



# Adaptation to predictive prosodic cues in non-native standard dialect

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## Abstract

Predicting word or sentence structure from prosodic cues (e.g., pitch, pauses, or duration) is an important mechanism in speech processing. The mechanism is readily employed by native listeners but considerably less so by second language learners except with extensive training. This prompts the question of how flexible and adaptive the predictive system is. Can listeners adjust to accommodate, for example, diverging predictive cues in a different dialect? The present paper tests this for prosody-based word structure prediction in mainland Scandinavian. Neurophysiological and behavioural results suggest that listeners from non-standard dialect areas can in fact predict word forms in the standard variety even when the predictive cues and their validity differ considerably. This suggests a certain degree of adaptability in the predictive system, potentially depending on factors like familiarity, prestige, and exposure onset.

**Index Terms:** speech processing, morphological prediction, prosody, second language learning, dialects, psycholinguistics

## 1. Introduction

The importance of prediction in rapid speech processing has received focal attention in recent years. Native listeners have been shown to use the speech input to predict various parts of the upcoming signal such as semantics [1, 2], potentially including specific word forms [3], or information about sentence [4, 5] or word structure [6, 7, 8, 9]. This paper focuses on prosody to structure predictions, investigating their adaptability to differently accented speech in non-native, standard language varieties. It assumes that high familiarity, prestige, and early exposure can make listeners from non-standard dialect areas native-like in their processing of the standard variety.

### 1.1. Prosody-to-structure predictions

The prosodic features of words or larger units of speech change frequently while sentences are constructed. There are a multitude of factors conditioning speech prosody including local, word-level processes like stress or tone assignment during morphological composition and more global processes like stress timing, phrasal creak, or boundary tones. When these processes are regular and consistent, the prosody can turn into cues to structure. A low tone in Swedish, for instance, indicates a right phrase boundary cueing listeners to expect the beginning of a new phrase [4]. Similarly, stress on the stem of a Spanish verb cues a present tense ending. If instead another ending, for instance a past tense inflection, emerges in the speech input, this would cause surprise [8]. Accordingly, different prosodic features in many languages can act as predictors of sentence or word structure and listeners are unknowingly intimately attuned to them.

Cases of prosody-based prediction have thus far been attested in several different languages and for a range of prosodic features. As one of the earliest bodies of work, research on Swedish has observed word structure prediction for tonal phenomena [10, 11, 6, 12, 13]. Swedish has two word accents which differ phonetically as a function of pitch timing both within and across dialects [14, 15] and lead to tonal alternations within the inflectional system [16, 17, 18]. The definite singular *båt-en* ‘boat-the’, for instance, is realised with a low-tone bearing accent 1 on the word stem while the indefinite plural *båt-ar* ‘boat-s’ starts with a high-tone bearing accent 2. Accent 1 is more restrictive than accent 2, as it has fewer associated structural continuations. Interestingly, a reflection of this difference has been observed in brain activity patterns and behavioural responses [6, 11] prompting the hypothesis that hearing the two tonal patterns must result in a prediction based pre-activation of associated word structures: the fewer possible morphological structures an accent is associated with, the stronger can the morphological endings be activated before they occur in input [6]. This assumption has since been confirmed through correlation analyses [12] and analyses of individual response time effects [19] suggesting that pitch in Swedish functions as a predictive cue at the word level. Prediction has been tested and found for the pitch patterns of both the standard variety (Central Swedish) [19] and a non-standard dialect (South Swedish) [20]. The Swedish findings are paralleled by results for vowel duration in English [7], stress in Spanish [8], and voice quality in Danish [9]. In an eye-tracking study, English listeners have been seen to infer the correct continuation of phrases such as ‘The dog was *punched* by the bear.’ or ‘The dog was *punching* the bear.’ from subtle prosodic differences in the carrier sentence, crucially including the main verb’s vowel duration. This suggests that duration in English can be used as a predictor of words’ morphological structure [7]. Similarly, in Spanish, the prosodic correlates of stress (duration, pitch, and intensity) allow listeners to reconstruct fragmented word forms above chance accuracy. Like for the English listeners, eye movement patterns from Spanish listeners are indicative of prediction of correctly inflected word forms (e.g., *toma* /‘toma/ ‘s/he takes’, *tomó* /to‘mo/ ‘s/he took’) from the prosodic cues [8]. In Danish, native listeners have been shown to use voice quality cues (creaky [so-called *stød*] vs. modal voice [*nonstød*]) for predicting possible word structure. Definite singulars such as *båd-en* ‘boat-the’ are, for instance, realised with nonmodal phonation in the word stem while indefinite plurals, *båd-e* ‘boat-s’, have modal phonation throughout. Behavioural and neurophysiological indicators of surprise emerge in Danish when word structure is not preceded by the associated prosodic cues [9]. Collectively, these findings suggest that the prosodic features that interact with morphology can turn into predictive signals for word structure and that native speakers readily use these during rapid speech processing.

## 1.2. Prosody-based prediction in non-native listeners

While prosody-to-structure predictions happen automatically for native listeners, adult second language (L2) learners seem to less consistently exploit the strong relationship between prosodic and morphological structure during speech processing. Studies with pre-advanced learners of Swedish and Spanish suggest that word structure prediction is at most rudimentary and not at all systematic [13, 8]. Specifically, a study on Swedish pitch-to-structure prediction in beginner learners has shown brain activity patterns which appear unresponsive to the differential predictive strength of the Swedish word accents and no indications of surprise when prosody-based predictions are not met [13]. A Spanish study has further revealed a lack of eye movements indicative of stress-to-structure predictions in a beginner learner group and their inability to complete word fragments based on prosody alone [8]. Interestingly, behavioural data from Swedish and behavioural and eye tracking data from Spanish suggest that prediction might become possible at later acquisition stages but that it potentially remains slower and less efficient than for native speakers [8, 21].

Yet, training can positively affect L2 learners' word structure prediction abilities. To this effect, associative prosody-to-structure training has been shown to result in prediction-related brain responses, post-training, in intermediate learners of Swedish [22]. Similar results have been seen with eye tracking and gating tasks for Spanish interpreters [23, 24]. Anticipating what will be said plays a crucial role in smooth and successful interpreting, and interpreters have ample training and experience in actively predicting upcoming speech input. Their strengthened prediction capabilities allow them to use prosodic features as signals to word structure in a similar way as native speakers do [23]. Thus, while adult L2 learners generally struggle with the type of prosody-to-morphology predictions commonly found in natives, targeted training can allow them to predict more actively.

## 1.3. Intermediate cases

Native speakers and adult L2 learners, however, only form the extreme ends of a gradual scale of language competency. There are many intermediate cases on the continuum from fully native to fully non-native including early bilinguals or early and late bi- or multidialectals. These cases are interesting on many levels but importantly for this paper they can give crucial insights into morphological prediction.

To the best of my knowledge, no studies have yet investigated word structure prediction in populations that have a less clear status with respect to nativeness. Some previous work on dialects has been able to show that the standard dialect is often perceived and parsed as good as or even better than the local variety [25, 26, 27]. Still, other studies have found a small but distinct difference between native and non-native dialect perception [28, 29, 30]. Specifically looking at prosody, [25] has shown that the standard dialect's prosody (Tokyo Japanese word accents) is identified better than the native non-standard prosody (Kyoto Japanese word accents) yet not as well as it is by native speakers of the dialect. [28] has supplemented this by suggesting that speakers from different Japanese dialects attend to different parts of the prosodic cues. Thus, interestingly, the results for non-native dialect perception suggest that non-native standard dialects are perceived well and that bidialectal speakers may be better at identifying prosodic features of the standard dialect than of their native

one. This concurs perfectly with the concept of speaker normalization where previous research has shown that listeners can dynamically adjust their speech perception system to accommodate individual features of the speaker [31, 32]. However, this leaves open the question of whether prediction adjusts flexibly alongside perception. If this is the case, we would expect listeners with early exposure and high familiarity to a prestigious, standard dialect to predict much like native speakers.

## 2. Methods

The data presented in this paper stems from two experiments with comparable stimulus material and participant groups: an event-related potential (ERP) study on standard Swedish and a response time study on standard Danish. Both studies test non-standard dialect speakers and expect their high familiarity with and early exposure to the standard dialect to result in brain responses and response time patterns that are similar to those of native speakers. Danish and Swedish are closely related North Germanic languages and have a similar system of prosody-morphology alternations, making them well suited for direct comparison.

### 2.1. Participants

16 native speakers of non-standard Swedish dialects – mean age 24; all right-handed; 7 female, 9 male – participated in the Swedish experiment. Four participants were speakers of South Swedish, seven of West Swedish and five of Gothenburg Swedish. These dialects have diverging pitch patterns compared to the standard Central Swedish variety, see Figure 1. The Swedish data was collected originally for a larger study. Findings not related to dialects have been published in [X].

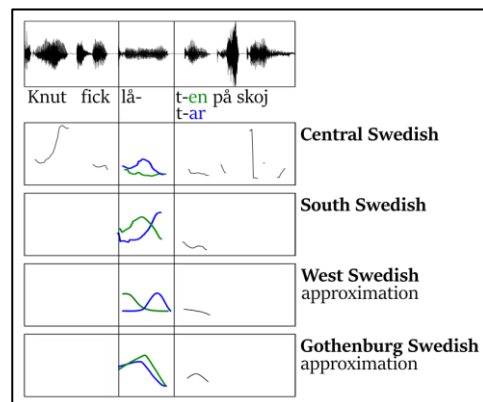


Figure 1: Pitch patterns for a definite singular (green) and indefinite plural (blue) across Swedish dialects in the sentence 'Knut got song-the / song-s for fun.' Approximations based on [33, 34].

13 native speakers of non-standard Danish dialects – mean age 26; all right-handed; 8 female, 5 male – participated in the Danish experiment. All participants grew up in areas with different prosodic distributions than the *stød-nonstød* patterns of Copenhagen Danish: Two participants came from areas without *stød* and thus identical singular and plural forms. One participant had tonal differences instead of creak. Seven participants came from areas without *stød* in words with unvoiced after voiced consonants (e.g., *kamp* 'fight'), such that there would be *nonstød* in both singular and plural forms for 64 % of the stimulus material. Three participants came from

areas with West Jutlandic *stød* (*vestjysk stød*) where disyllabic words get *stød* before -p, -t, and -k [35]. They would have *stød* in both singular and plural in 64% of the stimuli.

## 2.2. Stimuli

Both experiments used spoken stimuli with target nouns embedded in carrier sentences. The carrier sentence in the Swedish material was of the type *Knut fick X till jul*. ‘Knut got X for Christmas’, see Figure 1. The prepositional phrase after the target word (X) differed between sentences. The Danish material, on the other hand, embedded the targets in the fixed structure *Det var X, Brit sagde*. ‘It was X, Brit said.’ Target words in both experiments were monosyllabic noun stems, e.g., *båt/båd* ‘boat’, with definite singular *-en* and indefinite plural *-ar/-e* suffixes. The prosodic pattern in these nouns is such that definite singular suffix requires the word stem to be produced with accent 1 or *stød*, in Swedish and Copenhagen Danish respectively, while the indefinite plural suffix causes a change to accent 2 or non-*stød*. All words were recorded within the carrier sentence by a phonetically trained male speaker of Central Swedish and Copenhagen Danish.

The targets words were spliced in Praat [36] where word stems were combined with the opposing suffix to form prosody-suffix mismatches. Thus, four conditions existed for each target word: validly and invalidly cued definite singulars, as well as validly and invalidly cued indefinite plurals. The Swedish material had 120 stimulus sentences, 30 per noun condition. The Danish material had the same distribution but 240 stimulus sentences, 120 with common (*båd-en/-e*, ‘boat-the/s’) and 120 with neuter (*telt-et/-e*, ‘tent-the/s’) gender.

## 2.3. Procedure

Both experiments were conducted in agreement with the Declaration of Helsinki. Ethical approval was granted separately for both experiments. The ethical approval did not specify data sharing and participants were not informed that data would be made public. We can therefore not share our data publicly.

The Swedish participants were sat in front of a computer in an electrically shielded room, fitted with headphones and an electrode cap (EASYCAP GmbH, Hersching, Germany) with 64 Ag-AgCl electrodes. They passively listened to the Central Swedish stimuli while looking at a fixation cross on a screen and indicated through button presses when they perceived a sentence to be over. Naturally occurring electrical potentials on their scalp were picked up by the electrodes, amplified via a SynAmps<sup>2</sup> amplifier (Compumedics Neuroscan, Victoria, Australia), and recorded via Curry Neuroimaging Suite 7 (Compumedics Neuroscan) using M1 as online reference and AFz as ground. Sampling rate was set at 500 Hz with a 200 Hz low-pass filter. Sentences were cued automatically with a fixed stimulus onset asynchrony (SOA) of 4 seconds and interstimulus interval (ISI) from 1.38 to 1.77 seconds.

The Danish experiment was conducted online using the Gorilla Experiment Builder [37]. Participants could participate from a laptop or stationary computer. They were instructed to make sure they would not be interrupted, sit in a quiet room, and use earphones. The participants listened to sentences one at a time and indicated whether the target word in the sentence was singular or plural by pressing two keys on their keyboard. Response options were visible on the screen. Button presses ended the current stimulus presentation and cued the next stimulus after a 0.5 second ISI.

## 2.4. Data processing and statistical analysis

### 2.4.1. Central Swedish ERPs

For the Swedish experiment, electroencephalographic (EEG) data was filtered offline with a 0.01 Hz high-pass and a 30 Hz low-pass filter. Event-related potentials were extracted in epochs of 1200 ms around both prosody (predictor) onset and suffix (predictee) onset, each including a 200-ms baseline. Epochs were cleaned from artefacts via independent component analysis (ICA) and subsequent rejection of abnormal values ( $\pm 100 \mu\text{V}$ ). Drawing on previous literature, three time windows related to prediction were constructed: 150-280 ms after prosodic cue (predictor) onset for the PrAN and 300-500 ms and 550-800 ms after suffix (predictee) onset for N400 and P600. Mean values from nine electrode regions (5 electrodes each) per participant were submitted for each time window to a repeated measures analysis of variance (rmANOVA) in IBM SPSS Statistics for Windows, Version 28, with the experimental factors “Predictor” (accent 1, accent 2) and “Validity” (valid, invalid) and the topographical factors “Laterality” (left, mid, right) and “Posteriority” (anterior, central, posterior).

### 2.4.2. Copenhagen Danish response times

For the Danish part, the response time data was cleaned initially by removing premature responses defined as all responses that were given before the onset of the word stem vowel. Response times were time-locked to vowel onset. They were subsequently normalised through inverse transformation to remove outliers and reduce the influence of inter-subject variation [38]. The cleaned and normalised data was submitted to an rmANOVA with the experimental factors “Noun Gender” (common vs neuter), “Predictor” (*stød* vs non-*stød*), and “Validity” (valid vs invalid).

## 3. Results

For the Central Swedish stimuli, the analysis of the predictor onset time window revealed a significant Accent by Posteriority interaction,  $F(2,30) = 4.69, p = .041$ . This broke down into a main effect for Accent at anterior electrode locations,  $F(1,15) = 4.81, p = .045$ , indicative of a negativity (PrAN) for Accent 1 (see Figure 2). There were no further significant effects or interactions with Accent. For predictee onset, there were no interactions or main effect for Validity in the early time window ( $p > .4$ ). In the late time window, a main effect of Validity emerged,  $F(1,15) = 5.23, p = .037$ , but no interactions with Accent or topographical factors.

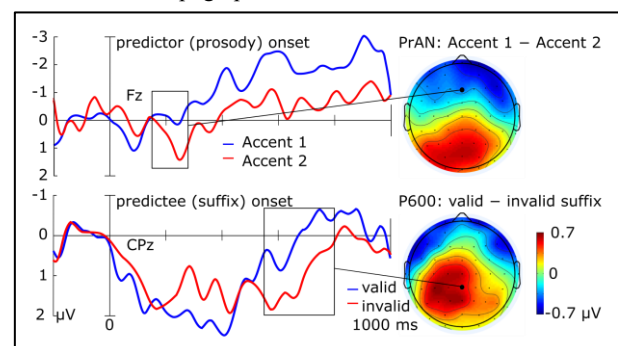


Figure 2: ERPs results for the Swedish experiment (displayed with 15 Hz low-pass filter). PrAN at predictor onset (above). P600 at onset (below).

For the Copenhagen Danish stimuli, a main effect for Validity,  $F(1,12) = 5.14$ ,  $p = .043$ , was found. Responses were significantly slower when the prosodic predictor was invalid with respect to the predictee ( $M = 900.09$  ms,  $SD = 137$ ) compared to cases where it was valid ( $M = 731.53$  ms,  $SD = 175$ ). A lack of interactions ( $p > .4$ ) revealed that this pattern was present for both predictors (stød vs nonstød) and both noun genders.

#### 4. Discussion

The present results suggest that it is possible for Swedish and Danish listeners to carry out prosody-to-structure predictions in a non-native standard variety of a language. The prosodic cues themselves elicited brain responses in non-standard Swedish listeners related to the cues' differential predictive strength in the standard variety. The same brain activity patterns had previously been observed in native speakers of the standard dialect and shown to be related to ongoing predictive processes being stronger the more a prosodic feature restricts word structure [6, 12]. For listeners from a different native dialect to produce the same brain response and activity distribution as native speakers, they need to be intimately aware with the realisation of the prosodic features in the standard variety and with how the features are distributed across word structures both of which differed from the native, non-standard varieties.

Besides the evidence of active prediction based on the standard prosodic features' restrictiveness and predictive strength, the presented experiments also found indications of processing difficulties due to non-met predictions. Apparent in the behavioural measure in the Danish experiment, listeners from non-standard dialect areas were significantly delayed in their assessment of the standard words' morphological properties when these were cued with the wrong prosodic features according to the standard variety's rules. Interestingly, the invalidly morphology cues in the standard variety would in many cases be the valid ones in the native varieties. Being exposed to standard speech, the listeners' predictive system seems to have adapted to the non-native variety and made predictions based on the associations in the standard dialect. The same pattern can be observed in the neurophysiological data in the Swedish experiment where listeners respond to invalidly cued morphology in the standard variety with a larger P600 response. The P600 is considered a signal of structural reanalysis and often found in cases of failed prediction [39, 40, 41, 42, 20, 13]. The fact that it is present in the non-native standard data is yet another indication that listeners can form predictions for the standard dialect even when they are not native speakers of that dialect and when the standard's prosody differs from that of their own. Future studies should, however, look in more detail the phonetic differences between native and standard dialects to see if the degree of dissimilarity affects processing, as the present study groups speakers with different phonetic distances from the standard.

The present findings for non-native speakers of the standard dialect listeners adapt their language perception mechanisms, crucially including morphological prediction, to their surroundings. The listeners analysed here could adapt their predictions to cues in the standard variety to which we know that they had ample exposure through media or friends and relatives from the standard dialect area. Thus, the Swedish participants reported first exposure to Stockholm or Central Swedish at five years of age (range 0 to 12) and the Danish participants reported an average familiarity with Copenhagen or Zealand

Danish of 87 on a scale from 0 (not at all familiar) to 100 (very familiar) with a range of 25 to 100. The school system also predominantly uses the standard variety [43, 44]. Consequently, there is a high degree of familiarity, early exposure, and prestige associated with the standard variety which all potentially contribute to the listeners' ability to process standard language in a way that is indistinguishable from previous native speaker results. The present study cannot disentangle the influence of the different sociolinguistic factors.

While providing important information about the potential adaptability of the predictive processing system, the present results leave open the question of how listeners process other non-standard or unfamiliar varieties or languages. Depending on the relative importance of familiarity, exposure, prestige, and language similarity, other speaker-listener dialect combinations might evoke processing similar to adult L2 learners with a lower tendency for morphological prediction. Thus, expanding this kind of research to a large variety of participant groups from different dialects and different languages and but also groups of early bilinguals or L2 learners from differently closely related language would strongly complement the present research and give us an even clearer picture of how flexible we are with respect to forming predictions based on the prosodic input and what factors are the most important for successful prediction of word structure in non-native speech.

#### 5. Conclusions

The current study investigated whether non-standard dialect listeners could predict word structure from prosodic cues in the non-native, standard variety of their language. It found neurophysiological and behavioural evidence indicative of predictive processing in standard Swedish and Danish for listeners from non-standard dialects. A PrAN showed ongoing prediction as a factor of the prosody's predictive strength before the predicted word ending occurred. A P600 for incorrectly predicted word endings as well as a significant drop in the speed of grammatical decision illustrated showed negative consequences of failed predictions. These results exactly mirror previous findings for native speakers and are distinct from findings for non-specifically trained adult L2 learners. On this basis, the paper argues that a listener's internal system for prosody to morphology predictions is relatively flexible and can adapt to familiar, prestigious varieties that listeners are exposed to early in life. However, the possibilities and limits of the adaptability of the system need to be examined further through the inclusion of more diverse listener populations and speech samples.

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