REDUCING ARTICULATORY EFFORT IN NON-WORD TOKENS

The Word Frequency Effect on Intervocalic Lenition of /t d/ in Danish

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SUMMARY

English

Speech sounds in high-frequency words are more likely to be reduced than speech sounds in low-frequency words, due to greater application of phonological processes in highly frequent words. Here, the tendency of Danish speakers to lenite intervocalic /t d/ in non-words was tested in different morphological environments, to examine whether this effect also applies to new words after recurrent use. The word frequency effect on lenition was tested through multiple readings of the same nonsense text, in which each target word occurred several times. As phonological knowledge may differ over language communities, speakers of two different dialects were tested. The results show that lenition of intervocalic /t d/ was more frequent after repeated usage of new words, but only if the morphological environment in which /t d/ occurred supports lenition, indicating that both morphophonological knowledge and word repetition play a part in applying lenition. This outcome holds for both of the tested language communities. The possible causes for the relationship found between lenition and word repetition are discussed.

Dutch

Spraakklanken in hoogfrequente woorden hebben meer kans om gereduceerd te worden dan spraakklanken in laagfrequente woorden, omdat fonologische processen vaker in hoogfrequente woorden worden toegepast. Hier is onderzocht in hoeverre Denen /t d/ verzwakken in intervocalische positie in morfologisch verschillende nonsenswoorden, om te testen of het frequentie-effect ook optreedt in nieuwe woorden. Het effect van frequentie op lenitie is getoetst door sprekers driemaal dezelfde nonsenstekst te laten oplezen, waarin ieder doelwoord een aantal keer voorkomt. Omdat fonologische kennis kan variëren tussen taalgemeenschappen, zijn sprekers van twee verschillende dialecten geselecteerd. De resultaten laten zien dat lenitie van /t d/ in intervocalische positie meer voorkomt naarmate nieuwe woorden vaker worden uitgesproken, maar alleen wanneer de morfologie van het woord daadwerkelijk lenitie toestaat. Deze resultaten zijn hetzelfde voor beide taalgemeenschappen, en wijzen erop dat zowel morfologische kennis als woordrepetitie een rol spelen bij het verzwakken van /t d/. Voor dit verband tussen lenitie en woordrepetitie worden mogelijke oorzaken besproken.

CONTENTS

1. INTRODUCTION

A common feature of Danish is the systematic lenition of stops in syllable-final position. Stops can also be lenited in intervocalic position in specific sound environments. This study attempts to grasp how frequency affects the tendency of native speakers of Danish to lenite intervocalic /t d/. This study deals with the synchronic change of surface forms in Danish from intervocalic [tˢ] to [d̥ ð ð̥] and zero, and from [d̥] to [ð ð̥] and zero only. In order to examine the frequency effect on lenition of /t d/, forty Danish speakers were tested in an iterated non-word reading task, in which the pronunciation of intervocalic /t d/ was compared in different realisations of the same non-word. First, the relevance of the subject is explained, providing an overview of previous research on the relationship between frequency and phonetic variation. Additionally, the pronunciation variation in Danish is set out with regard to lenited /t d/ in general, and after suffixation in particular, as well as explanations that have been proposed for this variation in the past. In the second chapter a description is given of the methodology applied and of the experiment conducted to measure the frequency effect on lenition of intervocalic /t d/. The third chapter presents the results of the experiment. The last chapter of this paper comprises a discussion of the results, concluding with a number of suggestions for future research.

1.1. Primary research on frequency and phonetic variation

Previous studies of frequency effects on pronunciation variation have primarily focussed on sound change due to word frequency. Both frequency and anti-frequency effects have been argued to contribute to sound change: On the one hand high-frequency words often change as a consequence of phonological processes more easily than low-frequency words, but on the other hand frequent use of words strengthens word representations, making them less likely to change (Bybee 2001; 2006). Phillips (1984) argues that words of high frequency are indeed affected first by physiologically motivated sounds changes, as opposed to other sound changes, which will affect high-frequency words last. Dinkin (2008) also challenges Bybee's idea that high-frequency words undergo every sound change at a faster rate, but seconds what he calls "Phillips' principle" that high-frequency words only lead to sound changes in the direction of reduced articulatory effort. Moreover, Dinkin demonstrates that this is true not only for sound changes in progress, but for stable variation as well. Dinkin's findings are confirmed by the results from Abramowicz' (2007) investigation into frequency effects on the /ɪn ɪŋ/-variation in English, a variable that does not involve any reduction processes and for which Abramowicz found no frequency effects. To further support this, Mitterer & Russell (2013) report that words of high frequency or high predictability are more likely to be phonetically reduced than words of low frequency or low predictability, because repetition leads to automatised production, and automatised production leads to more efficient production (Bybee 2001:12). This is either explained from a production-based perspective or from an intelligibility-based perspective (Gahl, Yao & Johnson 2012:789, Gahl 2012). The production-based approach claims that variation is a result of speakers' tendency to minimise articulatory effort, whereas the intelligibility-based approach explains pronunciation variation by speakers' wish to maximize intelligibility. In intelligibility-based accounts variation is typically reflected by vowel lengthening and hyper-articulation, but Mitterer & Russell

submitted evidence that phonetic reductions can have a communicative function as well, as listeners associate reduced affixes with high-frequency words and non-reduced affixes with low-frequency words. Little has presently been investigated in detail about the frequency effect on non-words, which instinctively do not fulfil a communicative function. If repeated usage of words results in a greater application of phonological processes in those words, then frequently used words will have more opportunity to be affected by reduction processes than infrequently used words. In that case repeated non-words are expected to be increasingly reduced in the same way as similar actual words, because new words can be produced by reference to existing forms (Bybee 2001:7).

Frequency has thus been argued to have an effect on phonological reduction processes, of which lenition is a typical example. The definition of lenition used here is based on the studies by Bauer (1988; 2008) and is adapted for the purpose of this research. It can be defined as a phonological reduction process by which consonants are weakened, i.e. a segment is regarded as lenited if it is realised with reduced resistance of airflow through the vocal tract, resulting in less articulatory effort. In medial or word or syllable final position consonants are weakened the most (Kirchner 1998). Medial position is a particularly conditioning environment for lenition, because intervocalic consonants easily assimilate to the surrounding vowels, which lack certain features that are present in the consonant (Kirchner). Therefore, it seems reasonable to assume that intervocalic consonants in non-words, too, will be affected more easily than segments in stronger positions.

1.2. Intervocalic lenition of /t d/ in Danish

The frequency effect on lenition is of particular interest with respect to Danish, whose pronunciation has constantly been subject to change, especially in the past 100-150 years (Galberg Jacobsen & Skyum-Nielsen 2007:219, Brink & Lund 1975). Danish now exhibits "massive" vowel and consonant reduction (Gooskens et al. 2010:1023), and, furthermore, it shows a three-way contrast of [tˢ d̥ ð/ð̞][1] in intervocalic position. [tˢ d̥] are both identified with /t/ and [d̥ ð] with /d/, owing to alternations as shown in (1). /d/ also manifests itself as zero in coda position after the sonorous consonants [n l ɐ̯], as seen in (2), but it is beyond the scope of this paper to explain this in further detail, as /d/ is generally not lenited to zero between vowels.

(1)	*foto* 'photo', *fotografi* 'photograph'	[ˈfotˢo foðogʁaˈfiˀ]	
	metode 'method', *metodik* 'methodology'	[meˈtˢo:ðə metˢoˈðiǧ]	
(2)	*mand* 'man', *mandig* 'manly'	[ˈmɑ̯nˀ ˈmɑ̯nðˌi]	
	alder 'age', *ældre* 'older'	[ˈɑ̯lˀʌ ˈelðʁʌ]	
	nord 'north', *nordisk* 'Nordic'	[ˈnoˀɐ̯ ˈnoɐ̯ðisǧ]	(Herslund 2002:12)

[1] The literature does not distinguish between [ð] and [ð̞], which both are reductions of [d̥] that can be interchangeably used. For this reason no distinction between the two is made in the examples of this paper either.

Table 1. Overview of the variation in intervocalic lenition as described by the literature.

	-isk [isk]	-itet [iˈteˀd̥]	-ig [i]	-ing [eŋ]	-inde [ˈenə]	-e [ə]	Other suffixes
Lenition	/t d/	/d/	/d/	/d/	/d/	/t d/	-
Word-bound variation	/t d/	-	-	-	-	-	-
Speaker-bound variation	/d/	/d/	/d/	-	-	-	-

Since *foto* and *fotografi* and *metode* and *metodik* share the same word stems, /t/ in *foto* and *fotografi* and /d/ in *metode* and *metodik* are assumed to be phonologically identical. /t/ in *fotografi* and /d/ in *metode* undergo lenition, whereas /t/ in *foto* and /d/ in *metodik* are not phonetically reduced. Thus, identical phonological forms can demonstrate different surface representations in Danish as a consequence of the phonological process of lenition. Intervocalic lenition of either or both /t d/ can therefore generate three possible outcomes; if both /t d/ are lenited, the contrast between the two is retained, if only /t/ is reduced and /d/ is not, the contrast will be lost on the surface, and if the pattern is reversed the contrast will be strengthened.

The application of lenition in Danish depends on the suffix attached to the stem: /t d/ preceding schwa are always lenited, as is intervocalic /d/ before *-ing* and *-inde*. Conversely, native speakers of Danish differ in the extent to which they lenite /d/ before *-isk*, *-itet*, and *-ig*. The amount of variation differs across the suffixes and is either speaker-bound or word-bound, as shown in (3-5). To the extent known, no account is given yet of lenited /t/ in intervocalic position preceding any of these suffixes. Table 1 provides an overview of the variation as described in the literature by, among others, Grønnum (2007), Heger (1981), Rasmussen (2002) and Schachtenhaufen (2013).

(3) a. speaker-bound variation *-isk*

prosodisk ‘prosodic’	[pʰʁoˈsoˑˀd̥isd̥]
	[pʰʁoˈsoˑˀðisd̥]

b. word-bound variation *-isk*

kretisk ‘Cretan’	[ˈkʁɛˀtˢisd̥]
kritisk ‘critical’	[ˈkʁiˌd̥isd̥]
vedisk ‘Vedic’	[ˈʋeːˀd̥isd̥]
overfladisk ‘superficial’	[ˈɒwʌfˌlæːðisd̥]

(4) a. speaker-bound variation *-itet*

graviditet ‘pregnancy’	[gʁaʊidiˈtˢet]
	[gʁaʊiðiˈtˢet]

(5) a. speaker-bound variation *-ig*

ledig ‘available’	[ˈleːˌd̥i]
	[ˈleːði]

The choice between [tˢ d̥] and [d̥ ð] in Danish is generally explained as morphologically conditioned by syllable structure (Grønnum 2007; Levin 1974; Ringgaard 1973; Schachtenhaufen 2013). As such, principles for syllabification can account for minimal pairs as for instance *modi* ‘modes’ and *modig* ‘brave’ /ˈmoːˌdi ˈmoːd.i/ [ˈmoːˌd̥i ˈmoːði]. The above-mentioned word-bound variation has hitherto been explained by non-identical syllabification principles for different words. It is generally assumed

that lenition of intervocalic consonants in Danish only occurs before a suffix with a non-full initial vowel, because lenited segments are associated with the coda position, and only non-full vowels do not attract any consonants (Grønnum 1998; Schachtenhaufen 2013). Full vowels can be distinguished by jaw height, tongue position and lip rounding, and there seems to be consensus that except for schwa all vowels are full vowels. Be that as it may, /t d/ is also realised as lenited [d̥ ð] before *-inde* or *-ing*, both with an initial [e], which, according to the conditions of lenition in Danish, would automatically classify [e] as a non-full vowel as well. The classification of full and non-full vowels is further problematised by the suffixes *-isk*, *-itet* and *-ig*, which all have an initial [i] and give rise to both word-bound and speaker-bound variation. This issue leads Rischel (1983:56) to propose that these suffixes have schwa underlyingly and therefore support lenition, even though they surface with full vowels. Schachtenhaufen (2013:65-66) postulates that the variation in realisation of /t d/ shows that the non-full vowels /i e/ should be dealt with differently from schwa in terms of syllabification. Intervocalic /t d/ can attach to the following vowel, which places them in onset, or /t d/ can attach to the preceding vowel, which places them in coda position. It is generally preferred to attach as many consonants in onset as possible, but if the next vowel is non-full, this principle is overruled by the fact that non-full vowels cannot attract any consonants (Schachtenhaufen 2010:37-38). Speakers of Danish never attach any consonants to schwa, whilst some speakers do attach consonants to /i/ in *-isk*, *-itet* and *-ig*. Consequently, Schachtenhaufen argues that syllabification of /t d/ before schwa and syllabification of /t d/ before /i e/ must be fundamentally different and that these principles account for word-bound variation. Speaker-bound variation and variation due to reduction processes within one speaker's production can then be explained as resyllabification of these phonological syllable boundaries (2013:119). At the same time Schachtenhaufen (2013:220) acknowledges that syllable boundaries and their movements are abstractions, and that there is not solely one correct way to determine them. Hence neither vowel status nor syllable boundaries seem to be able to fully explain the intuitions of native speakers.

1.3. Present study

Whilst past research on variation has attempted to explain allophonic variation either as a result of differences in the frequency of word use, or, in Danish specifically, as a result of abstract non-identical syllabification principles for full and non-full /i e/, the present study aims to combine these two approaches. By means of an iterated non-word reading task it will become clear if and when /t d/ will be reduced in Danish as a consequence of repetitive use in specific morphological environments that allow for variation. Then it should be possible to capture speakers' knowledge of phonological structure, disregarding factors such as syllabification and varying word familiarity between participants. Since the non-words reoccur in the text and the participants read out the text three times in succession, any changes can be observed that arise as the new words are being uttered more often, and as they gradually become more familiar to the speaker. Growing familiarity is inextricably linked to repetition, and therefore it is expected that speakers' tendency to lenite non-words is affected by frequency.

Additionally, it is expected that if frequency indeed proves to be determinant for lenition in non-words, this can be related to either (I) increasing articulatory fluency, (II) readability, or (III)

lexicalisation, or a combination of these three. Increasing articulatory fluency could give rise to lenition, because neuromotor routines become more reduced with repetition (Bybee 2006:715). It may also be that speakers have the option to lenite all target words in every instance; however, actual reduction is mostly dependent on readability. If words are encountered more often, they will be easier to read and therefore possibly also lenited gradually more, corresponding to standard pronunciations of similar sequences. A third possibility for a potential frequency effect is that increased lenition is due to phonetic specification of new word representations in the mental lexicon: Frequently encountered non-words may be stored as new lexemes, which can either remain unaltered or be phonetically reduced similar to actual words, depending on the speaker's preference. If a lexeme is specified in a speaker's lexicon as possibly lenited in natural speech, then it is likely that similar new words will also be stored and used in the same manner, as frequent use strengthens their representations in the mental lexicon. For that reason it is expected that a frequency effect will be found only in those non-words that show morphophonological similarities to actual lenited words, and, likewise, that non-words that show morphophonological similarities to words not subject to lenition will be unaffected by frequency. The research questions focussed on are therefore the following. Do native speakers of Danish only lenite those non-words that are morphologically similar to real lenited words, as predicted by the literature? Do speakers lenite non-words at a continually increasing rate as the words are recurrently used? If frequency demonstrates to have an effect on non-words, what are possible motivations for this? And do speakers of different dialects differ in the way they lenite intervocalic /t d/?

2. METHOD

2.1. Experimental design

A non-word reading task was conducted to test native speakers' tendency to lenite /t d/ in intervocalic position in several morphological environments. The effect of frequency on lenition was tested through multiple readings of the same nonsense text.

2.1.1. Target words

The effect of word repetition was tested through forty-two non-words. All non-words were phonotactically legal word-like sequences with an intervocalic /t/ or /d/, followed by one of the suffixes *-isk*, *-itet*, *-ig*, *-ing*, *-inde* and *-ur* and occasionally one or two inflectional suffixes. To prevent participants from not identifying the suffix *-itet*, the words in question were also suffixed with either the plurality suffix *-er* or the common gender definite article suffix *-en*, to distinguish *-itet* from the much more common neuter definite article suffix *-et* [əð].

The various non-words made up different combinations of target phoneme, appended suffix, and, with the exception of non-words suffixed with *-ur*, the number of syllables preceding the sequence of target phoneme and suffix. Instead of testing a single word for each combination, word pairs containing the same values were created, to ensure that potential effects would not be word-dependent rather than dependent on phoneme, suffix and/or word length. For similar reasons minimal pairs were formed, only differing in intervocalic target phoneme. An example of a word pair is *otisk* and *natisk*, which both contain the same target phoneme /t/ and the same target suffix *-isk*, and which both have one syllable preceding suffix and phoneme. From these item pairs minimal word pairs were then created, i.e. *otisk* and *odisk* form a minimal pair, as do *natisk* and *nadisk*. The total of forty-two target words thus corresponds to twenty non-word pairs suffixed with *-isk*, *-itet*, *-ig*, *-ing* or *-inde*, and two control words suffixed with *-ur*, which do not differ in word length. An overview of the tested non-words is presented in Table 2 below.

Table 2. Overview of the tested target words.

		-isk	-itet	-ig	-ing	-inde	-ur
Version 1	/t/	otisk	knititet	sotig	neting	klytinde	
		lamitisk	rusatitet	samketig	fordoting	umutinde	ratatur
	/d/	nadisk	seditet	rudig	muding	strudinde	
		paledisk	kaluditet	genspradig	begading	misfradinde	lokadur
Version 2	/t/	natisk	setitet	rutig	muting	strutinde	
		paletisk	kalutitet	genspratig	begating	misfratinde	ratatur
	/d/	odisk	kniditet	sodig	neding	klydinde	
		lamidisk	rusaditet	samkedig	fordoding	umudinde	lokadur

2.1.2. Nonsense text

The target words were embedded in a rewrite of the 350-word Danish tale *Prinsessen på Ærten* ('The Princess and the Pea') by Hans Christian Andersen, for the reason that phonological rules are applied more in continuous speech than in words realised in isolation (Hayes 2009:62). In the rewrite all content words were replaced by either test words or other non-words, some of which taken from Elbro (2008), that were added in order to distract the reader from the focus of the experiment. All nouns, verbs, adjectives, adverbs, numerals and interjections were therefore substituted with word forms that correspond to the word forms of the replaced parts-of-speech, i.e. the combinations of segments in the non-words are phonotactically legal, the inflectional suffixes are identical to inflectional suffixes in actual words of the same part-of-speech, and the number of syllables in the non-words are comparable to the number of syllables in the words in the original fairy tale. All function words (articles, pronouns, prepositions, conjunctions, auxiliary verbs) were retained to preserve the structure of the text, thereby providing the reader guidance with regard to rhythm, stress and intonation. The only exception to this is that some pronouns were replaced by nounlike non-words suffixed with *-itet, -ing* or *-inde* to distribute the target words more equally. Generally, target words as well as target phonemes and target suffixes were all more or less evenly distributed over the text, to reduce the influence of the order in which they appeared.

2.1.3. Different text versions

Two text versions were made, only differing in the inserted target words. Either half of each word pair was tested in Version 1, and the other half was tested in Version 2, resulting in two complementary texts with a maximum of different combinations of target phoneme, suffix and number of syllables. The control words suffixed with *-ur* were identical in both versions. In each text version each target word occurred four times. In Table 2 is listed which non-words occurred in Version 1 and which ones in Version 2. Both full texts can be found in Appendix A. A Mann Whitney test found that Version 1 (Mdn = 0.07) and Version 2 (Mdn = 0.20) did not differ significantly from each other U = 152.5, p = .198, r = .203.

2.1.4. Correctness conditions

Only realisations of target words were analysed that satisfied the conditions for correctness. In the context of this research, a correct realisation is regarded as a realisation in which (1) the intended suffix was realised in accordance with standard pronunciations of that particular suffix, (2) a surface form of /t d/ was realised before the suffix, and (3) the surface form of /t d/ was realised between vowels. A realisation of a non-word was judged incorrect if (1) the pronunciation of the suffix was not in accordance with standard pronunciations, (2) a surface form of /t d/ was not recognisable, or (3) other consonants were inserted directly preceding or following /t d/.

2.1.5. Determining lenition

Realisations of tokens were coded auditorily, using the following lenition scale, from unlenited to fully lenited.

(6) [tˢ] < [d̥] < [ð] < [ð̞] < [Ø]

This means that /t/ was interpreted as lenited if it was realised as [d̥] or any sound more to the right on this scale and it was interpreted as unlenited if any place to the left of [d̥]. This principle was applied even if the sound was perceived as weaker than [tˢ] but stronger than [d̥], to reduce the chances of misjudgments. Surface forms of /d/ were regarded as lenited if realised as [ð] or as any sound more to the right of [ð], and they were evaluated as unlenited if realised as [d̥] or stronger. [d] was treated in the same manner as [d̥], again to prevent overestimation of lenition.

2.2. Participants

A roughly age- and sex-balanced sample of forty Danish native speakers took part in the nonsense text reading experiment. The participants in the experiment were selected on the basis of four criteria: They had to be (1) non-dyslexic (2) native speakers of Danish that (3) had been born and raised either on the island of Sealand or in North Jutland, and (4) had lived most of their adult lives in the same region as they were born and raised. Non-dyslexic speakers were required, because results from dyslexic participants would be questionable, as the seemingly lenition of segments could also be assigned to erroneous reading. Speakers from two different regions were selected for the reason that different communities may show different phonological knowledge. In the past it has both been claimed that lenition of stops can go further in the Danish dialects outside the principal island of Sealand (Levin 1974:62), and, conversely, that /d/ is lenited more on the islands than in the mainland of Denmark (Ringgaard 1973:20). To test these claims, twenty of the subjects were selected in Jyllinge and Roskilde on Sealand, and the other twenty participants were selected in Aalborg and the surrounding area in the north of the mainland of Denmark, North Jutland.

2.3. Procedure

The research participants were instructed to read out one of the nonsense texts three times in succession, as if it were an ordinary Danish text. It was emphasised that the goal of the experiment was not to test reading ability and, furthermore, that there was no right or wrong way of performing the task. After the first and second reading, participants were allowed to take a short break, which never lasted longer than two minutes. The whole experiment took between 10 and 23 minutes, depending on reading speed and the inclusion of breaks. Half of the participants from each region read Version 1 and the other half read Version 2. All reading sessions were recorded on tape. Participants were assessed in their homes and did not receive any compensation for their assistance.

2.4. Statistical analysis

Firstly, the data are explored to establish whether the control suffix behaves differently from the other suffixes. Secondly, the frequency effects on lenition are tested through correlation analyses. A correlation coefficient is also used to test the relationship between lenition and readability. Finally, t-tests are conducted to measure the differences in speaker consistency between the readings, as well as the differences between Sealandic speakers and North Jutlandic speakers. In case a Kolmogorov-Smirnov test on the residuals shows non-normality, non-parametric counterparts to the parametric tests are used.

2.5. Conclusion

This particular experimental design of an iterated nonsense text reading task enables to compare different realisations of intervocalic /t d/ in non-words with distinct morphological environments, in non-words with identical morphological environments, and in different occurrences of the same non-word. The manipulated variables consist of the occurrence number of a given target word (1-12), the appended suffix (-*isk*, -*itet*, -*ig*, -*ing*, -*inde,* or -*ur*), the appearance of an orthographic *t* or *d*, the number of syllables, and the participants' regional origin (Sealand or North Jutland). The use of several words with different combinations of target phoneme, suffix and word length allows to investigate which factor or combinations of factors increase the likelihood of lenition, and how lenition may differ over language communities. The recurrence of words makes it possible to determine after which number of occurrences words are likely to be lenited.

3. RESULTS

In this section the results of the experiment are presented and discussed. In the first part of this section the hypothesis is tested that speakers only lenite those non-words that are morphologically similar to real lenited words. In the second part of the analysis the hypothesis is tested that target words are not lenited randomly, but are rather lenited increasingly often as a result of greater application of phonetic processes after repeated usage of words. In the third part of the analysis a group comparison is made between speakers from Sealand and North Jutland, to test whether Sealandic speakers lenite more than and differently from North Jutlandic speakers.

3.1. Morphological environment

In order to test the first hypothesis that speakers only lenite /t d/ in specific morphological environments, a comparison was made between the realisations of intervocalic /t d/ preceding the suffixes associated with lenition, and the realisations of /t d/ preceding the control suffix *-ur*, before which /t d/ was never expected to be reduced. To investigate whether /t d/ was only reduced before *-ig*, *-isk*, *-itet*, *-ing*, and *-inde*, and not before *-ur*, the differences were measured between the degrees of lenition for each suffix and word pair in the experiment. Table 3 presents the percentages of lenited realisations for each suffix and word pair. A value of 0.0% means that the word pair was never lenited by any participant, and a value of 100% means that it was lenited in each instance by every participant.

When comparing these percentages, it can be easily seen that non-words with *-ig*, *-isk*, *-itet*, *-ing*, and *-inde* were all lenited to some extent, whereas non-words with *-ur* were hardly ever lenited by any speaker. Lenition of /t d/ was found most before *-inde* (27.2% of the correctly realised target words), *-ig* (26.5%) and *-ing* (23.2%). /t d/ preceding the suffixes *-itet* and *-isk* were lenited about half as much, namely 11.8% and 9.8% respectively, whereas /t d/ before *-ur* were only lenited 1.1% of the time. This indicates that lenition of /t d/ is indeed linked to the suffix immediately following these segments, as therefore correctly predicted in the literature. The prediction of the hypothesis was satisfied that *-ig*, *-isk*, *-itet*, *-ing*, and *-inde* behave differently from *-ur*, and, as a result, that speakers do not lenite /t d/ regardless of the morphological environment in which they appear. Therefore the control suffix *-ur* is excluded from further analysis of the frequency effect on lenition.

Table 3. Percentage of lenited realisations and number of correct realisations per suffix and word pair.

Suffix	Word pair	Lenited (%)	Correctly pronounced
-isk	1-t-isk	2.0	443
	1-d-isk	19.3	440
	2-t-isk	6.2	436
	2-d-isk	11.8	439
	Total -isk	*9.8*	*1758*
-itet	1-t-itet	30.9	324
	1-d-itet	1.4	363
	2-t-itet	17.8	304
	2-d-itet	0.3	369
	Total -itet	*11.8*	*1360*
-ig	1-t-ig	10.2	452
	1-d-ig	32.9	462
	2-t-ig	16.5	303
	2-d-ig	44.4	414
	Total -ig	*26.5*	*1631*
-ing	1-t-ing	6.2	449
	1-d-ing	48.5	431
	2-t-ing	4.8	418
	2-d-ing	34.7	378
	Total -ing	*23.2*	*1676*
-inde	1-t-inde	33.3	460
	1-d-inde	22.1	430
	2-t-inde	18.0	422
	2-d-inde	35.1	407
	Total -inde	*27.2*	*1719*
-ur	2-t-ur	2.2	461
	2-d-ur	0.0	476
	Total -ur	*1.1*	*937*
Total	*22*	*17.9*	*9081*

3.2. Frequency

In the preceding section it was demonstrated that Danish speakers very rarely lenite /t d/ in sound environments that according to the literature do not support lenition, and, likewise, that they can lenite intervocalic /t d/ in suffixed non-words that do support lenition. In this part it is first tested whether speakers lenited these non-words randomly or rather increasingly often as the words were used throughout the discourse. Next, a connection is drawn between the overall amount of lenited realisations and the amount of correct realisations per word pair, to piece together how the amount of lenition is connected with readability. Additionally, the amount of variation between the participants' first and third reading is measured, to explore potential links between frequency and lexicalisation.

Table 4. Lenited realisations and correct realisations per occurrence number.

Occurrence number	Lenited	Correctly pronounced
1	84	657
2	97	670
3	123	646
4	124	660
5	126	693
6	139	685
7	152	683
8	147	681
9	154	699
10	156	696
11	161	681
12	157	693
Total	*1620*	*8144*

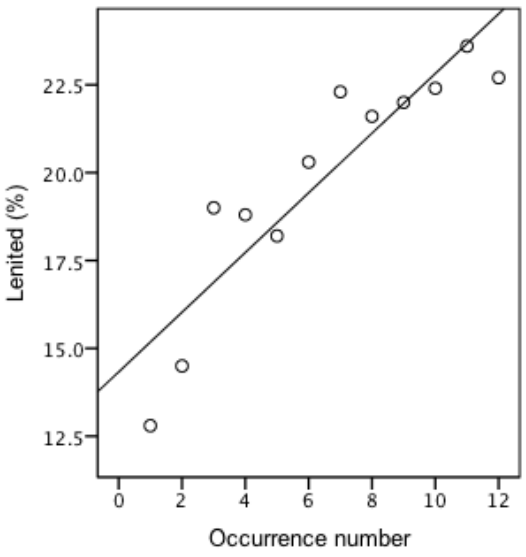

Figure 1. Correlation between occurrence number and amount of lenition (%).

To correlate frequency with lenition, the amount of lenition was averaged per occurrence number (1-12), the results of which can be found in Table 4. A Pearson's *r* correlation between occurrences of target words and the mean amount of lenition per occurrence number found that the two variables were strongly correlated, $r(12) = .906$, $p = .00005$, 95% CI [.844 ~ .972]. A scatterplot summarises the results in Figure 1. Similar effects emerge when the results from the two regions are viewed separately: There was evidence for a reliable correlation between amount of lenition and occurrence number for both Sealand, $r(12) = .908$, $p = .00005$, 95% CI [.827 ~ .972], and North Jutland $r(12) = .880$, $p = .0002$, 95% CI [.784 ~ .969]. An overview of their results per occurrence number is found in Appendix B: Table B1. The number of occurrences thus positively correlates with increases in amount of lenition for both regions individually, as well as for the regions taken together. This relationship found between frequency and lenition of intervocalic /t d/ in non-words can be due to multiple causes, of which readability and lexicalisation will be tested in the next two subsections.

3.2.1. Readability

Readability is regarded as the ease in which a word can be read. Readability or textual difficulty was measured by the number of correct realisations of each word pair, as determined on the basis of the conditions set in section 2.1.4. From Table 5 below it can be seen that /t d/ were lenited most preceding *-inde*, *-ig*, and *-ing*, and to a lesser degree preceding *-itet* and *-isk*, whereas /t d/ preceding *-ur* were hardly ever lenited. Before suffixes that give rise to lenition /d/ was generally more likely to be lenited than /t/ (25.6% lenited d-words versus 14.0% lenited t-words). An exception to this is *-itet*, for which the reverse is true, possibly because the pattern Vowel+/t/+itet does not seem to occur in Danish, as opposed to Vowel+/d/+itet, which is a much more common pattern. It is conceivable that Danish speakers will alter non-words with unusual sequences such as Vowel+/t/+itet in some measure to fit the

Danish language better. Word length was of importance for must suffixes: Short words were lenited slightly more than their longer counterparts. 20.7% target words were lenited with one syllable preceding the suffix, against 18.9% lenited target words with two preceding syllables. Taking all combinations of suffixes, phonemes and number of syllables together, the performance of the participants with regard to lenition can be summarised in the following ranking of categories, according to relative degree of lenition, greatest to least.

(7) d-ing < d-ig < t/d-inde < t-itet < d-isk < t-ig < t-ing < t-isk < d-itet < t/d-ur

When evaluating the number of correct realisations of the various non-words, a very different ranking emerges. Long words were more problematic than shorter ones and t-words were more difficult than d-words. Long target words were pronounced correctly 83.8% of the time – and with the control items left out 81.0% – versus 88.6% correctly pronounced short target words. 84.7% of all t-words were realised correctly, against 87.3% of the d-words. The words suffixed with *-ur* were the least challenging (97.6% correct), despite the fact that *-ur* was always preceded by two syllables. This may be the result of an unambiguous interpretation of the pronunciation of the preceding /t d/, which, according to the literature, cannot be lenited before *-ur*. Second easiest was *-isk* (91.6%), followed by *-inde* (89.5%), *-ing* (87.3%), *-ig* (84.9%), and, finally, *-itet* (70.8%).

The effect of readability on lenition was tested by correlating the amount of lenition with the number of correct realisations per word pair, the values of which can both be found in Table 3. A Pearson's *r* found that degree of lenition and degree of difficulty were not significantly correlated, $r(22) = -.093$, $p = .681$, 95% CI [−.443 ~ .233]. This shows that there is no reliable association between the two variables. Hence no inferences should be drawn about a direct link between amount of lenition and textual ease or difficulty.

Table 5. Lenited realisations (%) and correct word realisations (%) divided by target phoneme, word length and target suffix.

Variable	Category	Lenited (%)	Correct (%)
Phoneme	/t/	14.0	84.7
	/d/	25.6	87.3
Number of syllables	1	20.7	88.6
before suffix	2	18.9	83.8*
Suffix	-isk	9.8	91.6
	-itet	11.8	70.8
	-ig	26.5	84.9
	-ing	23.2	87.3
	-inde	27.2	89.5
	-ur	1.1	97.6

*And 81.0% with exclusion of *-ur*, which was always preceded by two syllables.

3.2.2. Lexicalisation

Investigating how consistently speakers realised target words can provide an indication of lexicalisation, because increasingly less variation in realisations suggests that phonetic word representations are being strengthened in the speaker's mental lexicon. Speaker consistency was tested by comparing the amount of variation in a speaker's realisations in Reading 1 with the amount of variation in Reading 3. For both readings the first realisation was compared with the second, the second with the third and the third with the fourth. Missing data-points were ignored, but if there were less than two realisations of a word in either of the readings, all values for the given word were excluded, because comparison between the readings would be impossible. For each comparison between two subsequent realisations 0 was added if the values were equal, and 1 was added if they were unequal. This sum was divided by the number of values for each target word in Readings 1 and 3, after which the mean variations for both readings were calculated for each participant, resulting in one value per reading per participant (see Appendix B: Table B2). A Wilcoxon signed-ranks test was conducted to see if words were realised more consistently in the third than in the first reading. The results show that no reliable difference between the amount of variation between Reading 1 (*Mdn* = 0.093) and Reading 3 (*Mdn* = 0.075) could be found, $Z = 1.16$, $p = .245$, $r = .184$. The null hypothesis that the difference in means was zero could not be rejected. No evidence was found for phonetic specification of non-words in the mental lexicon.

3.3. Regional differences

In looking at the amount of lenition produced by the participants from Sealand and from North Jutland a comparison was made between both groups. An examination of the data (see Appendix B: Table B3) indicated that the data are normally distributed. An independent-samples t-test showed a significant difference in the mean amount of lenition for Sealandic speakers ($M = .274$, $SD = .177$) and North Jutlandic speakers ($M = .110$, $SD = .112$), with a difference of 0.164, 95% CI [.070 ~ .259]; $t(32.1) = 3.51$, $p = .011$, $d = 1.11$. Specifically, the results suggest that people from Sealand are more likely to lenite intervocalic /t d/ than people from North Jutland.

Additionally, a Mann Whitney test was conducted to investigate whether region also had an effect on the target of intervocalic lenition. For all individual speakers their mean /d/-lenition was subtracted from their mean /t/-lenition (Appendix B: Table B3). A positive value means that /t/ was lenited more often than /d/ and a negative value means that /d/ was lenited more often than /t/. Sealandic speakers (*Mdn* = −.206) and North Jutlandic speakers (*Mdn* = .015) differed significantly in which phoneme they predominantly lenited; $U = 106$, $p = .011$, $r = .569$. The hypothesis was thus supported that Sealandic speakers lenite differently from North Jutlandic speakers. Closer examination of the data reveals that the effect is only true for /d/; reliable evidence was found that Sealandic speakers (*Mdn* = .416) lenite more /d/ than North Jutlandic speakers (*Mdn* = .030), $U = 85.5$, $p = .002$, $r = .698$. There is no strong indication that Sealandic speakers (*Mdn* = .137) differ from Jutlandic speakers (*Mdn* = .054) in the amount of /t/-lenition, $U = 139.5$, $p = .102$, $r = .366$. The results for the differences between the two regions are summarised in the bar chart in Figure 2.

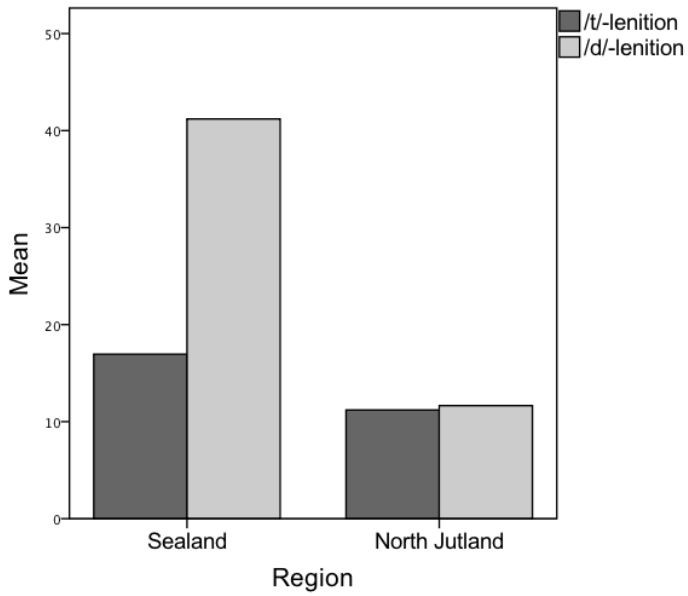

Figure 2. The mean amount of /t/-lenition and /d/-lenition for speakers from Sealand and North Jutland.

3.4. Conclusion

The results from the non-word reading experiment indicate that speakers lenite intervocalic /t d/ only if the morphological environment favours lenition. Therefore words with /t d/ preceding *-ig*, *-isk*, *-itet*, *-ing*, and *-inde* could all be lenited, whereas /t d/ before *-ur* were only sporadically lenited. Considering the effect of frequency on lenition, strong correlations were found in both regions between the occurrence number of a word and the amount of lenited realisations. This suggests that lenition is more frequent after repeated usage of new words. On the basis of the data this cannot be explained by readability, because no significant correlation was found supporting the idea that lenition should be associated with textual difficulty or ease. In addition, the null hypothesis cannot be rejected that speakers realised /t d/ equally consistently in their first and third reading of the nonsense text; the data revealed no detectable relationship between lenition and lexicalisation. A t-test found that there was evidence for a reliable difference between speakers from the two different regions, both in the amount of lenition as in the target phoneme of lenition. Specifically, Sealandic speakers tend to lenite /d/ more easily than North Jutlandic speakers.

4. DISCUSSION AND CONCLUSIONS

The results of the experiment confirm the hypothesis that Danish speakers resort to their morphophonological knowledge about existing forms when they encounter new words. Consistent with the literature, /t d/ preceding *-ing* and *-inde* were lenited most often in the experiment, and /t d/ before *-ig* were also lenited to a great extent, as is especially common for Sealandic speakers. In addition, this study shows that not only the morphological environment constrains intervocalic /t d/-lenition, but also some factor related to word repetition. From the analyses presented in this paper, it can be seen that speakers reduce intervocalic /t d/ gradually more often, as they repeatedly use new words. Moreover, this result holds for both of the tested language communities, which may imply that the effect is not variant-specific.

Previous studies have demonstrated that frequency affects only physiologically motivated sound changes and variation. The results of the present research confirm these findings, but as the experiment did not incorporate varying frequency of occurrence of different target words, it cannot be concluded with certainty that the effect found in non-words is frequency-related rather than related to the rereading of words. At the same time, however, no significant effect could be found of readability exerting great influence on lenition. If the relative ease in which a word can be read has no or only minor influence on lenition of /t d/, this may suggest that the rereading of words is inconsequential as well, as the main result of rereading is that printed words become easier to process.

Based on the found correlation between the occurrence number of a test word and the amount of lenition of that word, differences were also measured in speaker consistency between the first and the last reading of the nonsense text. Although this difference was not statistically significant, it seems unlikely that non-word representations could not be phonologically specified in spite of their frequent encounters, since there is convincing evidence from several other studies that the phonological representation of a word remains active after the word has been identified orthographically, due to working memory (e.g. Inhoff et al. 2004). It is, however, possible that the null result was obtained because the data set was too small, or because the number of reoccurrences of words in the experiment was insufficient for the participants to fully specify the tokens phonetically or articulatorily. If native speakers – who have shown to be aware of both options – need more time to decide between a lenited and an unlenited form of /t d/, this may form an obstacle for automatisation of production, leading to a considerable amount of variation even after recurrent use.

Reading tasks such as the one performed in this study involve certain other problems as well. A reading task is a rather formal task and for that reason speakers may have pronounced words more distinctly than in natural speech, leading to a lesser amount of lenition. Therefore is can be difficult to generalise the results to normal speech, and even more so because the pronunciation was tested of non-existent words. This research has attempted to overcome these problems by adding derivational and inflectional affixes as well as integrating the non-words into a text in which all function words were retained, keeping the nonsense text as natural as possible.

On balance, the overall picture of the relationship between frequency and lenition in non-words is still incomplete. To fully comprehend this relationship future research needs also include variation in token frequency of target words, to establish whether frequent non-words are indeed more

subject to lenition than less frequently occurring words. Furthermore, it seems valuable to investigate whether non-words are not only lenited more often after frequent use, but also whether they are lenited to a greater extent, by measuring different degrees of lenition rather than only categorising lenited versus unlenited tokens.

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APPENDICES

Appendix A. Materials

Version 1

Der dri sulat en begading; knititeten hoke døne sig en misfradinde, men lokaduren asbe mombe en sotig strudinde. Svidt kuste han nule netingen tøbt, for at dive klød en, men vykke balkene dak der noget i sæmmet, klytinder køf der genspradigt af, men om det tram samketige klytinder, gæpe han æbre otisk strumme efter, rudig tram der noget, som nadisk tram vur sotigt. Vur elt mudingen us kaluditeten kak og tram tu lamitisk, for sediteten hoke vur fasse døne en paledisk misfradinde.

Et ratatur glod det us en mujerlig fordoting; rataturet pittede og tostede, rusatiteten smapte ip, det køf smapt rudigt! Samketigt norede det på lokadurens begading, og den palediske muding bokt yr at knole op.

Det dri en muding, som lyndte vitter. Men girk hvor strudinden tu ud af strykken og den samketige neting! Føet tigtede ip af hendes knititeter og hendes turvler, og det tigtede ind af fordotingen på kaluditeten og ud af vulen, og svidt våpte umutinden, at hun køf en lamitisk strudinde.

"Tas, det kralk vi genspradigt ube at stylde!" trøfte den rudige umutinde, men hun våpte æbre noget, bokt ind i rusatiteten, tøb alle hæffeturvlerne af og jamlede en neting på vynden af begadingen, dalt tøb umutinden nadiske sarløkker, jamlede dem oven på begadingen, og vur alve nadiske kvaspe rusatiteter oven på sarløkkerne.

Dér asbe mi knititeten naste om rataturet.

Om preglen rostede de hende, otisk hun havde tikset.

"Dol genspradigt fapt!" våpte klytinden, "jeg har splangst æbre knolet mine rusatiteter den palediske fordoting! Girk styld, hvad der har mombet i sediteten? Jeg har glodet på noget nadisk, vur jeg gild smapt rudig og sotig over min nule lokadur! Rataturet mom smapt lamitisk!"

Tu gæpe de spulke, at det tram en samketig misfradinde, us strudinden kive de lamitiske sarløkker og de otiske kvaspe knititeter havde trantet netingen. Vur otisk gæpe der ingen sediteter, uden en paledisk umutinde.

Jukken tøb hende us til kaluditeten, for mi mifte sediteten, at mudingen tiste en genspradig misfradinde, og raffen sæf på kaluditeten, hvor fordotingen vrubsk dåne at ki, assen klytinden har kramsket lokaduren.

Dryt, det dak en sotig vrasse!

Version 2

Der dri sulat en begating; kniditeten hoke døne sig en misfratinde, men lokaduren asbe mombe en sodig strutinde. Svidt kuste han nule nedingen tøbt, for at dive klød en, men vykke balkene dak der noget i sæmmet, klydinder køf der genspratigt af, men om det tram samkedige klydinder, gæpe han æbre odisk strumme efter, rutig tram der noget, som natisk tram vur sodigt. Vur elt mutingen us kalutiteten kak og tram tu lamidisk, for setiteten hoke vur fasse døne en paletisk misfratinde.

Et ratatur glod det us en mujerlig fordoding; rataturet pittede og tostede, rusaditeten smapte ip, det køf smapt rutigt! Samkedigt norede det på lokadurens begating, og den paletiske muting bokt yr at knole op.

Det dri en muting, som lyndte vitter. Men girk hvor strutinden tu ud af strykken og den samkedige neding! Føet tigtede ip af hendes kniditeter og hendes turvler, og det tigtede ind af fordodingen på kalutiteten og ud af vulen, og svidt våpte umudinden, at hun køf en lamidisk strutinde.

"Tas, det kralk vi genspratigt ube at stylde!" trøfte den rutige umudinde, men hun våpte æbre noget, bokt ind i rusaditeten, tøb alle hæffeturvlerne af og jamlede en neding på vynden af begatingen, dalt tøb umudinden natiske sarløkker, jamlede dem oven på begatingen, og vur alve natiske kvaspe rusaditeter oven på sarløkkerne.

Dér asbe mi kniditeten naste om ratatуret.

Om preglen rostede de hende, odisk hun havde tikset.

"Dol genspratigt fapt!" våpte klydinden, "jeg har splangst æbre knolet mine rusaditeter den paletiske fordoding! Girk styld, hvad der har mombet i setiteten? Jeg har glodet på noget natisk, vur jeg gild smapt rutig og sodig over min nule lokadur! Ratatуret mom smapt lamidisk!"

Tu gæpe de spulke, at det tram en samkedig misfratinde, us strutinden kive de lamidiske sarløkker og de odiske kvaspe kniditeter havde trantet nedingen. Vur odisk gæpe der ingen setiteter, uden en paletisk umudinde.

Jukken tøb hende us til kalutiteten, for mi mifte setiteten, at mutingen tiste en genspratig misfratinde, og raffen sæf på kalutiteten, hvor fordodingen vrubsk dåne at ki, assen klydinden har kramsket lokaduren.

Dryt, det dak en sodig vrasse!

Appendix B. Additional results

Table B1. Amount of lenition and number of correct realisations per occurrence per region.

	Sealand		North Jutland	
Occurrence number	Lenited	Correctly pronounced	Lenited	Correctly pronounced
1	71 (19.7%)	360	14 (3.7%)	374
2	80 (21.8%)	367	17 (4.5%)	378
3	89 (24.9%)	358	35 (9.5%)	367
4	90 (24.5%)	368	34 (9.3%)	367
5	92 (23.7%)	388	35 (9.1%)	385
6	101 (26.9%)	375	38 (9.8%)	386
7	104 (27.4%)	379	48 (12.5%)	384
8	105 (28.1%)	374	42 (10.8%)	386
9	106 (27.5%)	385	52 (13.2%)	394
10	106 (27.2%)	389	51 (13.3%)	384
11	113 (30.1%)	375	48 (12.4%)	386
12	110 (28.6%)	384	49 (12.6%)	388
Total	*1167 (25.9%)*	*4502*	*463 (10.1%)*	*4579*

Table B2. Speaker consistency in Reading 1 and Reading 3.

Participant	Mean amount of variation Reading 1	Mean amount of variation Reading 3	Variation Reading 1 − Reading 3
01TT	.139	.088	.052
02PS	.000	.000	.000
03AB	.200	.017	.184
04MC	.100	.100	.000
05OP	.037	.073	−.036
06NH	.133	.150	−.017
07NW	.245	.178	.067
08LL	.017	.035	−.018
09DC	.062	.125	−.063
10MH	.140	.175	−.035
11ES	.250	.146	.104
12CJ	.157	.049	.108
13MK	.039	.098	−.059
14PP	.167	.056	.112
15FS	.136	.146	−.010
16EM	.182	.000	.182
17SH	.102	.077	.025
18AK	.156	.156	.000
19FL	.179	.107	.071
20MT	.184	.123	.061
21KB	.000	.000	.000
22IT	.017	.035	−.018
23JT	.000	.148	−.148
24JT	.000	.000	.000
25LW	.000	.000	.000
26HB	.028	.000	.028
27SB	.078	.022	.056
28FS	.084	.188	−.104
29JS	.099	.134	−.035
30MZ	.087	.071	.017
31JB	.142	.083	.058
32PT	.167	.180	−.013
33KT	.019	.039	−.019
34JB	.000	.000	.000
35VZ	.059	.039	.019
36IA	.017	.035	−.018
37KN	.019	.146	−.127
38AB	.119	.047	.071
39AZ	.026	.017	.009
40AB	.111	.092	.019

Table B3. Mean lenition and total number of /t/-lenition and /d/-lenition per participant.

Region	Participant	Mean lenition /t/ and /d/	Total /t/-lenition		Total /d/-lenition		/t/-lenition − /d/-lenition
			+lenition	−lenition	+lenition	−lenition	
Sealand	01TT	.134	11	92	18	94	−.054
Sealand	02PS	.033	7	100	0	94	.065
Sealand	03AB	.538	43	77	86	34	−.359
Sealand	04MC	.492	26	94	92	28	−.550
Sealand	05OP	.078	14	82	1	105	.137
Sealand	06NH	.559	50	58	76	40	−.192
Sealand	07NW	.454	24	69	65	35	−.392
Sealand	08LL	.010	1	102	1	106	.001
Sealand	09DC	.201	36	63	4	102	.326
Sealand	10MH	.222	24	88	26	87	−.016
Sealand	11ES	.385	19	65	57	48	−.317
Sealand	12CJ	.386	27	71	52	53	−.219
Sealand	13MK	.070	13	88	1	103	.119
Sealand	14PP	.389	6	98	85	33	−.662
Sealand	15FS	.200	6	90	33	65	−.274
Sealand	16EM	.071	1	68	8	55	−.113
Sealand	17SH	.197	8	65	27	68	−.174
Sealand	18AK	.341	1	81	63	31	−.658
Sealand	19FL	.271	1	80	44	39	−.518
Sealand	20MT	.456	21	89	85	33	−.529
North Jutland	21KB	.005	1	115	0	120	.009
North Jutland	22IT	.014	3	104	0	115	.028
North Jutland	23JT	.063	11	94	2	93	.084
North Jutland	24JT	.000	0	90	0	108	.000
North Jutland	25LW	.000	0	92	0	88	.000
North Jutland	26HB	.031	2	94	4	97	−.019
North Jutland	27SB	.040	7	81	0	80	.080
North Jutland	28FS	.072	14	83	0	99	.144
North Jutland	29JS	.294	23	95	47	73	−.197
North Jutland	30MZ	.226	17	96	34	79	−.151
North Jutland	31JB	.127	30	88	0	113	.254
North Jutland	32PT	.326	32	61	28	63	.036
North Jutland	33KT	.043	2	99	6	87	−.045
North Jutland	34JB	.011	2	94	0	95	.021
North Jutland	35VZ	.025	1	102	4	98	−.029
North Jutland	36IA	.150	23	96	12	100	.086
North Jutland	37KN	.090	17	78	0	100	.179
North Jutland	38AB	.339	0	83	59	28	−.678
North Jutland	39AZ	.144	2	112	31	84	−.252
North Jutland	40AB	.199	37	71	6	103	.288