Danish stød as a cue to upcoming suffixes:

An ERP and response time study

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Abstract

Prosodic cues such as stress and tones can help listeners predict upcoming structures and get a first crack at rapidly unfolding speech. The prosodic feature stød in Danish can distinguish word meanings but also signal imminent structures. For instance, monosyllabic nouns with stød lose stød when followed by the plural indefinite suffix *-e*. Suffixes invalidly cued by stød or non-stød have been found to produce longer response times (Clausen & Kristensen 2015), but so far, stød has not been examined with the event-related potential technique (ERP). An ERP study can give insights into what neural processes cause the previously found longer response times. In this study, effects of mismatches between stød or non-stød on stems and suffixes were tested for 16 speakers of Danish in a combined response time/ERP study. Invalidly cued suffixes produced longer response times and the ERP components N400 and P600, which have been associated with prediction error and reanalysis of forms, indicating that expectations were not met. Further, stød produced a negativity at 260-430 ms after stød onset which was interpreted as a pre-activation negativity (PrAN). This is in line with stød occurring under more restricted conditions and thus being a more reliable cue than non-stød because it activates fewer forms in the mental lexicon. The findings indicate that stød has a predictive function and that speakers use it as a cue to make forecasts about upcoming structures.

Keywords: Stød, Danish, prosody, N400, P600, pre-activation negativity, PrAN.

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Content

1 Introduction

Humans are capable of making sense of rapid speech as it unfolds. Understanding language requires processing a noisy input of complex structures from phonemes to syntax, relating these to general world knowledge and eventually extracting meaning from this relationship (Kutas, DeLong & Smith 2011, p. 2). All this happens at rates of up to 15 phonemes (Perkell 1997, p. 336) or 2-3 words (Levelt 1995, p. 17) per second. To keep up with this sweeping stream of information, listeners use prosodic cues such as stress, tone and pitch accents to predict upcoming structures, enabling listeners to get a first crack on imminent speech (Cutler, Dahan & Donselaar 1997; Kutas, DeLong & Smith 2011, pp. 3-4). This thesis investigates Danish stød as a potential prosodic predictor of upcoming speech, using event-related potential technique (ERP). Stød is intriguing because it is a prosodic cue different from rhythm, stress and tone. Response time studies with Danish have shown that suffixes invalidly cued by stød or non-stød produce longer response times (Clausen & Kristensen 2015), but stød is unexplored in neural correlates. An ERP study can provide further insight into the neural processes behind these longer response times.

It has been proposed that the brain is constantly in the process of making predictions about the future rather than passively waiting to be stimulated. Predictions are probability-based expectations based on previous experiences and facilitate perception by activating relevant representations (Bar 2007; Friston 2005). For language processing, this means linguistic items or their features are pre-activated prior to being perceived. When predicted lexical candidates do not manifest themselves despite this pre-activation, prediction violations occur and probability likelihoods are adjusted for the future. Such 'prediction errors' have been found to give rise to event-related potentials (ERPs) such as the mismatch negativity (MMN) and P600 effect (Kutas, Delong & Smith 2011, pp. 10-17; Friston 2005).

ERPs are brain responses associated with specific events, e.g. hearing a specific phoneme or prosodic cue. They are measured using a non-invasive technique in which a cap with electrodes picks up and amplifies electrical activity above the head. By using an averaging technique, neural responses associated with specific events can be extracted (Luck 2014, pp. 3-4). ERP components are named after their latency and whether the deflection of the amplitude is positive or negative (Kemmerer 2015, p 62). The P600 component, for instance, is a positive deflection peaking at around 600 ms after stimulus onset. Different ERP components have been associated with different neural functions.

Swedish word accents, which are historically and systematically related to Danish stød, have been found to cue upcoming suffixes, enhancing rapid word-processing. Invalidly cued suffixes lead to longer response times (Söderström, Roll & Horne 2012), and cause a P600 effect, indicating prediction error and reprocessing (Roll, Horne & Lindgren 2010; Roll, Söderström & Horne 2013; Roll et al 2015; Söderström, Horne, Frid & Roll 2016; Söderström et al. 2017). Also, in ERP studies, words with accent 1 produce a more negatively charged 'pre-activation negativity' (PrAN) compared to accent 2. PrAN is proposed to reflect the predictive strength of phonological cues. Since accent 1 is associated with a more limited number of possible word endings (Riad 1998), it is a better predictor than accent 2. While ERP components such as the P600 have been linked to prediction error, Roll, Söderström & Horne (2020, submitted) view the PrAN as a reflection in the ERP signal of the actual pre-activation of linguistic representations (Söderström et al 2016; Roll et al 2017; Roll, Söderström & Horne 2020, submitted).

There are no word accents (except for in a few dialects spoken in peripheral areas) in Danish, but there is a systematic link between word accents and stød. Danish words corresponding to Norwegian and Swedish accent 1 words typically have stød while those corresponding to accent 2 words typically do not have stød (Grønnum 2005, p. 216). As with Swedish word accents, Danish stød can signal upcoming grammatical categories such as singular or plural because stød/non-stød alternations are associated with specific endings (Grønnum 2005, pp. 236; Riad 2000, pp. 263-264; Basbøll 2003, pp. 37-38).

2 Aim and hypotheses

The historical and systematic relationship and the recent discoveries about Swedish word accents as predictors of upcoming structures make it relevant to examine whether Danish stød has a similar function. The aim of the study is to examine the function of stød for native speakers of Danish. In this study, the following hypothesis is tested:

H: L1 speakers of Danish use associations between stød/non-stød and suffix to predict word endings already when hearing stød or non-stød on the stem.

The hypothesis has some test implications. If the listener's predictions turn out to be incorrect (as for invalidly cued suffixes), it would lead to prediction error and reanalysis. This would be seen in increased response times, indicating increased cognitive load (Clausen & Kristensen 2015), and a P600 effect, indexing revision and reanalysis in order to interpret the test word. Since stød – as accent 1 – is associated with a more restricted set of suffixes, it is assumed to be a more useful prosodic cue than non-stød for the listener in predicting upcoming structures. The ERP component PrAN is proposed to be modulated by the predictive strength of prosodic cues, and stød is therefore expected to produce higher pre-activation negativity (PrAN) amplitudes than non-stød. These can be formulated as the following test implications:

1. Suffixes invalidly cued by stød/non-stød produce longer response times than validly cued suffixes.
2. Suffixes invalidly cued by stød/non-stød produce a P600 effect.
3. Stems with stød produce higher PrAN amplitudes than stems without stød.

3 Theoretical background

3.1 Danish stød

3.1.1 Distribution

Stød is a Danish prosodic phenomenon connected with certain syllables. Phonetically, it can be described as a creaky voice, a creak and, if emphasized or exaggerated, a complete glottal stop (Fischer-Jørgensen 1989, pp. 131; Grønnum 2005, pp. 215-216). The term stød means ‘shock’ or ‘thrust’ in Danish and was invented by Høysgaard in 1747 (Gårding 1977, p. 5).

Syllables require “a certain stretch of voicing” (Fischer-Jørgensen 1989, p. 8) to have stød, so stød is only found in syllables with either a long vowel or a short vowel followed by a sonorant consonant. Or according to Basbøll (2003), only bimoraic syllables can carry stød, and only sonorants are moraic in Danish. Short vowels followed by an obstruent therefore cannot have stød. Syllables which can carry stød are said to have ‘stødbasis’, while syllables which cannot, lack stødbasis (Fischer-Jørgensen 1989, p. 8). Examples of words with stødbasis are *huˀs* ‘house’ and *kælˀk* ‘sledge’, while *hest* ‘horse’ lacks stødbasis. In the following, example words and test words will be written in italics. They will be written orthographically, but stød will be marked with a ˀ symbol. Stød will only be marked in test words, not in e.g. other words with stød in carrier sentences. Full phonetic transcriptions will only be given if they are relevant in the context, and in that case, they will be written in square brackets. Phonetic transcriptions of all test words can be found in the appendix.

Unstressed syllables cannot have stød (Grønnum 2005, pp. 218-220) and, generally, neither can penultimate syllables (Basbøll 2003).

Itô & Mester (2015) argue that the presence or absence of stød can be understood within the framework of the 'perfect prosodic word', which is equal to one foot. A foot consists of two mora, μ, and since syllables with stødbasis are bimoraic, monosyllabic words can constitute a foot in their own right. Itô & Mester combine the previously mentioned stød constraints in the condition 'accentbasis'. Accentbasis requires 1) a sonorous second mora, e.g. the second half of a long vowel, that 2) occurs in a heavy syllable, and 3) the heavy syllable has to constitute its own monosyllabic foot. If there is more than one monosyllabic foot in a word, stød occurs only in the last foot. This means stød marks the right edge of a prosodic word, ω.

3.1.2 Stød phases, articulation and acoustics

A distinction can be made between the first and the second phases of the stød. The 'first phase' approximately corresponds to the first half of a long vowel or a short vowel followed by a sonorant consonant. Compared to words without stød, the first stød phase is characterized by a higher pitch, often higher intensity and somewhat more energy in higher formants. The 'second phase' corresponds to the latter half of a long vowel or the sonorant consonant with stød after a short vowel. In both cases, this is around 100-150 ms after vowel onset. Stød proper is typically considered a feature of the second stød phase. This phase is characterized by a strong decrease in intensity, and often irregular vibrations and a decrease in fundamental frequency. Fiberscopy has shown constriction of the vocal folds, adduction of the ventricular folds and often strong activity of the vocalis muscle. The vocalis muscle is a subset of the thyroarytenoid muscles and lies beneath the vocal folds. This phase is often described with the term 'creaky voice' (Fischer-Jørgensen 1989, p. 128-133).

Creaky voice is a type of voice quality typically defined in relation to 'modal' and 'breathy' voices. Voicing with less vocal fold approximation is called breathy, more is creaky and in between is modal (Gordon & Ladefoged 2001). Several scholars have expanded on this model, some arguing that the term creaky really consists of a bundle of different voice qualities with some perceptual characteristics in common (Garellek 2019). These characteristics are low pitch, irregular pitch and 'constricted-sounding', which means lower spectral tilt, i.e. difference in amplitude between harmonics. According to Garellek (2019), although articulation and acoustics differ, either one of the above-mentioned features can be enough for a voice to be perceived as creaky. Creaky voice has generally been found to be produced by contracting the thyroarytenoid muscles, thickening vocal folds. This leads to increased mass per unit length which typically lowers frequency. According to Esling, Moisik, Benner & Crevier-Buchman (2019), the ventricular folds (false vocal folds) can also couple with vocal folds during creaky voice, increasing vibrating mass, which lowers frequency, dampens vibrations and adds more freedom to the system, potentially leading to irregular vibrations (Esling, Moisik, Benner & Crevier-Buchman 2019).

Although stød is often described as 'creaky voice', there are divergences between creaky voice and stød, e.g. a decrease of overall intensity in the second phase of stød, which is not a characteristic feature of creaky voice (Fischer-Jørgensen 1989, p. 132-133). A high degree of variability in the articulation and acoustics of stød has been observed: Some persons have strong activity for pitch rise and some very little, some have strong adduction of the ventricular folds and others hardly any (Fischer-Jørgensen 1989, pp. 146). In terms of acoustic properties, Riber Petersen (1973) found that some speakers consistently produce stød with irregular vibrations and, in some instances, a complete glottal stop, while other speakers have no irregularity but a fall in intensity. For one speaker, there was no visible difference at all in the spectrogram, even though words sounded adequate. In fact, for this speaker stød was identified correctly in 85-90 % of cases whereas for another speaker with a more visible stød, that number was only 70-81 % (Riber Petersen 1973). Fischer-Jørgensen concludes that what speakers aim for when producing stød is not invariance but perceptual equivalence and that "sufficient, but not necessarily identical acoustic cues are supplemented by top-down predictability" (1989, p. 146).

3.1.3 Relation to Swedish and Norwegian word accents

The aim of this study is to investigate whether the finding that Swedish word accents function as cues to upcoming suffixes also hold true for Danish stød. In this section, I therefore describe in what ways word accents and stød are similar and in what ways they are different. I also go into the relationship between pitch and creaky voice. Finally, I describe some hypotheses about the possible origin of word accents and stød which cast light on relations between the two prosodic features.

3.1.3.1 Similarities and differences

Danish, Swedish and Norwegian are all Mainland Scandinavian languages, a branch within the North Germanic language family also including the insular Faroese and Icelandic. North Germanic is a subbranch of the Germanic branch of Indo-European language family (Pereltsvaig 2017, p. 23). In Swedish and Norwegian, there are two word accents, accent 1 and accent 2, which can be understood as a high or low tone on the stem, realized differently in different dialects (Bruce 2010, p. 68-94). Although Danish is grammatically and lexically closely related to Swedish and Norwegian, only a few peripheral dialects have word accents. Instead, most dialects, including Standard Danish, have stød.

Danish words with stød typically correspond to words with accent 1 in Norwegian and Swedish, while words without stød typically corresponds to words with accent 2 (Grønnum 2005, pp. 215-218). Both word accents and stød can distinguish meaning, as in the minimal pairs Swedish/Danish *tanken/tanˀken* 'the tank' (accent 1, stød) and *tanken* 'the thought' (accent 2, non-stød). Stød and word accents can also be induced by suffixes attached to the stem (Riad 2012; Rischel 1963/2009). For instance, Swedish *hatt* 'hat' in definite singular, *hatten* 'the hat', has accent 1 while the corresponding indefinite plural, *hattar* 'hats', has accent 2. Correspondingly, Danish *huˀs* 'house' has stød in definite singular, *huˀset* 'the house', while the corresponding indefinite plural form, *huse* 'houses', does not.

Some principal differences between stød and word accents are that while word accents are features of the word, stød is a feature of the syllable. A word can thus have more than one stød. Also, while all words have either accent 1 or accent 2 in Norwegian and Swedish, only syllables with stødbasis can have stød in Danish (Grønnum 2005, p. 214-216). Finally, following the 'Prague School notion of markedness', Danish stød is the marked term while in Norwegian and Swedish, accent 2 is the marked term (Gårding 1977, p. 23). The marked form is the form that stands out compared to the more general, unmarked form which is typically seen as the default. In terms of phonetics, Trubetzkoy (1969) suggested the unmarked form was the least different from normal breathing. Accent 2 (Roll, Söderström & Horne 2011) and stød deviate more from normal breathing than accent 1 and non-stød and are therefore considered the marked forms. Also, in areas where the accent or stød distinction is lost, accent 1 is typically generalized in Swedish whereas in Danish, non-stød is generalized (Riad 1998).

3.1.3.2 Creaky voice and pitch

Low or falling pitch and creaky voice are intimately related, e.g. in Mandarin (Kuang 2017). A Swedish example is discussed in Svensson Lundmark (2017), who, when investigating the articulatory correlates of South Swedish word accents, found a higher degree of creaky voice for accent 1 than accent 2. The occurrence of creaky voice was suggested to be related to low or sharply falling F_0.

Several scholars have discussed the relationship between word accents and stød. In Riber Petersen's investigation of the acoustics properties of stød, most speakers had a fall in pitch for stød (1973). According to Gårding (1977, pp. 39-40) this was true for *all* speakers, even the previously mentioned speaker without a visible stød. Gårding goes on to suggest that it is in fact this sudden drop of pitch that is the common feature of all stød variants. A further proposal is that stød should be understood as tones, not just in terms of origin, but for phonological representation as well. Riad (2000, 2009) interprets stød as the manifestation of a HL tonal contour compressed within one syllable. Others refute the idea that stød is an accompaniment to a compressed HL pitch accent. Grønnum, Basbøll and Vazquez-Larruscaín (2013, pp. 33) argue that on the contrary, "F_0 perturbation is a side effect of laryngealization and not invariably present. Laryngealization is the articulatory, acoustic and perceptual constant in stød production, F_0 is not".

3.1.3.3 Origin

Most scholars agree that stød and word accents are historically related. While it has been proposed that word accents developed from stød (Liberman 1976), and that the co-existence of stød and word accents in Funen dialects represents a transitional stage, a more popular view seems to be that a common Scandinavian tone difference preceded stød (Riad 2000, p. 261; Fischer-Jørgensen 1989, p. 17). An argument for the latter view is that tonal accents in Danish are found in isolated, peripheral areas. This is typical for relic areas, i.e. areas where older linguistic forms are preserved (Fischer-Jørgensen 1989, p. 19). Riad (2009) proposes that Danish stød system originated from a tonal dialect similar to the one spoken today in Eastern Mälardalen where facultative stød and loss of distinctive accent 2 occur. Finally, stød and word accents could have developed as parallels in different dialects out of an earlier distinction (Fischer-Jørgensen 1989, Rischel 2008/2009; Gårding 1977, pp. 94-98, Oftedal 1952).

The rise of stød and word accents has been associated with the vowel syncope which happened in Old Scandinavian around 600-800 AD. During the syncope, many words lost a syllable, and the syncope has been interpreted as either the cause or the consequence of word accents. Stød and accent 1 occur in words that were monosyllabic in Old Scandinavian after the syncope, while non-stød and accent 2 occur in words which were disyllabic at the time (Oftedal 1952). Riad argues that what determined accents was whether a word had secondary stress or not. Within this framework, accent 2 has its origins as a pitch contour accompanying two stresses. When stress was lost due to syncope, pitch remained (Riad 1998).

After the syncope, the definite articles (*–inn/-it*) were separate words following the noun, but later became actual suffixes. This explains why old monosyllabic nouns have accent 1 and stød, even when inflected in definite singular, e.g. Danish *huˀset* ‘the house’. When the articles were suffixed around 1200 AD, word pairs like Old Swedish *and-inn* “the duck” and *andi-nn* ‘the spirit’ emerged, dawning the distinctive function of word accents to keep such words apart (Oftedal 1952; Fischer-Jørgensen 1989, p. 16). Support for this idea comes from the finding that several minimal pairs with different word accents in Swedish and Norwegian are definite singular forms of monosyllabic nouns with accent 1 and disyllabic nouns with accent 2 respectively (Gårding 1977, pp. 96-97).

3.1.4 The function of stød

To be able to interpret findings from the ERP and response time study, it is necessary to understand what role stød plays in language. In the following, I will describe the distinctive function of stød as well as its function as a cue to upcoming structures.

3.1.4.1 Distinctive function, apocope and schwa-assimilation

Stød distinguishes meaning in words like *tanˀken* ‘the tank, the petrol station’ and *tanken* ‘the thought’. However, it is difficult to quantify the functional load. While Elert counted 350 minimal pairs with word accents in Swedish and 2400 in Norwegian (Elert 1972, pp. 151-152), a more exact number of minimal pairs in Danish does not seem to have been calculated. However, according to Grønnum & Basbøll (2001, p. 231) “when inflected and derived words are admitted into the analysis, stød is unquestionably and abundantly contrastive”.

In Jutland dialects, the number of minimal pairs is even higher than in Standard Danish, because there is apocope, i.e. loss of final schwa, in disyllables. This leads to minimal pairs with stød/non-stød such as *huˀs* [huˀs] ‘house’ and *huse* [hu:s] ‘houses’ (Fischer-Jørgensen 1989, p. 12, Gårding 1977, p. 43, Ejskjær 1990). Even in dialects without absolute apocope, stød has an important function in keeping singular and plural forms apart, since a characteristic feature of Danish is that in spontaneous speech, a final schwa is assimilated to the preceding vowel or consonant. For instance, the final schwa in *lande* ‘countries’ is assimilated to the preceding sonorant consonant which is prolonged and the last part of the sound carries the unstressed syllable, [lann̩] (Grønnum 2005, pp. 186-187). Such reduction processes often result in almost identical singular and plural forms, e.g. *land* [lanˀ] ‘country’ and *lande* [lann̩] ‘countries’, but if the singular has stød, they are kept dissimilar (Basbøll, Kjærbæk & Lambertsen 2011, pp. 88-89), enhancing the distinctive function of stød.

3.1.4.2 Stød as cue to grammatical categories

Stød is also associated with certain word structures and thus functions as a signal of forthcoming structures (Grønnum 2005, pp. 217). According to Basbøll, stød/non-stød has an important function in communication, and to the listener, "it is a potential key to morphological structure and identification of the grammatical morphemes of the phonological string" (Basbøll 2003, pp. 37).

Stød alternations occur when a morpheme attains or loses stød due to inflections or derivations. As previously mentioned, Basbøll (2003) interprets stød as a feature of the second mora of bimoraic syllables, e.g. the second half of a long vowel. Basbøll considers stød in a bimoraic syllable the *unmarked case* and argues that the absence, rather than the presence, of stød in such syllables must be accounted for through principles. One source of stød alternations is the interaction between the principle that penultimate syllables of minimal words do not have stød - and lexicalised endings (Basbøll 2003; 2005, p. 378-380). Basbøll introduces a wordform analysis in which word endings are categorized based on how independent they are from following morphemes; i.e. how likely they are to be lexicalised and thus integrated into the basic word. The most integrated type, 'unproductive endings' (UPE), are lexicalized and thus included in minimal words, meaning that stem and suffix are treated phonologically as one unit. An example of such an unproductive ending is the plural suffix *–e* (Basbøll 2005, pp. 354-359). Therefore, monosyllabic nouns with stød, e.g. *kælˀk* 'sledge' lose stød when pluralized with *–e*, e.g. *kælke* 'sledges'. Stød is lost because *kælke* 'sledges' is treated as one phonological unit and penultimate syllables of minimal words generally do not have stød (Basbøll 2005, pp. 434-435).

The least integrated group are 'fully productive endings' (FPE) which are added to new words per default. Fully productive endings are merely added to words, forming maximal words without being treated as the same phonological unit. The singular definite suffixes *–et* and *–en* belong to this group. Thus, the addition of the singular suffixes does not affect the stød, and words with stød such as *kælˀk* 'sledge' retain stød in *kælˀken* 'the sledge' – even if stød is now on the penultimate syllable. Therefore, a general rule is that all monosyllabic nouns with stødbasis have stød in definite singular. This even applies to words with stødbasis which do not have stød in the stem (Grønnum 2005, p. 172-192). For instance, the word *stød* 'shock, thrust' itself has no stød, but its singular definite manifestation, *støˀdet* 'the shock/the thrust', does.

An exception to the rule is short vowels followed by /r/ which used to be produced as a fricative consonant [ʁ] but have weakened into the semivowel [ɐ̯] in postvocalic positions. Words with a short vowel followed by [ʁ] did not have stødbasis, but acquired it with the vocalization of the final /r/. According to Grønnum (2005, pp. 221-223), there is an ongoing process in which words which have acquired stødbasis are attaining stød, meaning some currently have stød (e.g. *porˀt* 'port') while others do not (e.g. *hjort* 'deer') and some can be produced either way (e.g. *slurk/sluˀrk* 'sip') (Den Danske Ordbog 2018). In a master thesis, Høeg (2020) found that a higher proportion of words in this category has stød within the younger generation (63 %) than the older (56 %), so the process seems to be ongoing.

3.1.4.3 Compounds

In Swedish and Norwegian, compounds generally have accent 2, although there are exceptions, especially in some dialects (Gårding 1977, p. 22). In Danish, the picture is a bit more complex. Monosyllabic words generally lose stød when they constitute the first part of a well-established compound (Basbøll 2003, p. 14), e.g. *kælˀk* 'sledge' and *kælkebakke* 'sledging hill'. However, while stød is lost when compounds are connected with *–e* or *–Ø*, it is retained when connected with *–s* (Grønnum 2005, p. 237), e.g. *lanˀd* 'country' loses stød in *landevejˀ* 'country road', and *landmandˀ* 'farmer', but retains it in *lanˀdsmandˀ* 'countryman'. Longer words also retain stød when they constitute first members of compunds, e.g. *elefanˀtfoˀd* 'elephant foot'. As just demonstrated, stød is retained in the second part of compounds and words can have more than one stød.

Kalivoda & Bellik (2018) build upon Itô & Mester's (2015) proposal that stød marks the right edge of a prosodic word, ω. The authors explain the disappearing stød on monosyllabic parts of compounds with them not forming their own prosodic word. Since the monosyllabic first member is no longer aligned with the right edge of a prosodic word, stød is lost, e.g. *toˀg* 'train' loses stød in *togpassagˀer* 'train passenger'. However, longer first members, e.g. *passageˀr* 'passenger', retain stød because they are long enough to form their own prosodic words, e.g. *passageˀrtoˀg* 'passenger train'. To sum up on compounds, monosyllabic first members tend to lose stød while longer first members tend to retain it in compounds.

In conclusion, as for accent 1, stød seems to be associated with a more limited number of word endings and only occur under specific phonological and morphological conditions. Put in other words, there is a number of limitations on the conditions under which stød can occur, e.g. not in penultimate syllables of minimal words and monosyllabic first members of compounds, or, within the framework of Itô & Mester, stød is restricted to the rightmost edge of prosodic words. Therefore, stød appears to be a more restricted prosodic cue on a stem than non-stød. Stød is therefore expected to be a better predictor of word endings in that it pre-activates less words in the mental lexicon than non-stød.

3.1.5 Geographical distribution of stød

Stød only occurs in dialects north of the 'stød boarder' which goes from Rømø in Southern Jutland to Præstø in Southern Zealand. Dialects south of the stød boarder either have no stød or have pitch accents similar to those in Swedish and Norwegian (Ejskjær 1990). The distributional rules differ somewhat within the stød area so that Jutland dialects tend to have stød in fewer words, while some Zealand dialects have stød in more words than Standard Copenhagen Danish (Fischer-Jørgensen 1989, p. 12-13). According to Ejskjær (1990, pp. 70-71), monosyllabic words with a short vowel + voiced consonant + unvoiced consonant', e.g. *folʔk* 'people', do not have stød in Funen and Jutland (except for Djursland) dialects. However, according to Michael Ejstrup (p.c 2020), a change is under way in Jutland dialects, and especially in bigger cities such words are acquiring stød as in Standard Copenhagen Danish.

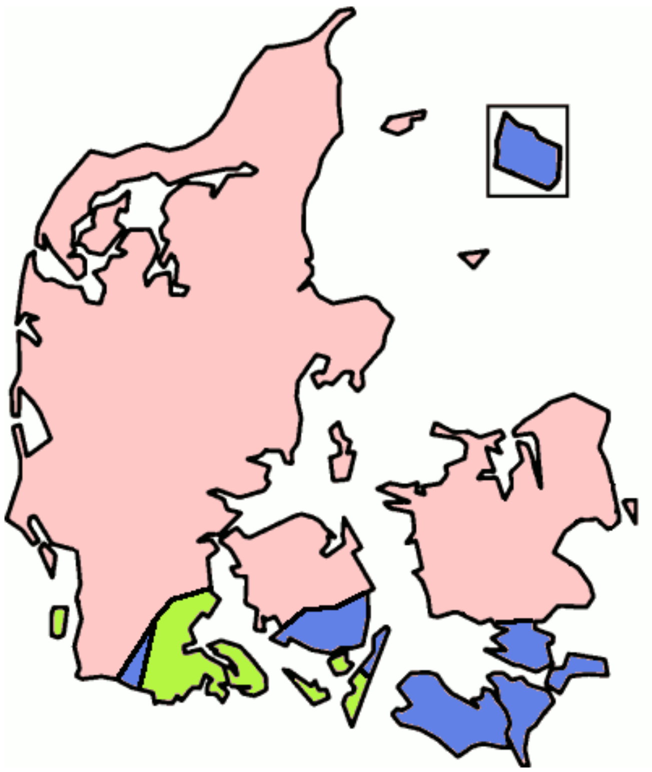

Figure 1: Only dialects north of stød border (pink area) have stød while dialects south of the border either do not have stød (blue area) or have pitch accents (green area) © Twid.

Another type of stød is the so-called 'West Jutland stød' which has a completely different distribution than the standard stød and is found in polysyllabic words and old apocated words before the stops /ptk/ (Fischer-Jørgensen 1989, p. 13). West Jutland dialects have standard stød as well as West Jutland stød (Ejskjær 1990). Because of the fundamental distributional differences, West Jutland stød will not be treated here.

3.2 Prediction

In recent years, it has been proposed that the brain is constantly making predictions about the future rather than just waiting to be activated by different sensations or perceptions. Within this framework, 'feedback connections' carry predictions from higher to lower order cortical areas. 'Feedforward connections', on the other hand, carry differences between predictions and the actual perceptions of the lower levels back. Prediction errors occur when predictions and the perceived input clash (Friston 2005, Bar 2007, Rao & Ballard 1999). The predictions are based on 'subjective Bayesian probability', which is the perceived or believed probability of certain events based on past experiences. The predictions are guided by what is more appropriate to expect in a given context according to the statistical history of events and stimuli in the surroundings (Friston 2005; Bar 2007).

For language processing, this means linguistic items or their features are pre-activated prior to being perceived. This pre-activation might be followed by prediction errors when a predicted lexical candidate did not manifest itself - and probability likelihoods are adjusted for the future. For instance, the ERP component N400 has been found to be larger for nouns that do not fit semantically into the preceding context, indicating it reflects the degree to which the word could be anticipated. Another ERP component, the P600, has been associated with prediction violations and reanalysis (Kutas, Delong & Smith 2011) and mismatch negativity (MMN) is associated with rare events, i.e. events that were not predicted (Friston 2005).

To sum up, subjective Bayesian probability is what a person expects given a certain condition, e.g. all previous experiences as a language user. Speakers of Danish, who have lifelong experience hearing stød on a stem followed by a definite singular suffix, likely deem it more probable to hear a definite singular suffix than an indefinite plural suffix upon hearing stød on the stem. When expectations are not met, prediction errors are likely to occur. However, when predictions *are* met – as they are in most cases of natural language processing - they likely allow listeners to deal with words faster, facilitating rapid speech processing.

3.2.1 Prosodic cues

Listeners make use of prosodic information such as stress, tones and pitch accents to facilitate rapid speech processing. They function as cues to upcoming structures on the sentence level (Cutler, Dahan & Donselaar 1997) and even within words (Roll, Horne & Lindgren 2010).

A few comments have to be made on the lateralization of prosody in the brain. For most people, the brain is left hemisphere dominant for language (96 % of right-handers, 70 % of left-handers (Knect et al. 2000)), but the right hemisphere has been found to be important in processing emotional and syntactic prosody. Zatorre, Belin & Penhune (2002) suggest that the hemispheres have developed to optimize acoustic processing: The left hemisphere has a better temporal resolution and the right a better spectral resolution. Increasing resolution in one realm comes at the expense of the other.

Therefore, the work load has been distributed between hemispheres. According to Poeppel's 'asymmetric sampling in time hypothesis' (2003), the hemispheres have different 'sampling rates'. The left hemisphere prefers extracting information from shorter (20-40 ms) time windows, e.g. formant transitions, and the right hemisphere from longer windows (150-250 ms) such as syllables and prosodic features.

In their 'dynamic dual pathway model', Friederici & Alter (2004) suggest that while syntactic and semantic information is primarily processed in the left hemisphere, suprasegmental information, e.g. accentuation and boundary marking, both typically expressed through pitch, are processed primarily in the right hemisphere. Pitch and linguistic information are integrated via the corpus callosum, which is a large fibre tract connecting the hemispheres and linking the two types of information. Support for the model comes from an ERP study with healthy controls and patients with lesions in the anterior and posterior corpus callosum respectively (Sammler, Kotz, Eckstein, Ott and Friederici 2010). For the first two groups, mismatches between syntactically predicted structures and prosodic pitch lead to an anterior negativity, showing interactions between prosody and syntax. For the group with posterior corpus callosum lesions, no effect was found, pointing to the posterior portion of the corpus callosum as important during interhemispheric prosody-syntax interactions. Within this framework, pitch is in its own right right-lateralized but when its nature and function is linguistic, it becomes more left-lateralized (Friederici & Alter 2004). Thus, although stød is not equal to pitch, the perception of it relies on integrating spectral information (low pitch, irregular vibrations) with linguistic function and should therefore be expected to be more left-lateralized.

3.3 Event related potentials

3.3.1 EEG and ERP

Neurons are brain cells which communicate with other cells by transmitting electrical signals. Altogether, the human brain contains nearly 100 billion neurons and, in the cerebral cortex alone, 1 million billion connections. Each neuron receives hundreds or even thousands of inputs from other cells and in turn pass them on to other cells (Kemmerer 2015, pp. 5-8). When that happens, neurons produce electrical activity, and when large portions of neurons receive information at the same time, that activity can be measured by placing electrodes at the surface of the head. The resulting fluctuating voltage propagating across the scalp is called an 'electroencephalogram' (EEG). There is one trace per electrode (Kemmerer 2015, p. 60).

The electrical activity comes in two main types: 'Action potentials', which are voltage spikes roaming down the axons of neurons, and 'postsynaptic potentials' which are voltages that arise when ion channels in the neuron open, leading to a change in voltage across the membrane. With a few exceptions, it is the latter that is picked up in ERP studies, because postsynaptic potentials last longer, allowing activity from multiple cells to summate (Luck 2014, pp. 39-40; Kemmerer 2015, pp. 60-61). EEG represents several sources of neural activity, but within these are neural responses associated with specific sensory or motor events. Event-related potentials (ERPs) can be extracted from the overall EEG with an averaging technique (Luck 2014, pp. 3-4). The main advantage of the ERP technique is its excellent temporal resolution which means differences in the signal can be measured down to the millisecond. This makes the technique particularly useful for studying the processing of the rapidly changing speech signal.

3.3.2 ERP components

ERP components are positive or negative deflections with specific scalp distributions and timings and are associated with specific functions. The components are named after their timing in ms after stimulus onset and whether they give rise to a positive (P) or negative (N) deflection (Kemmerer 2015, p. 62). A P600, for instance, is a positive deflection at around 600 ms. The polarity of an ERP component usually does not per se tell us anything about the cognitive function it indexes. Rather, the polarity depends on whether the postsynaptic potentials measured are excitatory or inhibitory, where they occur in relation to the cell body, how neurons are oriented in relation to the measuring electrode and the reference site. If three of these four factors are known, the fourth can be derived, but usually they are not (Luck 2014, p. 42). The same holds true for scalp distribution. Spatial resolution is quite poor for ERP and a distribution of electrical activity could in theory have emerged from anywhere in the brain. Polarity and distribution over the scalp are therefore mainly used to tell different components apart. What is really of interest in ERP studies are systematic differences between waveforms elicited by experimental conditions as compared to those in a control condition, e.g. invalidly versus validly cued suffixes, because this tells something about the cognitive processes involved (Kemmerer 2015, p. 62). There are numerous different components. In the following, I will describe the three components relevant for the present thesis: The P600, the N400 and PrAN.

3.3.2.1 P600

As mentioned above, the P600 is characterized by a positive-going bend of the waveform, usually peaking at around 500-600 ms after stimuli onset (Osterhout & Holcomb 1992). It seems to be triggered by syntactic violations. One interpretation is that the P600 reflects a repair process occurring when expectations and actual input are at conflict (Kim & Osterhout 2005). In terms of neural sources, different studies have shown activation in the bilateral posterior and middle frontal gyri, and left inferior parietal lobule (Kuperberg, Sitnikova & Lakshmanan 2008), posterior middle temporal gyrus (Service, Helenius, Maury & Salmelin 2007; Kwon et al. 2005) and basal ganglia (Frisch, Kotz, von Cramon & Friederici 2003).

3.3.2.2 N400

The ERP component N400 is associated with semantic processing and amplitudes vary with semantic expectations and degree of difficulty of integrating words into semantic contexts (Kutas & Hillyard 1980). More difficult and semantically less expected words lead to larger N400 amplitudes. The neural substrates of N400 have been found to be activity spreading from the left posterior middle temporal gyrus and forward to anterior temporal and inferior frontal regions. Lau, Philips & Poeppel (2008) present a model in which the temporal lobe is associated with lexical access, while the anterior temporal regions are involved in incorporating information into contextual representations. The inferior frontal regions control retrieval of lexical representations based on predictions and facilitates selection between activated lexical candidates. The left anterior negativity (LAN) is another ERP component with the same latency as N400, but a different scalp distribution (Friederici, Pfeifer & Hahne 1993). While N400s are broadly distributed, LANs are frontal and left-lateralized which indicates that the components are generated by different neural structures.

3.3.2.3 Pre-activation negativity

Pre-activation negativity (PrAN) is a left-lateralized negativity over frontocentral sites at 136-280 ms after stimuli onset. According to Roll, Söderström & Horne (2020, submitted) the component is a trace in the ERP signal linked to the actual pre-activation of linguistic representations. Such a pre-activation would to a large extent be based on phonological cues and Roll et al. propose that PrAN reflects the predictive strength of phonological cues.

PrAN amplitudes increase when speakers listen to word beginnings with highly predictable continuations such as high frequency and few lexical competitors (Söderström, Horne, Frid & Roll

2016; Roll et al 2017; Roll, Söderström & Horne 2020, submitted). Also, words with accent 1 have been found to produce more negative PrAN amplitudes compared to accent 2. Accent 1 is associated with a well-defined set of endings, mainly definite singular *-en/ett* and present *-er*, whereas most other suffixes induce accent 2 (Riad 1998). In addition, in Central Swedish accent 2 occurs in all words with secondary stress and thus in all transparent compound words (Gårding 1977, pp. 22). Therefore, words with accent 2 are on average associated with 11 times as many lexical items as accent 1. Accent 1 is thus a better predictor of word endings than accent 2 (Roll et al. 2015; Söderström, Horne, Frid & Roll 2016). PrAN has also been found for syntactic structures (Söderström, Horne, Mannfolk, Westen & Roll 2018).

In fMRI studies, PrAN has been found to correlate with increased blood-oxygen-level dependent (BOLD) contrast, indicating that the increased negativity indexes greater neural activity. PrAN is therefore considered an electrically negative effect for lower lexical competition rather than a positive effect for higher lexical competition (Roll, Söderström & Horne, 2020 submitted).

The PrAN can be divided into two phases: The early phase, occurring between 50-150 ms, reflects increased pre-activation in the primary auditory cortex. The increased activity is found for sounds that are more predictively useful, e.g. accent 1 being more predictively useful than accent 2. The late phase, after 200 ms, engages Broca's area and appears to be associated with inhibition of irrelevant forms, morphemes or syntactic structures (Roll, Söderström & Horne, 2020 submitted).

4 Method

4.1 Participants

Sixteen right-handed L1 speakers of Danish speaking dialects from north of the stød border participated in the study. Mean age was 27.6 years, SD = 4.9, 10 women. Stød is realised slightly differently in different dialects, but this was assumed not to influence processing significantly since sentences were recorded by a speaker of Standard Copenhagen Danish, a dialect which most people are used to hearing. There is no stød in dialects south of the stød boarder and speakers from this area were therefore excluded from the study because they may have grown up without hearing stød. While 96 % of right-handers have left hemisphere dominance for language, this is only true for about 70 % of left-handers (Knecht et al. 2000). To ensure a homogenous group in terms of hemispheric language dominance, left-handers were excluded. Participants were recruited via a poster.

4.2 Stimuli

4.2.1 Stimulus words

Stimuli consisted of 40 monosyllabic nouns with stødbasis, all of which can be pluralized with *–e*. Monosyllabic nouns were chosen because they are good examples of stød alternations between different grammatical categories. In Standard Copenhagen Danish, if these words have stødbasis, they have stød in definite singular, taking the suffix *–et* or *–en*, e.g. *kælˀken* 'the sledge'. In plural indefinite, they lose stød, taking the suffix *–e*, e.g. *kælke* 'sledges'. Also, test words in Roll, Söderström & Horne (2013) and Roll (2015) were monosyllabic nouns as well, increasing comparability between studies.

Seven words with stød in long vowels, e.g. *skaˀb* 'closet', and 33 words with a short vowel followed by a sonorant consonant, e.g. *kælˀk* 'sledge', were included. Words ending in plosives were chosen for ease of splicing, i.e. cutting the words between e.g. stem and suffix. As mentioned earlier, stød can only occur in syllables with stødbasis, meaning either a long vowel or a short vowel followed by a sonorant consonant. An exception is a short vowel followed by /r/, which used to be produced as a fricative consonant [ʁ] but has weakened into the semivowel [ɐ̯] in postvocalic positions. In the present study, only words with stød in definite singular were included while words without stød or which can be produced either way were excluded, because exceptions to the general rule might confuse participants. When these criteria were applied, the number of potential test words was limited considerably. Some words were well-known, e.g. *telˀt* 'tent' while others were probably unknown to many participants, e.g. *ulˀk* 'sculpin'.

Forty-eight test words in carrier sentences were recorded. A few words were discarded because they did not live up to criteria, were ambiguous or could not be edited so that they sounded "good" despite having wrong suffixes. Thus, 40 words remained. Phonetic realization and stød status were checked for all words in Den Danske Ordbog (2018). The test words were incorporated into carrier sentences with the structure *Ruth fandt kælˀken/kælke på loftet* 'Ruth found the-sledge/sledges on the-loft'.

4.2.2 Recording

A female speaker of Standard Copenhagen Danish recorded the sentences in an anechoic chamber. Recordings were made in the recording programme Audacity. Two sentences were recorded for each test word, once with the test stimulus word in singular, once in plural. For every other sentence, the singular condition was read before the plural and vice versa to avoid production being systematically affected by intonation patterns. All carrier sentences were read as answers to questions such as *hvor fandt Ruth kælˀken?* 'where did Ruth find the sledge?' to avoid focus on test words, because focusing a lexical item has a lengthening effect in Standard Danish. Long vowels can be lengthened freely while the stød phase of vowels cannot be drawn out at will (Grønnum & Basbøll 2001, p. 245-246) which would affect durations of test words.

4.2.3 Editing and definition of stød onset

Sentences were cut in four places in Praat to create eight different combinations with validly and invalidly cued suffixes (Figure 2).

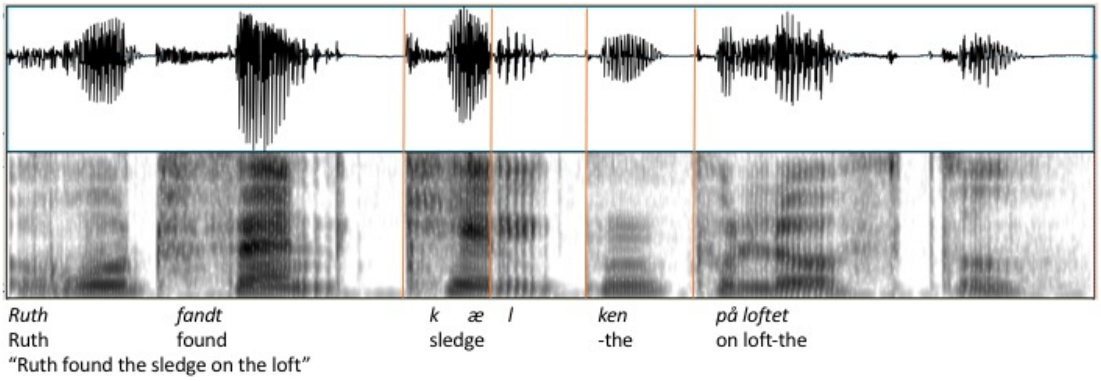

Figure 2: Sentences were cut in four places: Word onset, between the first and second stød phase, suffix onset and onset of the final prepositional phrase.

In this study, 'stød onset' was operationalised as the onset of the second stød phase, i.e. the stød proper. The onset of the stød proper was defined as when vibrations started getting irregular (Figure 3), because this was found to be the most salient boundary between the first and second phases of stød.

In words without stød, 'non-stød onset' was operationalised as the corresponding duration after F_0 onset. For instance, the sound wave in the word *kælˀken* 'the sledge' becomes irregular 61 ms after F_0 onset, meaning non-stød in *kælke* 'falcons' was also defined as 61 ms after vowel onset. On average, irregular vocal fold vibrations started 92 ms after F_0 onset. In the following, the term 'prosody' will be used to refer to the presence or absence of stød on the stem (or what has previously been referred to as stød/non-stød). When referring to 'prosody onset', what is meant is 'stød onset' and 'non-stød onset' respectively, as defined above.

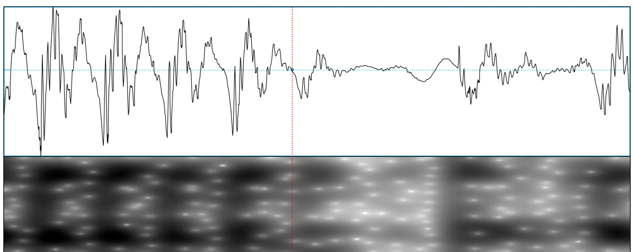

Figure 3: Stød proper onset was operationalised as the onset of irregular vibrations (red line).

Stød can possibly be detected already during the first stød phase, i.e. during the first half of long vowels or a short vowel followed by a sonorant consonant. To avoid the first phase systematically cueing the stød proper, all test words occurred in two conditions: Once with the first phase taken from stød test words and once with the first phase taken from non-stød test words. This will be referred to as the ‘first stød/non-stød phase’. However, it is outside the scope of this thesis to examine the impact of the first stød phase on processing.

Test words were edited so that different conditions of the same test word had the same duration from word onset to suffix onset, M = 292 ms, SD = 46, and from F_0 onset to stød onset, M = 92 ms, SD = 12. In most cases, F_0 onset was equal to vowel onset. However, in words such as *svamˀp* ‘mushroom’ and *greˀb* ‘pitchfork’, F_0 started already at the onset of the sonorant consonant which was in those cases considered the F_0 onset. Another option would have been to define F_0 onset simply as vowel onset, but since a potential difference in pitch could be identified already during the sonorant consonant, this was operationalised as the F_0 onset. Most importantly, F_0 onset was the same for different conditions of the same test word.

This was to avoid differences in duration affecting processing. Test words had an average duration of 417 ms. Table 1 shows the 8 different conditions and what sentences different parts of the stimulus words came from.

Table 1: Condition	**Test word: Kælk ‘sledge’**	**Carrier sentence**	**Stem**		**Suffix**	**Carrier sentence**
			First stød phase	**Second stød phase**		
a	kælˀken ‘the-sledge’	Ruth fandt “Ruth found”	Singular	Singular	Singular	på loftet ‘on the-loft’
b	kælˀken ‘the-sledge’		Plural	Singular	Singular	
c	Kælke ‘sledges’		Plural	Plural	Plural	
d	kælke ‘sledges’		Singular	Plural	Plural	
e	kælken ‘the-sledge’		Singular	Plural	Singular	
f	kælken ‘the-sledge’		Plural	Plural	Singular	
g	kælˀke ‘sledges’		Plural	Singular	Plural	
h	kælˀke ‘sledges’		Singular	Singular	Plural	

4.3 Procedure

Participants sat in front of a screen, wearing EEG caps and looking at a fixation cross, and listened to randomized stimuli through headphones. They were instructed to respond as fast as possible to whether the test word in question was singular or plural, if it represented one or more things (*fandt*

Ruth én eller flere? 'Did Ruth find one or more?') They responded by pressing either 1 or 2 on the keyboard with the index finger and middle finger respectively. The experiment was conducted on a stationary PC using Psychopy (Peirce et al. 2019), which is an experimental software program.

Stimuli were presented in randomized order with stimulus onset asynchrony (SOA) jittered between 4 and 6 seconds. The SOA jitter helps filter out activity from the previous trials. Also, it helps preventing alpha oscillations (brain waves with relatively slow oscillation cycles which become larger when a participant is drowsy) from aligning with stimuli because the stimulus occurs at different points in the alpha cycle on each trial (Luck 2014, p. 17, pp. 144-145)

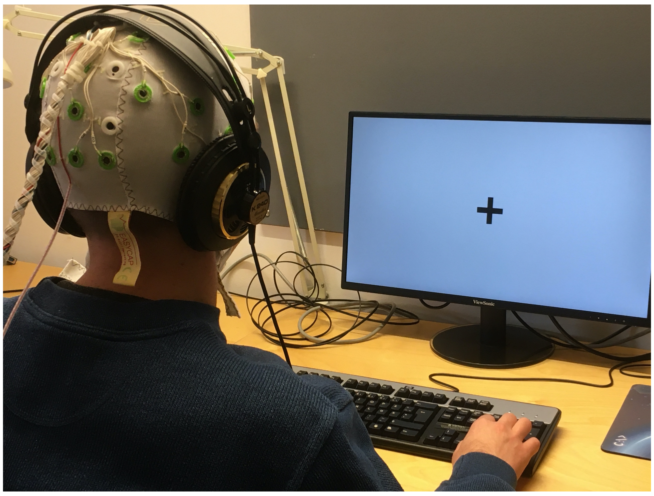

Figure 4 Participants sat in front of a screen with a fixation cross and listened to stimuli via headphones.

The duration of the experiment was approximately 50 minutes with stimuli divided into six blocks of 6-7 minutes each. In total, 320 stimuli words were presented. See complete stimulus list in appendix.

4.4 Behavioural data

Differences in response accuracy and response times can indicate whether e.g. invalidly cued suffixes influence word processing. Longer response times can be interpreted as reflecting increased difficulty. The same is true for lower response accuracy. Response accuracy and response times were recorded with Psychopy for all trials. Response times were measured from suffix onset because this was the disambiguation point from which words could be identified as either singular or plural. Only response times for correct responses were measured.

4.5 ERP study

4.5.1 EEG recording

The EEG was recorded with a 32-channel Braincap-MR from EasyCap using BRAINAMP MR PLUS Amplifier and Brainvision recorder (BrainProducts). Participants wore EasyCaps in different sizes depending on head circumference and caps were placed so that the central electrode, Cz, was exactly midways between nasion (between eyes) and inion (the little protrusion at the back of the head) and exactly between earlobes. Electrodes are named based on their distribution over the head. For instance, ‘Cz’ is central and medial and ‘Fz’ frontal and medial. Uneven numbers, e.g. ‘F3’, are to the left and even numbers, e.g. ‘F8’, to the right. The higher the number, the more lateral the electrode.

What is recorded in EEG is the potential for current to flow from one, ‘active’ electrode to another electrode. This other electrode is called the ‘ground’ electrode. In addition, to cancel out noise from the ground electrode, a third electrode, the ‘reference’, is used. The amplifier records the potential between the active and the ground electrodes as well as the potential between reference and ground electrodes. The output is the difference between the active electrode, e.g. F3, and the reference electrode (Luck 2014, pp. 150-151). In this study, a frontal electrode was used as ground and a centro-frontal as online reference. Impedances were kept below 5kΩ. ‘Impedance’ is how much resistance a system presents to the flow of electrical current and in EEG recordings, it is modulated by e.g. sweat (Luck 2014, pp. 172-173). Impedances were kept low by applying a gel and rubbing the skin at electrode sites with the wooden part of a cotton swab. The sampling rate was 500 Hz.

4.5.2 Time-locking points

‘Time-locking points’ are triggers sent from the stimulus computer to the recording computer. They are sent for the onsets of specific events, linking auditory stimuli and EEG. This makes it possible to extract epochs and calculate averages for different stimuli in the same condition, e.g. onset of invalidly cued suffixes, and to compare these to onsets of stimuli in another condition, e.g. validly cued suffixes. Time-locking points were inserted for 1) sentence onset, 2) stød/non-stød onset in *fandt* ‘found’, 3) test word onset, 4) F_0 onset, 5) stød onset, 6) suffix onset and 7) onset of the final prepositional phrase. Time-locking points were sent from Psychopy to the recording PC via a parallel port.

4.5.3 Number of trials

A trial is one instance of a participant having heard a test word incorporated into a carrier sentence. In an ideal world, this study would be based on an infinite number of trials. However, in the real world, this is not possible. It would be unreasonable to ask participants to sit through three days of listening to auditory stimuli. What should be aimed for is a trade-off between what is ideal and what is doable. If there were very few trials per subject, most variance would be due to noise, but as the number of trials increases, the influence of noise decreases. Exactly how many trials are needed depends on factors such as true variance across subjects in relation to the variance due to EEG noise, number of participants and the ERP components of interest (Luck 2014, p. 264; Luck 2014, online chapter 8 supplement). Within-participant studies, such as this one, generally require fewer trials. For studies with 12-16 participants, Luck recommends 150-200 trials for components at around 200 ms after stimuli onset (such as PrAN) and 30-40 trials per condition for larger components like the P600 (2014, pp. 262-263). In this study, there were 160 trials per condition for trials where the component of interest was PrAN and 80 trials per condition for P600.

5 Analysis

5.1 Data cleaning and preparation

EEG data was cleaned in the MATLAB programme EEGLAB (Delorme & Makeig 2004) to prepare it for analysis. First, electrodes were re-referenced to the average of the right and left mastoids, TP9 and TP10. This is a convenient re-reference site because bias toward one hemisphere is avoided, and the electrode does not introduce a lot of noise, as e.g. electrodes above the temporalis muscle which also pick up muscle activity (Luck 2014, pp. 162-163). This was also the reference site for the studies with Swedish word accents (Roll et al. 2010, Roll 2015), making findings relatable to previous research (Luck 2014, p. 164).

EEG was low-pass filtered at 30 Hz to filter out noise from e.g. muscular activity (Luck 2014, p. 245). Eye blinks were removed using independent component analysis (ICA). Epochs starting 200 ms before and ending 800 ms after suffix and prosody onsets were extracted. Baselines were corrected to minimize effects of skin hydration, static charges and gradual drifts (Luck 2014, p. 251). Epochs with values exceeding +100 uV and -100 uV were interpreted as artefacts and rejected. Averages for the eight different conditions for prosody as well as suffixes were calculated for each subject.

ERPs (i.e. averages for all subjects over every instance of a specific condition) for different conditions, e.g. stød or non-stød, and ERPs were visually inspected in EEGLAB. Potential components were tested for statistical significance in SPSS. Subtractions were made in MATLAB to examine scalp distributions of ERP components. Finally, microvolt (μV) averages were calculated for the proposed components in the time intervals they occurred to prepare data for statistical analysis.

5.2 Statistical analysis

Repeated measures analyses of variance (ANOVA) for behavioural as well as ERP data were performed in SPSS. Inferential statistics provide a probabilistic measure of the likelihood that the null-hypothesis (that there is no difference between conditions) is true. There are numerous different statistical methods. ANOVAs were chosen because they are useful in studies with multiple independent variables to compare variance within variables to variance between variables (Rasinger 2013, pp. 210-214). A 'repeated measures ANOVA' can be used to compare data within subjects. This was necessary in this study because the same participants were subjected to more than one condition (e.g. validly and invalidly cued suffixes).

The statistical prediction (p-value) gives the probability that the null-hypothesis is true (Litosseliti 2018, pp. 140-145). If $p \leq 0.05$, the null-hypothesis can be rejected. If $p > 0.05$, the null-hypothesis cannot be rejected (Litosseliti 2018, pp. 140-145). F is the variance (mean squares) between groups (variables) divided by the variance within groups (variables). If F is e.g. 4, variance between variables is 4 times larger than variance within variables.

For the ERP measure prosody, there were two ANOVA factors (variables) with two levels within each. These factors were prosody (stød/non-stød) and suffix (singular/plural). For the ERP measure validity and the behavioral measures response accuracy and response time, there were two ANOVA factors with two levels within each as well: Validity (valid/invalid) and suffix (singular/plural).

6 Results

6.1 Behavioural

6.1.1 Response accuracy

Response accuracy was higher for validly cued suffixes, 96 %, SD = 4, than for invalidly cued suffixes, 85 %, SD = 19 (Figure 5). An ANOVA confirmed that this difference was significant, $F(1,15) = 5.1$, $p = 0.039$.

For validly as well as invalidly cued suffixes, response accuracy was higher for singular (valid suffixes 97 %, SD = 3, invalid 87 %, SD = 19) than plural forms (valid suffixes 94 %, SD = 5, invalid 83 %, SD = 22). However, there was no effect of suffix, F(1,15) = 3.65, p = 0.75, nor was there any validity × suffix interaction, F(1,15) = 1.17, p = 0.68.

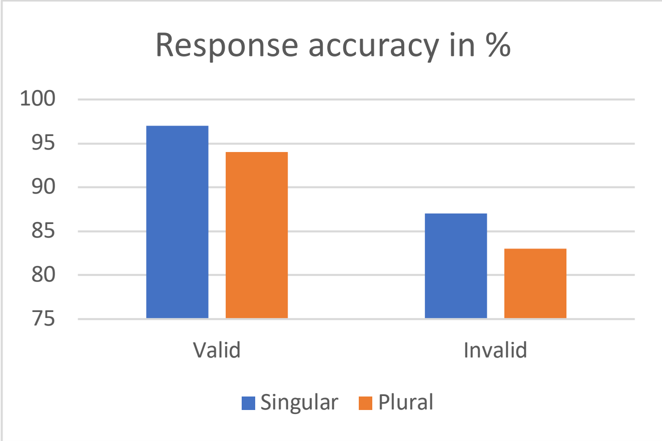

Figure 5 Response accuracy was higher for validly than invalidly cued suffixes.

6.1.2 Response times

Response times for validly cued suffixes were longer for mismatch than match. Participants on average responded 131 ms faster to suffixes validly cued by stød or non-stød, M = 1183 ms, SD = 129 ms, than to invalidly cued suffixes, M = 1314 ms, SD = 158 ms. The ANOVA confirmed that the difference for validity was significant, F(1,15) = 30.15, p < 0.001.

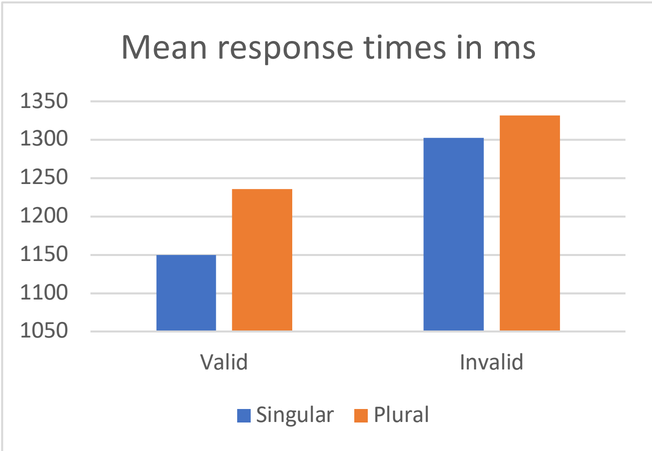

Figure 6 Nouns in plural produced longer response times than nouns in singular.

The longest response times were found for invalidly cued plural, e.g. *kælˀke* “sledges’, M = 1332 ms, SD = 200, while being somewhat faster for invalidly cued singular, M = 1302, SD = 144. Response times were also generally slower for nouns in plural, but the difference was not significant, F(1,15) = 3.81, p = 0.070, nor was the interaction between suffix and validity, F(1,15) = 0.92, p = 0.345.To sum up, only validity had a significant effect on response accuracy and response times.

6.2 ERP

In the following, ERPs for prosody onset (i.e. the onset of the second stød phase, operationalised as the onset of irregular vibrations for stød – or corresponding for non-stød) as well as suffix onset (i.e. the onset of definite singular suffixes *-et*/*-en* and plural indefinite *-e*) will be presented.

6.2.1 Prosody

For stød there was a negativity as compared to non-stød at 260-430 ms following prosody onset with an anterior, slightly right-skewed distribution (Figures 7). An ANOVA showed a main effect for prosody $F(1,15) = 6.86$, $p = 0.019$ (for electrodes Fz, F4, FC2).

This effect was rather late, meaning subjects had already heard suffixes at this point in time, but there was no significant effect neither for suffixes, $F(1,15) = 1.98$, $p = 0.180$, nor any prosody × suffix interaction, $F(1,15) = 1.95$, $p = 0.183$.

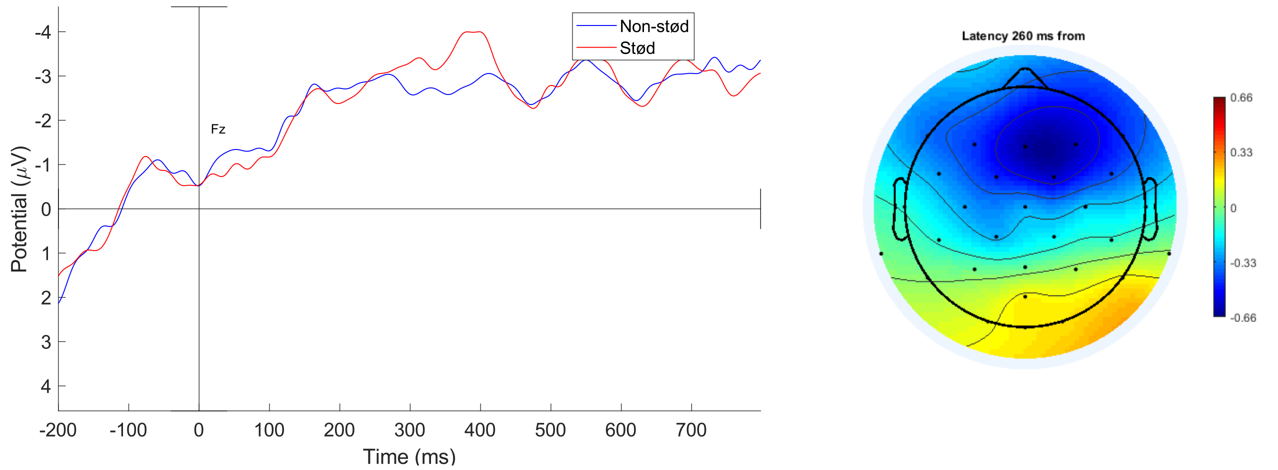

Figure 7 Stød produced a frontal, slightly right-skewed negative deflection at 260 to 430 ms. ERP from electrode Fz (left). The topographic plot to the right shows stød-non-stød subtraction between 260-430 ms.

6.2.2 Suffixes

For invalidly cued suffixes, a centro-anteriorly distributed negativity between 250 ms and 500 ms after suffix onset was found. An ANOVA showed that the main effect was due to validity, $F(1,15) = 11.23$, $p = 0.004$ (electrodes Fz, Cz, FC1, FC2, CP1, CP2). The ERP component was identified as an N400 because of the broad distribution over the scalp.

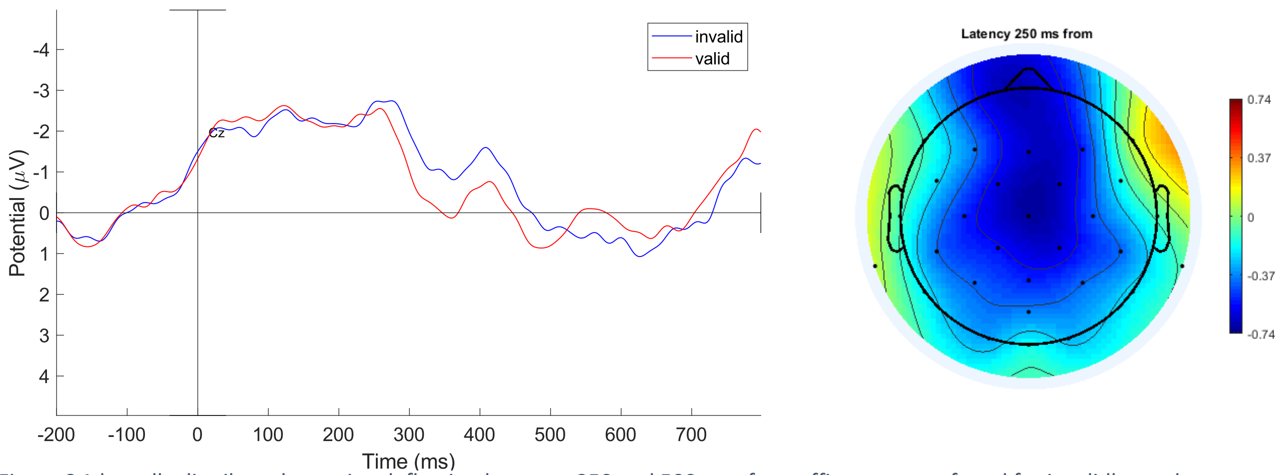

Figure 8 A broadly distributed negative deflection between 250 and 500 ms after suffix onset was found for invalidly cued suffixes. ERP from electrode Cz (left). The topographic plot to the right shows invalid-valid subtraction between 250-500 ms.

The negativity was followed by a posterior positivity at 550-750 ms which was also found to produce a main effect of validity, $F(1,15) = 4.82$, $p = 0.044$, (electrodes Oz and POz). The ERP component was identified as a P600 because of its peak at around 625 ms after stimuli onset and the posterior distribution.

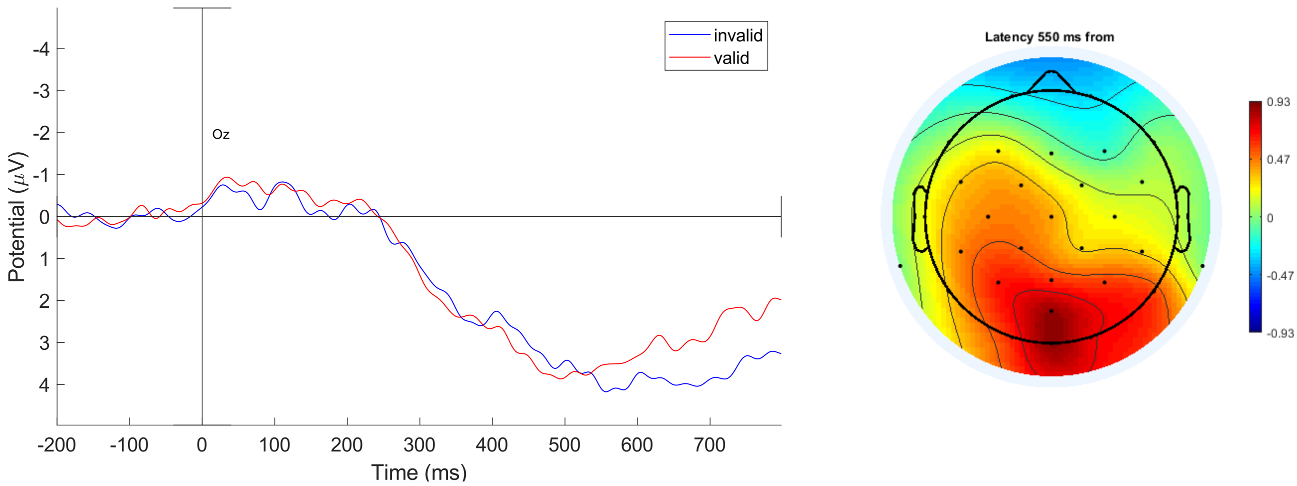

Figure 9 Invalidly cued suffixes produced a posterior positivity between 550 and 750 ms. ERP from electrode Oz. Topographic plot to the right shows invalid-valid subtraction between 550-770 ms.

7 Discussion

Within the predictive processing frameworks, the brain is constantly making forecasts about what auditory, visual and sensory stimuli are to be expected within the next milliseconds, seconds and beyond. The findings of the present study indicate that stød/non-stød alternations allow listeners to make such prognoses for upcoming linguistic structures. This is indicated by the decreased response accuracy and longer response times for invalidly cued suffixes as well as ERP effects reflecting prediction and prediction errors.

7.1. Response accuracy and response times

Test implication 1, that invalidly cued suffixes would produce less accurate and longer response times, was confirmed. Invalidly cued suffixes produced less accurate responses (85 %) than validly cued suffixes (96 %). Response times for invalidly cued suffixes were also 131 ms longer for invalidly cued suffixes, M = 1314, than for validly cued suffixes, M = 1183.

These patterns correspond to those found by Clausen & Kristensen (2015), although they reported slightly lower response accuracies. Findings from the two studies are compared in table 2. Test words in Clausen & Kristensen (2015) were also monosyllabic nouns with stødbasis validly or invalidly cued by stød. However, in their study, test words were presented in the dummy sentence *ordet er…* "the word is…' whereas in the present study, test words were presented in carrier sentences of the type *Ruth fandt …. på loftet* 'Ruth found … on the loft'. Also, Clausen & Kristensen used keyboard arrows as response keys and counter-balanced within participants whereas in the present study, response keys were 1 for singular and 2 for plural and not counterbalanced within participants.

Table 2: Response accuracy	Clausen & Kristensen (2015)	Present study
Validly cued singular	92 %	97 %
Validly cued plural	92 %	94 %
Invalidly cued singular	81 %	87 %
Invalidly cued plural	83 %	83 %

Table 3: Response times	Clausen & Kristensen (2015)	Present study
Validly cued singular	1207 ms	1150 ms
Validly cued plural	1202 ms	1236 ms
Invalidly cued singular	1532 ms	1302 ms
Invalidly cued plural	1404 ms	1332 ms

A noticeable difference is that Clausen & Kristensen found the longest response times and lowest response accuracies for invalidly cued singular while in the present study, the lowest response accuracies and longest response times were for invalidly cued plural. However, it should be kept in mind that for neither of the studies were differences in response accuracy significant. Differences in response times were not significant for the present study either, but in Clausen & Kristensen's study, there was an interaction between validity and suffix type with invalidly cued singular producing the longest response times. In the studies with validly and invalidly cued Swedish word accents, response accuracies were not reported, but the longest response times were systematically found for invalidly cued accent 2-associated suffixes (Söderström, Roll & Horne 2012; Roll 2015, Roll et al 2015, Söderström et al 2017). I use the term 'accent 2-associated suffixes' because in some studies, test words were verbs and non-words, but accent 2-associated suffixes correspond to invalidly cued plural.

Altogether, in line with the findings of Clausen & Kristensen, invalidly cued suffixes lead to lower response accuracy and longer response times than validly cued suffixes, indicating increased cognitive load.

7.2 Prediction errors

The posterior positivity between 550 and 750 ms for invalidly cued suffixes was interpreted as a P600 effect. Test implication 2, that invalidly cued suffixes would produce a P600 was thus met. In addition, a centro-anterior negativity for invalidly cued suffixes between 250 and 500 ms was found. This component was interpreted as an N400 and had actually also been found in some studies with Swedish word accents (Roll 2015; Gosselke Berthelsen, Horne, Brännström, Shtyrov & Roll 2018)

These ERP components have been associated with prediction errors, which can be understood as ‘surprise’ caused by incongruency between what was predicted and what was actually perceived. For instance, since stød is associated with monosyllabic words (with stødbasis) in singular definite, e.g. *kælˀken* ‘the sledge’, stød on the stem naturally leads participants to expect upcoming suffixes to be singular definite *-en/-et.* When predictions are not met, prediction errors occur. However, when predictions *are* met – as they are most of the time in natural language processing - they likely allow listeners to deal with words faster, facilitating rapid speech processing.

Although both are associated with prediction error, N400 and P600 have been linked to different neural processes and areas. Thus, N400 has been associated with semantic violations, e.g. words that are incongruent in a semantic context, e.g. ‘He spread the warm bread with socks’ (Kutas & Hillyard 1980). Further, N400s vary with expectation and have been found to increase for words which are semantically congruent but the less likely continuations of a given sentence (Kutas & Hillyard 1984). This could explain the N400 found for invalidly cued suffixes, since they were unexpected upon hearing the prosody cue. Another interpretation of the N400 component is that stem and suffix were processed as a full form and first simply identified as non-words or at least words unknown to the participants. Blomberg, Roll, Frid, Lindgren & Horne (2020) compared words differing in concreteness with pseudo-words and found that the largest N400 amplitudes were produced by pseudo-words; patterns which could be explained by pseudo-words activating large numbers of semantic features, making it difficult for listeners to suppress the activation of phonological neighbours and stop searching for the right lexeme.

Supporting the interpretation of words being processed as pseudo-words is that some words indeed sounded very odd and that some participants after the study informally commented on words being very “odd”, “not real words” or that they “did not know some of the words”. Invalidly cued plural words, e.g. *kælˀke* ‘sledges’, likely sounded the oddest. Thus, invalidly cued singular words, e.g. *kælken* ‘the sledge’, one the one hand, 1) are realized this way in dialects without stød, e.g. Lolland and Falster, and 2) could be *disyllabic* words in definite singular and thus real words, although unknown to participants. Invalidly cued plural words, e.g. *kælˀke* ‘sledges’, on the other hand, are *not* pronounced this way in any dialect and are very unlikely to be real words due to stød constraints.

The ERP component P600 is associated with syntactic and morphological violations, but has also been found for semantic structures. In a combined ERP/fMRI study with Swedish word accents (Roll et al. 2015), invalidly cued suffixes were associated with greater activation of the supplementary motor areas and the middle frontal gyrus bilaterally as well as the left inferior parietal lobe. The latter has been found to be involved in processing numbers, e.g. ‘2’ or ‘two’ (Piras & Marangolo 2009) suggesting that it was meanings of suffixes that were reprocessed. If stem and suffix were processed independently, the P600 would be due to participants having predicted a different suffix than they heard. Thus, they would have to revise and reinterpret the invalidly cued suffixes to decide what category words belonged to.

If the N400 occurred because participants perceived test words as non-words, the P600 could have been caused by participants being forced by the task of the experiment to assign test words to one of the categories singular or plural either based on the presence or absence of stød or based on suffix. In an experiment with auditory semantically anomalous stimuli, Kyriaki, Schlesewsky & Bornkessel-Schlesewsky (2020) found larger P600 amplitudes for active judgement tasks than passive comprehension, indicating that the P600 is also in part modulated by task demands. In the present stød study, the nature of the task required participants to make an active judgement about whether words were singular or plural which could probably influence the P600.

As mentioned above, the N400 component was also found in some Swedish studies with word accents – but in most studies, it was not. This indicates that the Danish mismatched words were more difficult to integrate semantically than the Swedish, perhaps because the Danish words to a higher degree than the Swedish were processed as non-words. While the function of Swedish word accents is highly predictive, the N400 suggests that the function of stød, in addition to being predictive, is distinctive.

7.3 Prosody as determiner of grammatical category

While participants listened to words, they were asked to respond as quickly as possible to whether the test word in question was singular or plural (*fandt Ruth én eller flere?* 'Did Ruth find one or more?')

An interesting finding was that for one subject, the presence or absence of stød appeared to be the principal factor in determining whether a test word was singular or plural. On the surface, this participant appeared to have very low response accuracy, but there was actually a careful systematicity in answers. For 93 % of words with stød, the participant responded that the word was singular and for 81 % of words without stød, the participant deemed the words to be plural, which is not very different from the general response accuracy (92 % for singular and 89 % for plural). For this participant, words with stød – and despite suffixes - e.g. *kælˀken* 'the sledge' and *kælˀke* 'sledges' were generally deemed singular, while words without stød were deemed plural, e.g. *kælken* 'the sledge' and *kælke* 'sledges'. Similar, but somewhat weaker patterns, were seen for two other participants. For one of them, stød was a quite salient cue to singular, and the participant responded that 66 % of words with stød were singular. Another participant responded that 63 % of words without stød were plural.

These instances appear to be more than just mistakes due to invalidly cued suffixes. Rather, the presence or absence of stød seems to be a quite salient determinator in whether words are singular or plural. For these participants, especially the one who displayed very systematic stød-singular/non-stød-plural patterns, the function of stød and non-stød was more than just predictive; it was the actual distinction between singular and plural. Considering that complete schwa apocope in some dialects have led to minimal stød/non-stød pairs with singular and plural (Fischer-Jørgensen 1989, p. 12), this would not be all that peculiar.

Speculating, since response accuracies were lower in Clausen & Kristensen's study, it would be interesting to know if some of their participants displayed similar systematic stød-singular/non-stød-plural patterns.

7.4 Pre-activation negativity

A negativity was found for stød at 260-430 ms after prosody onset. Test implication 3 for this study was that stød would produce a pre-activation negativity (PrAN) because it is associated with a more restricted set of suffixes. The negativity was frontal and slightly right-skewed which points to the right as well as the left hemisphere being activated. This is also what would be expected since stød is pitch-related prosody carrying linguistic information. Prosody has been found to be primarily processed in the right hemisphere but becomes more left-lateralized the more linguistic the function. This frontal, slightly right-skewed distribution fits well with Friederici & Alter's dynamic pathway model (2004) suggesting that pitch with a linguistic function gives rise to interhemispheric interactions via the corpus callosum. However, it should be kept in mind that event-related potential technique does not have high spatial resolution and the component could in theory have emerged from anywhere in the brain.

The latency of the negative deflection is later than what has previously been found for PrAN (136-280 ms). As previously mentioned, PrAN can be divided into two phases: An early (50-150 ms) with increased activation in the primary auditory cortex for more predictively useful sounds and a late (after 200 ms) with activation in Broca’s area. The first has been interpreted as being associated with more predictively useful sounds (e.g. accent 1 being more predictively useful than accent 2) and the later with inhibition of irrelevant structures. It could be that only the second phase of PrAN applies to stød – that stød is useful for excluding unfit forms: Upon hearing the stød, all forms which do not have stød can immediately be discarded.

It is harder to explain why the first phase would not apply to stød, but an explanation could be that stød is processed more slowly than word accents. The design of this study meant that the presence or absence of stød could only be identified from the second stød phase, i.e. on average 92 ms after F_0 onset. Further, while word accents can probably be perceived rather quickly, immediately upon hearing the tone at F_0 onset, it might take longer to process the presence or absence of stød. According to Repp (1988), integration and segregation are vital components in mapping speech sounds onto mental structures in the brain. Integration implies combining units that go together, e.g. harmonics of periodic speech sounds, while segregation implies keeping apart units that do not go together, e.g. the voices of two different people. As mentioned earlier, there is high variability in the acoustics of stød (Riber Petersen 1973) which could be interpreted as there being trading relations between the cues irregular vocal fold vibration, low pitch and low intensity. Perceiving stød would imply integrating one or more of these cues and mapping them onto the mental structure ‘stød’ in the brain. This might be less straightforward and take longer than identifying a high or low pitch as with Swedish word accents.

The rather late negativity for stød has a parallel in the negativity (identified as an N400) which also occurs somewhat later than in the studies with Swedish word accents. Roll (2015) and Gosselke Berthelsen et al. (2018) found N400-like negativities between 110-240 and 235-415 ms after suffix onset respectively, while those found for Danish stød or non-stød occurred at 250-500 ms. This could be interpreted as Danish stød being processed later and listeners thus taking longer to realize the prediction error between prosody and suffixes.

To sum up, the ERP components N400 and P600 associated with prediction errors as well as the possible pre-activation negativity indicate that participants already upon hearing stød or non-stød on the stem start making predictions about how words end. Such predictions are likely to be based on listeners' previous experiences as perceivers and processors of the Danish language in which e.g. stød on a monosyllabic noun stem is likely to be followed by one of the singular definite suffixes *-et/en* and highly unlikely to be followed by the plural indefinite *-e.* If the latter, as in this study, happen to occur in a stød context, it is unexpected and likely to lead to prediction error.

8 Conclusion

Invalidly cued suffixes produced longer response times and N400 and P600 components, indicating that suffixes were predicted based on the presence or absence of stød. Incongruency led to prediction error with expectations of suffixes not being met. For at least one participant, the presence or absence of stød weighed more on the scale than suffixes when determining if a word was singular or plural, indicating that stød may – at least for some people – be more than just a predictor, but what determines grammatical category.

A frontal, slightly right-skewed negativity at 260-430 ms after prosody onset was found for stød. This was interpreted as a pre-activation negativity (PrAN) since stød is a stronger predictor of upcoming suffixes than non-stød because it occurs under more restricted conditions. The negativity was later than that found for Swedish accent 1, but this could be due to different cues to stød, e.g. irregular vocal fold vibrations, being integrated more slowly, taking longer to be mapped onto the mental structure 'stød' than tones do to word accents.

These findings point to native speakers of Danish using the presence or absence of stød on a stem to make predictions about upcoming suffixes in ways similar to how native speakers of Swedish use word accents. Such predictions are likely to be based on previous experiences and world knowledge, in this case lifelong experience as speakers and listeners of Danish.

9 Outlook for future research

A proposal for future studies is to look into the role of the first stød phase, the phase before the stød proper. The first phase is characterized by a higher pitch and often higher intensity (Fischer-Jørgensen 1989, p. 128-133) and it would be valuable to know if these cues play roles in the perception of stød already *before* the stød proper. Since every test word occurred in two conditions, once with the first phase taken from stød words and once with the first phase from non-stød words, and a trigger was sent for word onsets, this could be examined using the data collected in this study. However, it falls outside the scope of the present study.

Examining words without stødbasis, e.g. word pars such as *hest-en* 'the horse' and *hest-e* 'horses' could also provide valuable insights into the role of prosodic cues in prediction. Since only Danish words with stødbasis can have stød, words without stødbasis can function as controls, enabling comparison between words with and without stødbasis to further examine the role of stød as a predictor of upcoming suffixes.

A response time study including more participants could provide insights into whether the pattern of systematically assigning words to grammatical categories based on the presence or absence of stød is common or just a rare coincidence. Such an investigation could also look into whether this varies between dialects, e.g. if this pattern is stronger in dialects with complete apocope. Furthermore, it would be valuable to examine if some words, e.g. less frequent words, were more likely to be assigned to singular or plural based on prosody than others.

Finally, it could be examined, as has been done for Swedish (Söderström, Horne, Frid & Roll 2016; Roll, Söderström, Frid, Mannfolk & Horne 2017) if PrAN amplitudes correlate with lexical competition and frequency.

10 Ethical considerations

The study was approved by the Swedish Ethical Review Authority. Participants received written and oral information in Danish about research plan, the aim of the research, methods used, consequences and risks, who the researcher and supervisor were and that participation was voluntary and they could cease participation at any time. They gave informed written consent (see appendix).

10.1 COVID-19 precautions

Keyboard, mouse, headphones and caps were disinfected between participants. The researcher always wore a face mask during experiments. Participants were asked to disinfect hands when entering the lab and were offered a face mask – the latter was optional. When possible due to weather conditions, a window was kept open to ensure ventilation. When restrictions become more severe, the experiment was aborted. At that time, however, a sufficient number of participants had been recorded.

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Appendix

Words in grey columns were excluded.

Number	Stimul word	Realization	Carrier sentence
1	Alk ‘razorbill’	/alˀg/	Ruth fandt alken/alke på græsset
2	Bold ‘ball’	/bʌlˀd/	Ruth fandt bolden/bolde på græsset
3	Bænk ‘bench’	/bɛŋˀg/	Ruth fandt bænken/bænke på loftet
4	Damp ‘steam’	/dɑmˀb/	Ruth fandt dampen/dampe på pladsen
5	Dunk ‘can’	/dɔŋˀg/	Ruth fandt dunken/dunke på loftet
6	Falk ‘falcon’	/falˀg/	Ruth fandt falken/falke på græsset
7	Fjært ‘fart’	/fjæɐ̯ˀd/	Ruth fandt fjærten/fjærte på loftet
8	Flab ‘lout, mouth’	/flæˀb/	Ruth fandt flaben/flabe på pladsen
9	Font ‘font’	/fʌnˀd/	Ruth fandt fonten/fonte på pladsen
10	Greb ‘pitchfork’	/gʁɛˀb/	Ruth fandt greben/grebe på græsset
11	Hank ‘handle’	/hɑŋˀg/	Ruth fandt hanken/hanke på loftet
12	Helt ‘hero’	/hɛlˀd/	Ruth fandt helten/helte på pladsen
13	Hingst ‘stallion’	/heŋˀsd/	Ruth fandt hingsten/hingste på græsset
14	Hjord ‘herd’	/jɒˀd/	Ruth fandt hjorden/hjorde på græsset
15	Hob ‘crowd’	/hoˀb/	Ruth fandt hoben/hobe på pladsen
16	Hvalp ‘puppy’	/valˀb/	Ruth fandt hvalpen/hvalpe på græsset
17	Kalk ‘chalice’	/kalˀg/	Ruth fandt kalken/kalke på loftet
18	Kamp ‘fight’	/kɒmˀb/	Ruth fandt kampen/kampe på pladsen
19	Kilt ‘kilt’	/kilˀd/	Ruth fandt kilten/kilte på loftet
20	Krank ‘crank’	/kʁɑŋˀg/	Ruth fandt kranken/kranke på loftet
21	Kælk ‘sledge’	/kɛlˀg/	Ruth fandt kælken/kælke på loftet
22	Lort ‘crap’	/loɐ̯ˀd/	Ruth fandt lorten/lorte på græsset
23	Læg ‘calf’	/lɛˀg/	Ruth fandt læggen/lægge på pladsen
24	Milt ‘spleen’	/milˀd/	Ruth fandt milten/milte på pladsen
25	Pilk ‘jig’	/pilˀg/	Ruth fandt pilken/pilke på græsset
26	Pjevs ‘weakling’	/pjɛwˀs/	Ruth fandt pjevsen/pjevse på pladsen
27	Port ‘gate’	/poɐ̯ˀd/	Ruth fandt porten/porte på pladsen
28	Pulk ‘pulk’	/pulˀg/	Ruth fandt pulken/pulke på loftet

29	Punsch ‘punsch’	/pɔnˀɕ/	Ruth fandt punschen/punsche på pladsen
30	Salt ‘salt’	/salˀd/	Ruth fandt salten/salte på pladsen
31	Skab ‘closet’	/sgæˀb/	Ruth fandt skabet/skabe på loftet
32	Skalk ‘trickster’	/sgalˀg/	Ruth fandt skalken/skalke på pladsen
33	Skalp ‘scalp’	/sgalˀb/	Ruth fandt skalpen/skalpe på loftet
34	Skank ‘shank’	/sgɑŋˀg/	Ruth fandt skanken/skanke på loftet
35	Skib ‘ship’	/sgiˀb/	Ruth fandt skibet/skibe på pladsen
36	Skilt ‘sign’	/sgeˀld/	Ruth fandt skiltet/skilte på pladsen
37	Skænk ‘sideboard’	/sgɛŋˀg/	Ruth fandt skænken/skænke på loftet
38	Slurk ‘sip’	/sluɐ̯ˀg/ or /sluɐ̯g/	Ruth fandt slurken/slurke på pladsen
39	Stab ‘staff’	/sdæˀb/	Ruth fandt staben/stabe på pladsen
40	Stank ‘stink’	/sdɑŋˀg/	Ruth fandt stanken/stanke på loftet
41	Stilk ‘stalk’	/sdelˀg/	Ruth fandt stilken/stilke på græsset
42	Svamp ‘mushroom’	/svɑmˀb/	Ruth fandt svampen/svampe på græsset
43	Sump ‘swamp’	/sɔmˀb/	Ruth fandt sumpen/sumpe på græsset
44	Tank ‘tank’	/tɑŋˀg/	Ruth fandt tanken/tanke på loftet
45	Tolk ‘interpretor’	/tʌlˀg/	Ruth fandt tolken/tolke på pladsen
46	Telt ‘tent’	/tɛlˀd/	Ruth fandt teltet/telte på græsset
47	Ulk ‘sculpin’	/ulˀg/	Ruth fandt ulken/ulke på pladsen
48	Væg ‘wall’	/vɛˀg/	Ruth fandt væggen/vægge på loftet

Information til forsøgspersonerne

Vi vil spørge dig, om du vil deltage i et forskningsprojekt. I dette dokument får du information om projektet, og om hvad det indebærer at deltage.

Hvad er det for et projekt, og hvorfor vil I have at jeg skal deltage?

Formålet med projektet er at undersøge, hvordan talere af dansk bruger stød til at bearbejde talesprog. Stød er et sprogligt fænomen, som findes i nogle danske ord og kan bedst beskrives som en speciel stemmekvalitet. Det kan blandt andet adskille ords betydninger, for eksempel i ord som *maler* (verbet) og *maler* (navneordet). Stød er meget unikt for dansk og findes ikke i andre nordiske sprog.

Forskere ved Lunds Universitet har i tidligere studier undersøgt, hvordan talere af svensk bruger ordaccenter til at forudsige information. Ordaccenter består af en høj eller en lav tone på et ords stamme og kan som det danske stød adskille ordbetydninger. Stød og ordaccenter er systematisk og muligvis også historisk relaterede.

Det er interessant at få information om, hvordan talere af dansk bruger stød, da det kan belyse, hvilken rolle stød spiller for talesprogsbearbejdning.

Vi spørger netop dig, fordi du er modersmålstaler af en dansk dialekt med stød.

Forskningshovedmand for projektet er Lunds Universitet. Med forskningshovedmand menes den organisation, som er ansvarlig for studiet.

Hvordan foregår studiet?

Inden du kommer til eksperimentet beder vi dig vaske og rede håret.

Først vasker vi med alkohol bag ørene for at få bedre kontakt med elektroderne som skal sidde der. Derefter sætter vi en hue med elektroder på dit hoved for at måle den elektriske spænding, som forekommer naturligt over hovedet på grund af hjerneaktiviteten. Efter det sprøjter vi en ledende gelé ind i elektroderne. Geléen er kendt for ikke at være allergifremkaldende. Vi kommer også til at røre i hårbunden med små træpinde for at få endnu bedre kontakt mellem hovedet og elektroderne. Det tager 20-45 minutter at få elektroderne på plads.

Mens elektroderne sættes på, skal du udfylde en formular om din sprogbaggrund og om, hvorvidt du er højre- eller venstrehåndet, samt om du har haft hjerneskader.

Selve eksperimentet foregår ved at du lytter til forskellige sætninger og svarer på, om hovedordet udtrykker én eller flere ting. Samtidig måles din hjerneaktivitet ved hjælp af elektroderne. Elektroderne måler altså kun den elektriske aktivitet, som naturligt findes over hovedet.

Du lytter til sætninger ad to omgange. Første gang lytter du i 20-40 minutter. Hvert 5-7 minut får du mulighed for at tage en pause. Anden gang lytter du i 10-20 minutter. Også her får du mulighed for at tage en pause hvert 5-7 minut.

Efter eksperimentet tages huen af, og du kan vaske geléen af. Det tager 5-10 minutter. I alt i alt varer studiet mellem 2 og 2 ½ timer.

Mulige følger og risici ved at deltage i studiet

Der er en lille risiko for, at nogle personer kan opleve ubehag ved udstyret. Hvis du oplever ubehag, bliver studiet afbrudt. Du kan når som helst afbryde studiet uden at give nogen grund, og uden at det får nogle konsekvenser.

Du vil i en formular blive spurgt om, hvorvidt du har haft en tidligere hjerneskade. Du skal også udfylde en relativt detaljeret formular om din sprogbaggrund. Det kan i princippet bruges til at udlede din etniske oprindelse. Formularerne bliver kun brugt til at garantere gruppens homogenitet. De vil blive opbevaret i en mappe i et aflåst rum indtil al data er blevet pseudoanonymiseret (kodet) og formularerne destrueres.

Hvad sker der med mine oplysninger?

Projektet kommer til at indsamle og registrere information om dig.

Først og fremmest måler vi dine hjernebølger (EEG) for at se, hvordan de forandres, når du lytter til forskellige fænomener i sprog. Dataene bliver analyseret på gruppeniveau sammen med andre personers resultater. EEG-dataene vil blive opbevaret i pseudoanonymiseret (kodet) form på en server, som kun forskningsgruppen har adgang til. Hjernebølger fra enkelte deltagere vil ikke blive præsenteret.

I et spørgeskema skal du beskrive din sprogbaggrund mere nøjagtigt, hvor du er opvokset og hvilke sprog, du har lært. Den information vil blive præsenteret som en sammenskrivning på gruppeniveau for at vise, at forsøgspersoner med relevant dialekt har deltaget. Du vil også blive spurgt, hvilken hånd du bruger til forskellige gøremål, og om du har haft en hjerneskade. Den information vil blive brugt til at garantere forsøgspersonernes homogenitet og bliver, i det omfang, den præsenteres, også præsenteret sammenstillet på gruppeniveau. Ingen information vil kunne ledes tilbage til enkelte individer. Kun forsøgslederen og projektlederen vil have adgang til individrelateret information. Informationen i papirformularen vil blive overført til digital, pseudoanonymiseret form. En kodenøgle vil blive opbevaret separat, også denne låst inde på projektlederens kontor. Originalformularen i papirform og kodenøglen vil blive destrueret højst to år efter deltagelsen i studiet. Al information og data gemmes så længe, det er muligt at lagre det sikkert for adgang for uvedkommende. Det sker for ved senere behov at kunne kontrollere oplysninger og gøre senere dataanalyser. Dataene kan, i pseudoanonymiseret form, blive lagt op på en alment tilgængelig database. Hvis det sker, bliver det efter at papirformularen og kodenøglen er blevet destrueret.

Dine svar og dine resultater vil blive behandlet, så uvedkommende ikke kan få adgang til dem. Den ansvarlige for personoplysninger er Lunds Universitet. Ifølge EU's databeskyttelsesforordning har du ret til gratis at få adgang til de oplysninger om dig, som behandles i studiet, og ved behov få eventuelle fejl rettet. Du kan også anmode om, at oplysninger om dig slettes, og at behandlingen af dine personoplysninger begrænses. Hvis du vil have adgang til oplysningerne skal du kontakte:

Mikael Roll, besøgsadresse: SOL-centrum, Helgonabacken 12, postadresse: SOL-centrum, Lunds universitet, Box 201, 22100 Lund, e-mail: mikael.roll@ling.lu.se, tlf. 046-2229905. Databeskyttelsesombud kan kontaktes på dataskyddsombud@lu.se. Hvis du er utilfreds med, hvordan dine personoplysninger behandles, har du ret til at klage til Datainspektionen, som er tilsynsmyndighed.

Hvordan får jeg information om resultatet af studiet?

Resultat af studiet vil blive publiceret i en bacheloropgave og en open access-artikel. Kontakt gerne forsøgslederen eller projektlederen mindst omkring seks måneder efter deltagelsen, hvis du vil vide mere. For at få adgang til dine individuelle resultater, kan du også kontakte os. Det er dog vigtigt at huske, at individuelle data fra EEG er meget svære at tolke. Du behøver ikke få del i resultaterne, hvis du ikke vil.

Forsikring og erstatning

Under din deltagelse er du forsikret gennem en forsikring for særlig personskadebeskyttelse, som er tegnet af Språk- och litteraturcentrum.

Din løn for deltagelsen er 125 svenske kroner i timen før skat. Lønnen er skattepligtig. Du kan også få erstatning for rejse til og fra Lund. Denne erstatning er ikke skattepligtig.

Deltagelsen er frivillig

Din deltagelse er frivillig, og du kan når som helst vælge at afbryde deltagelsen. Hvis du vælger ikke at deltage eller vil afbryde din deltagelse, behøver du ikke angive hvorfor, og det kommer heller ikke til at få nogle konsekvenser for dig.

Hvis du vil afbryde din deltagelse, skal du kontakte den ansvarlige for studiet eller forsøgslederen (se nedenfor).

Ansvarlig for studiet

Ansvarlig for studiet er Mikael Roll, besøgsadresse: SOL-centrum, Helgonabacken 12, postadresse: SOL-centrum, Lunds universitet, Box 201, 22100 Lund, e-mail: mikael.roll@ling.lu.se, tlf 046-2229905

Dansk stød i hjernen

Forsøgsleder er Anna Hjortdal, besøgsadresse: SOL-centrum, Helgonabacken 12, postadresse: SOL-centrum, Lunds universitet, Box 201, 22100 Lund, e-mail: anna.hjortdal@ling.lu.se

Samtykke til at deltage i studiet

Jeg har fået mundtlig og skriftlig information om studiet og har haft mulighed for at stille spørgsmål. Jeg må beholde den skriftlige information.

☐ Jeg samtykker til at deltage i studiet Dansk stød i hjernen.

☐ Jeg samtykker til at oplysninger om mig behandles på den måde, som beskrives i forskningspersoninformationen.

Plads og dato	Underskrift