

# Grammaticalization of prosody in the brain

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## Abstract

*Based on the results from three Event-Related Potential (ERP) studies, we show how the degree of grammaticalization of prosodic features influences their impact on syntactic and morphological processing. Thus, results indicate that only lexicalized word accents influence morphological processing. Furthermore, it is shown how an assumed semi-grammaticalized left-edge boundary tone activates main clause structure without, however, inhibiting subordinate clause structure in the presence of competing syntactic cues.*

## Introduction

In the rapid online processing of speech, prosodic cues can in many cases be decisive for the syntactic interpretation of utterances. According to constraint-based processing models, the brain activates different possible syntactic structures in parallel, and relevant syntactic, semantic, and prosodic features work as constraints that increase or decrease the activation of particular structures (Gennari and MacDonald, 2008). How important a prosodic cue is for the activation of a particular syntactic structure depends to a large extent on the frequency of their co-occurrence. Another factor we assume to play an important role is how 'grammaticalized' the association is between the prosodic feature and the syntactic structure, i.e. to what degree it has been incorporated into the language norm.

Sounds that arise as side effects of the articulatory constraints on speech production may gradually become part of the language norm (Ohala, 1993). In the same vein, speakers seem to universally exploit the tacit knowledge of the biological conditions on speech production in order to express different pragmatic meanings (Gussenhoven, 2002). For instance, due to conditions on the exhalation phase of the breathing process, the beginning of utterances is normally associated with more energy and higher fundamental frequency than the end. Mimicking this tendency, the 'Production Code' might show the boundaries of utterances by associating the beginning with high pitch and the end with low pitch, although it might not be physically nec-

essary. According to Gussenhoven, the Production Code has been grammaticalized in many languages in the use of a right edge H% to show non-finality in an utterance, as well as a left-edge %H, to indicate topic-refreshment.

In the present study, we will first examine the processing of a Swedish left-edge H tone that would appear to be on its way to becoming incorporated into the grammar. The H will be shown to activate main clause structure in the online processing of speech, but without inhibiting subordinate clause structure when co-occurring with the subordinating conjunction *att* 'that' and subordinate clause word order. The processing dissociation will be related to the low impact the tone has on normative judgments in competition with the conjunction *att* and subordinate clause word order constraints. This shows that the tone has a relatively low degree of grammaticalization, probably related to the fact that it is confined to the spoken modality, lacking any counterpart in written language (such as commas, which correlate with right-edge boundaries). We will further illustrate the influence of lexicalized and non-lexicalized tones associated with Swedish word accents on morphological processing.

The effects of prosody on syntactic and morphological processing were monitored online in three experiments using electroencephalography (EEG) and the Event-Related Potentials (ERP) method. EEG measures changes in the electric potential at a number of electrodes (here 64) over the scalp. The potential changes are due to electrochemical processes involved in the transmission of information between neurons. The ERP method time locks this brain activity to the presentation of stimuli, e.g. words or morphemes. In order to obtain regular patterns corresponding to the processing of specific stimuli rather than to random brain activity, ERPs from at least forty trials per condition are averaged and statistically analyzed for twenty or more participants. In the averaged ERP-waveform, recurrent responses to stimuli in the form of positive (plotted downwards) or negative potential peaks, referred to as 'components', emerge.

In this contribution, we will review results related to the 'P600' component, a positive

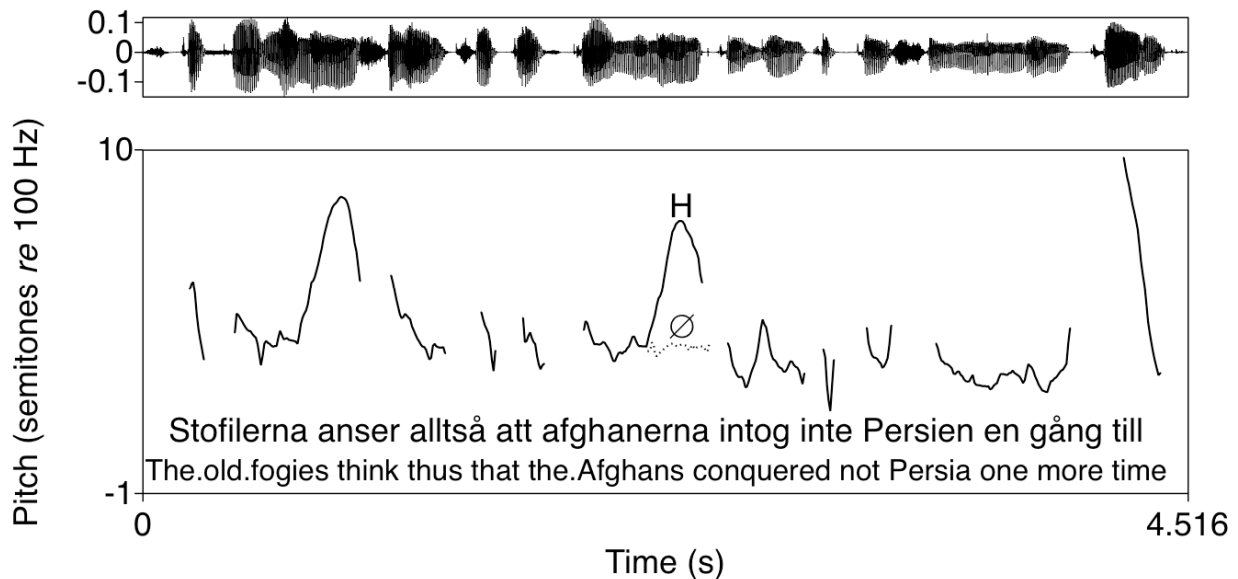


Figure 1. Waveform and F0 contour of an embedded main clause sentence with (H, solid line) or without (∅, dotted line) a left-edge boundary tone.

peak around 600 ms following stimuli that trigger reprocessing due to garden path effects or syntactic errors (Osterhout and Holcomb, 1992). The P600 often gives rise to a longer sustained positivity from around 500 to 1000 ms or more.

### A semi-grammaticalized tone

In Central Swedish, a H tone is phonetically associated with the last syllable of the first prosodic word of utterances (Horne, 1994; Horne et al., 2001). Roll (2006) found that the H appears in embedded main clauses but not in subordinate clauses. It thus seems that this ‘left-edge boundary tone’ functions as a signal that a main clause is about to begin.

Swedish subordinate clauses are distinguished from main clauses by their word order. Whereas main clauses have the word order S–V–SAdv (Subject–Verb–Sentence Adverb), as in *Afghanerna intog inte Persien* ‘(literally) The Afghans conquered not Persia’, where the sentence adverb *inte* ‘not’ follows the verb *intog* ‘conquered’, in subordinate clauses, the sentence adverb instead precedes the verb (S–SAdv–V), as in *...att afghanerna inte intog Persien* ‘(lit.) ...that the Afghans not conquered Persia’. In spoken Swedish, main clauses with postverbal sentence adverbs are often embedded instead of subordinate clauses in order to express embedded assertions, although many speakers consider it normatively unacceptable. For instance, the sentence *Jag sa att [afghanerna intog inte Persien]* ‘(lit.) I said that the

Afghans conquered not Persia’ would be interpreted as an assertion that what is expressed by the embedded main clause within brackets is true.

Roll et al. (2009a) took advantage of the word order difference between main and subordinate clauses in order to study the effects of the left-edge boundary tone on the processing of clause structure. Participants listened to sentences similar to the one in Figure 1, but with the sentence adverb *ju* ‘of course’ instead of *inte* ‘not’, and judged whether the word order was correct. The difference between the test conditions was the presence or absence of a H left-edge boundary tone in the first prosodic word of the embedded clause, as seen in the last syllable of the subject *afghanerna* ‘the Afghans’ in Figure 1. Roll et al. hypothesized that a H left-edge boundary tone would increase the activation of main clause structure, and thus make the S–V–SAdv word order relatively more expected than in the corresponding clause without a H associated with the first word.

When there was no H tone in the embedded clause, the sentence adverb yielded a biphasic positivity in the ERPs, interpreted as a P345–P600 sequence (Figure 2). In easily resolved garden path sentences, the P600 has been regularly observed to be preceded by a positive peak between 300 and 400 ms (P345). The biphasic sequence has been interpreted as the discovery and reprocessing of unexpected structures that are relatively easy to reprocess (Friederici et al. 2001).

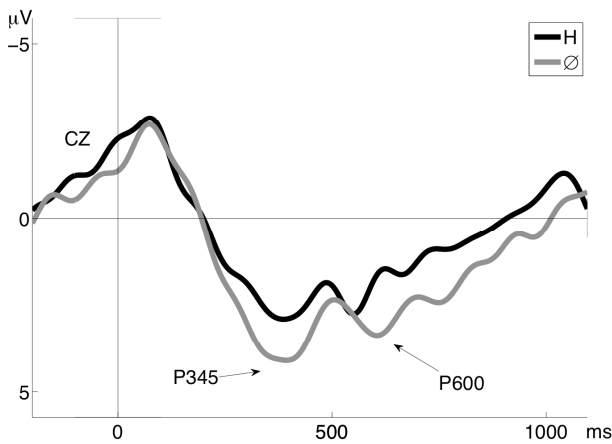


Figure 2. ERPs at the sentence adverb *ju* ‘of course’ in sentences with embedded main clauses of the type *Besökaren menar alltså att familjen känner ju...* ‘(lit.) The visitor thinks thus that the family feels of course...’ In the absence of a preceding left-edge boundary tone ( $\emptyset$ , grey line), there was increased positivity at 300–400 (P345) and 600–800 ms (P600).

The effect found in Roll et al. (2009a) hence indicates that in the absence of a left-edge boundary tone, a sentence adverb showing main clause word order (S–V–SAdv) is syntactically relatively unexpected, and thus triggers reprocessing of the syntactic structure. The word order judgments confirmed the effect. Embedded main clauses associated with a left-edge boundary tone were rated as acceptable in 68% of the cases, whereas those lacking a tone were accepted only 52 % of the time. Generally speaking, the acceptability rate was surprisingly high, considering that embedded main clauses are limited mostly to spoken language and are considered inappropriate by many speakers.

In other words, the tone was used in processing to activate main clause word order and, all other things being equal, it influenced the normative judgment related to correct word order. However, if the tone were fully grammaticalized as a main clause marker, it would be expected not only to activate main clause structure, but also to *inhibit* subordinate clause structure. That is to say, one would expect listeners to reanalyze a subordinate clause as an embedded main clause after hearing an initial H tone.

In a subsequent study (Roll et al., 2009b), the effects of the left-edge boundary tone were tested on both embedded main clauses and subordinate clauses. The embedded main clauses were of the kind presented in Figure 1. Corresponding sentences with subordinate clauses were recorded, e.g. *Stofilerna anser alltså att*

*afghanerna inte intog Persien...* ‘(lit.) The old fogies think thus that the Afghans not conquered Persia...’ Conditions with embedded main clauses lacking left-edge boundary tones and subordinate clauses with an initial H tone were obtained by cross-splicing the conditions in the occlusion phase of [t] in *att* ‘that’ and *intog* ‘conquered’ or *inte* ‘not.’

For embedded main clauses, the ERP-results were similar to those of Roll et al. (2009a), but the effect was even clearer: A rather strong P600 effect was found between 400 and 700 ms following the onset of the sentence adverb *inte* ‘not’ for embedded main clauses lacking a left-edge boundary tone (Figure 3).

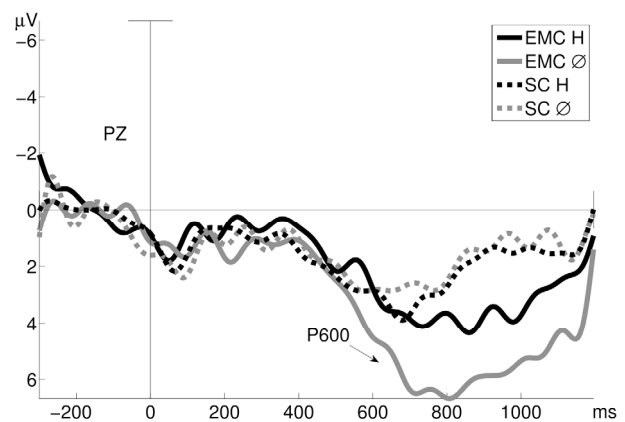


Figure 3. ERPs at the disambiguation point for the verb *in-tog* ‘conquered’ (embedded main clauses, EMC, solid lines) or the sentence adverb *in-te* ‘not’ (subordinate clauses, SC, dotted line) in sentences like *Stofilerna anser alltså att afghanerna in-tog/te...* ‘(lit.) The old fogies thus think that the Afghans con/no-quired/t...’ with (H, black line) or without ( $\emptyset$ , grey line) a left-edge boundary tone. Embedded main clauses showed a P600 effect at 400–700 ms following the sentence adverb, which was reduced in the presence of a left-edge tone.

Thus, it was confirmed that the left-edge boundary tone increases the activation of main clause structure, and therefore reduces the syntactic processing load if a following sentence adverb indicates main clause word order. As mentioned above, however, if the tone were fully grammaticalized, the reverse effect would also be expected for subordinate clauses: A left-edge boundary tone should inhibit the expectation of subordinate clause structure. However, the tone did not have any effect at all on the processing of the sentence adverb in subordinate clauses. The left-edge boundary tone thus activates main clause structure, albeit without inhibiting subordinate clause structure.

Interestingly, in this experiment, involving both main and subordinated embedded clauses, the presence of a left-edge boundary tone did not influence acceptability judgments. Rather, the speakers made their grammaticality decisions based only on word order, where subordinate clause word order was accepted in 89% and embedded main clause word order in around 40% of the cases. Hence, the left-edge boundary tone would appear to be a less grammaticalized marker of clause type than word order is. In the next section, we will review the processing effects of a prosodic feature that is, in contrast to the initial H, strongly grammaticalized, namely Swedish word accent 2.

### A lexicalized tone

In Swedish, every word has a lexically specified word accent. Accent 2 words have a H\* tone associated with the stressed syllable, distinguishing them from Accent 1 words, in which a L\* is instead associated with the stressed syllable (Figure 4). Accent 2 is historically a lexicalization of the postlexical word accent assigned to bi-stressed words (Riad, 1998). Following Rischel (1963), Riad (in press) assumes that it is the suffixes that lexically

specify whether the stressed stem vowel should be associated with Accent 2. In the absence of an Accent 2-specification, Accent 1 is assigned postlexically by default. A stem such as *lek-* ‘game’ is thus unspecified for word accent. If it is combined with the Accent 2-specified indefinite plural suffix *-ar*, the stressed stem syllable is associated with a H\*, resulting in the Accent 2-word *lekar* ‘games’ shown in Figure 4. If it is instead combined with the definite singular suffix *-en*, which is assumed to be unspecified for word accent, the stem is associated with a L\* by a default postlexical rule, producing the Accent 1 word *leken* ‘the game’, with the intonation contour shown by the dotted line in Figure 4.

Neurocognitively, a lexical specification for Accent 2 would imply a neural association between the representations of the Accent 2 tone (H\*) and the grammatical suffix. ERP-studies on morphology have shown that a lexical specification that is not satisfied by the combination of a stem and an affix results in an ungrammatical word that needs to be reprocessed before interpreting in the syntactic context (Lück et al., 2006). Therefore, affixes with lexical specifications left unsatisfied give rise to P600 effects.

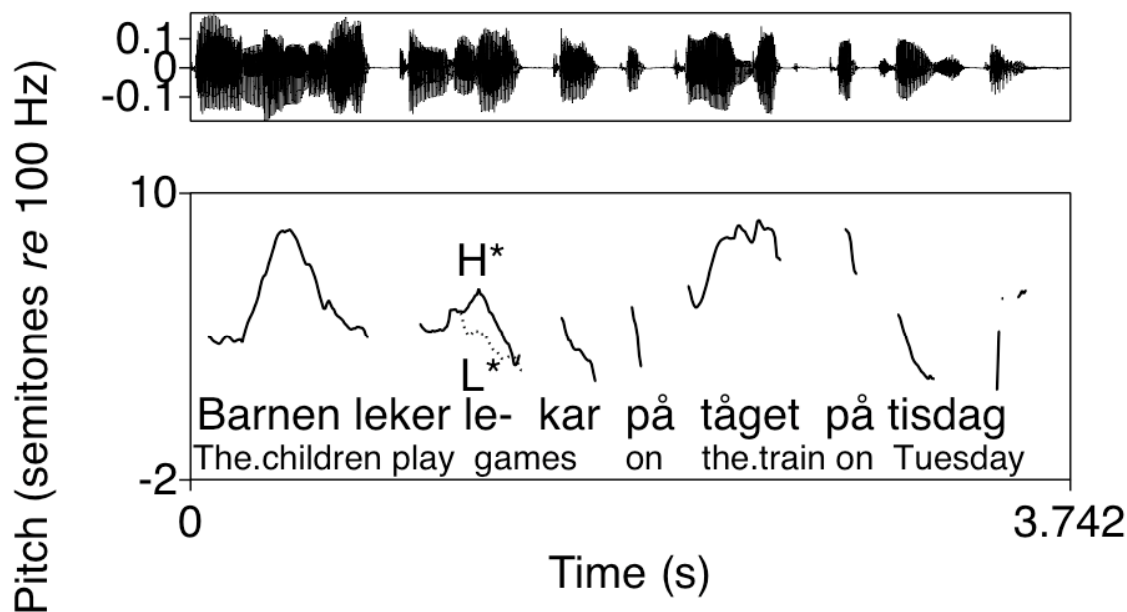


Figure 4. Waveform and F0-contour of a sentence containing the Accent 2 word *lekar* ‘games’ associated with a H\* (solid line). The F0 contour for the Accent 1 word *leken* ‘the game’ is shown by the dotted line (L\*).

A H\*-specified suffix such as *-ar* in *lekar* ‘games’ would hence be expected to produce an ungrammatical word if combined with a stem associated with a clashing L\*. The word would have to be reprocessed, which would be reflected in a P600 effect. No such effect would be expected for suffixes that usually co-occur with Accent 1, such as *-en* in *leken* ‘the game’, since they are assumed to be unspecified for word accent.

Roll et al. (2009c) found the expected dissociation when they compared 160 sentences containing words with either the H\*-specified suffix *-ar* or the unspecified suffix *-en*, and stems phonetically associated with a H\* or a L\*, obtained by cross-splicing. The effects were compared with another 160 sentences containing words involving declension errors, such as *lekor* or *leket*, which have 1<sup>st</sup> and 5<sup>th</sup> declension instead of 2<sup>nd</sup> declension suffixes, and therefore yield a clash between the lexical specification of the suffix and the stem. The results were similar for declension mismatching words and words with a H\*-specifying suffix inaccurately assigned an Accent 1 L\* (Figure 5). In both cases, the mismatching suffix gave rise to a P600 effect at 450 to 900 ms that was stronger in the case of declension-mismatching suffixes. The combination of the lexically unspecified singular suffix *-en* and a H\* did not yield any P600 effect, since there was no specification-mismatch, although *-en* usually co-occurs with Accent 1.

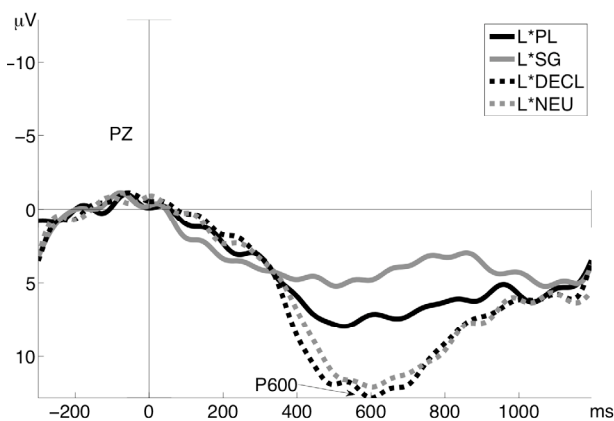


Figure 5. ERPs for the Accent 2-specifying plural suffix *-ar* (L\*PL), the word accent-unspecified definite singular suffix *-en* (L\*SG), as well the inappropriately declining *-or* (L\*DECL) and *-et* (L\*NEU), combined with a stem associated with Accent 1 L\*. The clash of the H\*-specification of *-ar* with the L\* of the stem produced a P600 similar to that of the declension errors at 450–900 ms.

The study showed that a lexicalized prosodic feature has similar effects on morphological processing as other lexicalized morphological features such as those related to declension marking.

## Summary and conclusions

In the present contribution, two prosodic features with different degrees of grammaticalization and their influence on language processing have been discussed. It was suggested that a Swedish left-edge boundary tone has arisen from the grammaticalization of the physical conditions on speech production represented by Gussenhoven’s (2002) Production Code. Probably stemming from a rise naturally associated with the beginning of phrases, the tone has become associated with the syntactic structure that is most common in spoken language and most expected at the beginning of an utterance, namely the main clause. The tone has also been assigned a specific location, the last syllable of the first prosodic word. When hearing the tone, speakers thus increase the activation of main clause structure.

However, the tone does not seem to be fully grammaticalized, i.e. it does not seem to be able to override syntactic cues to subordination in situations where both main and subordinate embedded clauses occur. Even when hearing the tone, speakers seem to be nevertheless biased towards subordinate clause structure after hearing the subordinate conjunction *att* ‘that’ and a sentence adverb in preverbal position in the embedded clause. However, embedded main clauses are easier to process in the context of a left-edge boundary tone. Thus we can assume that the H tone activates main clause structure. Further, the boundary tone influenced acceptability judgments, but only in the absence of word order variation in the test sentences. The combination of syntactic cues such as the conjunction *att* and subordinate word order (S–SAdv–V) thus appears to constitute decisive cues to clause structure and cancel out the potential influence the initial H could have had in reprocessing an embedded clause as a main clause.

A fully grammaticalized prosodic feature was also discussed, Swedish Accent 2, whose association with the stem is accounted for by a H\* lexically specified for certain suffixes, e.g. plural *-ar* (Riad, in press). When the H\*-specification of the suffix clashed with a L\*

inappropriately associated with the stem in the test words, the words were reprocessed, as reflected in a P600 effect in the ERPs. Significantly lower acceptability judgments confirmed that the effect was due to the ungrammatical form of these test words. Similar effects were obtained for declension errors.

The results reviewed in this paper indicate that prosodic features with a low degree of grammaticalization can nevertheless influence processing of speech by e.g. increasing the activation of a particular syntactic structure without, however, inhibiting the activation of parallel competing structures. The studies involving the semi-grammaticalized left-edge boundary tone show clearly how prosodic cues interact with syntactic cues in the processing of different kinds of clauses. In the processing of subordinate embedded clauses, syntactic cues were seen to override and cancel out the potential influence of the prosodic cue (H boundary tone). In embedded main clauses, however, the prosodic cue facilitated the processing of word order. In contrast to these results related to the left-edge boundary tone, the findings from the study on word accent processing show how this kind of prosodic parameter has a much different status as regards its degree of grammaticalization. The Swedish word accent 2 was seen to affect morphological processing in a way similar to other morphological features, such as declension class, and can therefore be regarded as fully lexicalized.

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