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# Prosodic Breaks in Sentence Processing Investigated by Event-Related Potentials

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## Abstract

Prosodic breaks (PBs) can indicate a sentence's syntactic structure. Event-related brain potentials (ERPs) are an excellent way to study auditory sentence processing, since they provide an on-line measure across a complete sentence, in contrast to other on- and off-line methods. ERPs for the first time allowed investigating the processing of a PB itself. PBs reliably elicit a closure positive shift (CPS). We first review several studies on the CPS, leading to the conclusion that it is elicited by abstract structuring or phrasing of the input. Then we review ERP findings concerning the role of PBs in sentence processing as indicated by ERP components like the N400, P600 and LAN. We focus on whether and how PBs can (help to) disambiguate locally ambiguous sentences. Differences in results between different studies can be related to differences in items, initial parsing preferences and tasks. Finally, directions for future research are discussed.

## *Introduction*

A spoken utterance is not just a string of words, but always comes with a certain intonation ('melody'), rhythm, intensity and timing. Prosody is the collective term for these kinds of features (Ladd and Cutler 1983). The prosody of an utterance can express various things, such as the emotional state of the speaker or whether the sentence is ironic. Prosody can also indicate how to understand a sentence. For example, the same sentence (e.g. *Peter loves Mary*) with a rising or a flat intonation at the end, can be meant as a question or a statement, respectively.

In this review, we focus on prosodic breaks (PBs) in sentence comprehension. A PB, also referred to as prosodic boundary or intonational phrase boundary, consists of one or more of the following elements: a pause in a sentence, a boundary tone preceding this pause and the lengthening of the word before the pause (e.g. Kjelgaard and Speer 1999). PBs often coincide with syntactic boundaries (e.g. boundaries between clauses or phrases) in a sentence, although there is no one-to-one correspondence between PBs and syntactic boundaries. If a PB coincides with a syntactic boundary, the PB can help listeners to structure the sentence syntactically. For example, the phrase *old men and women*, uttered with a PB after *men*, will be interpreted such that only the men are old. In contrast, no PB (or one after old) indicates that both the men and the women are old (adapted from Beach 1991).

We will start by briefly discussing how the role of PBs in sentence comprehension has been investigated in the past and why event-related brain potentials (ERPs) are especially useful to study this topic. Following, we will turn to ERP research on PBs in sentences. This research for the first time allowed studying not only the role of PBs in sentence comprehension, but also the processing of a PB itself. Finally, some challenges for future research are discussed.

*How to Study PBs in Sentence Processing*

Studies on the role of PBs in the syntactic parsing of sentences generally make use of ambiguous sentences. So-called globally ambiguous sentences remain ambiguous throughout the whole sentence, see (1) (from Schafer 1995; # stands for PB).

(1) Paula phoned ($\#^1$) her friend ($\#^2$) from Alabama.

In the study by Schafer (1995), participants listened to such sentences with a PB at one of the two positions indicated in (1). Then they had to choose between the two possible interpretations of the sentence ('the friend is from Alabama' or 'Paula phoned from Alabama'; where $\#^1$ matches the first interpretation and $\#^2$ the second). It was found that the position of the PB affected the participants' choice (see also e.g. Streeter 1978).

In contrast to globally ambiguous sentences, locally ambiguous sentences such as (2) (from Beach 1991) are only ambiguous up to a certain point in the sentence at which the ambiguity is resolved.

(2) Mary suspected (#) her boyfriend…
  a. …immediately.
  b. …was lying.

By manipulating the length and the boundary tone of the word *suspected*, Beach (1991) created versions of (2) with and without (two of the components of) a PB. Participants were presented with the two versions of sentences like (2), and then had to choose between the two possible endings (a) and (b). Participants more often chose (a) in the absence of a PB and (b) in the presence of one (see also Stirling and Wales 1996).

These studies use off-line measures and thus do not tell us whether listeners use prosodic cues immediately during on-line speech comprehension. To investigate the on-line use of PBs during sentence comprehension, researchers have turned to on-line tasks, like cross-modal naming or cross-modal lexical decision. For example, Kjelgaard and Speer (1999) presented participants with the beginning of locally ambiguous sentences like (3), which can be disambiguated as in (a) or as in (b).

(3) When Roger leaves ($\#^1$) the house ($\#^2$) …
  a. …is dark.
  b. …it's dark.

Immediately after hearing the ambiguous part, listeners had to name a visually presented word (cross-modal naming) which was the first word of either continuation (a), fitting the ambiguous part with $\#^1$ after *leave*, or continuation (b), fitting the ambiguous part with $\#^2$ after *house*. Words that fitted the prosody of the sentence beginning were named faster than those that did not (see also Marslen-Wilson et al. 1992; Warren et al. 1995 for similar results; but see Watt and Murray 1996). Although these studies demonstrate on-line effects of PBs on sentence comprehension, they use rather artificial tasks; participants are asked to listen to sentence fragments and then to perform a naming task or a lexical decision task on a visually presented continuation of the sentence. (For reviews of off- and on-line studies on the role of PBs in sentence processing see Carlson 2009; Cutler et al. 1997.)

The problems associated with the methods described above can be avoided by the use of ERPs (see Rugg and Coles 1995; Kutas and Dale 1997 for introductions on the use of ERPs to investigate cognitive functions and see Brown and Hagoort 1998 for the use of ERPs in language research). ERPs are especially well-suited to investigate spoken sentence processing since they provide a measure of processing across the sentence as it unfolds. Therefore, complete sentences can be presented continuously and participants (ideally) do nothing else than listen for comprehension. However, although no additional task is needed when using ERPs as a dependent measure, in many ERP studies, participants nevertheless perform some additional task. We will come back to this issue later.

*Studying PBs With Event-Related Potentials*

Steinhauer et al. (1999) used ERPs to investigate the on-line processing of locally ambiguous sentences which can be disambiguated by a PB. Participants listened to German sentences such as (4), (5), and (6).

(4) Peter verspricht Anna zu arbeiten… (see sound file S1)
*Peter promises Anna to work… (literal translation/paraphrase)*

(5) Peter verspricht # Anna zu entlasten… (see sound file S2)
*Peter promises Anna to support… (literal translation)*
*Peter promises to support Anna… (paraphrase)*

(6) Peter verspricht # Anna zu arbeiten… (see sound file S3)
*Peter promises Anna to work… (literal translation/paraphrase)*

In German, in contrast to English, these sentences have the same word order and they are only disambiguated by the second verb (*arbeiten/entlasten*). In (4) this verb (*arbeiten*, 'to work') is intransitive and thus cannot take *Anna* as its (direct) object. Therefore, *Anna* has to be interpreted as the indirect object of the first verb (*verspricht*, 'promises'). In contrast, in (5) the second verb (*entlasten*, 'to support') is obligatorily transitive such that *Anna* has to be the direct object of *entlasten*, and thus cannot be the indirect object of *verspricht*. Steinhauer et al. hypothesized that a PB after *verspricht* disambiguates the sentence towards an interpretation in which *Anna* is not the indirect object of *verspricht* (as in 5) and thus leads to processing problems when the sentence is continued with an intransitive verb (*arbeiten*, 'to work'), as in (6). The paraphrase of this ungrammatical analysis in English would be *Peter promises to work Anna…. The intransitive disambiguating verb *arbeiten* in (6) elicited an N400 and a P600 component in the ERP as compared to the transitive verb *entlasten* in (5). The N400 (Kutas and Hillyard 1984) is a negative peak in the ERP around 400 ms after onset of the critical word (i.e. the second verb) and its amplitude varies as a function of how well a word fits in a context (see Kutas et al. 2006; for a review). Steinhauer et al. interpreted the N400 as a reflection of lexical re-access to confirm the violation of the intransitive argument structure. The P600, a positive wave starting around 600 ms after onset of the critical word, is reliably elicited by syntactic violations and by unexpected disambiguations of locally ambiguous sentences (e.g. Osterhout et al. 1994). Steinhauer et al. regarded it as an indication of structural revision, in which *Anna* has to be attached to a different verb. Although the precise functional

significance of the P600 is currently under debate (e.g. Friederici 2002; Kuperberg 2007; Van de Meerendonk et al. 2009), the N400 and P600 on the intransitive disambiguating verb (*arbeiten*) show that PBs can affect the syntactic analysis that listeners pursue.

Steinhauer et al. (1999) also compared sentences (4) and (6), which contain the same words, but differ in the presence versus absence of a PB. For sentences such as (6), which contain a PB, they found a new ERP component at the position of the PB. This component is related to the processing of the PB itself. They termed it the Closure Positive Shift (CPS), since it took the form of a positive shift at the closure of an intonational phrase. Figure 1 gives an example of a CPS taken from a study by Kerkhofs et al. (2007). A clear positive shift is visible in the waveforms for the sentences with a PB (dotted line) as compared to the sentences without a PB (solid line; especially for the midline electrodes: Fz, Cz and Pz). This CPS is a representative example for the CPS component found in ERP studies from different labs, in terms of distribution and shape.

The Steinhauer et al. (1999) study provided two important insights. First, the use of ERPs allows studying the processing of the PB itself. Steinhauer et al. discovered that a PB elicits a CPS, which they related to prosodic processing. Second, Steinhauer et al. also showed that PBs can have an effect on syntactic processing. This is in line with the behavioural on- and off-line studies reported above. However, ERPs allow studying the role of prosody in sentence processing in a more natural situation, i.e. with complete and continuously presented sentences. The Steinhauer et al. study has triggered a lot of research following-up on both of these aspects. In the following, we will first discuss the relevant evidence on the processing of the PB itself, i.e. the evidence concerning the CPS. Then we will turn to evidence concerning the role of PBs in arriving at the eventual interpretation of a sentence.

## THE CLOSURE POSITIVE SHIFT

Since its discovery by Steinhauer et al. (1999), the finding of a CPS at the PB has been replicated in several languages such as German (e.g. Isel et al. 2005), Dutch (Bögels et al. 2010; Kerkhofs et al. 2007, 2008), English (Pauker et al. forthcoming), Japanese (Mueller

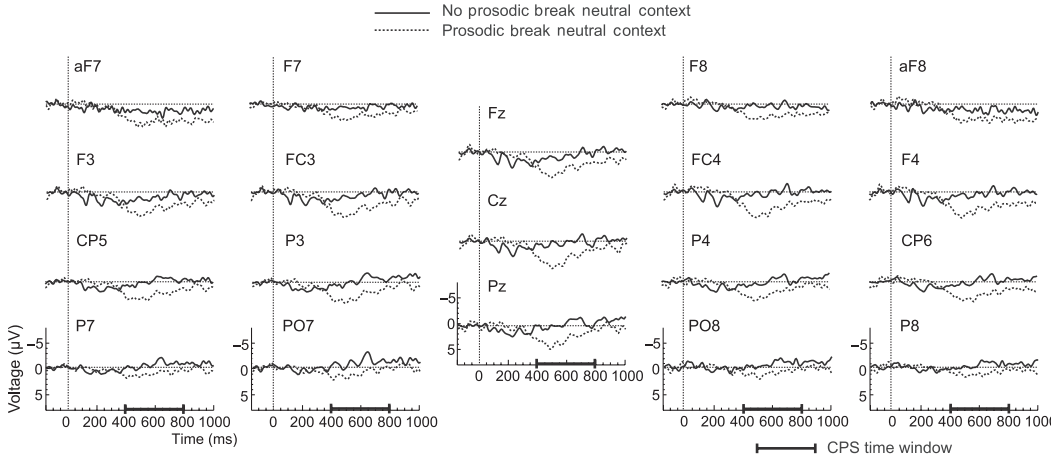


Fig 1. Standard closure positive shift (CPS) (taken from Kerkhofs et al. 2007, Experiment 1). Grand average waveforms time-locked to the onset of the pause (or the equivalent position in sentences without a prosodic break (PB)) for sentences with a PB (dotted line) and without a PB (solid line).

et al. 2005; Wolff et al. 2008), Chinese (Liu et al. 2009), and, recently, Korean (in reading: Hwang and Steinhauer forthcoming). These studies lead to the following general profile of the CPS (see also Figure 1). In terms of scalp distribution, the CPS is found bilaterally and is largest at midline electrodes. Steinhauer et al. found a centroparietal distribution, but some studies report an extension to anterior electrodes (e.g. Bögels et al. 2010; Pannekamp et al. 2005). The CPS generally starts around or even before pause onset (Steinhauer 2003), although Kerkhofs et al. (2007) found a later onset. Its offset appears to be triggered by the onset of the word after the pause (Pauker et al. forthcoming). Some studies have reported a small negativity preceding the CPS (see Figure 1; e.g. Bögels et al. 2010, forthcoming; Kerkhofs et al. 2007; Pannekamp et al. 2005; Pauker et al. forthcoming).

How can one establish that the CPS is specifically responsive to PBs? Several alternative accounts have been refuted. First, Steinhauer (2003) (and later, Bögels et al. 2010) argued against an interpretation of the CPS as an average of spread-out P2 components in response to the onset of the word after the pause. This is very unlikely since the CPS starts well before the average pause offset. Moreover, a low-pass filtering of 1 Hz led to a disappearance of P2 components elicited by sentence onset, while the CPS remained present. Second, despite a correspondence in polarity, the CPS does not seem to be a variety of the P600, because the CPS is elicited in correct and unambiguous sentences. However, it is possible that the CPS and the P600 share common sub-processes (Steinhauer and Friederici 2001). It has even been suggested by Hwang and Steinhauer (forthcoming), on the basis of a reading study, that the P600 can in some cases be regarded as an indication of prosodic revision, possibly reflecting a delayed CPS. Third, Steinhauer et al. (1999) showed that the CPS is not just a response to the pause in the speech signal. When they removed the pause, while keeping the other features of the PB (prefinal lengthening and boundary tone) intact, they still observed a CPS.

These findings support that the CPS is a response to the PB as a whole. However, it remains unclear which aspects of the PB are necessary for the elicitation of a CPS. Since the pause is apparently not necessary, the prefinal lengthening and/or boundary tone remain viable candidates for bringing about the CPS. The negativity preceding the CPS found in some studies is probably also elicited by these features, since it precedes pause onset (see also Pauker et al. forthcoming). Further research is needed to investigate the relative contributions of lengthening and boundary tone to the CPS and the preceding negativity.

Event-related brain potentials are generally computed by taking the average of several epochs of the electroencephalogram (EEG) time-locked to the onset of the event of interest. However, in the case of the CPS, it is not yet clear which elements of the PB elicit the CPS and thus it is not easy to determine an adequate time-locking point for the CPS. Steinhauer et al. (1999) circumvented this problem by time-locking the ERPs to the onset of the sentence. The (approximate) timing of the CPS was then determined relative to the average onset of the pause across all the experimental sentences used in the experiment. However, a disadvantage of this method is the considerable variation between experimental items in the onset of the pause (Steinhauer 2003:151). To counter this problem, Kerkhofs et al. (2007) time-locked the ERPs to the onset of the pause (see Figure 1). However, since the CPS is not (only) elicited by the pause (Steinhauer et al. 1999), lengthening and boundary tone should be taken into account as well, but they appear *before* pause onset. Bögels et al. (2010) investigated this methodological problem in detail by comparing different time-locking points (see Bögels et al.: Appendix A). In addition to the two methods described above, they tried to establish the onset of the PB

by acoustic analyses. These analyses revealed that the boundary tone started on the last word before the pause, and that prefinal lengthening was clearly present only from the onset of the last stressed syllable before the pause. Bögels et al. thus considered the onset of the last stressed syllable as 'onset of the PB', and as the theoretically most appropriate time-locking point. Furthermore, they obtained a CPS for all three time-locking points, which shows the robustness of this ERP component. However, the CPS was less pronounced for sentence onset, probably due to greater variability in the onset of the PB. Moreover, sentence onset as time-locking point required a longer epoch to be extracted from the EEG. Therefore, more experimental trials had to be removed because they contained artefacts (like eye-blinks), leading to a loss of data. The CPS time-locked to the last stressed syllable before the pause seems to have a less broad and more focal shape with a sharper peak than the CPS obtained with the other two time-locking points, suggesting less jitter in the onset of the CPS in the former case. This would imply an important role for prefinal lengthening and boundary tone in the elicitation of the CPS (K. Steinhauer, personal communication). Thus, although the CPS is a robust phenomenon and observed across different time-locking points, one has to be aware of the relative (dis)advantages of the different methods.

Several follow-up studies on the CPS have extended the scope of this ERP component. First, Pannekamp et al. (2005) found that no linguistic content is needed to elicit a CPS, as a CPS in response to a PB also occurs in jabberwocky sentences (with pseudo content-words, preserving syntax), pseudo sentences (exclusively pseudo words and no semantics or syntax) and even in hummed 'sentences' without any phonological-segmental content (see also, e.g. Steinhauer and Friederici 2001). The CPS has a more anterior and right distribution for sentences with less linguistic content. Second, a CPS-like effect was also elicited by breaks that indicate phrasing in music (Knösche et al. 2005; Nan et al. 2006, 2009; Neuhaus et al. 2006). However, this 'music CPS' occurs later than the linguistic CPS. Specifically, it appears to be time-locked to the offset of the pause (coinciding with the onset of the next element). The music CPS might have a delayed latency because the perception of a boundary in music requires more contextual information (Pauker et al. forthcoming). Third, a (small) CPS has also been found in response to a comma in written sentences in German and Chinese (Liu et al. 2010; Steinhauer and Friederici 2001), suggesting that commas can have the same function in reading as PBs in listening. In Korean, a CPS has been found in the absence of a comma, after reading a long constituent (Hwang and Steinhauer forthcoming). The visual CPS can be interpreted as some kind of visual phrasing or as reflecting subvocal prosodic phrasing, which readers apply to written sentences (Steinhauer 2003; Steinhauer and Friederici 2001). This 'visual' CPS was only elicited for participants with strict punctuation habits. Kerkhofs et al. (2008) did not replicate the CPS in response to a comma in Dutch, possibly because Dutch has less strict comma rules than German. Fourth, there has been some debate about the age at which the CPS can be observed in children. Pannekamp et al. (2006) reported a CPS for 8-month-old infants. In contrast, for 5-month-olds, Männel and Friederici (2009) found only obligatory components (cf. N1-P2 components), signalling lower-level perceptual processing of acoustic cues. These components disappeared when the pause was removed from the speech signal, also casting some doubt on the Pannekamp et al. (2006) study. Recent studies from the same laboratory found a CPS in children only from about 3 years old (Männel and Friederici forthcoming), suggesting that syntactic knowledge seems to affect the development of prosodic phrasing. Fifth, despite reported reduced speech processing abilities in elderly listeners, in older adults (65–80 years of age) a normal CPS is elicited (Steinhauer et al. 2010). Sixth, in question-answer pairs, a CPS appears also to be elicited by new

information (Hruska and Alter 2004; Toepel et al. 2007). These authors argue that those elements that are important for structuring the utterance are the elicitors for the CPS.

Taken together, the available evidence strongly suggests that the CPS reflects some kind of structuring or phrasing of the input. Whether this structuring is specific to the auditory modality or whether it is modality independent needs further investigation. However, it is clear that the CPS is not just a response to low level (acoustic-phonetic) cues of PBs. Rather, the CPS reflects phrasing based on (the integration of) several cues, which might be different for different domains such as music and language.

A related point concerns the factors determining the size of the CPS. Steinhauer (2003) argues that the CPS amplitude depends on the amount of activation of phonological representations in the brain. He reports a smaller CPS for covert prosodic phrasing, either in reading a comma, or in applying a de-lexicalized intonation contour to a written sentence (see also Hwang and Steinhauer forthcoming). Kerkhofs et al. (2008) propose that the size of the CPS depends on the salience of prosodic boundary markers. A comma might be less salient than a PB in a language with lax comma rules (like Dutch), leading to reduction or the absence of a CPS in response to a comma. Also, a larger CPS is elicited by a less expected PB, which is therefore more salient (Kerkhofs et al. 2007; see below).

### ROLE OF THE PB IN SENTENCE PROCESSING

As described above, Steinhauer et al. (1999) showed an effect of a PB at the disambiguating verb of their experimental sentences (see (4) to (6) above). A disambiguating intransitive verb that did not fit the presence of a PB in the sentence (*arbeiten* in (6)) led to a biphasic N400/P600 pattern relative to a transitive verb that fitted the presence of a PB (*entlasten* in (5)). These authors assumed that there is a general parsing preference for an intransitive verb (as in 4) in these sentences. This is precisely the opposite of what the PB suggests, since the PB signals that the NP after the PB (i.e. *Anna*) cannot be the indirect object of the verb preceding the PB (*to promise*). However, these authors did not include a fourth condition that would complete the design, namely (5) without a PB. Bögels et al. (2010) addressed this shortcoming by using Dutch sentences with the same syntactic structure in a full two-by-two design, i.e. sentences with a transitive and an intransitive second verb, both in versions with and without a PB after the first verb.

Moreover, they observed that in the sentences used by Steinhauer et al. (1999) as well as in their own sentences two different types of sentences have to be distinguished, so-called subject-control and so-called object-control sentences (due to space limitations, we refer the reader to the Introduction of Bögels et al. 2010 for examples and an explanation of these two types of sentences). When they compared sentences such as (5) and (6) (see sound files S4 and S5), they replicated the N400 effect (but not the P600 effect) in response to intransitive disambiguating verbs, as in (6), as compared to transitive verbs, as in (5) for both types of sentences. For sentences without a PB (see sound files S6 and S7), the results differed depending on the type of sentence. For object-control sentences, no difference was found between the disambiguating verbs, suggesting no specific parsing preference. However, for subject-control items an N400 effect for intransitive verbs was found, suggesting a preference for a transitive disambiguating verb, as in sentences with a PB.

In conclusion, different constellations of the relation between parsing preferences and PBs have been observed in these studies. First, if – in the absence of relevant prosodic cues – no specific parsing preference exists for a given type of locally ambiguous

sentences, the presence of a PB can induce a parsing preference (e.g. the object-control sentences in Bögels et al. 2010). Second, if a specific parsing preference in absence of relevant prosodic cues exists, and if the PB goes against this preference, the PB can 'reverse' it (e.g. the original interpretation that Steinhauer et al. 1999 gave for their results). Finally, if the disambiguation signalled by the PB goes in the same direction as the general prosody-independent parsing preference, no specific effects are obtained (see the subject-control items in Bögels et al.).

Kerkhofs et al. (2008) used a different type of Dutch sentences to study the role of PBs in sentence processing, see the English translations in (7a) and (7b).

(7) The sheriff protected the farmer (#) and the farm hand…
  a. …in front of the shed.
  b. …defended the ranch.

In (7a), the NP *the farmer* is coordinated with the NP *the farm hand* by *and* (NP-coordination), and together they are direct object of *protected*. In contrast, in (7b) the NP *the farmer* is the beginning of a new sentence, which is coordinated with the first sentence by *and* (sentence-coordination). It was already known from a reading-study by Hoeks et al. (2002) that readers prefer a sentence beginning as in (7) to continue as an NP-coordination (7a). Kerkhofs et al. hypothesized that, for spoken sentences, a PB after *the farmer* should reverse this preference to a preference for a sentence-coordination, as in (7b). They presented participants with spoken sentences like (7b), with a PB (see sound file S8) or without a PB (see sound file S9) after *the farmer*. The disambiguating verb (*defended*) for sentences without a PB as compared to sentences with a PB elicited typical reflections of processing difficulty: a P600 or a left-anterior negativity (LAN: an ERP component elicited for example by word category violations; Friederici 1995). Apparently, the PB changed the parsing preference from a preference for an NP-coordination to a preference for a sentence-coordination.

Wolff et al. (2008) investigated the role of PBs in Japanese sentences. Japanese has a relatively free word order and uses case marking to identify for example subjects and objects. A PB after the first NP of a sentence indicates word order scrambling, deviating from the canonical subject-object-verb order. Wolff et al. compared sentences starting with either a (case-marked) object NP or a (case-marked) subject NP, followed by a PB or not. First, they found that sentences with a PB elicited a standard CPS as compared to sentences without a PB. Furthermore, the initial object NP (as compared to the initial subject NP) elicited a negativity in the ERPs indicating word order scrambling, but only when the initial NP was followed by a PB. In contrast, in the absence of a PB, no negativity occurred. The authors took this as indicating that listeners expected a simpler structure with only an object (which is acceptable in Japanese because the subject can be dropped).

Pauker et al. (forthcoming) tested the role of PBs in English locally ambiguous sentences, such as (8) and (9).

(8) When a bear is approaching the people # the dogs come running.

(9) When a bear is approaching # the people come running.

Without PBs, so-called early closure sentences like (9) are more difficult to understand than so-called late closure sentences like (8) (Frazier and Rayner 1982). In (8) and (9), the position of the PBs is in line with the eventual disambiguation of the sentences (see sound files S10 and S11). In addition, there were two mismatching conditions: for (8), this condition had an additional (superfluous) PB after *approaching* (see sound file S12), and for (9), this condition had no PB at all, i.e. a condition with a missing PB (see sound file S13). For sentences with a superfluous PB, a biphasic N400/P600 pattern was found at the second PB, while sentences with a missing PB only gave rise to a small P600 at the disambiguation (*come*). The authors concluded that a superfluous PB is more difficult to process than a missing PB (see below). For the same type of sentences, Itzhak et al. (2010) showed that a correctly placed PB as in (9) can override both the general parsing preference and verb biases towards a late-closure interpretation.

In summary, the above studies in German, Dutch, English and Japanese show that a PB can affect the processing of sentences. However, the ERP effects found in these studies differ in nature and strength. One factor that may explain these differences is the nature of the disambiguation. For example, a violation of argument structure (encountering an intransitive instead of a transitive verb; Bögels et al. 2010; Steinhauer et al. 1999) typically leads to N400 effects or a biphasic N400/P600 pattern (e.g. Frisch et al. 2004). In contrast, word category violations (encountering a verb instead of a noun; Kerkhofs et al. 2007, 2008; Pauker et al. forthcoming) are more likely to elicit a LAN or P600.

A second important factor might be the task. It is known that, for example, P600 effects can be influenced by task demands (e.g. Kolk et al. 2003; and see Isel et al. 2005; Astésano et al. 2004 for task effects related to prosody). Various tasks were used in the above studies, such as judging the appropriateness of the sentence prosody (e.g. Pauker et al. forthcoming), answering comprehension questions (e.g. Steinhauer et al. 1999), an occasional sentence recognition task (e.g. Bögels et al. 2010), or just passively listening to the sentences (e.g. Kerkhofs et al. 2008). Probably, listeners pay more attention to the (relation between) prosody and syntax of the sentences when the appropriateness of the sentence prosody has to be judged or when comprehension questions about syntactic relations have to be answered. Therefore, researchers have to be careful when choosing a task. In order to generalize to natural situations outside the laboratory, the task should match the listener's goals in daily life. These goals will usually not involve tasks like rating the (prosodic) naturalness of utterances.

In addition to task effects, all aspects of the stimuli that focus the listener's attention on the prosody of the sentences might artificially raise the chances of finding an effect of PBs. These aspects presumably include the proportion of sentences with a prosodic unnaturalness or with prosody–syntax mismatches in the experiment, the presence of prosodic manipulations in the filler sentences (see e.g. Bögels et al. forthcoming), and repetition of the same sentences with different prosody within the same participant. Finally, the exact acoustic realization of the PB and of other parts of the sentence might also affect the kinds of ERP effects that are found (see below).

### *Future Directions, Challenges, and Open Questions*

As was noted by Pannekamp et al. (2005:407), the CPS 'has made it possible to examine at least prosodic processing at sentence level on-line and without the need of structural violations in the experimental design'. However, as can be seen from the preceding sections, most studies have focused either on the CPS as a reflection of processing of the PB itself or on the processing consequences of the PB at some later point in the sentence.

To date, only a few studies deviate from this general picture. Kerkhofs et al. (2007) used the CPS as a dependent measure to investigate whether syntactic and prosodic information are matched with each other right at the position of the PB. They used the same sentences as Kerkhofs et al. (2008), see (7a) and (7b) above. In addition, they induced the expectation of a syntactic break at the position of the PB (after *farmer*) by means of a discourse context preceding the critical sentence (see Hoeks et al. 2002; for the construction of the contexts and the calibration of the effectiveness of these contexts). Then, the exact same sentences (like 7b), with a PB, were placed either in a neutral context (leading to the default preference for an NP-coordination) or in a context biasing towards a preference for a sentence-coordination, and thus towards the expectation of a PB after *the farmer*. The PB elicited a larger CPS when the PB was unexpected (i.e. in the neutral context; see Figure 2, panel A) as compared to when the acoustically identical PB was expected (i.e. in the sentence-coordination biasing context; see Figure 2, panel B). For a direct comparison of the CPS in the two contexts, see Figure 2, panel C. Similarly, a CPS has been found when a PB was strongly expected due to parsing preferences and verb biases, even though no PB was present in the actual acoustic signal (Itzhak et al. 2010). This result indicates that strong cues other than the PB can also lead to (prosodic) phrasing.

The studies discussed in the preceding sections either investigated the processing of the PB itself (via the CPS) or the processing consequences of the PB at some later point in the sentence (using ERP components like the N400, LAN and P600). In contrast, the studies by Kerkhofs et al. and Itzhak et al. demonstrate that the CPS can also

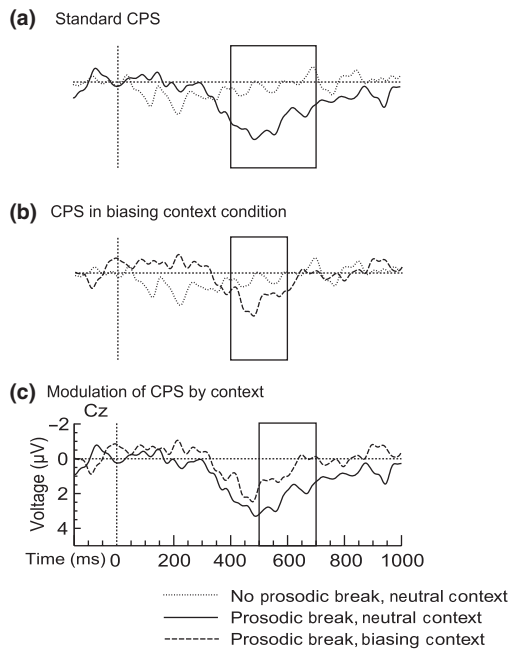


Fig 2. Modulation of the closure positive shift (CPS) as in Kerkhofs et al. (2007). Grand averages for the central midline electrode (Cz) time-locked to pause onset. Panel A shows a standard CPS for sentences preceded by a neutral context. Panel B shows a standard CPS for sentences preceded by a biasing context (eliciting an expectation for a syntactic break at the prosodic break (PB)). Panel C shows the CPS modulation as a result of context. The CPS is smaller for the biasing context (syntactic break expected) than for the neutral context (no syntactic break expected).

provide insights into the processing *consequences* for sentence understanding right at the PB. This requires varying expectations for the upcoming syntactic structure of a sentence before the PB is processed. This in turn allows investigating whether prosodic information (like PBs) and syntactic processing interact immediately when the prosodic information becomes available. This approach opens interesting directions for future research.

In the literature on prosodic phrasing, PBs are by far the most studied prosodic device. However, other prosodic devices might also play a role in this process. A recent study by Bögels et al. forthcoming investigated the combined role of PBs and pitch accents in prosodic phrasing. Pitch accents are often related to information structure, as they indicate new, focused information (see Bögels et al. 2011; Heim and Alter 2006, 2007; Hruska and Alter 2004; Johnson et al. 2003; Magne et al. 2005; Toepel et al. 2007 for ERP studies on the role of pitch accents). However, a pitch accent on a given word can sometimes provide focus to more than this one word (Gussenhoven 1999), thereby grouping several words together and creating a kind of prosodic phrasing. Bögels et al. forthcoming showed that in sentences like (4) and (5) above, the combination of a PB and a pitch accent on the noun following the PB can create a strong tendency to group the noun and the following verb together. When this grouping turned out to be syntactically and semantically impossible, this led to a strong violation, reflected in an N400/P600 pattern. By contrast, when the grouping was semantically plausible, this led to a disappearance of processing difficulty (absence of ERP effects). This study reveals that pitch accents can also play a role in prosodic phrasing. Future research will have to clarify the relative strength of accentuation and PBs as cues to prosodic phrasing. In any case, researchers should take into account that other aspects of prosody, next to PBs, can also play a role in prosodic phrasing.

With regard to models of language processing, the role of prosody has not received much attention yet, despite the available evidence that prosodic information can play an important role in sentence processing. Bornkessel and Schlesewsky (2006) assign the role of prosodic phrasing by PBs to the first stage of their model, where prosody is assumed to affect syntactic template selection. Friederici (2002), although incorporating a prosody–syntax interaction in her model, does not specify the precise temporal structure of this interaction. Eventually, models of language processing will have to specify the precise role of prosodic information in sentence processing. Studies like Kerkhofs et al. (2007) suggest that at least some parts of prosody can be used on-line, immediately when they come available. However, before prosody can be fully integrated in the above models, some important topics still have to be addressed.

As Cutler et al. (1997:169) noted in their review, prosodic cues related to phrasing can either signal syntactic breaks by a PB or they can signal syntactic cohesion by the absence of a PB. Most studies described above have focused on the first aspect. In contrast, the absence of a PB has often been confounded with the general parsing preference of a sentence; both pointed to the same disambiguation. Therefore, it remained impossible to determine whether a certain effect was due to the absence of a PB or due to a general prosody-independent parsing preference (e.g. Kerkhofs et al. 2008; Pauker et al. forthcoming). However, the absence of a PB can not only be a cue for syntactic coherence. Rather, it could also be the case that a PB at this position would make perfect sense, but that it is simply not realized by the speaker. In this context, Pauker et al.'s boundary deletion hypothesis (BDH) is relevant, stating that the mental deletion of a superfluous PB is more costly than the insertion of a missing PB (even if this goes against general parsing preferences). One reason for this might be that the closure of an

intonational phrase goes together with integration processes, which are hard to change later on. The BDH appears to be supported by Pauker et al. forthcoming and Bögels et al. (2010) (see above). On the other hand, it would be surprising if it were indeed very hard to (in retrospect) ignore any PB. PBs do not have a one-to-one correspondence to syntactic breaks but might also be inserted for non-syntactic reasons. For example, irrespective of the syntactic analysis, a PB is more likely to occur before or after a very long constituent (Frazier et al. 2006). Alternatively, a PB could just be a reflection of a hesitation or word-finding problem. It would be useful for listeners if they were able to exclude such PBs as being cues to syntactic boundaries. It is also interesting to note that the relation between superfluous and missing PBs proposed by Pauker et al. is the opposite of what has been suggested for other prosodic devices like contrastive pitch accents. For pitch accents, more processing difficulty has been found for missing accents than for superfluous accents (e.g. Bögels et al. 2011; Hruska et al. 2001; Hruska and Alter 2004; Toepel et al. 2007; but see Magne et al. 2005), while the BDH predicts the opposite pattern for PBs. Future research has to clarify the relative role of the presence versus absence of a PB, and how to disentangle prosodic effects from general parsing preferences.

The discussion about the role of PBs in language comprehension obviously also leads to the question about its role in language production. Frazier et al. (2006) have postulated the rational speaker hypothesis: a speaker uses prosody in a rational manner and a listener assumes that this is the case. Some version of this hypothesis is an (implicit or explicit) assumption behind most of the studies on PBs; it only makes sense for listeners to use prosodic information like PBs to structure sentences if speakers (rationally) exploit PBs to signal such a structure. However, this assumption leads to several predictions that still have to be tested. First, listeners should take into account individual differences between speakers. That is, a listener should rely more on PBs as a cue to syntactic structure when the respective speaker marks syntactic breaks consistently by PBs, and he should do less so for a speaker who is more 'sloppy' in this respect. Second, listeners should interpret a PB relative to the other boundaries in a sentence. According to Carlson et al. (2001), off-line interpretations are affected not merely by the presence of a PB at a syntactic break, but rather by whether this PB is the largest in the sentence. ERP studies can reveal whether the relativity of PBs is also important in on-line processing. Third, listeners should take into account that PBs can also be inserted for non-syntactic reasons, as described above; a 'rational listener' should be less likely to interpret a PB as a syntactic break when it follows a very long constituent, or when it signals a disfluency in the utterance of the speaker. ERPs are an excellent tool to track whether the above predictions hold for on-line sentence processing.

Finally, an important question is whether speakers are indeed 'rational' in everyday conversation. To our knowledge, all studies cited above used recorded speech from speakers, who were explicitly instructed to insert PBs at the 'appropriate' places indicated by the experimenters. There is considerable debate about whether naive speakers spontaneously produce the 'appropriate' prosodic patterns. Some researchers found it very hard to elicit those patterns in locally ambiguous sentences when speakers were not aware of the ambiguity (Allbritton et al. 1996; Snedeker and Trueswell 2003), whereas others found that speakers in an interactive context reliably produce prosodic cues, both in ambiguous and unambiguous sentences (Kraljic and Brennan 2005; Schafer et al. 2000). It is crucial, both for language production and comprehension research, to investigate under which circumstances speakers use PBs consistently to indicate syntactic breaks and how much variability exists between them.

*Supporting Information*

**Sound file S1.** German example sentence from Steinhauer et al. (1999) without (early) PB and with an intransitive disambiguating verb.
*Peter verspricht Anna zu arbeiten # und das Büro zu putzen.*
'Peter promises Anna to work # and the desk to clean.' (literal translation)
'Peter promises Anna to work # and to clean the desk.' (paraphrase)

**Sound file S2.** German example sentence from Steinhauer et al. (1999) with PB and with a transitive disambiguating verb.
*Peter verspricht # Anna zu entlasten # und das Büro zu putzen.*
'Peter promises # Anna to support # and the desk to clean.' (literal translation)
'Peter promises # to support Anna # and to clean the desk.' (paraphrase)

**Sound file S3.** German example sentence from Steinhauer et al. (1999) with PB and with an intransitive disambiguating verb (condition with a mismatch between prosody and disambiguation).
*Peter verspricht # Anna zu arbeiten # und das Büro zu putzen.*
'Peter promises # Anna to work # and the desk to clean.' (literal translation)
'Peter promises # Anna to work # and to clean the desk.' (paraphrase)

**Sound file S4.** Dutch example sentence from Bögels et al. (2010) with PB and with a transitive disambiguating verb. (condition with a mismatch between prosody and disambiguation).
*De leerling bekende # de leraar te hebben gespiekt # tijdens het eerste uur.*
'The pupil confessed # the teacher to have cheated # during the first hour.' (literal translation)
'The pupil confessed # to the teacher to have cheated # during the first hour.' (paraphrase)

**Sound file S5.** Dutch example sentence from Bögels et al. (2010) with PB and with an intransitive disambiguating verb.
*De leerling bekende # de leraar te hebben opgesloten # tijdens het eerste uur.*
'The pupil confessed # the teacher to have locked up # during the first hour.' (literal translation)
'The pupil confessed # to have locked up the teacher # during the first hour.' (paraphrase)

**Sound file S6.** Dutch example sentence from Bögels et al. (2010) without (early) PB and with an intransitive disambiguating verb.
*De leerling bekende de leraar te hebben gespiekt # tijdens het eerste uur.*
'The pupil confessed the teacher to have cheated # during the first hour.' (literal translation)
'The pupil confessed to the teacher to have cheated # during the first hour.' (paraphrase)

**Sound file S7.** Dutch example sentence from Bögels et al. (2010) without (early) PB and with a transitive disambiguating verb.
*De leerling bekende de leraar te hebben opgesloten # tijdens het eerste uur.*
'The pupil confessed the teacher to have locked up # during the first hour.' (literal translation)
'The pupil confessed to have locked up the teacher # during the first hour.' (paraphrase)

**Sound file S8.** Dutch example sentence-coordination sentence from Kerkhofs et al. (2008) with PB.
*De sheriff beschermde de boer # en de knecht verdedigde wanhopig de boerderij tegen Johnson's bende.*
'The sheriff protected the farmer # and the farm hand defended desperately the farm against Johnson's gang.' (literal translation)
'The sheriff protected the farmer # and the farm hand desperately defended the farm against Johnson's gang.' (paraphrase)

**Sound file S9.** Dutch example sentence-coordination sentence from Kerkhofs et al. (2008) without PB.
*De sheriff beschermde de boer en de knecht verdedigde wanhopig de boerderij tegen Johnson's bende.*
'The sheriff protected the farmer and the farm hand defended desperately the farm against Johnson's gang.' (literal translation)
'The sheriff protected the farmer and the farm hand desperately defended the farm against Johnson's gang.' (paraphrase)

**Sound file S10.** English example late closure sentence from Pauker et al. forthcoming with an appropriate PB.
*When a bear is approaching the people # the dogs come running.*

**Sound file S11.** English example early closure sentence from Pauker et al. forthcoming with an appropriate PB.
*When a bear is approaching # the people come running.*

**Sound file S12.** English example late closure sentence from Pauker et al. with two PBs.
*When a bear is approaching # the people # the dogs come running.*

**Sound file S13.** English example early closure sentence from Pauker et al. forthcoming without any PBs.
*When a bear is approaching the people come running.*

*Short Biographies*

Sara Bögels holds a PhD in Social Sciences from the Radboud University Nijmegen, The Netherlands, which she obtained at the Donders Centre for Cognition of the Donders Institute for Brain, Cognition and Behaviour. Her dissertation deals with the role of prosody (prosodic breaks and pitch accents) in sentence comprehension and in the processing of referential communication, mainly investigated with ERP measurements. From April 2011 she works as a post-doctoral fellow at the University of Glasgow. In her research she uses MEG measurements to look at listeners' use of common ground in conversation.

Herbert Schriefers is a full professor for Cognitive Psychology and Psycholinguistics at the Donders Centre for Cognition of the Radboud University Nijmegen (The Netherlands). He did his PhD research at the Max-Planck-Institute for Psycholinguistics, Nijmegen. After that, he was a senior researcher at the Max-Planck-Institute for Psycholinguistics, visiting researcher at the University of Massachusetts at Amherst, and associate professor at the Free University in Berlin (Germany). His main research interests concern lexical processing in language production, and auditory and visual sentence processing.

Wietske Vonk is a professor emeritus of psycholinguistics at the Radboud University Nijmegen. She holds a PhD in Psychology from the University of Groningen, where she

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Dorothee J. Chwilla is a cognitive neuroscientist in the field of language at the Donders Centre for Cognition at the Radboud University Nijmegen. She investigates semantic, syntactic and prosodic processes in language comprehension across contexts (single words, sentences and discourse). Recent research areas are the processing of semantics in a second language, the interaction of language and attention, and the interaction of language and emotion.

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## *Works Cited*

Allbritton, David W., Gail McKoon, and Roger Ratcliff. 1996. Reliability of prosodic cues for resolving syntactic ambiguity. Journal of Experimental Psychology: Learning, Memory, and Cognition 22. 714–35.

Astésano, Corine, Mireille Besson, and Kai Alter. 2004. Brain potentials during semantic and prosodic processing in French. Cognitive Brain Research 18. 172–84.

Beach, Cheryl M. 1991. The interpretation of prosodic patterns at points of syntactic structure ambiguity: evidence for cue trading relations. Journal of Memory and Language 30. 644–63.

Bögels, Sara, Herbert Schriefers, Wietske Vonk, and Dorothee J. Chwilla. 2011. Pitch accents in context: how listeners process accentuation in referential communication. Neuropsychologia. doi: 10.1016/j.neuropsychologia.2011.03.032.

——, ——, ——, and ——. forthcoming. The role of prosodic breaks and pitch accents in grouping words during on-line sentence processing. Journal of Cognitive Neuroscience.

——, ——, ——, ——, and Roel Kerkhofs. 2010. The interplay between prosody and syntax in sentence processing: the case of subject- and object-control verbs. Journal of Cognitive Neuroscience 22. 1036–53.

Bornkessel, Ina, and Matthias Schlesewsky. 2006. The extended argument dependency model: a neurocognitive approach to sentence comprehension across languages. Psychological Review 113. 787–821.

Brown, Colin M., and Peter Hagoort. 1998. The neurocognition of language. Oxford: Oxford University press.

Carlson, Katy. 2009. How prosody influences sentence comprehension. Language and Linguistics Compass 3. 1188–200.

——, Charles Clifton, and Lyn Frazier. 2001. Prosodic boundaries in adjunct attachment. Journal of Memory and Language 45. 58–81.

Cutler, Anne, Delphine Dahan, and Wilma van Donselaar. 1997. Prosody in the comprehension of spoken language: a literature review. Language and Speech 40. 141–201.

Frazier, Lyn, Katy Carlson, and Charles Clifton. 2006. Prosodic phrasing is central to language comprehension. Trends in Cognitive Sciences 10. 244–9.

——, and Keith Rayner. 1982. Making and correcting errors during sentence comprehension: eye movements in the analysis of structurally ambiguous sentences. Cognitive Psychology 14. 178–210.

Friederici, Angela D. 1995. The time course of syntactic activation during language processing: a model based in neuropsychological and neurophysiological data. Brain and Language 50. 259–81.

——. 2002. Towards a neural basis of auditory language processing. Trends in Cognitive Sciences 6. 78–84.

Frisch, Stefan, Anja Hahne, and Angela D. Friederici. 2004. Word category and verb-argument structure information in the dynamics of parsing. Cognition 91. 191–219.

Gussenhoven, Carlos. 1999. On the limits of focus projection in English. Focus: linguistic, cognitive, and computational perspectives, ed. by P. Bosch and R. van der Sandt, 43–55. Cambridge: University Press.

Heim, Stefan, and Kai Alter. 2006. Prosodic pitch accents in language comprehension and production: ERP data and acoustic analyses. Acta Neurobiologiae Experimentalis 66. 55–68.
——, and ——. 2007. Focus on focus: the brain's electrophysiological response to focus particles and accents in German. Language, context and cognition: interfaces and interface conditions, ed. by A. Späth, 277–98. Berlin: Walter de Gruyter.
Hoeks, John C. J., Wietske Vonk, and Herbert Schriefers. 2002. Processing coordinated structures in context: the effect of topic-structure on ambiguity resolution. Journal of Memory and Language 46. 99–119.
Hruska, Claudia, and Kai Alter. 2004. Prosody in dialogues and single sentences: how prosody can influence speech perception. Language, context and cognition, Information structure: theoretical and empirical aspects, ed. by A. Steube, 211–26. Berlin: Walter de Gruyter.
——, ——, Karsten Steinhauer, and Anita Steube. 2001. Misleading dialogs: human's brain reaction to prosodic information. Orality and gestures. Interactions et comportements multimodaux dans la communication, ed. by C. Cave, I. Guaitella and S. Santi, 425–30. Paris: L'Hartmattan.
Hwang, Hyekyung, and Karsten Steinhauer. forthcoming. Phrase length matters: the interplay between implicit prosody and syntax in Korean 'garden path' sentences. Journal of Cognitive Neuroscience.
Isel, Frédéric, Kai Alter, and Angela D. Friederici. 2005. Influence of prosodic information on the processing of split particles: ERP evidence from spoken German. Journal of Cognitive Neuroscience 17. 154–67.
Itzhak, Inbal, Efrat Pauker, John E. Drury, Shari R. Baum, and Karsten Steinhauer. 2010. Event-related potentials show online influence of lexical biases on prosodic processing. NeuroReport 21. 8–13.
Johnson, Shaun M., Charles Clifton, Mara Breen, and Joanna Morris. 2003. An ERP investigation of prosodic and semantic focus. Journal of Cognitive Neuroscience 14(Suppl.). 174.
Kerkhofs, Roel, Wietske Vonk, Herbert Schriefers, and Dorothee J. Chwilla. 2007. Discourse, syntax, and prosody: the brain reveals an immediate interaction. Journal of Cognitive Neuroscience 19. 1421–34.
——, ——, ——, and ——. 2008. Sentence processing in the visual and auditory modality: do comma and prosodic break have parallel functions? Brain Research 1224. 102–18.
Kjelgaard, Margareth M., and Shari R. Speer. 1999. Prosodic facilitation and interference in the resolution of temporary syntactic closure ambiguity. Journal of Memory and Language 40. 153–94.
Knösche, Thomas R., Cristiane Neuhaus, Jens Haueisen, Kai Alter, Burkhard Maess, Otto W. Witte, and Angela D. Friederici. 2005. Perception of phrase structure in music. Human Brain Mapping 24. 259–73.
Kolk, Herman H. J., Dorothee J. Chwilla, Marieke van Herten, and Patrick J. Oor. 2003. Structure and limited capacity in verbal working memory: a study with event-related potentials. Brain and Language 85. 1–36.
Kraljic, Tanya, and Susan E. Brennan. 2005. Prosodic disambiguation of syntactic structure: for the speaker or for the addressee? Cognitive Psychology 50. 194–231.
Kuperberg, Gina R. 2007. Neural mechanisms of language comprehension: challenges to syntax. Brain Research 1146. 23–49.
Kutas, Martha, and Anders Dale. 1997. Electrical and magnetic recordings of mental functions. Cognitive neuroscience, ed. by M. D. Rugg, 197–241. Hove: Psychology press.
——, Cyma K. Van Petten, and Robert Kluender. 2006. Psycholinguistics Electrified II 1994–2005. Handbook of Psycholinguistics, 2nd edn, ed. by M. Traxler and M. A. Gernsbacher, 659–724. New York: Elsevier Press.
——, and Steven A. Hillyard. 1984. Brain potentials during reading reflect word expectancy and semantic association. Nature 307. 161–3.
Ladd, D. Robert, and Anne Cutler. 1983. Introduction. Models and measurements in the study of prosody. Prosody: models and Measurements, ed. by A. Cutler and D. Robert Ladd, 1–10. Berlin: Springer-Verlag.
Liu, Baolin, Zhixing Jin, Wenjun Li, Yanli Li, and Zhongning Wang. 2009. The pragmatic meanings conveyed by function words in Chinese sentences: an ERP study. Journal of Neurolinguistics 22(6). 548–62.
——, Zhongning Wang, and Zhixing Jin. 2010. The effects of punctuations in Chinese sentence comprehension: an ERP study. Journal of Neurolinguistics 23(1). 66–80.
Magne, Cyrille, Astésano Corine, Anne Lacheret-Dujour, Michel Morel, Kai Alter, and Mireille Besson. 2005. On-line processing of "pop-out" words in spoken French dialogues. Journal of Cognitive Neuroscience 17. 740–56.
Männel, Claudia, and Angela D. Friederici. 2009. Pauses and intonational phrasing: ERP studies in 5-month-old German infants and adults. Journal of Cognitive Neuroscience 21. 1988–2006.
——, and ——. forthcoming. Intonational phrase structure processing at different stages of syntax acquisition: ERP studies in 2-, 3-, and 6-year-old children. Developmental Science.
Marslen-Wilson, William D., Lorraine K. Tyler, Paul Warren, P. Grenier, and C. S. Lee. 1992. Prosodic effects in minimal attachment. The Quarterly Journal of Experimental Psychology 45. 73–87.
Mueller, Jutta L., Anja Hahne, Yugo Fujii, and Angela Friederici. 2005. Native and nonnative speakers' processing of a miniature version of Japanese as revealed by ERPs. Journal of Cognitive Neuroscience 17. 1229–44.
Nan, Yun, Thomas R. Knösche, and Angela D. Friederici. 2006. The perception of musical phrase structure: a cross-cultural ERP study. Brain Research 1094. 179–91.
——, ——, and ——. 2009. Non-musicians' perception of phrase boundaries in music: a cross-cultural ERP study. Biological Psychology 82. 70–81.

Neuhaus, Christiane, Thomas R. Knösche, and Angela D. Friederici. 2006. Effects of musical expertise and boundary markers on phrase perception in music. Journal of Cognitive Neuroscience 18. 472–93.

Osterhout, Lee, Phillip J. Holcomb, and David A. Swinney. 1994. Brain potentials elicited by garden-path sentences: evidence of the application of verb information during parsing. Journal of Experimental Psychology: Learning, Memory, and Cognition 20. 785–803.

Pannekamp, Ann, Christiane Weber, and Angela D. Friederici. 2006. Prosodic processing at the sentence level in infants. NeuroReport 17. 675–8.

——, Ulrike Toepel, Kai Alter, Anja Hahne, and Angela D. Friederici. 2005. Prosody-driven sentence processing: an event-related brain potential study. Journal of Cognitive Neuroscience 17. 407–21.

Pauker, Efrat, Inbal Itzhak, Shari R. Baum, and Karsten Steinhauer. forthcoming. Co-operating and conflicting prosody in spoken English garden path sentences: ERP evidence for the Boundary Deletion Hypothesis. Journal of Cognitive Neuroscience.

Rugg, Michael D., and Michael G. H. Coles. (1995). The ERP and cognitive psychology: conceptual issues. Electrophysiology of mind: event-related brain potentials and cognition, ed. by M. D. Rugg and M. G. H. Coles, 27–39. Oxford: Oxford University Press.

Schafer, Amy J. 1995. The role of optional prosodic boundaries. Paper presented to the Eight Annual CUNY Conference on Human Sentence Processing, Tucson, AZ. March 16–18.

——, Shari R. Speer, Paul Warren, and S. David White. 2000. Intonational disambiguation in sentence production and comprehension. Journal of Psycholinguistic Research 29. 169–82.

Snedeker, Jesse, and John Trueswell. 2003. Using prosody to avoid ambiguity: effects of speaker awareness and referential context. Journal of Memory and Language 48. 103–30.

Steinhauer, Karsten. 2003. Electrophysiological correlates of prosody and punctuation. Brain and Language 86. 142–64.

——, and Angela D. Friederici. 2001. Prosodic boundaries, comma rules, and brain responses: the closure positive shift in ERPs as a universal marker for prosodic phrasing in listeners and readers. Journal of Psycholinguistic Research 30. 267–95.

——, Kai Alter, and Angela D. Friederici. 1999. Brain potentials indicate immediate use of prosodic cues in natural speech processing. Nature Neuroscience 2. 191–6.

——, Shani H. Abada, Efrat Pauker, Inbal Itzhak, and Shari R. Baum. 2010. Prosody–syntax interactions in aging: event-related potentials reveal dissociations between on-line and off-line measures. Neuroscience Letters 472. 133–8.

Stirling, Lesley, and Roger Wales. 1996. Does prosody support or direct sentence processing? Language and Cognitive Processes 11. 193–212.

Streeter, Lynn A. 1978. Acoustic determinants of phrase boundary location. Journal of the Acoustical Society of America 64. 1582–92.

Toepel, Ulricke, Ann Pannekamp, and Kai Alter. 2007. Catching the news: processing strategies in listening to dialogs as measured by ERPs. Behavioral and Brain Functions 3. 53.

Van de Meerendonk, Nan, Dorothee J. Chwilla, Herman H. J. Kolk, and Constance Th. W. M. Vissers. 2009. Monitoring in language perception. Language and Linguistics Compass 3. 1211–24.

Warren, Paul, Esther Grabe, and Francis Nolan. 1995. Prosody, phonology and parsing in closure ambiguities. Language and Cognitive Processes 10. 457–86.

Watt, Sheila M., and Wayne S. Murray. 1996. Prosodic form and parsing commitments. Journal of Psycholinguistic Research 25. 291–318.

Wolff, Susann, Matthias Schlesewsky, Masako Hirotani, and Ina Bornkessel-Schlesewsky. 2008. The neural mechanisms of word order processing revisited: electrophysiological evidence from Japanese. Brain and Language 107. 133–57.