.41 in the radio news broadcast and SUS data, respectively. Even if the number of phonetic syllables is counted automatically in our corpus and manually in Almberg's (2000), the numbers of phonetic syllables produced per second in the two studies match.

Unfortunately, no previous quantitative studies exist of articulation rates of phonetic (or phonological) syllables for Danish and Swedish. The consistency of our Norwegian data in relation to that of Almberg (2000) would lead us to expect, however, that the overall measurements made for the Danish and Swedish are equally constant.

4.4 Implications of this research

The sections above have shown that on the one hand, there is a substantial difference between the articulation rates of phonological syllables and degree of phonetic reduction that occurs in Danish and that which occurs in Norwegian and Swedish. On the other hand, the phonetic rate differences between the three languages are negligible. Speakers of the three languages produce similar numbers of phonetic syllables per time unit in both data sets. We argue, however, that the differences found in rates of phonological syllable production and the subsequent phonetic reduction are more disadvantageous for a description of Danish, Norwegian and Swedish as mutually intelligible languages than differences in rates of phonetic syllables would have been. The fact that about one in every four phonological syllables is deleted on

the phonetic surface is likely to have an effect on speech comprehension. Non-native listeners who learn the phonological syllables of Danish through its orthography, or listeners from Norway and Sweden who rely on the phonological syllables in their own varieties for comprehension, could struggle when confronted with the largely elided or reduced realisation of these phonological syllables in spoken Danish.

Even though the three Scandinavian languages are very closely related and share a large portion of their lexical inventories, large-scale reduction in Danish speech production could be one (of many) explanatory factors for communication problems that occur between Norwegians, Swedes and Danes when speaking their native languages. Delsing & Lundin Åkesson (2005) report that in certain test situations Norwegians and Swedes understand less than half of the spoken Danish presented to them. Similar results have been reported by Maurud (1976) and Bø (1978). To illustrate with an example, if Norwegian speakers rely on their own knowledge of phonological syllables for the phrase *behøver ikke* 'does not have to', they might expect to hear something like its full form /bø.hø:vø.ri.kə/ or even a reduced form like [bøk.kə], with just two syllables produced. In spoken Danish, however, canonical /be.hø:vø.e.gə/ can be reduced to the single syllable [bæg]. This shortening might cause comprehension problems for a Norwegian listener. More empirical research is needed to establish to what degree syllable reduction (and articulation rates) influence comprehension of a closely related variety.

5. CONCLUSION

The North Germanic languages spoken in Scandinavia exhibit differences in their degree of reduction in fluent speech: Danish speech contains more reduction than Swedish and Norwegian speech does. Phonetically, however, the three languages exhibit very similar patterns, the number of phonetic syllables produced per time unit does not differ substantially between speakers of the three languages. Although the latter finding suggests some degree of similarity between the three languages, we suggest that the large degree of reduction in Danish speech as opposed to Norwegian and Swedish speech could be an indicator of phonological change in progress occurring in Danish but not in the other Scandinavian national languages Norwegian and Swedish. Further research is needed to establish the nature and extent of syllabic reduction in Danish speech and its relationship to changes in phonology.

Differences in reduction or articulation rates of phonological syllables are also likely to negatively affect speech comprehension in Scandinavia. It is possible that syllable reduction is one of the traits of Danish speech that causes intelligibility problems for non-native as well as other Scandinavian listeners. The relative effect of this trait on intelligibility must be investigated in greater detail in future studies.

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APPENDIX. SEMANTICALLY UNPREDICTABLE SENTENCES (SUSs)

Norwegian version

En fri jord svarer en venn
 En god hånd ønsker et gulv
 En rød natt tar et navn
 En sjef eier en smak
 Et egg krever en tekst som håper
 Et folk deler en jobb som går
 Et grep kjøper en jakt som lyser
 Et hjørne savner et bord som sitter
 Hvordan når et brudd et fint ben?
 Kjenn en skyld eller et krav
 Når legger en prins en lav skog?
 Når retter en lengde en dyp feil?
 Skriv et land og en munn
 Støtt et valg og en strøm
 Hvor elsker en stein et sent hull?
 Vis en sol og en bok

Swedish version

En fri jord svarar en vän.
 En god hand önskar ett golv.
 En röd natt tar ett namn.
 En stark chef äger en smak.
 Ett ägg kräver en text som hoppas.
 Ett folk delar ett jobb som går.
 Ett grepp köper en jakt som lyser.
 Ett hörn saknar ett bord som sitter
 Hur når ett brott ett fint ben?

Känn en skuld eller ett krav.
När lägger en prins en låg skog?
När rättar en längd ett djupt fel?
Skriv ett land och en mun.
Stöd ett val och en ström.
Var älskar en sten ett sent håll?
Visa en sol och en bok.

Danish version

En fri jord svarer en ven.
En god hand önsker et gulv.
En rød nat tager et navn.
En stærk chef ejer en smag.
Et æg kræver en tekst som håber.
Et folk deler et job som går.
Et greb køber en jagt som lyser.
Et hjørne savner et bord som sidder.
Hvordan når et brud et fint ben?
Kend en skyld eller et krav.
Hvornår lægger en prins en lav skov?
Hvornår retter en længde en dyb fej
Skriv et land og en mund.
Støt et valg og en strøm.
Hvor elsker en sten et sent hul?
Vis en sol og en bog.

English translation

A free earth answers a friend
A good hand wishes a floor
A red night takes a name
A strong chef owns a taste
An egg demands a text that hopes
A people shares a job that walks
A grip buys a hunt that illuminates.
A corner misses a table that sits.
How does a breach reach a nice leg?
Know a blame or a demand
When does a prince lay a low forest?
When does a length correct a deep mistake?
Write a land and a mouth

Support a choice and a stream
 Where loves a stone a late hole?
 Show a sun and a book.

NOTE

1. For a short discussion of possible social variation in articulation rates in Scandinavian languages see Hilton, Gooskens & Schüppert (to appear) as well as Almberg 2000 (for Norwegian only).

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