The Interplay of Prosody and Syntax in Sentence Processing: Two ERP-studies

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Abstract
In earlier studies, which were mostly reading studies, it has become clear that not only syntax but also other factors such as semantics and discourse context play an important role in sentence processing. Much less research has been done to investigate auditory sentence comprehension, although this is by far the most common way of human communication. The focus of the present study, prosody, is unique to *auditory* sentence processing. ERPs are presumably the best method to investigate auditory sentence comprehension, because they are the only straightforward, online method available. In this thesis, two experiments are described that used two different types of locally ambiguous sentences to investigate the role of prosody in sentence processing.

In Experiment 1, as a follow-up on Kerkhofs et al. (submitted-a), sentences with an NP/S-coordination ambiguity with and without a prosodic break (PB) were used (see sentences 1 and 2).

1. The mannequin kissed the designer (*PB*) and the photographer on the party. (NP)
2. The mannequin kissed the designer (*PB*) and the photographer opened a bottle of Champaign. (S)

According to late closure, the NP-coordination sentence should be preferred. However, we hypothesized that the PB could reverse this preference. At the PB, a Closure Positive Shift (CPS) was found, replicating Kerkhofs et al. Comparing the S-coordination sentences with and without a PB at the disambiguation point (*opened*), a mid-frontal P600 effect, which indicated processing difficulty, was found throughout the experiment. This result was different from Kerkhofs et al., who found a LAN-effect in the first half of their experiment. This difference could have been caused by a different ratio of items in the different conditions in the two studies. Comparing the NP-coordination sentences with and without a PB at the disambiguation point (*on the party*), a comparison that was not included in Kerkhofs et al., a mid-posterior P600 effect was found for the sentences with a PB, but only in the first half of the experiment. This asymmetrical pattern of effects is difficult to interpret. One possible explanation is that participants came to regard sentences with a PB in a special way in the course of the experiment.

In Experiment 2, as a follow-up on Steinhauer et al. (1999), sentences with another type of late closure ambiguity with and without a PB were used (see sentences 3 and 4).

3. De verpleegster hielp (*PB*) de zieke te lopen…

The nurse helped the patient to walk…

4. De verpleegster hielp (*PB*) de zieke te vervoeren…

The nurse helped to transport the patient…

According to late closure, sentence 3 should be preferred because *de zieke* (the patient) is the object of the previous verb *hielp* (helped). However, we hypothesized that a PB after *hielp* could reverse this preference. At the PB, the ERPs showed a CPS, which replicates Steinhauer et al. Comparing the sentences with a PB at the disambiguation point, an N400 effect was found for the condition with a mismatch between prosody and syntax (3). This contrasts with Steinhauer et al. who found a biphasic N400/P600 response in a similar comparison in German. The fact that we only find an N400 effect (without a P600) suggests that here, the PB is such a strong cue for a certain syntactic parse, that - in case of a mismatch - the disambiguating verb is picked up as a semantic anomaly, without triggering a revision of the incorrect syntactic analysis. Comparing the sentences without a PB at the disambiguation point, a LAN-like effect for the mismatch condition (4) was found, but only in the first half of the experiment. This suggests that listeners can use the absence of a PB in a strategic way while this appears to be impossible for the presence of a PB.

Overall the results suggest that the CPS is a reliable indicator of a PB. At the disambiguation point, the results of the two experiments are quite different. Both experiments show that prosody can influence the decision to analyze the sentence in a certain way, at least initially. Furthermore, the differences between the results of the two experiments make clear that the nature of processing difficulty in late closure sentences depends on the precise nature of the structures themselves.

Keywords: ERP, prosody, syntax

Introduction

When you process a sentence, you make use of a number of different factors. First, the meaning of the words and the syntactic structure these words are embedded in, determine how you process a sentence. For written sentences in isolation, this seems to be most of the story. However, when one encounters a sentence, this is normally embedded in a context or a discourse, which could also have an influence on the processing of this single sentence. On top of that, the type of communication that human beings are most concerned with is spoken communication. There is a unique quality to spoken sentences, compared to written ones, which is prosody. According to Cutler and Ladd (1983) prosody can be defined as "those phenomena that involve the acoustic parameters of pitch, duration and intensity" (p. 1). Prosody thus covers intonation, stress, phrasing and the precise timing of words in a sentence. These could all give very important cues as to how a sentence has to be interpreted. Unfortunately, only little attention has been paid to this aspect of sentence comprehension in the literature. In this study we will look at the effects of prosody on spoken sentence processing and we will do so using event related brain potentials (ERPs), which give an on-line measure of these effects.

Syntax first

To study sentence processing, locally ambiguous sentences are often used. Sentence (1) gives an example of a locally ambiguous sentence (Ferreira & Clifton, 1986).

1. The man played the tape and liked it/liked it.

Up until the word tape, this sentence can be interpreted as if the man has been playing a tape, or as if the tape has been played to the man by someone else. Only the last (underlined) part of the sentence disambiguates it to one of the two readings. Traditionally, research on sentence processing has focused on written sentences in isolation. In self-paced reading studies and eye tracking studies the reading times of parts of sentences are measured. It turns out that one type of disambiguation is mostly the "preferred" one. In example sentence (1) this is the first possibility (*and liked it*). This sentence poses no difficulties and participants read the sentence fast. The other type of sentence, however, leads one to slow down reading on the disambiguating words and, in eye tracking studies, to go back to earlier parts of the sentence to reanalyze them. Which is the preferred interpretation, mostly seems to depend on the syntactic structure of a sentence. On the basis of this and related research, syntax first theories of sentence processing were developed, which state that the syntactic structure of a sentence is the first thing that is processed; in first instance, one determines how to parse a sentence purely on the basis of syntax (for a review see Townsend & Bever, 2001). According to one of the syntax first theories, the Garden Path Theory (Frazier & Fodor, 1978; Frazier & Rayner, 1982), there are two important principles to help one decide on the initial parsing of a sentence. The first, the principle of *Minimal Attachment*, states that one, at first, always tries to parse a sentence in such a way that the minimal amount of nodes is used in a syntactic tree. In example sentence (1), the first possible ending (*and liked it*) is the one which needs the least amount of nodes (see Figure 1A and B, adapted from Ferreira & Clifton, 1986). According to the Garden Path Theory this interpretation is thus always pursued at first reading, regardless of any other cues one might have. If the continuation of the sentence after *tape* does not agree with this interpretation, a reanalysis is performed. This is costly and it is reflected in longer reading times in the disambiguating region of the sentence, and possibly in going back to earlier parts of the sentence.

The second garden path principle is that of *late closure*. This principle leads one to close the current syntactic clause as late as possible. One always first tries to extend the current clause to embrace new constituents one encounters. In (2) an example of such a sentence is given (Frazier & Rayner, 1982).

2. Since Ray always jogs a mile this seems / seems like a short distance to him.

The NP *a mile* can either be the object of the verb *jog* or the subject of the verb *seems*. In the first case, the constituent *a mile* is taken to belong to the current clause, which coincides with the principle of late closure.

According to the Garden Path Theory, one uses these two strategies to initially parse a sentence. If this parse turns out to be contradicted later on in the sentence, one is *led down the garden path* and has to reanalyze the sentence. This takes time and results in longer reading times for non-minimal attachment and early closure sentences. Several self-paced reading and eye tracking studies show that reading times are longer in the disambiguating region of an ambiguous sentence, compared to a similar unambiguous sentence. However, most studies find that this is only the case in non-minimal attachment and early closure sentences, and not in minimal attachment and late closure sentences. (e.g., Ferreira & Clifton, 1986; Tanenhaus & Trueswell, 1995).

thematic fit condition. However, in the poor thematic fit condition, there was no difference in reading times between ambiguous and unambiguous S-coordination sentences. This result shows that a semantic factor, thematic fit, had prevented the garden path effect in early closure sentences. Thematic fit, in the form of, for example, animacy or the frequency of verb

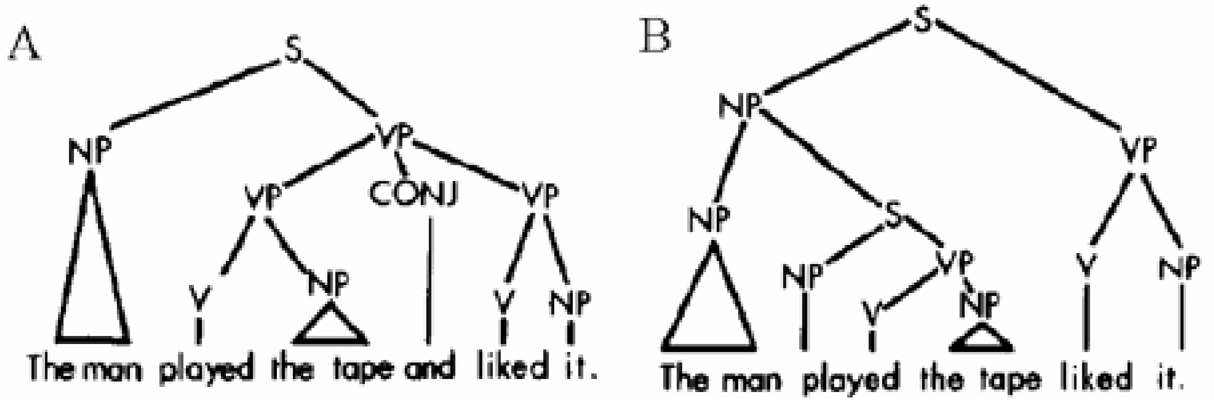

Figure 1. Syntactic trees for two different readings of a minimal attachment locally ambiguous sentence. The structure in Figure 1A has fewer nodes than the structure in 1B and is thus preferred according to the principle of minimal attachment (adapted from Ferreira & Clifton, 1986).

Challenges to syntax first

Although early studies seemed to support syntax first theories, later research challenged these theories. For example, Hoeks (1999) studied sentences that contain an NP/S-coordination ambiguity like (3), in the visual modality.

3. The thief shot the jeweler and the cop <u>this morning/followed the car</u>.

These sentences are locally ambiguous up until the third NP. This NP (*the cop*) can either be coordinated with the second NP (*the jeweler*), in which case it belongs to the current clause, or the third NP can be taken to start a new sentence. Hoeks used self-paced reading and eye tracking. First, he found longer reading times for ambiguous S-coordination sentences than for unambiguous ones (with a comma between *jeweler* and *and*, which clearly signals an S-coordination). This fits with the principle of late closure, because in S-coordination, the clause is closed before *and*. Thus, this is the early closure reading. Second, he manipulated a semantic factor, thematic fit. Some sentences were semantically compatible with both interpretations, like the example above. He introduced other sentences, however, that have a poor thematic fit if they are analyzed as NP-coordination sentences, like (4).

4. Jasper sands the board and the carpenter scrapes the paint from the doors.

In the eye tracking study, he again found longer reading times for the ambiguous than the unambiguous S-coordination sentences in the good subcategorization frames, has also been investigated in experiments with main clause/reduced relative clause ambiguities (e.g. Trueswell, Tanenhaus & Garnsey, 1994; Trueswell, Tanenhaus & Kello, 1993; McRae, Spivey-Knowlton, Tanenhaus, 1998). These studies show that there are immediate effects of these semantic factors on parsing preferences. Also a study with an object/subject relative clause ambiguity in Dutch shows that animacy can influence the initial syntactic preference (Mak, Vonk & Schriefers, 2002). Apparently syntax is not the only factor that plays a role in initial processing; semantic factors can have an influence, too.

Hoeks, Vonk and Schriefers (2002) showed, again with an NP/S-coordination ambiguity, that a discourse factor, topic structure, can also change parsing-preferences. In neutral contexts or in isolation, NP-coordination is the preferred interpretation, but when a context or question with two topics is introduced, the two-topic S-coordination structure is preferred. The influence of referential context on parsing preference was also shown in main clause/reduced relative clause ambiguities (Spivey-Knowlton, Trueswell & Tanenhaus, 1993), and in some other ambiguities (e.g. Altmann & Steedman, 1988).

As these studies show, syntactic factors are apparently not the only ones to have an influence on the initial parsing of a sentence. In line with this evidence, interactive theories argue for an interaction of different kinds of factors that together determine the initial parsing of a sentence. One type of interactive theories are constraint-based theories (for a review see Townsend & Bever, 2001) which state that there is competition between the different syntactic alternatives. Which of them is chosen depends on the evidence for each of the alternatives. This evidence can come from different sources such as syntax, semantics and discourse.

The experiments described so far are all reading studies. In fact, in the field of sentence comprehension, the majority of experiments is done in the visual modality. There are two main reasons for this. First, in this modality established methods are available that are used to tap on-line processes during reading, like self-paced reading and eye tracking. In the auditory modality good, on-line measures are much more difficult to find. Second, reading experiments are easy to control. In the auditory domain a new factor, prosody, comes into play that has to be carefully controlled when one wants to set up good research. However, prosody does not necessarily have to be viewed as a factor that has to be controlled, but it is also an interesting factor in its own right. In speech, sentences are naturally produced with a certain prosody. Now that we know that syntactic factors are not the only ones that are immediately used in understanding a sentence, the question arises whether listeners also use variations in prosody for that purpose. In the following paragraphs studies that addressed this question will be described.

Effects of prosody: off-line studies

The effect of prosody on syntactic parsing is difficult to study, because there is no one-to-one relationship between these two. Some prosodic cues correlate with certain syntactic groupings and parses, but the relation is not absolute. The first studies on the effect of prosody were done with normal sentences. Later on, also globally and locally ambiguous sentences came to be used in this domain of research.

Very early studies on the effects of prosody on sentence processing used a task in which a sentence is presented and somewhere in the sentence either a click occurs or the signal is switched from one ear to the other. Participants have to judge when in the sentence the click or switch occurs. The results indicated that it tends to migrate towards a syntactic boundary, to preserve the integrity of the units of the sentence. When prosodic and syntactic breaks do not match, the clicks migrate either towards the syntactic break (e.g. Garret, Bever & Fodor, 1965) or not towards any of the breaks (Wingfield & Klein, 1971). However, Geers (1978) showed that clicks do migrate to prosodic boundaries when these boundaries are placed at major or minor syntactic boundaries. This seems to imply that prosody can support, but does not guide the grouping of words.

Grosjean (1983) investigated if listeners can predict from the prosody of a sentence when that sentence will end. He presented participants with sentences that contained 0, 1, 2 or 3 prepositional phrases at the end. The participants heard the sentence up to the point just before the first prepositional phrase. Participants reliably predicted if zero, one or more than one prepositional phrase would come after the presented end of the sentence.

Studies on globally ambiguous sentences found that these can often, but not always, be disambiguated by prosody. This depends, for example, on the awareness of the speaker of the multiple possibilities of interpreting a sentence. Duration and pitch seem to be the most reliable cues, in comparison with amplitude, which is less important (e.g. Streeter, 1978). Schafer (1995) found that the place of a prosodic boundary can determine which interpretation participants report to have computed of a globally ambiguous sentence. In sentences like (5), participants attach the PP (*from Alabama*) to the verb when there is a late prosodic boundary (between *friend* and *from*) or no boundary at all and they attach it to the NP when the boundary is early (between *phoned* and *her*).

5. Paula phoned her friend from Alabama.

Another study (Schafer, Carter, Clifton & Frazier, 1996), that used an off-line question task, showed that pitch accents can also disambiguate globally ambiguous sentences. When a relative clause can belong to two noun phrases, the noun phrase that is accented attracts the relative clause. In sentence (6), the relative clause *that the mechanic was so carefully examining*, can refer back to *the plane* or to *the propeller* (*of the plane*). In the experiment participants were asked what the mechanic was examining. If *the propeller* had a pitch accent, participants reported that the mechanic was examining the propeller, but when the accent was on *the plane*, they answered that he was examining the plane.

6. The sun sparkled on the propeller of the plane that the mechanic was so carefully examining.

It is interesting to know if prosody can disambiguate globally ambiguous sentences, but these are presumably not encountered very often in everyday communication. It is likely, that we come across locally ambiguous sentences much more frequently (Cutler, Dahan & van Donselaar, 1997; p. 164). These sentences can have different interpretations up to a certain point, at which they are disambiguated. The critical question is whether prosody can disambiguate such a sentence before the disambiguating lexical element is encountered. Beach (1991) used synthesized speech materials with an object/complement ambiguity such as sentence (7).

7. Mary suspected her boyfriend immediately/ was lying.

The sentences differed in the length of the ambiguous part, which is the part that is not underlined. Participants heard the ambiguous part of the sentence and had to indicate in which of two ways they expected it to end. The prosody of the sentences was constructed in such a way that it favored one or the other reading by means of differences in syllable length and pitch contour, precisely controlled by the experimenter. Beach found an effect of prosody on the judgments in the expected direction and concluded that prosody is used already early in a sentence. No effect of sentence length was found. However, although the materials of Beach were controlled very well, synthesized stimuli are not very natural. Stirling and Wales (1996) therefore replicated Beach's study with natural speech. They found only an effect of prosody for short sentences, but not for longer sentences.

In summary, these off-line studies show that prosody can support the grouping of words into syntactic constituents, can help listeners predict the length of a sentence and can help to disambiguate a globally ambiguous sentence. Moreover, there is some evidence that listeners can use prosody already early in a sentence to help them predict what is coming. Apparently, listeners are able to use prosody in sentence processing, at least under certain circumstances.

Off-line methods have been the first step in investigating effects of prosody on parsing. A drawback of these studies, however, is that a conscious decision is measured that does not necessarily reflect 'normal' on-line sentence processing. It is much more interesting to investigate the automatic processes that occur immediately as one listens to a sentence. Other types of methods are necessary for those purposes.

Effects of prosody: on-line studies

One of the first studies on prosody and sentence parsing using an on-line method (Marslen-Wilson, Tyler, Warren, Grenier, Lee, 1992) used sentences with a minimal/non-minimal attachment ambiguity as in sentence (8).

8. The workers considered the last offer from the management of the factory/was a real insult.

In earlier research it was established that the default-reading is the Minimal Attachment (MA) structure, *of the factory*. The task was cross-modal naming. In this task participants hear the ambiguous part of the sentence and immediately afterwards, they see a visual target word on a screen that they have to name as quickly as possible. In this study, the target word was compatible with the Non-Minimal Attachment (NMA) reading (*was*). After this, participants had to judge whether this word was a good continuation of the sentence. Marslen-Wilson et al. found that naming of the target was faster after sentences with NMA prosody than with MA prosody. The prosody manipulation was as effective as the complementizer *that* in disambiguating the sentence. In the judgment task at the end, however, the MA prosody sentences were rated as acceptable as the NMA prosody sentences, and more acceptable than sentences with a syntactic violation. Apparently the off-line judgments gave a different outcome than the on-line task. This study seems to indicate strongly that prosody influences parsing decisions on-line. However, the precise prosody manipulation was not specified in this study and only a partial design was used. Furthermore, only a condition with target words that matched the NMA continuation was present, but no condition with targets words that matched the MA continuation. Warren, Grabe and Nolan (1995) used the same design and task as the previous study, but with an early versus late closure ambiguity, like sentence (9).

9. Whenever Parliament discusses Hong Kong problems….

The prosody was well defined in this study and consisted of differences in stress-patterns. In early closure sentences, an early prosodic boundary, after *Hong Kong*, was realized by a normal stress pattern on *Hong Kong* (stress on *Kong*). In late closure sentence, a late prosodic boundary, after *problems*, was realized by a stress-shift on *Hong Kong* (stress on *Hong*). The target word was always compatible with the early closure reading of the sentence (*arise* in the case of sentence (9)). The target word was read faster after sentences with early closure prosody than after sentences with late closure prosody. This study thus extends the results of Marslen-Wilson et al. (1992) to another type of ambiguity. However, also this study used only a partial design.

Watt and Murray (1996) addressed this shortcoming and tried to replicate the study of Marslen-Wilson et al. (1992) with a full design. Moreover, they left out the appropriateness judgment task at the end, because they hypothesized that it would promote metalinguistic processes. They replicated the result of Marslen-Wilson; they also found a faster naming of the NMA target word in the sentences with NMA prosody than with MA prosody. However, in the full design, the effects of prosody were not significant. When they used a cross-modal lexical decision task, instead of cross-modal naming, they found the same results. They concluded that prosody can not influence syntactic interpretation on-line. However, in this study the prosody of the sentences was not specified at all, so it cannot be compared to the prosody used in Marslen-Wilson et al. (1992) or in any other study. Effects of prosody were found in an off-line, appropriateness-rating task in the study by Watt and Murray (1996). Apparently, the participants did detect differences in prosody between the conditions, but these differences might not have been strong enough to influence on-line processes.

A study by Kjelgaard and Speer (1999), that used early versus late closure ambiguities, seems to have overcome most of the methodological problems of the studies discussed before. They used a full design and on- as well as off-line methods. Moreover, they used baseline conditions to be able to show interference as well as facilitation effects. The stimulus materials were early versus late closure ambiguities like sentence (10).

10. When Roger leaves the house is/it's dark.

There were three versions of each sentence: a baseline condition without prosodic boundaries, a cooperating condition with an appropriate prosodic boundary (after *leaves* in early closure and after *house* in late closure sentences) and a conflicting condition with an inappropriate prosodic boundary. Two different off-line tasks were used. In the first task participants had to indicate as fast as possible if the speaker had intended the sentence in this way, and in the second task they had to press a button as soon as they understood the sentence. The on-line task was a cross-modal naming task in which participants first had to name a visually presented target word which disambiguated the sentence (*is* or *it's*) and then had to complete the sentence. In the last experiment, this on-line task was used again, but the sentences were produced with less strong prosody. In all experiments the results were approximately the same. A facilitation effect for the appropriate prosody relative to the baseline condition was only present for the early closure sentences. An interference effect for the wrong prosody relative to baseline was found in both types of sentences. Moreover, the preference for late closure sentences was overcome by the appropriate prosody. These results provide corroborative evidence that prosody does influence the on-line parsing of a sentence.

Most studies described so far, that used on-line techniques, found that prosody has on-line effects on sentence parsing. Differences in the results probably have to do with different realizations of the prosody used in the studies. There is no one-to-one relation between prosody and syntax, so that there might be aspects of prosody that do not have effects on parsing, while others will. Therefore, it would be good if a specification of the used prosody (e.g. pause, pitch and length differences etc.) is provided in every study, so that it is easier to compare studies. Although these on-line studies can say more about immediate influences of prosody on parsing decisions, there are some serious disadvantages to the on-line methods used in the studies discussed thus far. First, sentences are often only presented partially. Second, the tasks are often very complex, unnatural and involve different modalities. Kjelgaard and Speer (1999) used on- and off-line methods to profit from the advantages of both. However, there is one disadvantage that the two types of methods share. They do not provide a profile of processing load across the whole sentence. These problems can be overcome, however, by the use of Event-Related Potentials.

ERP and language

The use of ERPs has many advantages in the study of spoken sentence comprehension, as compared to other methods. It measures on-line, immediate processing while presenting complete sentences to which the participants only have to listen. There is no need for an additional task that might distract participants or promote metalinguistic processes. In most ERP studies only a comprehension task is used in some percentage of the trials, to make sure participants are paying attention to the sentences and are trying to understand them. Moreover, ERPs make it possible to measure everywhere in a sentence. Different ERP-components have been found in the study of sentence processing. Two distinct components have been related to syntactic processing, the LAN and the P600. The N400 is primarily a reflection of semantic processing, and the CPS is a component that specifically has to do with prosody. A short description of these components is given below.

The N400 is a negative wave that peaks at around 400 milliseconds. The general view on this component is that it reflects how easy a word can be integrated into its context. It has been proposed that it is related to the degree a specific word is expected at that point (Kutas & Hillyard, 1984). Words that are expected are already activated to some extent and therefore elicit a smaller N400. Another view suggests that the N400 reflects lexical search costs, which appear when a word is looked up in the mental lexicon (Steinhauer, Alter & Friederici, 1999).

LAN stands for Left Anterior Negativity. This is a negative potential that is often found with a left anterior maximum. Its topography, however, differs between studies. The LAN is typically elicited when a word renders a sentence syntactically incorrect. It has been found in response to different syntactic violations and its timing differs as a function thereof. Phrase structure violations, such as word category errors, elicit an early LAN, about 100 to 300 ms after stimulus onset. For morphosyntactic violations, such as subject-verb agreement errors, a later LAN is found, around 300 to 500 milliseconds. The general view on the LAN is that it could either be a purely syntactic component (Friederici, 2002) or reflect working-memory load (Kluender & Kutas, 1993).

The P600 is a positive potential that typically extends from 500 to 800 milliseconds. It is found in response to different kinds of syntactic violations, and usually has a posterior scalp distribution. Locally ambiguous sentences also elicit P600 effects. For example, Osterhout, Holcomb and Swinney (1994) found an increase in P600 amplitude at the disambiguating word of non-minimal attachment sentences as opposed to minimal attachment sentences. For locally ambiguous sentences, the distribution of the P600 is more anterior or broader than for syntactic violations (e.g. Osterhout & Holcomb, 1992). It is generally agreed that the P600 reflects revision and repair processes.

The Closure Positive Shift (CPS) is an ERP-component that was discovered fairly recently. It is a positive shift in response to a prosodic break in a sentence (Steinhauer, Alter & Friederici, 1999) and occurs when an intonational phrase is closed. The CPS can not be explained by the occurrence of a pause in the signal, because even when the pause is taken out, the other cues of a prosodic break are enough to elicit the CPS (Steinhauer et al., 1999).

Traditionally, it has been thought that the LAN reflects early automatic syntactic processes. The P600 reflects later syntactic revision that is needed when something went wrong in the first syntactic stage. Support for this view comes from the finding that the P600 (and also the N400) are affected by changes in the proportion of anomalous sentences in an experiment and by task instructions, while the LAN is not (Hahne & Friederici, 1999). This suggests that the LAN is an automatic process and the other two components are much more controlled. Hagoort (2003), however, argued that if the P600 really reflects repair processes, it should appear later in the signal or be larger if the syntactic violation is stronger (when it is not immediately clear how it should be repaired). He found that in fact the opposite was the case; strong violations resulted in an earlier P600.

Recently, there have been some challenges to the view that the P600 is a purely syntactic component. A few studies (van Herten, Kolk & Chwilla, 2005; Kolk, Chwilla, van Herten & Oor, 2003; Kim & Osterhout, 2004) have found a P600 in response to semantic violations, more specifically, semantic reversal anomalies, as in sentence (11) (Kim & Osterhout, 2004).

11. The meal was devouring…

According to Kim and Osterhout (2004) the occurrence of a P600 at the word *devouring* shows that semantics is in control over syntax here. If the semantic cues to what the sentence would mean are strong enough, these cues will guide processing. When syntactic information is then encountered that does not match with this semantic interpretation (in this case, an active *devouring* instead of a passive *devoured*), a P600 is elicited. This is yet another indication that syntax first theories may be wrong. Van Herten, Kolk and Chwilla (2005), however, argue that there is no possible way to explain these data syntactically. They show that in sentences like (12) a P600 appears in response to the verb *joeg* (with the literal translation from Dutch).

12. De vos die op de stroper joeg…

The fox that on the poacher hunted (singular)…

In this sentence, the verb has the same form independent of which of the two NPs is analyzed as the subject. There is thus no syntactic violation in this sentence, even if one initially assumes that *the poacher* is the subject of the sentence. Their alternative account is that one computes both a plausibility heuristic, based on the semantics, and a syntactic parse in parallel. If these two clash, a P600 appears, which reflects checking of the parse to see where the mistake was made.

ERP and prosody

Steinhauer et al. (1999) conducted an ERP study on the role of prosody in locally ambiguous sentences like (13) and (14):

13. Peter verspricht Anna zu arbeiten…

Peter promises Anna to work…

14. Peter verspricht Anna zu entlasten…

Peter promises to support Anna…

Note that in sentence (14) the word order is reversed in German as compared to English. Therefore, the two different structures in (13) and (14) are exactly the same up to the second verb and can only be disambiguated by this verb. According to the late closure principle of the Garden Path Theory, *Anna* should initially be considered as the indirect object of the first verb *verspricht*. Whether this initial analysis is correct or not becomes clear at the second verb (*arbeiten* or *entlasten*). If this verb is intransitive (*arbeiten*), Anna can not be the object of this verb, so it has to be the object of the first verb (*verspricht*), which means that the initial analysis is correct. However, if the second verb turns out to be obligatory transitive (*entlasten*), Anna has to be analyzed as the direct object of this verb, else the sentence is ungrammatical. In that case, the initial analysis in which Anna was the object of *verspricht* must be incorrect, which presumably will lead to a garden path effect. However, an earlier disambiguation is possible, by a prosodic break. This consists of a pause, prefinal lengthening of the last syllable before the pause and a pitch rise on that syllable. A prosodic break after *verspricht* provides a boundary between *verspricht* and *Anna*, which is likely to prevent *Anna* from being considered as the object of *verspricht*. If this is so, the prosodic break disambiguates the sentence to the early closure interpretation (as in (14)) and an intransitive verb as *arbeiten* (in 13) should cause a garden path effect.

Steinhauer et al. found a combined N400/P600 effect on the disambiguating verb *arbeiten* relative to the verb *entlasten* in sentences like (13) and (14) with a prosodic break after *verspricht*. Thus, they showed that prosody can induce a reversed garden path effect. Moreover, they discovered a new ERP component, the CPS. In the ERP signal to sentences with a prosodic break a positive shift was present at the position of the prosodic break, whereas this was not the case for sentences without a prosodic break. To rule out that the CPS was only a response to the pause, the authors also removed the pause but left the other cues of a prosodic break (prefinal lengthening and pitch rise) intact. They again found a CPS. Whereas this study was the first to investigate the role of prosody with ERPs, a drawback is that only a partial design was used. That is, the authors only used the sentences like (13) and (14) with a prosodic break, and a version of sentence (14) without a prosodic break, but they did not use a version of sentence (13) without a prosodic break.

Later experiments tested the precise antecedent conditions of the CPS (Pannekamp, Toepel, Alter, Hahne & Friederici, 2005). It was found that the CPS is elicited by a prosodic break in normal sentences, in jabberwocky sentences with pseudo content words but the right function words and inflectional endings, in pseudosentences with only pseudowords and in hummed sentences without any lexical or phonological information. This study thus indicates that the CPS is a purely prosodic component.

Another recent study by Isel, Alter and Friederici (2005) investigated the predictive role of prosody. As stimuli, verbs with a separable particle, like *an-lächeln* (to smile at) and verbs without a particle, like *nennen* (to call), were used. Two of the relevant conditions were sentences in which *nennen* was used with the particle *an* at the end of the sentence, which yields an ungrammatical sentence, see (15). In one condition the prosodic contour of the verb stem (*nannte*) indicated an upcoming particle, mostly by putting more stress on this word and in the other condition this was not the case. These sentences were compared to a grammatical sentence with the verb *an-lächeln* with the right prosody as in sentence (16).

15. Sie nannte den Namen an…
She called at the names…
16. Sie lächelte den Arbeiter an…
She smiled at the worker…

An N400 was found in the first comparison, but not in the second. According to the authors this indicates that listeners try to integrate the particle in the sentence if they expect it will come. If not, they just ignore it. Furthermore, the prosody makes clear that the sentence will end after the particle, by an intonational phrase boundary. Therefore, the particle can not belong to any other word category and that is why no P600 was found, according to Isel, Alter & Friederici (2005).

Two recent ERP-studies by Kerkhofs et al. (submitted-a, submitted-b) also investigated the role of prosody in parsing. In these experiments sentences were used that contained a coordination ambiguity, like sentences (17) and (18).

17. The model kissed the designer and the photographer on the cheek.
18. The model kissed the designer and the photographer merrily took a bottle of Champaign.

Sentence (17) contains an NP-coordination. *The photographer* and *the designer* form a complex object NP. Sentence (18) contains an S-coordination in which *the photographer* is the beginning of a new sentence. In previous experiments in the visual domain (Hoeks, 1999) processing difficulty was found in S-coordination sentences. Kerkhofs, Vonk, Schriefers and Chwilla (submitted-a) hypothesized that a prosodic break after *designer* can disambiguate a sentence like (18) to an S-coordination sentence. The critical comparison concerned S-coordination sentences with and without a prosodic break. A CPS was found at the prosodic break. At the disambiguating verb (e.g. *took* in (18)) processing difficulty was found for sentences without a prosodic break relative to sentences with a prosodic break. This processing difficulty, however, was realized differently in the first and the second half of the experiment. In the first half it took the form of a LAN effect and in the second half, of a P600 effect. The authors explained this in the following way. In the first half of the experiment, the absence of a prosodic break may have been used as a cue signaling that the sentence will end as an NP-coordination. In the experimental sentences without prosodic break, this leads to a double violation: a violation of the default preference for an NP-coordination and a violation of the indication of an NP-coordination by the absence of a prosodic break. This strong violation may have caused the LAN effect. In the course of the experiment, however, listeners encountered sentences without a prosodic break that turned out to be S-coordination sentences, and thus may have learned not to expect an NP-coordination on the basis of the absence of a prosodic break. Now there was only one violation left which resulted in a P600.

In the experiments on prosody described so far the effect of prosody was always measured at the end of the sentence or a few words downstream, where the disambiguation took place. In those cases, the participants have some time to process the prosody before the eventual syntactic structure of the sentence becomes clear and the effect of prosody can be measured. In contrast, another experiment by Kerkhofs, Schriefers, Vonk and Chwilla (submitted-b) looked at the immediate interaction between syntax and prosody, right at the prosodic break. They used the same type of stimuli as Kerkhofs et al. (submitted-a), locally ambiguous NP/S-coordination sentences. However, these target sentences were preceded by two different kinds of context. In the two-topic context, two topics were introduced, for example a model and a photographer in the case of sentence (18). In such a context, as Hoeks, Vonk and Schriefers (2002) had already shown, listeners expect an S-coordination, because they assume that something will be said about both topics. In a neutral context, by contrast, they will expect NP-coordination, because that is the default, late closure analysis. This means that after a two-topic context, listeners expect a syntactic break before *and*, whereas in a neutral context, this syntactic break is not expected. Kerkhofs et al. (submitted-b) first replicated the finding of a CPS at the prosodic break. However, this CPS was larger in the condition with the neutral context, that is, where no syntactic break was expected, than in the two-topic context, where a syntactic break was expected. This means that the ERP signal to the exact same acoustic sentence is different when there is a different discourse context that precedes this sentence. A syntactic expectation is elicited by the context and this expectation interacts with the prosody of the sentence. This interaction takes place immediately at the prosodic break, thus at the moment when the prosodic information becomes available.

The present study

In this study the main question is whether prosody can affect sentence parsing in spoken sentence comprehension. Two ERP-experiments are done simultaneously that both address this question, but with different syntactic structures. In this last part of the introduction, we will give a preview of these experiments and present our hypotheses.

Experiment 1

Experiment 1 consists of a replication of the auditory study of Kerkhofs (submitted-a), but with a fully crossed design. The same stimulus materials are used as in that study. See sentences (19) to (22) for example sentences of the four conditions, in which square brackets indicate prosodic boundaries.

19. [Het model kuste de ontwerper en de fotograaf op het feestje.]

[The model kissed the designer and the photographer on the party].

20. [Het model kuste de ontwerper] [en de fotograaf op het feestje.]

[The model kissed the designer] [and the photographer on the party].

21. [Het model kuste de ontwerper en de fotograaf opende een fles champagne.]

[The model kissed the designer and the photographer opened a bottle of champagne.]

22. [Het model kuste de ontwerper] [en de fotograaf opende een fles champagne.]

[The model kissed the designer] [and the photographer opened a bottle of champagne.]

These sentences are played to the participants while their EEG is recorded. ERPs to sentences (19) and (20) are compared, as well as ERPs to sentences (21) and (22). There are two critical points in the sentence. The first critical point is the place of the presence or absence of the prosodic break, which is after the second NP (in this case *de ontwerper*). The second critical point is the lexical disambiguation, which is the PP in NP-coordination sentences (in this case *op het feestje*) or the second verb in S-coordination sentences (in this case *opende*).

At the first critical point (prosodic break present or absent) a CPS is expected in both comparisons. The CPS is expected to appear at the sentences with a prosodic break as compared to those without a prosodic break.

At the disambiguation point, our hypotheses are as follows. In the comparison between sentences (21) and (22), we expect processing difficulty in sentence (21). Hoeks (1999) has shown that S-coordination sentences lead to processing difficulty as compared to NP-coordination sentences. However, in sentence (22), the prosodic break gives a strong cue that an S-coordination ending is coming. We expect this cue to be strong enough to erase the processing difficulty in (22), while we should still observe signs of processing difficulty in (21). However, in what form the processing difficulty in sentence (21) will appear is not clear. It is possible that, in accordance with Kerkhofs et al. (submitted-a), a LAN will appear in the beginning of the experiment and a P600 in the end. However, in the present experiment, there are relatively more S-coordination sentences without a prosodic break than in Kerkhofs' experiment. This might lead to an earlier abandoning of the absence of a prosodic break as a cue by the participants. In that case, the LAN will change into a P600 earlier or a P600 will be found throughout the experiment.

The comparison between sentences (19) and (20) has not yet been tested by Kerkhofs et al. (submitted-a). Because of the results of Steinhauer et al (1999), however, we can expect that sentence (20), which has an inappropriate prosody, will lead to a reversed garden-path effect. Therefore, we expect processing difficulty in the form of a P600 for (20) as compared to (19) at the disambiguating PP. This hypothesis is based on the assumption that the prosodic break is a reliable cue that signals S-coordination. However, because sentences with a prosodic break that end as an NP-coordination also occur in this experiment, participants may learn that a prosodic break is not a fully reliable cue for an S-coordination. Therefore, they may come to rely less on this cue and the P600 may disappear gradually in the course of the experiment.

Thus, with this experiment we aim at replicating the reversed garden path effect that Steinhauer et al. (1999) found, however here with another type of ambiguity. Furthermore, we can test whether the prosodic break is a reliable cue that does not lose its function in the light of negative experience. Finally, with this experiment we are able to test the hypothesis of Kerkhofs et al. (submitted-a) that the absence of a prosodic break is used as a cue and that this can change with experience.

Experiment 2

Experiment 2 consists of a replication of the study of Steinhauer et al. (1999), but with a full design. The same sentence type is used, but the stimulus materials are in Dutch. See sentences (23) to (26) for examples of the four conditions in the experiment.

23. [De verpleegster hielp de zieke te lopen] [omdat hij na de behandeling nog te zwak was.]

[The nurse helped the patient to walk] [because he was still too weak after the treatment.]

24. [De verpleegster hielp] [de zieke te lopen] [omdat hij na de behandeling nog te zwak was.]

[The nurse helped] [the patient to walk] [because he was still too weak after the treatment.]

25. [De verpleegster hielp de zieke te vervoeren] [omdat hij na de behandeling nog te zwak was.]

[The nurse helped to transport the patient] [because he was still too weak after the treatment.]

26. [De verpleegster hielp] [de zieke te vervoeren] [omdat hij na de behandeling nog te zwak was.]

[The nurse helped] [to transport the patient] [because he was still too weak after the treatment.]

These sentences are played to the participants while their EEG is recorded. ERPs to sentences (23) and (24) are compared, as well as ERPs to sentences (25) and (26). There are two critical points in the sentence. The first critical point is the place of the presence or absence of the prosodic break per se, which is after the first verb (in this case *hielp*, helped). The second critical point is the lexical disambiguation, which is the second verb (in this case *lopen*, walk or *vervoeren*, transport).

At the first critical point (prosodic break present or absent) a CPS is expected for the sentences with a prosodic break, (24) and (26), as compared to the sentences without a prosodic break, (23) and (25).

The hypotheses at the disambiguation point are as follows. The expectations for the comparison of sentences (23) and (24) are mostly based on the findings of Steinhauer et al. In sentence (23) the default analysis according to the principle of late closure is followed. The prosodic break in (24), however, is expected to reverse this preference so that the second NP (*de zieke*, the patient) will in first instance be interpreted as the object of a second verb (*lopen*). Because *lopen* is an intransitive verb this will lead to ungrammaticality. It is thus expected that a reversed garden path effect will be found in sentence (24) in the form of a P600 and possibly an N400. However, it is possible that the strength of the prosodic break as a cue will diminish in the course of the experiment because numerous sentences with prosodic breaks are encountered that do not end in the expected way. In that case, the P600 (and N400) is expected to diminish over the experiment.

For the comparison between sentences (25) and (26), the general expectation is that (25) will lead to processing difficulties because the sentence will initially be analyzed according to the late closure principle and this analysis will turn out to be incorrect at the disambiguating verb. Another factor that could play a role here is the absence of the prosodic break. As argued in Kerkhofs et al. (submitted-a) it is possible that participants will use the absence of a prosodic break as a cue for a late closure analysis, which could lead to an extra processing difficulty. However, because many sentences without a prosodic break are encountered that eventually are disambiguated as early closure sentences, this cue might lose its strength in the course of the experiment. Processing difficulty should be absent in (26) because the prosody signals the right (early closure) interpretation of the sentence already before the disambiguating (transitive) verb is encountered.

Thus, with this experiment we aim at replicating the experiment of Steinhauer et al. with the same sentence type but in another language, namely Dutch, and, in contrast to Steinhauer et al., with a fully crossed design. Furthermore, we will investigate whether the prosodic break is a reliable cue that does not become weaker in the light of negative experience. Finally, this experiment provides another independent test of the hypothesis of Kerkhofs et al. (submitted-a) that the absence of a prosodic break can also be used as a cue and that the strength of this cue can change when sentences are encountered in which this cue does not lead to the right analysis.

Experiment 1

Experiment 1 addressed the question whether a prosodic break can affect syntactic parsing in spoken sentence processing by using NP/S-coordination sentences.

Methods

Participants

Thirty-six right-handed native speakers of Dutch, with no hearing problems, participated in the experiment. Of these, 28 were entered into the final analyses (5 male and 23 female), see the results-section. Their mean age was 21.7. The participants received 6 Euro per hour or course credit for their participation. They all gave written informed consent.

Materials

As a starting point, 60 NP-coordination and 60 S-coordination sentences were taken from an earlier experiment (Kerkhofs et al., submitted-b). These are hereafter referred to as the original NP- and S-coordination sentences. For the recordings, the following sentences were constructed. For each original NP-coordination sentence a corresponding S-coordination sentence was constructed which was exactly the same up to and including the third NP but which ended as an S-coordination. In the same way an NP-coordination sentence was constructed for each original S-coordination sentence. This procedure thus yielded 60 constructed NP-coordination sentences and 60 constructed S-coordination sentences. The first phoneme after the third NP was the same in the constructed and in the original sentence and both sentences were of about the same length. Examples of the original and constructed sentences are given in Table 1.

With this set of 60 original NP-, 60 constructed S-, 60 original S- and 60 constructed NP-coordination sentences a recording session was performed. The sentences were recorded by a female native speaker of Dutch. She was instructed to first read each sentence silently for herself and then read it out loud. For all sentences with a prosodic break, this was produced before *en* (and) in between the second and third NP.

The 60 original S-coordination sentences were

Table 1
Sentences that were used as the starting point for the recordings with their translations.

1	**Original S**	**De mannequin kuste de ontwerper en de fotograaf pakte vrolijk een fles bruisende champagne en wat kaviaar. The model kissed the designer and the photographer took merrily a bottle of bubbling champagne and some caviar.**
2	**Constructed NP**	**De mannequin kuste de ontwerper en de fotograaf pas nadat alle prijzen waren uitgereikt. The model kissed the designer and the photographer only after all the prizes had been awarded.**
3	**Original NP**	**De ridder bevrijdde de jonkvrouw en de dienares uit het donkere hol van de gevaarlijke draak. The knight freed the lady and the servant from the dark hole of the dangerous dragon.**
4	**Constructed S**	**De ridder bevrijdde de jonkvrouw en de dienares uitte haar dankbaarheid door voor hem te knielen. The knight freed the lady and the servant showed her gratitude by kneeling for him.**

recorded twice with a neutral intonation without a prosodic break and twice with a prosodic break. The corresponding constructed NP-coordination sentences were recorded twice without a prosodic break. From the two recordings of the same sentence, the best sentence was always chosen, according to the experimenter's intuition. The other sentence was discarded. From these materials, the experimental S-coordination sentences were constructed as follows. The chosen original S-coordination sentence with neutral intonation was used as a template sentence. The reason for choosing the neutral intonation was that no early cues for an upcoming prosodic break should be present in the template sentence. This sentence was duplicated. Second, from the original S-coordination sentence with prosodic break and the constructed NP-coordination sentence, the part of the sentence with or without the prosodic break, which consists of the second and third NP (*de ontwerper en de fotograaf*) was cut out. These two parts were both cross-spliced over the same part of one token of the duplicated template sentence. This was done for each item. This resulted in two times 60 experimental S-coordination sentences of the form of the original S-coordination sentences, 60 with and 60 without a prosodic break. See Table 2 for examples.

Each of the 60 original NP-coordination sentences was recorded three times without a prosodic break. The corresponding constructed S-coordination sentences were recorded twice with a prosodic break. From the three recorded NP-coordination sentences, one was chosen to serve as a template and one as 'no break condition'. The third was discarded. From the recorded constructed S-coordination sentences, one was chosen and the other one discarded. From these materials, the experimental NP-coordination sentences were constructed as follows. First, the template NP-coordination sentence was duplicated. Second, from the other NP-coordination sentence and the constructed S-coordination sentence, the part of the sentence with or without the prosodic break, which

Table 2
The experimental sentences. Intonational phrases are indicated with square brackets. Underlined words are the cross-spliced parts.

A	**NP Break**	**[De ridder bevrijdde de jonkvrouw] [en de dienares uit het donkere hol van de gevaarlijke draak.] [The knight freed the lady] [and the servant from the dark hole of the dangerous dragon.]**
B	**NP No Break**	**[De ridder bevrijdde de jonkvrouw en de dienares uit het donkere hol van de gevaarlijke draak.] [The knight freed the lady and the servant from the dark hole of the dangerous dragon.]**
C	**S No Break**	**[De mannequin kuste de ontwerper en de fotograaf pakte vrolijk een fles bruisende champagne en wat kaviaar.] [The model kissed the designer and the photographer took merrily a bottle of bubbling champagne and some caviar.]**
D	**S Break**	**[De mannequin kuste de ontwerper] [en de fotograaf pakte vrolijk een fles bruisende champagne en wat kaviaar.] [The model kissed the designer] [and the photographer took merrily a bottle of bubbling champagne and some caviar.]**

is the second and third NP (*de jonkvrouw en de dienares*) was cut out. These two parts were both cross-spliced over the same part of one token of the duplicated template sentence. This was done for each item. This resulted in two times 60 experimental NP-coordination sentences of the form of the original NP-coordination sentences: 60 with and 60 without a prosodic break. See Table 2 for examples. All experimental sentences of Experiment 1 are given in Appendix A.

Acoustic analyses of the experimental sentences showed that the sentences with and without a prosodic break clearly differed from each other. In the sentences with a prosodic break a pause between the second NP and *en* (and) was present, which lasted 312 milliseconds on average in the NP-coordination sentences and 326 milliseconds in the S-coordination sentences. This pause was absent in the sentences without a prosodic break. Moreover, the last stressed syllable before the break, which was the last stressed syllable of the second NP, had a boundary tone. This boundary tone consisted of pre-final lengthening of the syllable and a pitch rise. In the No Break condition these characteristics were absent. Instead, normal pitch accents occurred on the second and third NP of the sentence. We measured the length of the last word before the prosodic break (and the equivalent word in the sentences without a break), instead of the stressed syllable in this word, because the exact position of a syllable boundary is sometimes difficult to pinpoint. In the NP-coordination sentences, the last word before the prosodic break lasted on average 582 ms and the same word in the sentences without a break lasted on average 477 ms ($t(59) = 11.71$, $p < .001$). In the S-coordination sentences the last word before the break lasted 544 ms on average and the same word in the sentences without a break lasted 450 ms on average ($t(59) = 18.5$, $p < .01$). In Figure 2 the features of the two types of sentences are indicated in the speech signal for two example sentences. The prosodic structure of this sentence is transcribed using the ToDI system (Gussenhoven, 2004).

Design

The experiment consists of a fully crossed two factor design with the factors Prosodic Break (Prosodic Break/No Prosodic Break) and Structure (S-/NP-coordination). This resulted in four conditions. Four lists of experimental items were created and every list was heard by one fourth of the participants. One list contained half of the S- and NP-coordination sentences with a prosodic break and half without a break. A second list had the same order only the factor Prosodic Break was reversed. In this way the two lists together formed a full design. The other two lists were created by switching the halves of the first two lists, so that the same sentences did not always occur in the beginning or end of the experiment. In Table 3 the assignment of the conditions to the four lists is presented. The items occurred in a pseudorandom order, so that every condition had the same mean rank. This ensured an even distribution of the items of the different conditions over the experiment. The two halves of the lists followed the same constraints.

The 120 sentences in each list were combined

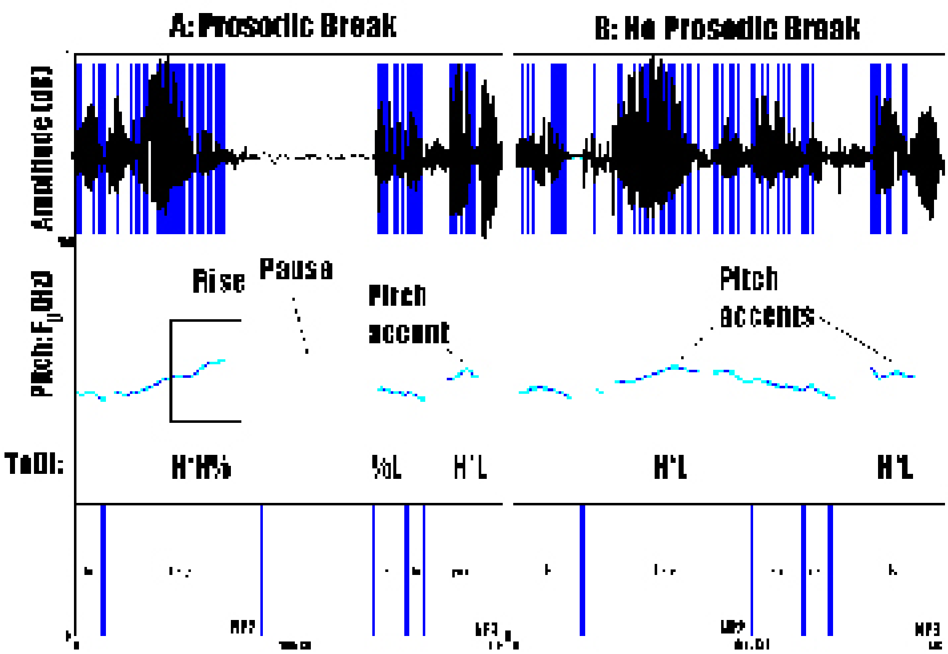

Figure 2. Acoustic analysis of the critical region of the sentences in Experiment 1.

with 192 sentences from another experiment (see Experiment 2) to a total of 312 sentences. For each list, a pseudorandom order of the experimental and filler sentences was determined with the restriction that there were never more than two experimental trials in a row. The 312 sentences were divided into 6 blocks of 52 sentences. At the beginning of each block, 2 starter sentences were added. One of those was of the structure used in the present experiment and one was of the same structure as the filler sentences.

Procedure

The participants were tested in a soundproof and dimly lit room and heard the sentences over headphones. A written instruction informed them about the course of the experiment. They were asked to listen carefully to the sentences and to try to imagine what they were about. A trial always started with a warning beep of 100 milliseconds. The sentence started 500 milliseconds after the offset of the warning beep. Participants were asked to look at a fixation point to avoid eye-movements and not to blink from the warning beep until the offset of a sentence. In between the offset of a sentence and the next warning beep 4000 ms of background noise were presented in which the participants could blink their eyes. Avoiding eye-movements and blinks was trained in a practice session of 20 sentences just before the experiment. Immediately after every block of 54 sentences, the participants were presented with two sentences on a piece of paper. They had to decide which of these they had heard in the previous block and which one not. The sentences were constructed such that both had the same structure as the items in the experiment but only one had really occurred in the previous block. This task was not very demanding and was given to ensure that the participants paid attention while listening to the sentences.

Apparatus

The EEG was recorded from 25 tin electrodes. The electrode positions were a subset of the international 10% system. Three midline electrodes (Fz, Cz, and Pz) and 22 lateral electrodes (AF7/8, F7/8, F3/4, FC3/4, T7/8, C3/4, CP5/6, P7/8, P3/4, and PO7/8) were used. This electrode montage has been used in earlier auditory ERP studies (Kerkhofs et al., submitted-a). Figure 3 shows the locations of the electrodes.

The left-mastoid was used as a reference during the recording, but the signal was re-referenced to software linked mastoids before the analysis. Eye blinks and eye movements were monitored by vertical EOG electrodes above and below the right eye and horizontal EOG electrodes beside the left and right eye. Electrode impedance was always below 5 kΩ for the EOG-electrodes and below 3 kΩ for all other electrodes. EEG and EOG signals were amplified with a time constant of 8 seconds and a bandpass filter of .05 to 100 Hz and digitized with a 16-bit A/D converter at a sampling frequency of 500 Hz.

Table 3
Assignment of the conditions to the four lists. S means S-coordination, NP means NP-coordination, b stands for Prosodic Break and nb for No Prosodic Break. The numbers 1 to 4 stand for the first, second, third and fourth 15 items of one condition.

half	List1	List2	List3	List4
1	**Sb1**	**Snb1**	**Sb2**	**Snb2**
	NPb1	**NPnb1**	**NPb2**	**NPnb2**
	Snb3	**Sb3**	**Snb4**	**Sb4**
	NPnb3	**NPb3**	**NPnb4**	**NPb4**
2	**Sb2**	**Snb2**	**Sb1**	**Snb1**
	NPb2	**NPnb2**	**NPb1**	**NPnb1**
	Snb4	**Sb4**	**Snb3**	**Sb3**
	NPnb4	**NPb4**	**NPnb3**	**NPb3**

Results

Data-analysis

The data were filtered with a low-pass filter of 30 Hz. All trials were time-locked to two different critical positions in the sentence. The first critical position (prosodic break) was the offset of the second NP (which was the onset of the prosodic break in the Prosodic Break conditions) and the second critical position (disambiguating word) was the onset of the disambiguating element (verb in the S-coordination sentences, PP in the NP-coordination sentences). A period of 150 ms before the critical position was used as a baseline. Trials with amplifier blocking, as well as excessive EEG (>100 μV) and EOG amplitude (>75 μV) in the period from 150 ms before until 1000 ms after the critical position, were excluded from the analysis. Of the 36 participants, 8 were excluded because of excessive artifacts, which left 28 participants to be entered in the analyses. In every condition a minimum of 75% of all trials (yielding a minimum number of 23 trials) remained for every participant.

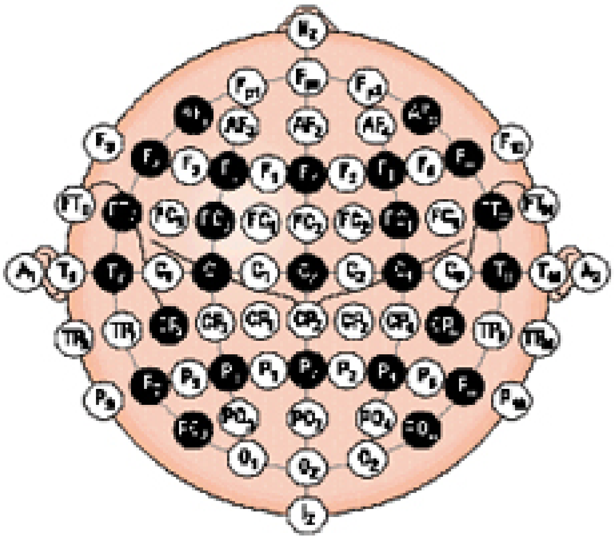

Figure 3. Electrode-montage used in the experiment. The black electrodes were used.

Two different types of analyses were performed on these preprocessed data. First, the following time windows were used to quantify the different ERP-components: a 300 to 700 ms window for the CPS, a 300 to 500 ms window for the N400 and a 600 to 800 ms window for the P600. A Midline MANOVA was performed for the midline electrodes with the factors Prosodic Break (Prosodic Break, No Prosodic Break) and Midline Electrode (Fz, Cz, Pz). A Lateral MANOVA was performed for the lateral electrodes. This analysis included the factors Prosodic Break (Prosodic Break, No Prosodic Break), Hemisphere (Left, Right), Region of Interest or ROI (Anterior, Posterior) and Electrode. The factors Hemisphere and ROI divided the electrodes into four quadrants with four electrodes each: Left Anterior (F3, AF7, F7, and FC3), Left Posterior (P3, CP5, P7, and PO7), Right Anterior (F4, AF8, F8, FC4) and Right Posterior (P4, CP6, P8, PO8). To test for possible changes over the course of the experiment, analyses were also performed including the factor Block (First, Second), in which the first block contained all the trials in the first half of the experiment, and the second block all those in the second half. Second, time-course analyses were performed to quantify the onset and the duration of the effects. Specifically, the same analyses were performed for ten 100-ms epochs starting at 0 until 1000 ms, measured from target onset. In all analyses, we were only interested in effects including the factor Prosodic Break. Other effects, such as main effects of Hemisphere or ROI, are thus not reported.

First, the participants' performance on the test questions is reported. Then the ERP-results are reported separately for the two critical positions in the sentence.

Performance on test questions

To check whether the participants paid attention to the sentences, two test sentences were presented after each of the six blocks in the experiment. One of the test sentences had occurred in the previous block and the participants had to indicate by putting a cross before that sentence, which of the two they had heard. The results of this test clearly showed that participants attentively listened to the sentences. Of the 28 participants, 26 participants made no errors at all and the other two made only one single error.

Prosodic break

We assumed that no differences existed between the NP- and the S-coordination sentences until the offset of the third NP and that thus, no differences in results at the prosodic break would be present. To test this assumption, we included the factor Structure (NP, S) in the analyses performed for the CPS window. These analyses confirmed that no differences existed between the two structures. This was reflected by the absence of an interaction between Prosodic Break and Structure, both in the Midline ($p > .90$) and in the Lateral analysis ($p > .60$). Moreover, no other interactions including Prosodic Break and Structure were present ($p > .15$). Therefore, in the final analyses we collapsed the data of the two Prosodic Break conditions together, as well as the data of the two No Prosodic Break conditions.

Grand average waveforms time-locked to the offset of NP2 are presented in Figure 4. The prosodic break elicited a large CPS which was widely distributed across the scalp. The CPS had the largest amplitude at the vertex and appeared to show a right hemispheric preponderance. The Midline analysis yielded a main effect of Prosodic Break ($F(1,27) = 23.08$, $p < .001$). The Lateral analysis also revealed a main effect of Prosodic Break ($F(1,27) = 30.85$, $p < .001$) as well as interactions with Hemisphere, ROI and/or Electrode (see Table 4). To follow-up the interaction between Prosodic Break and Hemisphere ($F(1,27) = 13.80$, $p < .001$), separate analyses for the two hemispheres were performed. For the right hemisphere a main effect of Prosodic Break ($F(1,27) = 46.84$, $p < .001$) and an interaction between ROI and Prosodic Break ($F(1,27) = 4.64$, $p < .05$) were obtained. Separate analyses for the anterior and posterior ROIs revealed a main effect of Prosodic Break for the right anterior ROI ($F(1,27) = 23.39$, $p < .001$), as well as for the right posterior ROI ($F(1,27) = 29.08$, $p < .001$). For the left hemisphere a main effect of Prosodic Break ($F(1,27) = 16.09$, $p < .001$) and an interaction between ROI and Prosodic Break ($F(1,27) = 8.74$, $p < .01$) were also obtained. Separate analyses for the left anterior ROI revealed a main effect of Prosodic Break ($F(1,27) = 8.91$, $p < .01$). Analyses for the left posterior ROI yielded no main effect of Prosodic Break ($p > .06$), but an interaction between Prosodic Break and Electrode ($F(3,27) = 12.88$, $p < .001$). Follow-up analyses for the

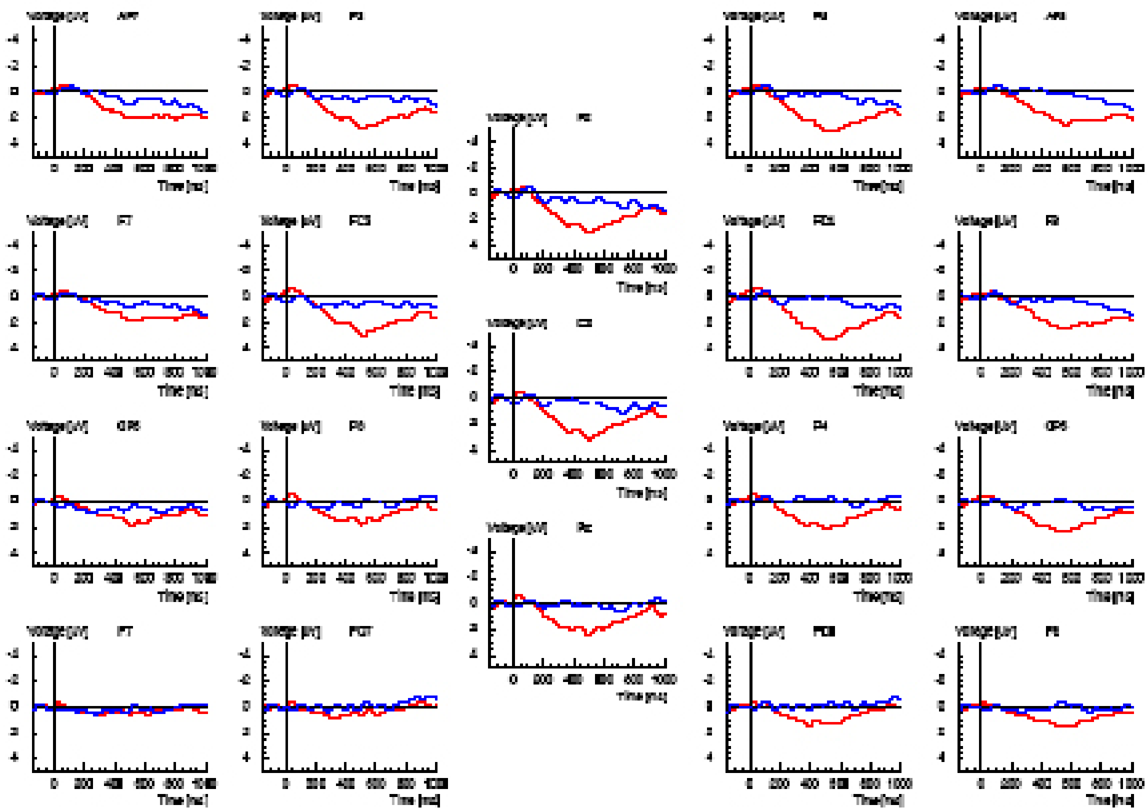

Figure 4. Grand average waveforms time-locked to the position of the prosodic break for the sentences with (red line) and the sentences without a prosodic break (blue line).

single sites revealed that a CPS was present at CP5 and P3 (ps < .05), but not at PO7 and P7 (ps > .05). Analyses including the factor Block revealed only one interaction effect between Prosodic Break, Block, Hemisphere and ROI (F(1,27) = 5.59, p < .05). However follow-up analyses for the single sites showed that no differences existed between the two blocks. The analyses and grand average waveforms for the two blocks are given in Appendix B.

Time course analyses allowed a further determination of the onset and the duration of the CPS. The Midline analyses yielded a main effect of Prosodic Break from 200 to 700 ms (ps < .05) and the Lateral analysis from 200 to 900 ms (ps < .05). In the Lateral analyses also an interaction between Hemisphere and Prosodic Break was present from 300 to 800 ms (ps < .05). Follow-up analyses for the separate hemispheres revealed that the effect of Prosodic Break was present earlier and had a longer duration for the right hemisphere (from 200 to 900 ms, ps < .05) than for the left hemisphere (from 300 to 700 ms, ps < .05). In the Lateral analyses also an interaction between ROI and Prosodic Break was found from 400 to 800 ms (ps < .05). Follow-up analyses for the separate ROIs indicated that the effects started at the same time, but lasted longer for the anterior ROI (from 300 to 900 ms, ps < .05) than for the posterior ROI (from 300 to 700 ms, ps < .05). Moreover, the time course analyses revealed an early main effect of Prosodic Break (p < .05) and an interaction between Prosodic Break, ROI and Electrode (p < .05) in the Lateral analyses between 0 and 100 ms. However, this effect does not reflect an early onset of the CPS, because it is in the opposite direction, i.e. more positive for the *No Prosodic Break* than for the Prosodic Break condition. This effect is for example visible in electrode FC3 in Figure 4. Follow-up analyses for the single sites revealed that it was present at the following electrodes: Pz, PO7, P7, P3, CP5, CP6, FC3 and F3 (all ps < .05). The distribution of this early effect was thus mainly restricted to the left hemisphere[1].

It is not yet clear what this early 'opposite' effect before the CPS reflects. However, it has been found before by Kerkhofs et al. (submitted) and Pannekamp et al. (2005). One possible explanation for this effect could lie in the early features of the prosodic break, such as prefinal lengthening and the pitch rise in the last stressed syllable before the break.

Disambiguation point

NP-coordination

Grand average waveforms time-locked to the onset of the disambiguating element are presented in Figure 5 for the conditions NP Prosodic Break (Prosody-Syntax Mismatch) and NP No Prosodic Break (Prosody-Syntax Match). Visual inspection suggests that no P600 effect was present. In accordance with that, the Midline analysis yielded no main effect of Prosodic Break (p > .20) and neither did the Lateral analysis (p > .40). The time course analyses revealed an interaction between Prosodic Break, ROI and Electrode in the following 100-ms time windows: 300-400, 400-500, 500-600 and 600-700 ms (ps < .05). Follow-up analyses for the separate ROIs indicated that only for the anterior ROI an interaction between Prosodic Break and Hemisphere was present between 400 and 700 ms (ps < .05). Further analyses for the four quadrants, revealed an interaction between Prosodic Break and Electrode in the right anterior ROI between 400 and 600 ms (ps < .05). However, no electrodes in this ROI showed a reliable effect (ps > .30). Thus, the

Table 4
F- and p-values for the main CPS analyses in the time-window from 300 to 700 ms.

Effect	Lateral analysis	Midline analysis
Prosodic Break	**F(1,27) = 30.85*****	**F(1,27) = 23.08*****
Prosodic Break*Midline Electrode		**F(2,26) = 2.15**
Prosodic Break*Hemisphere	**F(1,27) = 13.80*****	
Prosodic Break*ROI	**F(1,27) = 7.69****	
Prosodic Break*Electrode	**F(3,25) = 6.34****	
Prosodic Break*ROI*Electrode	**F(3,25) = 4.03***	

*** p < .001, ** p < .01, * p < .05

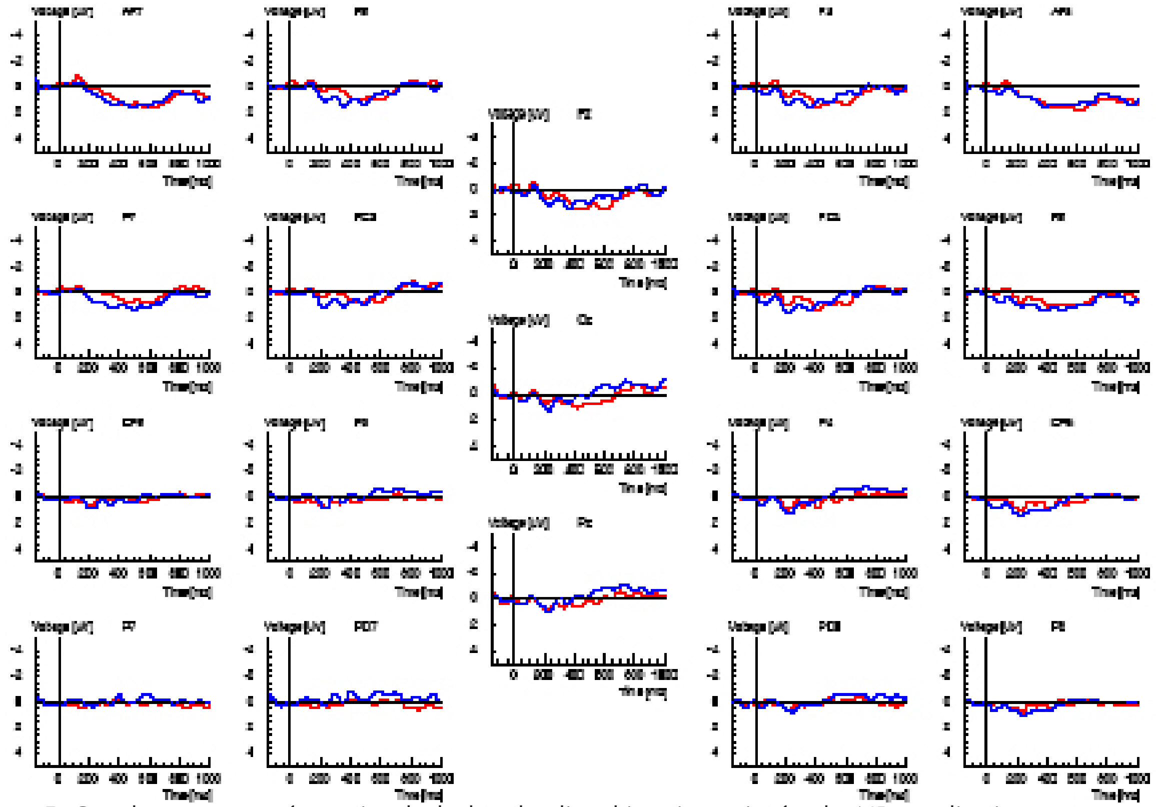

Figure 5. Grand average waveforms time-locked to the disambiguation point for the NP-coordination sentences with (mismatch, red line) and without a prosodic break (match, blue line).

time course analyses confirmed the window analyses in showing that no P600 effect was present.

To test for changes in the course of the experiment, analyses with the factor Block were performed for the P600 window. These analyses yielded an interaction between Prosodic Break and Block in both the Midline ($F(1,27) = 6.60$, $p < .05$) and the Lateral analysis ($F(1,27) = 5.25$, $p < .05$). In Figures 6 and 7 the grand average waveforms for the first and second block are presented separately. Visual inspection suggests that a P600 effect was present for the Mismatch (Prosodic Break) condition as compared to the Match (No Prosodic Break) condition in the first block, but not in the second block. Separate analyses for the first block revealed a main effect of Prosodic Break in the Midline analysis ($F(1,27) = 9.48$, $p < .01$) and in the Lateral analysis ($F(1,27) = 6.79$, $p < .05$). These main effects indicate that mean amplitudes were more positive for the Mismatch than for the Match condition. The Lateral analysis also yielded an interaction between Prosodic Break and Electrode ($F(3,25) = 5.46$, $p < .01$). Follow-up analyses for the single sites revealed an effect of Prosodic Break at the three Midline electrodes Fz, Cz and Pz ($ps < .05$), at four sites on the left hemisphere (FC3, C3, P3, PO7; $ps < .05$) and at seven sites on the right hemisphere (F4, FC4, C4, CP, P4, P8 and PO8, $ps < .05$). The analyses for the first block thus showed that a widely distributed P600 effect was present. In contrast, the analyses for the second block neither yielded main effects of Prosodic Break ($ps > .30$), nor any relevant interaction effects ($ps > .15$).

Inspection of Figure 6 and 7 suggests another, earlier, difference between the first and the second block. In the second block, around 200 to 400 ms, waveforms for the Match (No Prosodic Break) condition were more positive than those for the Mismatch (Prosodic Break) condition (see e.g. electrodes Cz and P4). No such difference seems to have been present in the first block. Supplementary time course analyses for the first block revealed a main effect of Prosodic Break between 300 and 400 ms for the Midline analysis ($p < .05$) and an interaction between Prosodic Break and Electrode in the Lateral analysis ($p < .05$). Follow-up analyses for the single sites, showed a more positive mean amplitude for the Mismatch condition between 300 and 400 ms at the following sites: PO8, Pz, Cz and P4 ($ps < .05$). This effect has the same direction as the later P600 effect that was observed in this first block, so it may reflect an early onset of the P600.

In time course analyses for the second block, the Lateral analyses yielded an interaction between Prosodic Break, Hemisphere and ROI in the following 100-ms windows: 200-300, 300-400 and 400-500 ms ($ps < .05$). Therefore, separate analyses for the four quadrants were performed. Only the

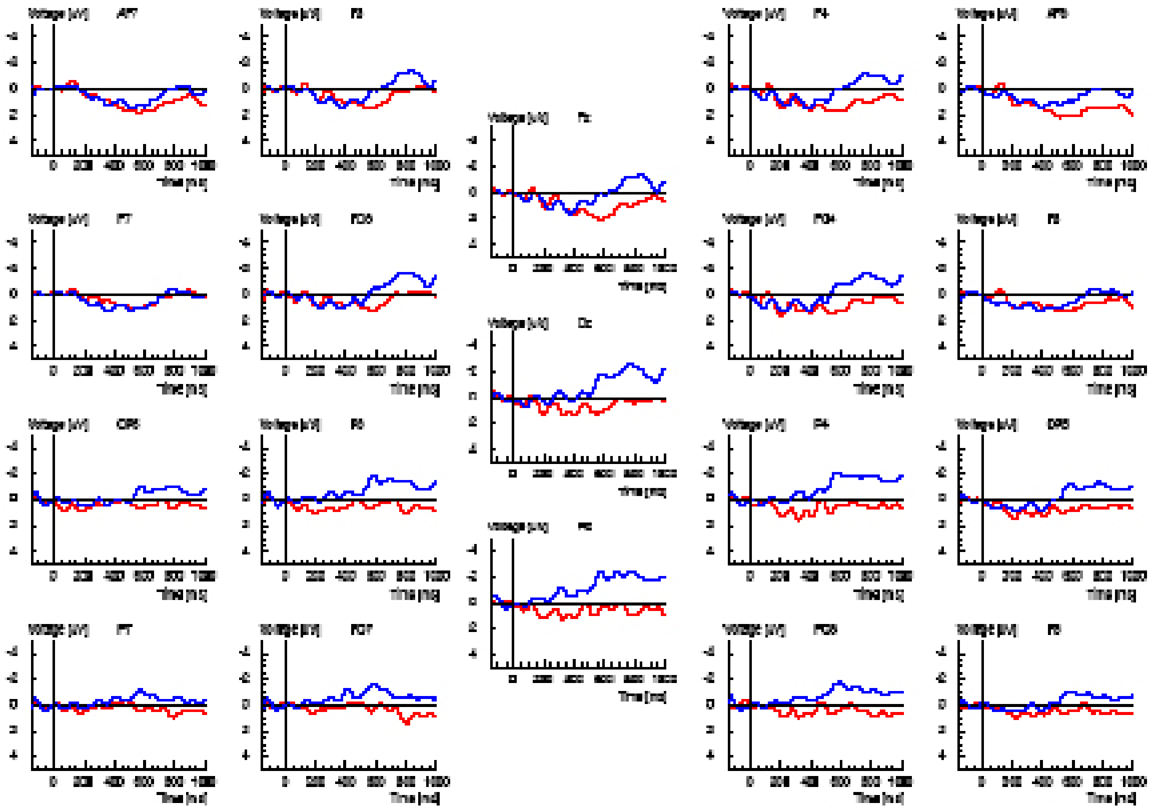

Figure 6. Grand average waveforms time-locked to the disambiguation point for block 1. Red lines represent the NP-coordination sentences with (mismatch) and blue lines without a prosodic break (match).

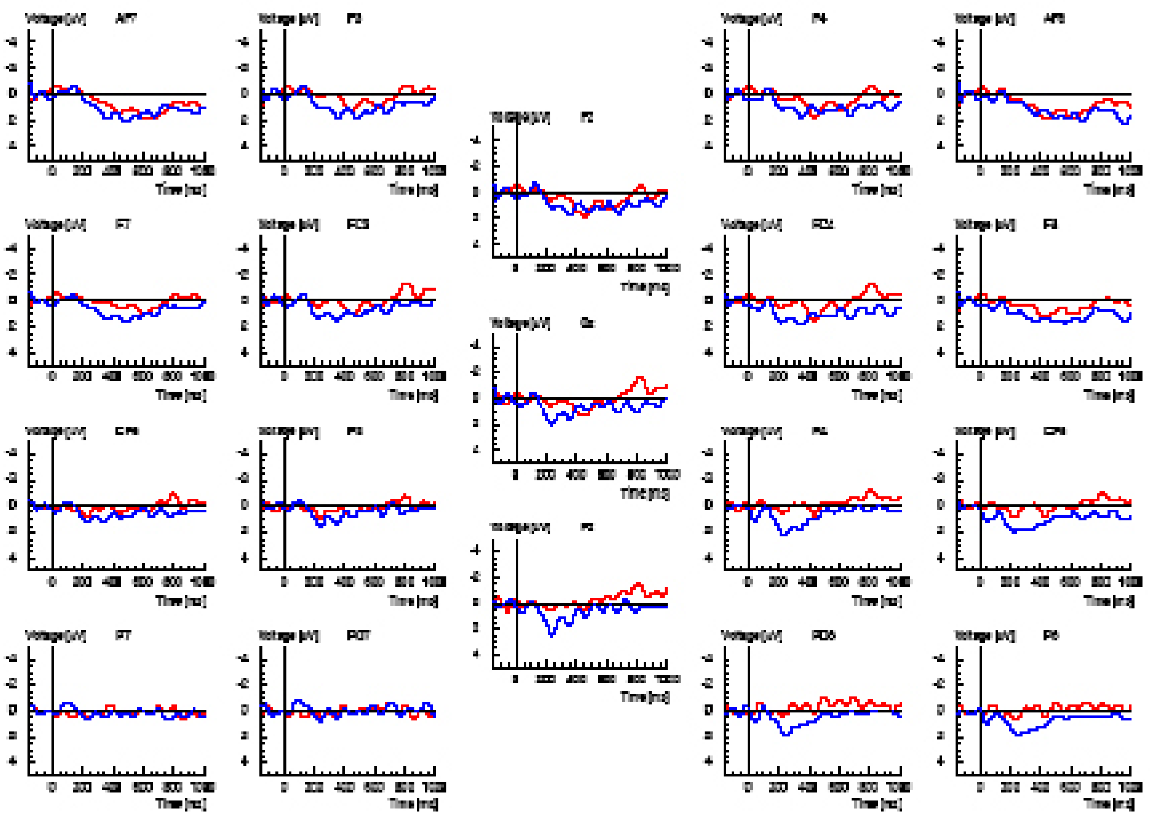

Figure 7. Grand average waveforms time-locked to the disambiguation point for block 2. Red lines represent the NP-coordination sentences with (mismatch) and blue lines without a prosodic break (match).

analyses for the right posterior ROI yielded a main effect of Prosodic Break in the 200-300 and 300-400 windows ($ps < .01$). The main effect reflected that the right posterior electrodes had a more positive amplitude for the Match than for the Mismatch condition between 200 and 400 ms in the second half of the experiment. This effect thus had the opposite direction as the P600 effect found in the first block.

S-coordination

In Figure 8 the grand average waveforms for the S-coordination conditions with Prosodic Break (Prosody-Syntax Match) and without Prosodic Break (Prosody-Syntax Mismatch) are presented. Visual inspection suggests that a P600 effect was present for the Mismatch (No Prosodic Break) condition. The Midline analysis yielded a main effect of Prosodic Break that approached significance ($F(1,27) = 4.18$, $p = .05$). In the Lateral analysis a three-way interaction between Prosodic Break, ROI and Electrode ($F(3,35) = 4.08$, $p < .05$) and a four-way interaction between Prosodic Break, Hemisphere, ROI and Electrode ($F(3,25) = 5.34$, $p < .01$) were present. Separate analyses for the two ROIs, revealed a trend towards a main effect of Prosodic Break in the anterior region ($F(1,27) = 3.03$, $p = .09$). For the posterior ROI an interaction between Prosodic Break, Hemisphere and Electrode ($F(3,25) = 4.56$, $p < .05$) was obtained. Follow-up analyses showed that a P600 effect was present at one midline site (Cz: $p < .05$) and one site of the left hemisphere (FC3: $p < .05$). Block analyses did not reveal any differences between the two blocks, nor were large differences visible in the grand average waveforms of the two blocks. For completeness, the waveforms are given in Appendix C.

The time course analyses revealed a main effect of Prosodic Break in the Midline analyses from 700 to 900 ms ($p < .05$) and an interaction between Prosodic Break and Midline Electrode between 700 and 800 ms ($p < .05$). In the Lateral analyses a main effect of Prosodic Break ($p < .05$) and an interaction between Prosodic Break, ROI and Electrode ($p < .05$) were found between 700 and 800 ms. In addition, a four-way interaction between Prosodic Break, Hemisphere, ROI and Electrode was present between 700 and 900 ms ($ps < .05$). Follow-up analyses for the single sites revealed that the mean amplitude was more positive for the Mismatch (No Prosodic Break) than for the Match (Prosodic Break) condition from 700 to 900 ms at the following sites: FC3, Cz and CP5 ($ps < .05$) and from 700 to 800 ms at the following sites: FC4, Fz, F3 and F4 ($ps < .05$). Thus, these time course analyses confirmed that a reliable P600 effect was elicited by

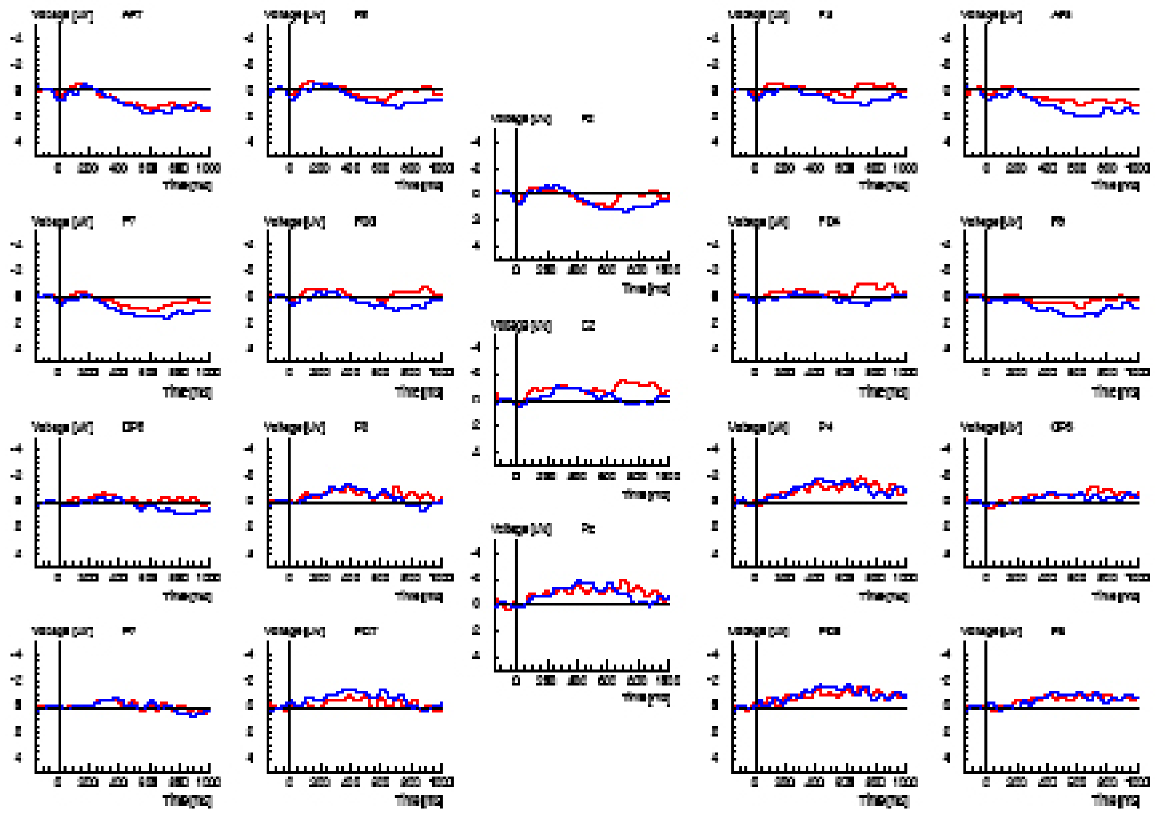

Figure 8. Grand average waveforms time-locked to the disambiguation point for the S-coordination sentences with (match, red line) and without a prosodic break (mismatch, blue line).

the Mismatch (No Prosodic Break) condition. The P600 effect showed an anterior/central distribution.

Discussion

In the following, first a short summary of the results and a discussion will be given for each of the critical points and comparisons separately. After that a more general discussion of all results of Experiment 1 will follow.

Effects of prosody

Taken together, the data at the prosodic break show a very clear CPS, which replicates the findings of Kerkhofs et al. (submitted-a) and Steinhauer et al. (1999). The CPS has a large amplitude, a broad time range (early on- and late offset) and a broad scalp distribution. However, its distribution could still be characterized as predominantly right and anterior. We will come back to these features of the CPS we found here, in the general discussion.

Furthermore, a small and very early reversed effect was found in addition to the CPS at some left hemisphere sites. This early effect has also been found by some other researchers (Kerkhofs et al, submitted-a; Pannekamp et al., 2005), but no one has yet investigated it more thoroughly. One could hypothesize that this early effect is a consequence of the early features of a prosodic break, like the boundary tone (prefinal lengthening and pitch rise). Systematic experiments, independently manipulating the different features of a prosodic break, should be done to test this hypothesis.

Effects of the prosody-syntax mismatch

S-coordination

We compared the S-coordination sentences without a prosodic break with the S-coordination sentences with a prosodic break. The sentences without a break elicited a P600 effect relative to the sentences with a prosodic break. This P600 effect was present during the whole experiment and had a central/anterior distribution.

These results show processing difficulty in the sentences without a prosodic break that was not present in the sentences with a break. First, this means that the prosodic break is able to erase any processing difficulty and thus clearly signals that an early closure (S-coordination) parse should be made.

The fact that processing difficulty was found in the sentences without a prosodic break could be explained in different ways. First, it is possible that, as Hoeks (1999) showed, a default preference for late closure (NP-coordination) exists in the absence of other cues (like a prosodic break). Another option is that participants use the fact that no prosodic break is present, as a cue for NP-coordination, because they expect a prosodic break if the sentence ends in S-coordination. A last possibility is that both cues are used together.

Kerkhofs et al. (submitted-a) made the same comparison between S-coordination sentences with and without a prosodic break. They found a LAN-effect in the first and a P600 effect in the second half of their experiment. They argued that in the first half, participants probably use both strategies (late closure and absence of prosodic break), which gives a double violation at the disambiguation point, since both strategies lead to the wrong conclusion. Such a double violation could elicit strong processing difficulty, resulting in a LAN. After a while, however, participants discover that the absence of a prosodic break does not always lead to NP-coordination in this experiment and they abandon the strategy of using the absence of a prosodic break as a cue. Therefore, only one violation is left, which elicits less strong processing difficulty, the P600.

In the present experiment, we only found a P600. The first possible explanation for this is that only one violation occurred, which is probably caused by the late closure strategy (following the reasoning of Kerkhofs et al.). However, an alternative explanation is possible, regarding the differences between the two experiments. In the present experiment relatively more S-coordination sentences without a prosodic break occur (50% of all sentences without a prosodic break) than in Kerkhofs' study (33%). Assume that the absence of the prosodic break is initially used as a cue in both experiments. In the present experiment, the evidence against this cue (S-coordination sentences without a break) builds up much faster than in Kerkhofs' experiment. This might have lead the participants to abandon the absence of a prosodic break as a cue earlier, which might make this effect invisible in the results of the first half. Another difference between the two studies is the type of fillers that was used. Kerkhofs et al. used fillers in which the prosody was not manipulated, whereas in our fillers this was the case (see Experiment 2). Thus, the fillers may also have played a role in the strategies that participants started to use in the course of the experiment regarding the absence or presence of a prosodic break.

Thus, there are several possibilities regarding the strategies that participants may have used that caused processing difficulty in the form of a P600. However, if we take into account the results of Kerkhofs et al., it is most likely that the late closure strategy was used during the whole experiment and that the absence of a prosodic break was not used as a cue at all or only in the very beginning of the experiment.

NP-coordination

For the NP-coordination sentences with a prosodic break, we found a P600 effect relative to the NP-coordination sentences without a prosodic break. This effect was present in the first half of the experiment and had a very broad central/posterior distribution. In the second half, this P600 effect disappeared but instead an early, negative effect was present with a right posterior distribution. Because we cannot place this effect in the context of known language related ERP components, we will not further discuss it here.

This comparison was not made by Kerkhofs et al., because in that study only S-coordination sentences were used as experimental sentences. However, we expected no processing difficulty for the NP-coordination sentences without break, because the late closure strategy and the use of the absence of a prosodic break would all lead to analysis of the sentence as NP-coordination, which was right in this case. However, when a prosodic break would be present, we expected this break to signal an S-coordination and thus lead to processing difficulty at the disambiguating word. We indeed found a P600, which means the prosodic break clearly signals S-coordination, but only in the first half of the experiment. In the second half this processing difficulty disappeared. If we only look at the results for the NP-coordination sentences, we could hypothesize that in the course of the experiment, participants stop using the prosodic break as cue for S-coordination. After all, they encounter many sentences (50%) in which this cue turns out to lead to the wrong analysis. In the next paragraph, we will discuss implications of the results of both comparisons together.

Prosody-syntax interaction: time course

If we look at all the results at the disambiguation point together, we see that the results in the first half of the experiment are quite straightforward and are in accordance with our predictions. In sentences where no prosodic break is present, both the late closure strategy and the absence of a prosodic break point to an NP-coordination, which leads to processing difficulty in S-coordination sentences without a prosodic break. However, in sentences with a prosodic break, this break signals an S-coordination, which erases the processing difficulty in the S-coordination sentences with a prosodic break but leads to processing difficulty in the NP-coordination sentences with a prosodic break. In other words, processing difficulty is elicited in both cases where a mismatch between prosody and syntax takes place.

However, in the second half of the experiment, the results become more difficult to interpret. This is mainly the case, because an asymmetry is present in the results regarding the two comparisons. In one comparison the results change and in the other they stay constant. In the following, some possible scenarios are brought forward and compared to the present results.

The most straightforward scenario is that participants start using prosody to analyze the sentence in a certain way and keep on doing this during the whole experiment. In that case, the prosodic break would keep on signaling S-coordination and NP-coordination sentences without a prosodic break would still elicit processing difficulty. This is not the case in the present experiment, because in the second half, the processing difficulty of NP-coordination sentences with a break disappears.

In a second scenario, participants start using prosody to analyze the sentence, but after a while they find out that in this experiment, it does not help to use prosody. In 50% of the cases the strategy works, but in the other 50% it does not. Thus, they stop using prosody altogether and fall back on the original late closure strategy, much like being in a reading experiment. Under this scenario, both types of NP-coordination sentences (with and without prosodic break) would not pose any problems, because the late closure strategy predicts NP-coordination. This coincides with our results, because in the second half of the experiment, no processing difficulty is found anymore for the comparison between the NP-coordination sentences. However, in this scenario, the S-coordination sentences would both lead to processing difficulty, because these are early closure sentences. If we would compare the two types of S-coordination sentences (with and without prosodic break), no differences should appear, because for both types processing difficulty would be present. In the present data, however, we still see stronger processing difficulty for the S-coordination sentences without a prosodic break, than for those with a break. Apparently this scenario does not fit the data either.

A third scenario goes as follows. During the experiment, the participants hear many sentences with prosodic breaks. In a large part of these sentences, it becomes clear in retrospect that something weird was going on with the break. This may make the participants suspicious of the break. When a prosodic break occurs in a sentence, they become cautious to make any inferences about how the sentence will end, because they know that in many cases those inferences have been wrong before. That would result in lack of processing difficulty for sentences with a prosodic break (in the second block), because participants cease to build up expectations for these sentences altogether, whether they are based on processing preference or on prosody. Participants do not pay so much attention and are not so suspicious of sentences without a prosodic break. For these sentences the late closure strategy is still used to predict NP-coordination. The only sentences that still elicit a processing difficulty at that point are thus the S-coordination sentences without a prosodic break. This is a scenario that fits the present data, because in the second half, processing difficulty was only found for S-coordination sentences without a prosodic break as compared to S-coordination sentences with a break and no effects were found in the comparison between the NP-coordination sentences.

In conclusion, some possible scenarios about the strategies participants used in the course of the experiment have been excluded and one possible scenario that fits the data has been identified.

Caveats

Regarding the distribution of the found P600 effects, the P600 found in the first half of the experiment in the comparison between the NP-coordination sentences had a very broad, but predominantly central/posterior distribution. The P600 effect found in the comparison between the S-coordination sentences was smaller in distribution and predominantly central/anterior. The typical P600 distribution is posterior. However, Kaan and Swaab (2003) observed that some studies have found a more frontal P600. They investigated the antecedents of these different P600s and found that a frontal P600 is mainly due to a high complexity in the sentences. In complex ambiguous sentences as compared to simple correct ones, the P600 was mostly anterior. This relates well to the present experiment, since the sentences were quite complex and thus taxing for the participants to understand. Moreover, they were locally ambiguous. This could thus be the cause for a more anterior distribution of the P600 found here.

A close look at the grand average waveforms in Figures 6 and 8, suggests that, instead of a positive deflection of the mismatch condition, it rather seems as if the match condition deflects negatively. One would expect the P600 to be a positive deflection from the baseline. However, in this experiment, we made use of connected speech in which many processes take place and words follow each other very quickly. In a study by Hagoort and Brown (2000), spoken sentences with a syntactic violation were used as stimuli. In response to the violations, they found P600 effects. However, in their Figures 7 and 8 (p.1542, 1543) it is clearly visible that a negative deflection of the correct conditions seems present here instead of a positive deflection of the incorrect conditions. Apparently this pattern is not so uncommon in ERPs in response to connected speech. The pattern could be caused by other language or non-language processes in the brain that are present during the time of the P600 and cause a negative slow wave. If so, in the present experiment this slow wave is returned to zero by the P600 in the mismatch condition, whereas the match condition stays negatively deflected. In conclusion, it is best just to look at relative differences between two conditions and not at deflections from the baseline.

As was clear from the time course analyses, the P600 effect in the S-coordination comparison appeared somewhat later than the P600 in the NP-coordination comparison. This could be explained by the fact that we measured the ERPs from the onset of the disambiguating verb and not from the uniqueness point, as Kerkhofs et al. (submitted-a) did, which would have been more precise. Only from the point where the word is uniquely recognized, the disambiguation really begins. We chose not to align our data at the uniqueness point, because, although that is possible for the verbs in the

S-coordination sentences, it is harder to see how one could find the uniqueness point for the disambiguating propositions in the NP-coordination sentences. They can, for example, overlap with later words and in this way form possible new words. However, it is still reasonable to suggest that propositions, since they are generally shorter, will be recognized earlier than verbs. Thus, it is to be expected that the P600 effect will appear somewhat later for the S-coordination sentences, because verbs have to be recognized before the sentence is disambiguated, in contrast to the NP-coordination sentences where only propositions have to be recognized.

Conclusions

First of all, a clear and broad Closure Positive Shift was found in response to the prosodic break, which replicates previous studies. Apparently, the CPS is a robust and reliable indicator of the processing of a prosodic break.

Second, it is clear that a mismatch between prosody and syntax leads to processing difficulty (here in the form of a P600) at least in the beginning of the experiment. This means that the prosodic break is used as a cue to signal a certain syntactic analysis. In the course of the experiment, the participants encounter so many sentences in which their expectations are not met, that they start to use strategies. Which strategies they use exactly is not yet clear at this point. It might be that they start to treat sentences with a prosodic break in a very special way.

Experiment 2

Experiment 2 was run concurrently with Experiment 1. Experiment 2 also addressed the question whether a prosodic break can affect syntactic parsing in spoken sentence processing, however for a different syntactic structure than the one used in Experiment 1.

Methods

Participants

Participants were the same as in Experiment 1.

Materials

As a starting point, 48 pairs of sentences were created. An example of such a pair is given in Table 5. The sentence always began with an NP, followed by a verb and another NP. This NP was followed by a verb in its infinitive form, preceded by *te*, and sometimes an auxiliary: *zullen* (will) or *hebben* (have). The two sentences of a pair were always the same up to the second verb. In one sentence of the pair this second verb was intransitive and in the other sentence this verb was transitive. Hereafter, the corresponding sentences will be referred to as intransitive sentences and transitive sentences. The part of the sentence after the second verb was always the same for the two sentences of a pair and contained at least four words. There were always two pairs of sentences with the same first verb (*hielp*), so 24 different first verbs were used overall in constructing the 48 sentence pairs. In Appendix D all sentence pairs are listed.

All these 48x2 sentences were recorded by a female native speaker of Dutch. She was asked to first read the sentences silently for herself and then to read them out loud. All sentences were recorded three times. The speaker was asked to produce all sentences with a prosodic break after the second verb. Transitive sentences were produced with an additional prosodic break after the first verb. See Table 5 for an indication of the intonational phrases in the recorded sentences.

Of the three transitive sentences, the best two were chosen by the experimenters on the basis of intuition. The third token was discarded. Both chosen sentences were cut in two parts in the silence before the [t] of *te* (to). Of one token only the first part (with the prosodic break) was used and of the other token only the last part (with the transitive verb) was used. Of the three intransitive sentences without prosodic break, also two were chosen. The third was discarded. The chosen sentences were cut in the same way as the transitive sentences. Again from one token only the first part (without the prosodic break) was used and from the other token only the second part (with the intransitive verb) was used. This resulted in two 'first parts' of sentences (with and without prosodic break) and two 'second parts' of sentences (with a transitive or intransitive verb). With these four parts, four new experimental sentences were created by cross-splicing: two transitive sentences (with and without prosodic

Table 5
Sentences that were used as the starting point for the recordings with their translations. Intonational phrases as realized in the recordings are indicated with square brackets.

1	[De verpleegster hielp de zieke te lopen] [omdat hij na de behandeling nog te zwak was.] [The nurse helped the patient to walk] [because he was still too weak after the treatment.]
2	[De verpleegster hielp] [de zieke te vervoeren] [omdat hij na de behandeling nog te zwak was.] [The nurse helped] [to transport the patient] [because he was still too weak after the treatment.]

Table 6
The experimental sentences. Intonational phrases are indicated with square brackets. A forward slash indicates the point of cross-splicing.

A	Intransitive Break	[De verpleegster hielp] [de zieke / te lopen] [omdat hij na de behandeling nog te zwak was.] [The nurse helped] [the patient to walk] [because he was still too weak after the treatment.]
B	Intransitive No Break	[De verpleegster hielp de zieke / te lopen] [omdat hij na de behandeling nog te zwak was.] [The nurse helped the patient to walk] [because he was still too weak after the treatment.]
C	Transitive Break	[De verpleegster hielp] [de zieke / te vervoeren] [omdat hij na de behandeling nog te zwak was.] [The nurse helped] [to transport the patient] [because he was still too weak after the treatment.]
D	Transitive No Break	[De verpleegster hielp de zieke te vervoeren] [omdat hij na de behandeling nog te zwak was.] [The nurse helped to transport the patient] [because he was still too weak after the treatment.]

break) and two intransitive sentences (with and without prosodic break). See Table 6 for an example of these four sentences.

Acoustic analyses of the first parts of the sentences showed clear differences between sentences with and without the first prosodic break. In the sentences with a prosodic break a pause was present between the first verb and the second NP, which lasted 325 milliseconds on average. Moreover, a boundary tone occurred on the last stressed syllable before the break, which was the last stressed syllable of the first verb. This boundary tone consisted of pre-final lengthening of the syllable and a pitch rise. In the sentences without a prosodic break these characteristics were absent. Instead, normal pitch accents occurred on the first verb and the second NP of the sentence. We measured the length of the last word before the prosodic break (and the equivalent word in the sentences without a break), instead of the stressed syllable in this word, because the exact position of a syllable boundary is sometimes difficult to pinpoint. The last word before a break (first

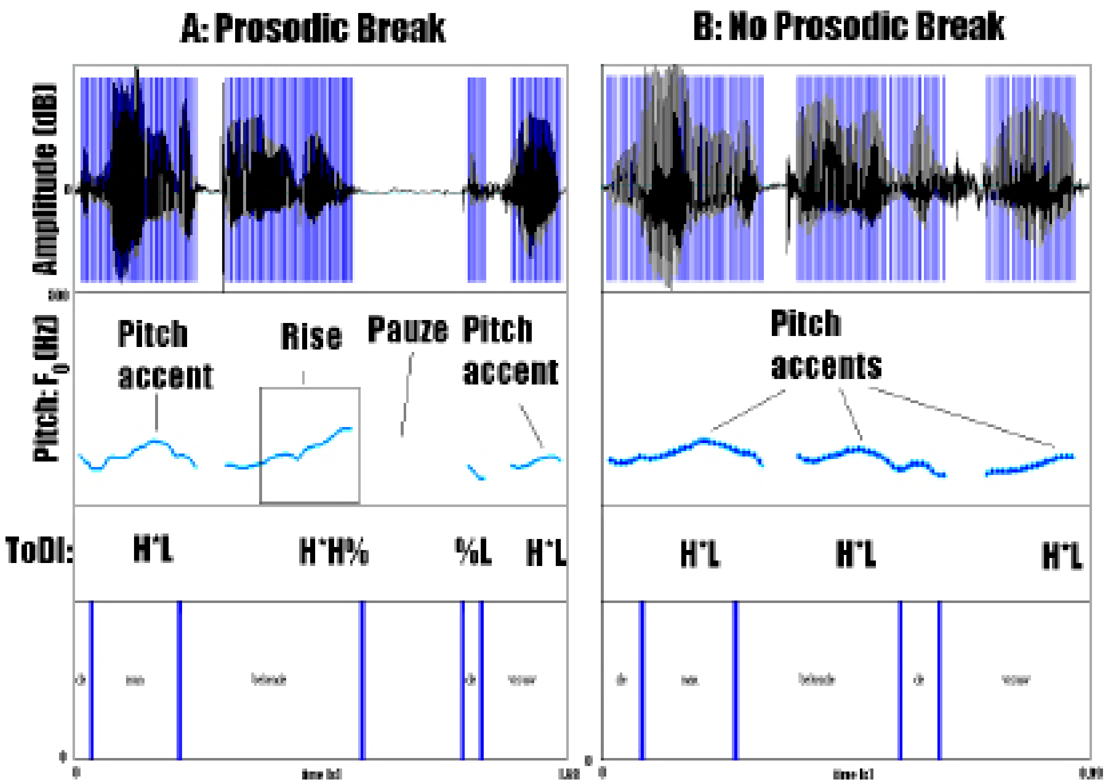

Figure 9. Acoustic analysis of the critical region of the sentences in Experiment 2.

verb) lasted on average 566 ms and the same verb in the sentences without a break lasted on average 387 ms ($t(47) = 25.13$, $p < .001$). In Figure 9 the features of the two types of sentences are indicated in the speech signal for two example sentences. The prosodic structure is transcribed for this sentence using the ToDI system (Gussenhoven, 2004). The second prosodic break, after the second verb, which occurred in all sentences, lasted 277 milliseconds on average.

Design

The experiment consists of a fully crossed two factor design with the factors Prosodic Break (Prosodic Break/No Prosodic Break) and Structure (Transitive/Intransitive). This resulted in four conditions. Four lists of experimental sentences were created. Each item (sentence starting with the same NP1, V1 and NP2) occurred in all 4 conditions in each list. Every item occurred only once in each quarter of a list. The quarters were counterbalanced so that across lists each item occurred in all four conditions in the four quarters. The conditions within each list and each quarter were counterbalanced so that every condition had the same mean rank over items. This ensured an even distribution of the items of the different conditions over the experiment and over the four quarters. In Table 7 the assignment of the conditions to the four lists is presented.

The 48 x 4 (196) sentences in each list were combined with 120 filler sentences from another experiment (see Experiment 1) to a total of 312 sentences. For each list, a pseudorandom order of the experimental and filler sentences was determined with the restriction that there were never more than three experimental trials in a row. The 312 sentences were divided into 6 blocks of 52 sentences. At the beginning of each block, 2 starter sentences were added. One of those was of the structure used in the present experiment and one was of the same structure as the filler sentences.

Procedure

The procedure was the same as in Experiment 1.

Apparatus

The apparatus was the same as in Experiment 1.

Results

Data-analysis

Table 7
Assignment of the conditions to the four lists. A to D stand for the four conditions in the experiment (see Table 6). The numbers 1 to 4 stand for the first, second, third and fourth 12 items.

quarter	List1	List2	List3	List4
1	A1	A2	A3	A4
	B2	B3	B4	B1
	C3	C4	C1	C2
	D4	D1	D2	D3
2	A2	A3	A4	A1
	B3	B4	B1	B2
	C4	C1	C2	C3
	D1	D2	D3	D4
3	A3	A4	A1	A2
	B4	B1	B2	B3
	C1	C2	C3	C4
	D2	D3	D4	D1
4	A4	A1	A2	A3
	B1	B2	B3	B4
	C2	C3	C4	C1
	D3	D4	D1	D2

The preprocessing operations of filtering, use of a baseline and exclusion of trials were performed in the same way as in Experiment 1. After exclusion of trials, in every condition a minimum of 33 trials (of a maximum of 48 trials) remained for every participant. All trials were time-locked to two different critical positions in the sentence. The first critical position (prosodic break) was the offset of the first verb (which was the onset of the prosodic break in the Prosodic Break conditions) and the second critical position (disambiguating word) was the onset of the disambiguating verb. The same analyses were performed as in Experiment 1. See the results section of Experiment 1 for the participants' performance on the test questions. In the following, the ERP-results are reported separately for the two critical positions in the sentence.

Prosodic break

In the two Prosodic Break conditions, as well as in the two No Prosodic Break conditions, the first parts of the sentences (*De verpleegster hielp de zieke*, the nurse helped the patient) consisted of the same tokens. Therefore, we assumed that no differences existed between these conditions up to the prosodic break and that thus, no differences in results at the prosodic break would be present. To verify this, analyses were performed for the CPS window, including the factor Structure (Intransitive, Transitive). If our assumption is correct, no interactions of Prosodic Break and Structure should be present. In line with this, no interactions between Prosodic Break and Structure (ps > .45) or other relevant interactions were obtained (all ps > .05). The only exception was an interaction between Prosodic Break, Structure and ROI ($F(1,27) = 7.20$, $p < .05$). Separate analyses for the Transitive and Intransitive structures revealed that the same general patterns for the CPS were present for Transitive and Intransitive sentences. For both structures a broadly distributed CPS effect occurred. The only difference was that at one single site, P3, a CPS was present for the Transitive sentences ($p < .05$), but not for the Intransitive ones ($p > .07$). Because the difference between the two structures thus consisted of only one electrode, we collapsed the data of the two Prosodic Break conditions together, as well as the data of the two No Prosodic Break conditions.

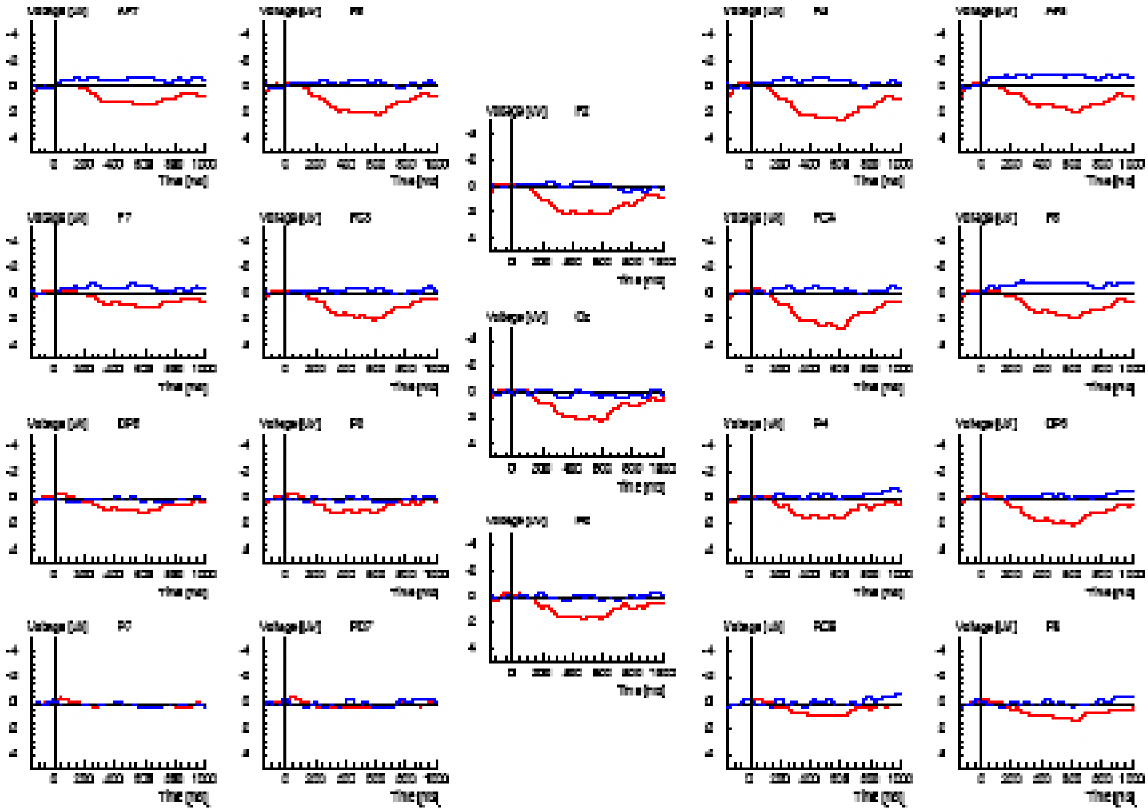

Figure 10. Grand average waveforms time-locked to the position of the prosodic break for the sentences with (red line) and the sentences without a prosodic break (blue line).

Grand average waveforms time-locked to the offset of NP2 are presented in Figure 10. The

Table 8
F- and p-values for the main CPS analyses in the time-window from 300 to 700 ms.

Prosodic Break	**F(1,27) = 60.03*** **	**F(1,27) = 35.76*** **
Prosodic Break*Midline Electrode		**F(2,26) = 2.29**
Prosodic Break*Hemisphere	**F(1,27) = 31.96*** **	
Prosodic Break*ROI	**F(1,27) = 19.92*** **	
Prosodic Break*Hemisphere* Electrode	**F(3,25) = 3.01***	
Prosodic Break*ROI*Electrode	**F(3,25) = 3.94***	

*** p < .001, ** p < .01, * p < .05

Table 9
F- and p-values for the CPS analyses in the 300-700 ms window at the four ROIs.

ROI	Prosodic Break	Prosodic Break*Electrode
Right Anterior	**F(1,27) = 84.51*** **	**p > .06**
Right Posterior	**F(1,27) = 56.36*** **	**F(3,25) = 21.46*** **
Left Anterior	**F(1,27) = 43.18*** **	**F(3,25) = 11.63*** **
Left Posterior	**F(1,27) = 4.67* **	**F(3,25) = 15.40*** **

*** p < .001, ** p < .01, * p < .05

prosodic break elicited a large CPS, widely distributed across the scalp. The Midline analysis yielded a main effect of Prosodic Break (p < .001). The Lateral analysis also revealed a main effect of Prosodic Break (F(1,27) = , p < .001) as well as interactions with Hemisphere, ROI and/or Electrode (see Table 8).

To follow-up the interaction between Prosodic Break and Hemisphere (F(1,27) = 31.96, p < .001), separate analyses for the two hemispheres were performed. For the right hemisphere a main effect of Prosodic Break (F(1,27) = 107.40, p < .001) and an interaction between Prosodic Break and ROI (F(1,27) = 19.81, p < .001) were obtained. Therefore we analyzed the two ROIs separately. These analyses revealed a main effect of Prosodic Break for the right anterior and right posterior ROI and a Prosodic Break by Electrode interaction for the right posterior ROI only (see Table 9). In the left hemisphere a main effect of Prosodic Break (F(1,27) = 33.95, p < .001) and an interaction between ROI and Prosodic Break (F(1,27) = 28.44, p < .001) were also obtained. Separate analyses for the two ROIs revealed that for both the left anterior and the left posterior ROI a main effect of Prosodic Break and interaction between Prosodic Break and Electrode were present (see Table 9). Follow-up analyses for the single sites revealed that a CPS was present at all electrodes (all ps < .05) except PO7 and P7 (ps > .45). Analyses including the factor Block did not reveal any interactions between Block and Prosodic Break. For completeness, we include the grand average waveforms and analyses for the separate blocks in Appendix E.

Time course analyses allowed a further determination of the onset and the duration of the CPS. The Midline analysis yielded a main effect of Prosodic Break from 200 to 900 ms (ps < .05) and the Lateral analysis from 200 to 1000 ms (ps < .01). An interaction between Prosodic Break and Hemisphere was found from 100 to 1000 ms (ps < .05). Separate analyses revealed that the effect started earlier in the left (at 100 ms, p < .05) than in the right hemisphere (at 200 ms, p < .05). In the main time course analyses also an interaction between Prosodic Break and ROI existed from 100 to 900 ms (ps < .05). Separate analyses revealed that the effect started earlier in the anterior ROI (at 100 ms, p < .05) than in the posterior ROI (at 200 ms, p < .05). Separate analyses for the four quadrants indicated that the left posterior ROI was mainly responsible for these differences. Here, the main effect of Prosodic Break was only present from 400 to 600 ms (ps < .05) and the interaction effect between Prosodic Break and Electrode from 300 to 700 ms (ps < .001). Thus, the effect was broadest in the right hemisphere and in the anterior ROI, not only in amplitude, but also in time.

Disambiguation point

In Figure 11 the grand average waveforms time-locked to the disambiguating verb are presented for the Intransitive Prosodic Break (Prosody-Syntax Mismatch) and Intransitive No Prosodic Break (Prosody-Syntax Match) conditions. Visual inspection of these waveforms suggests that the Prosodic Break condition was negatively shifted as compared to the No Prosodic Break condition. This negative shift can be characterized as a biphasic pattern, consisting of two peaks (e.g. see Cz). The second peak seems to have been in the N400 window, but the first peak started very early, right after the onset of the disambiguating verb.

In Figure 12 the grand average waveforms time-locked to the disambiguating verb are presented for the Transitive Prosodic Break (Match) and Transitive No Prosodic Break (Mismatch) conditions. Here a similar, but less pronounced negative shift seems to have been present for the Prosodic Break as compared to the No Prosodic Break condition, again with a very early onset at some sites (e.g. Fz). These early differences are unexpected, because after only

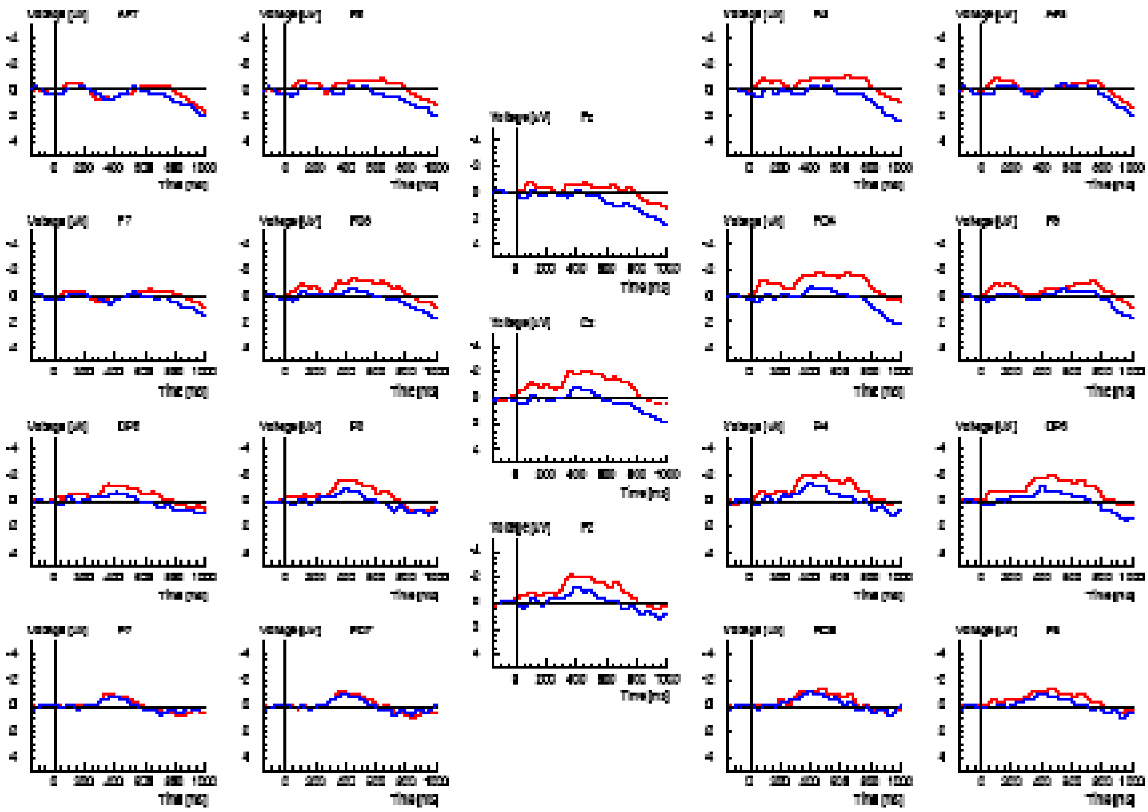

Figure 11. Grand average waveforms time-locked to the disambiguation point for the intransitive sentences with (mismatch, red line) and without a prosodic break (match, blue line).

one or a few phonemes have been heard, it is hardly possible to identify the disambiguating verb already as transitive or intransitive.

Could these early differences be caused by a prolongation of the CPS into the disambiguation region? To test this, we measured the difference in time between the two critical positions: prosodic break and disambiguating word. For the conditions with prosodic break, this difference was on average 973 ms. Because the 150 ms period before a critical point is used as a baseline, the baseline period before the disambiguation point extends on average from 823 to 973 ms after the start of the CPS. As can be seen in Figure 10 and as was clear from the time course analyses at the prosodic break, the CPS was very far outstretched in time and was present at least until 1000 ms after the start of the prosodic break at many sites. These facts together reveal that the CPS was still present during the baseline period of the disambiguating word, in which the two waveforms were both normalized. This makes a comparison of the Prosodic Break and No Prosodic Break conditions at the disambiguation word problematic. Further justification for this conclusion can be found in appendix F.

As a solution to this problem, we chose to compare the two Prosodic Break conditions and the two No Prosodic Break conditions instead of the two Transitive conditions and the two Intransitive conditions. A disadvantage of this method is that one compares the waveforms for different verbs. However, we make this same comparison twice, once between the Prosodic Break conditions and once between the No Prosodic Break conditions. We are thus able to contrast the result of one comparison with the other comparison. For these new comparisons, the same analyses were carried out as reported above, except that the factor Prosodic Break was replaced by the factor Structure (Transitive, Intransitive).

Transitive vs. intransitive verb with prosodic break

In Figure 13 grand average waveforms time-locked to the onset of the disambiguating verb are presented for the Transitive Prosodic Break (Prosody-Syntax Match) and Intransitive Prosodic Break (Prosody-Syntax Mismatch) conditions. Visual inspection suggests the presence of an N400 effect (an increase in negativity for the Mismatch as compared to the Match condition). Analyses for the N400 window (300-500 ms) yielded a main effect of Structure ($F(1,27) = 7.77$, $p < .01$) and an interaction between Structure and Midline Electrode ($F(2,26) = 4.04$, $p < .05$) in the Midline analysis, whereas the Lateral analysis yielded an interaction between Structure, ROI and Electrode ($F(3,25) = 5.32$, $p <$

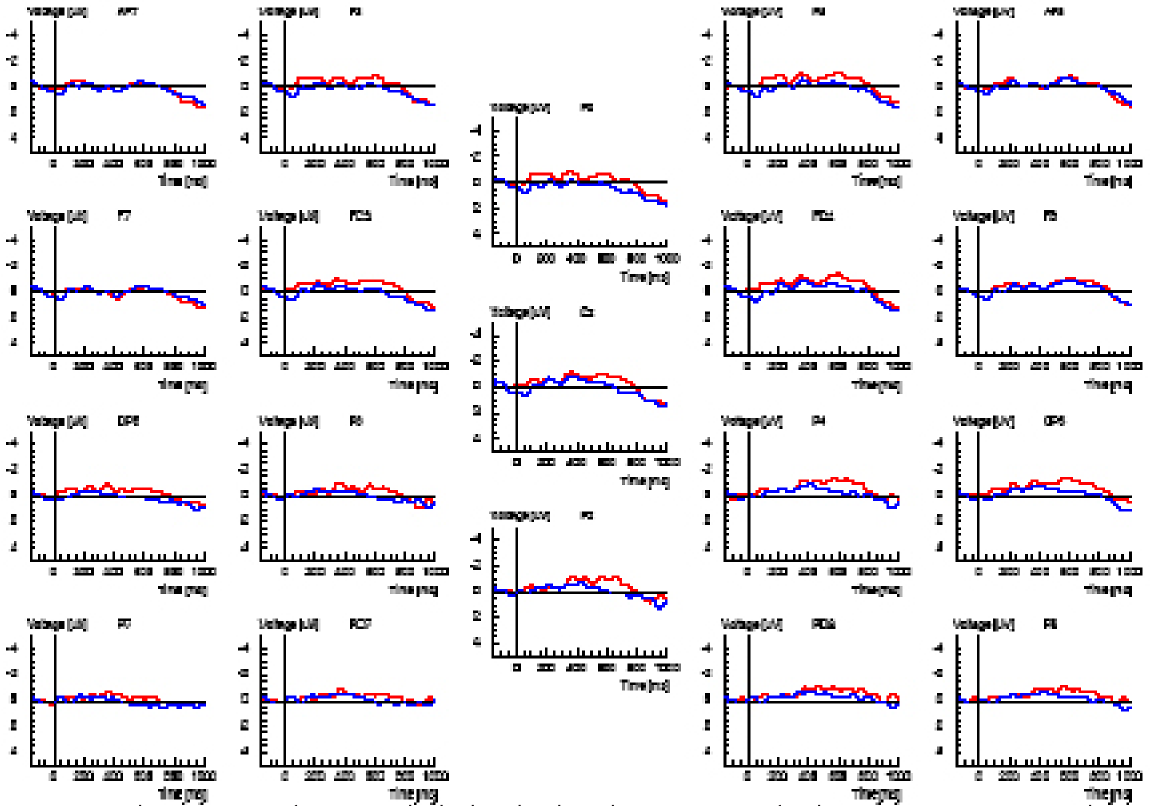

Figure 12. Grand average waveforms time-locked to the disambiguation point for the transitive sentences with (match, red line) and without a prosodic break (mismatch, blue line).

.01). Separate analyses were done for the two ROIs. No reliable effects were obtained for the anterior region (ps > .06), but a main effect of Structure ($F(1, 27) = 4.89$, $p < .05$) and an interaction between Structure and Electrode ($F(3,25) = 4.18$, $p < .05$) were found for the posterior region. Follow-up analyses for the single sites revealed that an N400 effect was present at the midline, at Cz and Pz (ps < .01) and at the following central/posterior electrodes: C3, C4, CP6, P3 and P4 (ps < .05). The N400 effect thus showed the characteristic centroparietal scalp-distribution. In the comparison between the Prosodic Break conditions, no differences between the first and second block were found, neither in the statistical analyses including the factor Block, nor by visual inspection of the grand average waveforms. This indicates that the N400 effect stayed the same over the experiment. For completeness, we included the grand average waveforms for the two blocks in Appendix G.

Time course analyses confirmed the findings of the window analyses. The Midline analyses yielded an interaction between Midline and Structure from 300 to 600 ms (ps < .05) and the Lateral analyses yielded an interaction between Structure, ROI and Electrode from 100 to 1000 ms (ps < .05) and an interaction between Structure, Hemisphere and Electrode in the 0-100 window (p < .05). Follow-up analyses for the single sites revealed an effect between 0 and 100 ms for the right anterior electrodes F8, AF8, T8 and FT8. These electrodes showed a more positive amplitude for the Mismatch than the Match condition (ps < 05). No other reliable effects were present before the N400 window (al ps > .10). Between 300 and 500 ms, electrodes Pz, C4, Cz, CP6 and P4 (ps < .05) and between 400 and 500 ms P3, FC4 and CP5 (ps < .05) showed a more negative amplitude for the Mismatch than for the Match condition, which confirmed the N400 effect found in the window analyses. Furthermore, two electrodes showed a later opposite effect, i.e. a more *positive* amplitude for the Mismatch than the Match condition: electrode PO7 for the 700-800 and 800-900 ms windows (ps < .05) and electrode PO8 for the 700-800 and 900-1000 ms windows (ps < .05).

Transitive vs. intransitive verb without prosodic break

In Figure 14 grand average waveforms time-locked to the onset of the disambiguating verb are presented for the Transitive No Prosodic Break (Prosody-Syntax Mismatch) and Intransitive No Prosodic Break (Prosody-Syntax Match) conditions. To make sure that the effects from the comparison of the Prosodic Break conditions were not due to item-specific effects, we did analyses in the N400 window. Both the Midline and Lateral analyses indicated that neither a main effect of Structure (ps

> .80) nor any interaction effects (ps < .15) were present. This indicates that the N400 effect found in the comparison between the Prosodic Break conditions was not just due to differences between like effect seems to have been present in the first, but not in the second block.

Time course analyses were used to quantify this effect. For the first block, the Midline time

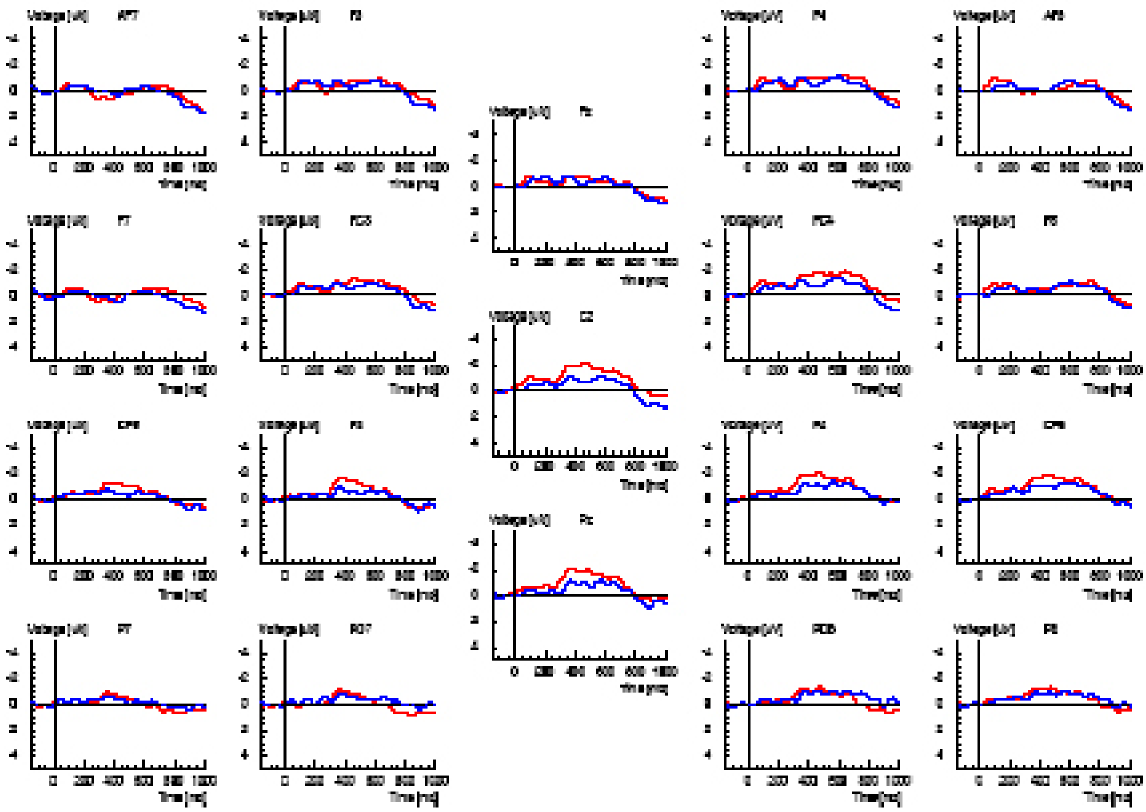

Figure 13. Grand average waveforms time-locked to the disambiguation point for the intransitive (mismatch, red line) and transitive sentences (match, blue line) with a prosodic break.

the verbs.

Time course analyses for the comparison between the two No Prosodic Break conditions revealed an interaction between Structure and Midline Electrode from 200 to 300 ms (p < .05) in the Midline analyses, but follow-up analyses revealed that no effects were present at the single sites (ps > .14). At 300 to 400 ms an interaction between Structure and ROI was present in the Lateral analysis. Separate analyses for the two ROIs revealed that only in the posterior ROI an interaction between Electrode and Structure was present (p < .05). Follow-up analyses for the single sites yielded only an effect in electrode F8 and FT8 (p < .05); amplitudes were more negative for the Mismatch (Transitive) than the Match (Intransitive) condition.

In the time-course analyses including the factor Block, no interaction effects between Prosodic Break and Block were found. However, visual inspection of the grand average waveforms of the No Prosodic Break conditions for the two blocks separately (presented in Figures 15 and 16), suggests a difference between the blocks. A LAN-course analyses revealed a main effect of Structure from 200 to 300 ms (p < .05) and an interaction between Structure and Midline Electrode between 200 and 400 ms (ps < .05). The Lateral analyses yielded an interaction between Structure and ROI from 300 to 400 ms (p < .01). Separate analyses for both ROIs revealed a main effect of Structure for the anterior ROI (F(1,27) = 7.96, p < .01) and an interaction between Structure and Electrode for the posterior ROI (F(3,25) = 3.29, p < .05). Follow-up analyses for the single sites revealed that Cz showed a more negative amplitude for the Mismatch than for the Match condition between 200 and 300 ms (p < .05). Between 300 and 400 ms this was the case for the Midline Electrode Fz (p < .05) and all anterior electrodes (ps < .05) except for AF8 (p > .07). Thus, for this comparison more negative amplitudes were present for the Mismatch condition than for the Match condition between 300 and 400 ms in the first block. This effect had an anterior and slightly left distribution.

For the second block, the Lateral analyses revealed an interaction between Structure and ROI

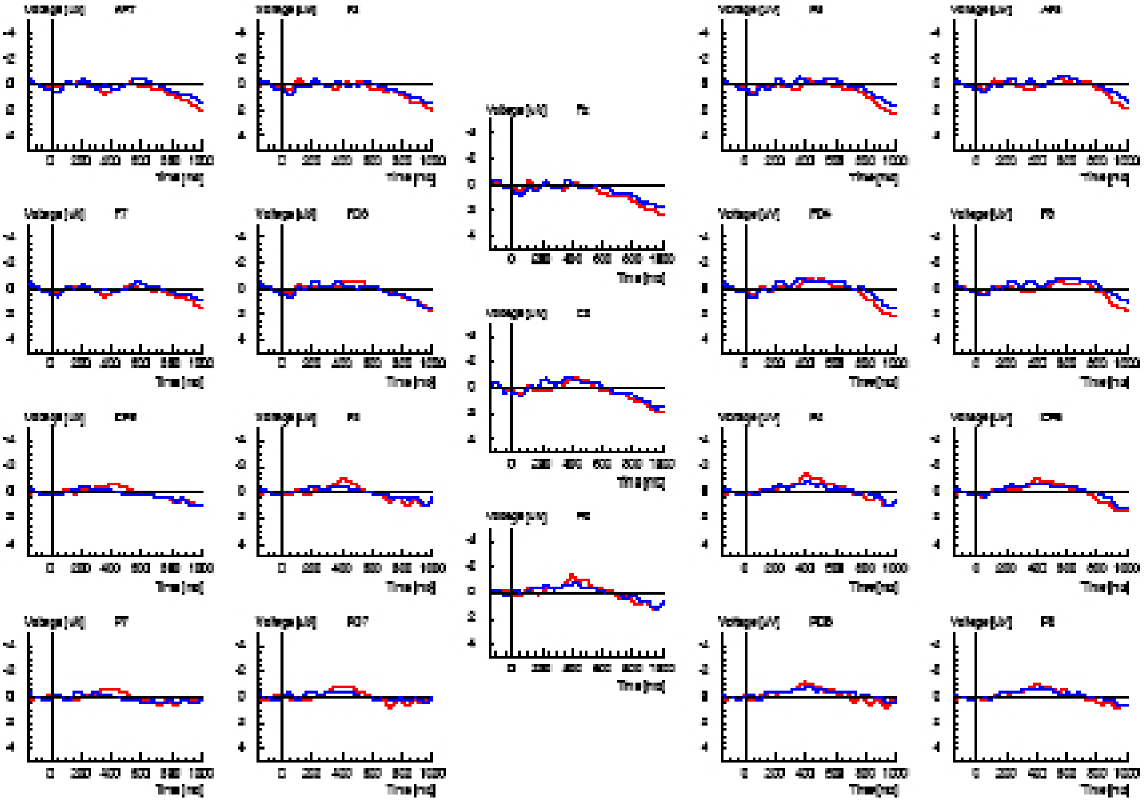

Figure 14. Grand average waveforms time-locked to the disambiguation point for the intransitive (match, red line) and transitive sentences (mismatch, blue line) without a prosodic break.

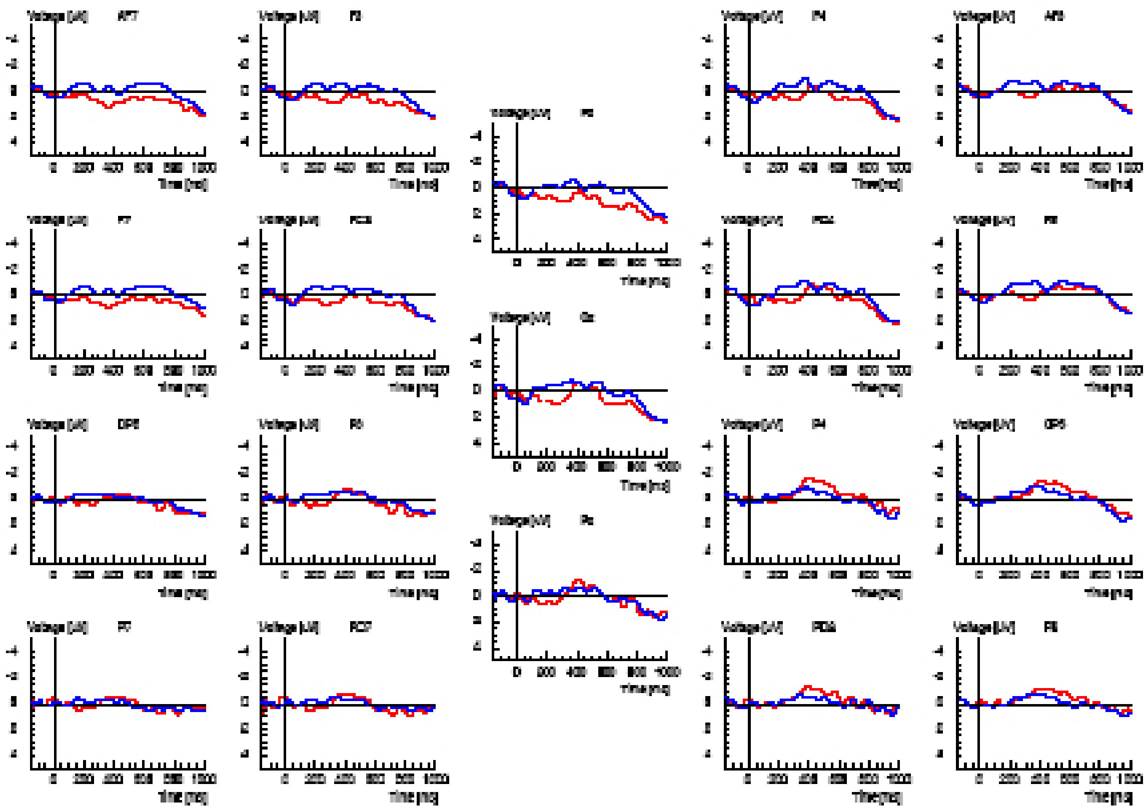

Figure 15. Grand average waveforms time-locked to the disambiguation point for block 1 for the intransitive (match, red line) and transitive sentences (mismatch, blue line) without a prosodic break.

from 0 to 100 ms ($p < .05$). Separate analyses for the two ROIs indicated that in the anterior ROI an interaction between Structure and Hemisphere was present ($p < .01$). However, separate analyses for the left and right anterior ROI yielded no effects ($ps > .10$). In the posterior ROI no effects were found ($ps > .08$). Finally, the main time course analyses revealed an interaction between Structure and Hemisphere between 400 and 500 ms ($p < .05$). However, separate analyses for the two hemispheres revealed no reliable effects ($ps > .06$). These analyses confirm that no LAN-like effect was present in the second block.

Discussion

In the following, a short summary of the results and a discussion will be given for each of the critical points and comparisons separately.

Effects of prosody

Taken together, the data at the prosodic break show a very clear CPS, which replicates the findings of Kerkhofs et al. (submitted-a) and Steinhauer et al. (1999). Like in Experiment 1, the CPS found here is quite large in amplitude and broad in scalp distribution. Though the distribution is broad, it can still be characterized as predominantly right and anterior. The CPS appears to show an even longer duration in this experiment than in Experiment 1. Furthermore, both the distribution and the other features of the CPS are very much like what we found in Experiment 1. Therefore, we will come back to those aspects in the general discussion.

In contrast to Experiment 1, the statistical analyses did not show an early reversed effect preceding the CPS in Experiment 2. However, in Figure 10 it is still possible to see a hint of such an effect in some of the electrodes (e.g. see electrode P3). Apparently this effect was too weak here to reach statistical significance. We can only speculate about the reason why this early effect is absent or weaker here than in Experiment 1. Maybe, the early features of the prosodic break (boundary tone) were realized less strongly in the sentences of Experiment 1 than in those of Experiment 2. The prosodic break was realized somewhat earlier in the sentence in Experiment 2, which lead to less room for the speaker to realize the prosodic break already early in the sentence. However, as pointed out in the discussion of Experiment 1, whether these considerations really play a role can only be investigated by systematic experiments.

Effects of the prosody-syntax mismatch

Transitive vs. intransitive verbs with prosodic break

In the comparison between the two Prosodic Break conditions an N400 with a classical

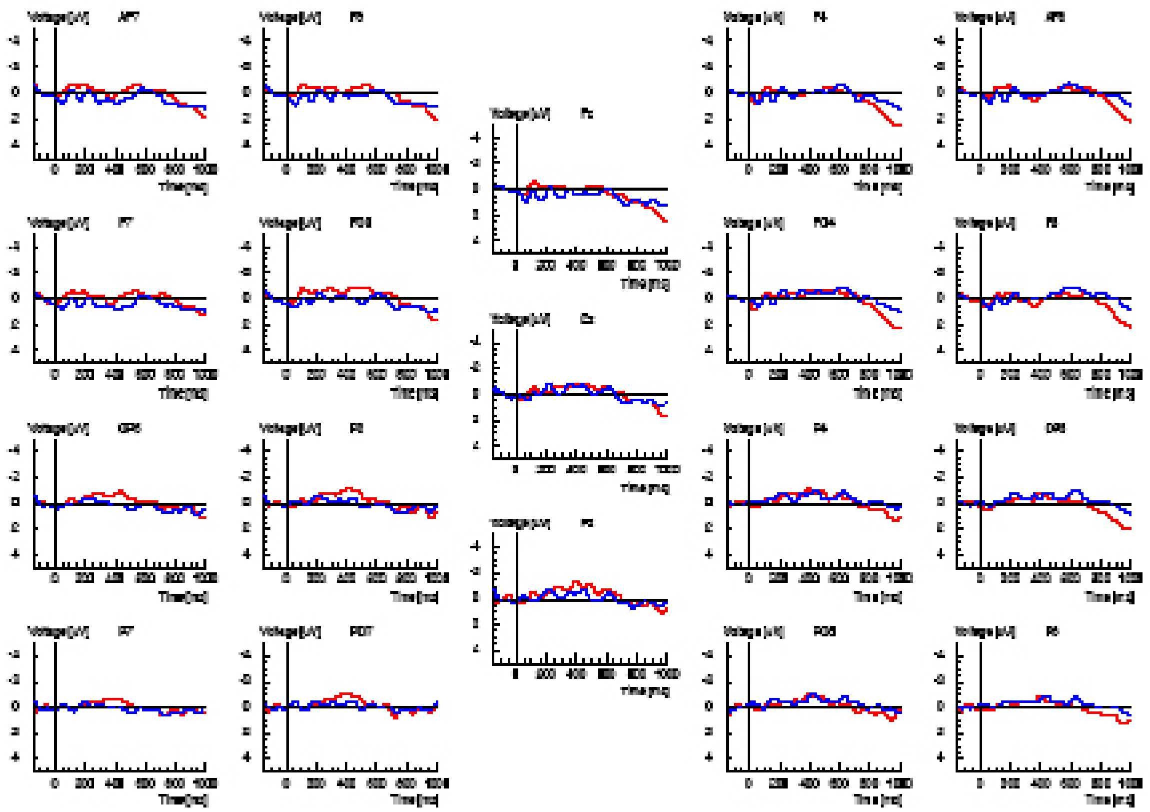

Figure 16. Grand average waveforms time-locked to the disambiguation point for block 2 for the intransitive (match, red line) and transitive sentences (mismatch, blue line) without a prosodic break.

centroparietal distribution was found during the whole experiment for the Mismatch (Intransitive) as compared to the Match (Transitive) condition.

For the Intransitive condition with a prosodic break we indeed hypothesized that processing difficulty would appear, because the prosodic break would indicate that the second NP should be the object of the second verb, whereas the nature of the second verb (intransitive) precluded that. In accordance with Steinhauer et al. (1999), we specifically expected a biphasic N400/P600 pattern.

There have been some earlier ERP-studies on argument structure in which violations of transitivity were investigated. See for example sentence (27) (Friederici & Frisch, 2000), where the verb *emigrierte* (emigrated) is intransitive although in this sentence it has an argument (*den Physiker*, the physicist).

27. *Paul weiß, dass der Chemiker den Physiker emigrierte.

*Paul knows that the chemist emigrated the physicist.

Participants were asked to read these kinds of sentences while their EEG was recorded. At the last verb (*emigrierte*) a biphasic N400/P600 pattern was found. The authors argued that the N400 could be explained by the fact that a violation of thematic structure is inherently semantic or because the sentence is difficult to interpret. The P600 reflected the consequences of the mismatch: the assigned transitive phrase structure must be repaired. In a second experiment, the same kind of violations were shown, however, the verb came before the second argument. In this experiment the same biphasic pattern was found, although the P600 had a smaller amplitude.

Frisch, Hahne and Friederici (2004) presented participants with (among others) argument structure violations in both the visual and the auditory modality. As in the study by Friederici and Frisch (2000) and the present study, an intransitive verb was encountered where a transitive one was expected. However, this was achieved by using passive sentences, like sentence (28).

28. *Der Garten wurde oft gearbeitet und…

*The garden was often worked and…

They also found a biphasic N400/P600 pattern in both the visual and the auditory modality. Rösler, Friederici, Pütz and Hahne (1993) looked at the same kind of passive sentences with an intransitive verb. They found a negative effect between 300 and 500 ms which was left-lateralized and mostly anterior and was regarded as a LAN effect. They also found a non-significant late positivity.

Osterhout, Holcomb and Swinney (1994) let participants read sentences like (29).

29. *The doctor forced the patient was lying

In this sentence the verb *forced* is obligatory transitive, so *the patient* has to be the object of *forced*. Only later, at *was lying* it becomes clear that this is in conflict with the continuation of the sentence. A biphasic N400/P600 pattern was again found. Another condition in this experiment comprised of locally ambiguous sentences, like (30).

30. The doctor believed the patient was lying

Here, the verb *believe* is biased towards transitivity, so *the patient* is first seen as the object of *believed*, whereas at *was lying* it becomes clear that this was wrong. Here only a P600 was found. The authors therefore interpreted the N400 as an indication that the sentence was very difficult to understand on a message level. Osterhout and Holcomb (1992) presented participants with locally ambiguous sentences in which a transitive verb was present that did not immediately get a direct object, like in sentence (31).

31. The woman persuaded to answer the door…

They found a P600 at the word *to* where it became clear that no argument was present.

Hagoort, Brown and Groothusen (1993) let participants read Dutch sentences in which an intransitive verb was followed by an argument, like in sentence (32).

32. De zoon pocht de auto van zijn vader.

The son boasts the car of his father.

At the argument (*de auto van zijn vader*) no ERP-components were found, but a P600 effect was found already at the verb. Hagoort et al. argued that an N400 together with a P600 might have been present and these two components might have cancelled each other out. According to Friederici and Frisch (2000), however, this study was set-up in such a way that the same kinds of verbs always occurred in anomalous sentences. Participants could therefore expect already at the verb that the sentence would be anomalous. It could be that therefore, the P600 effect was already present at the verb.

In summary, apart from the studies by Hagoort et al. (1993) and Rösler et al. (1993), the studies described here have found a biphasic N400/P600 effect in response to argument structure violations and only a P600 effect in response to locally ambiguous sentences that had to do with argument structure. One could thus argue, that an N400 only occurs when a sentence is seen as truly anomalous and when the 'message' of the sentence is hard to extract. In the present study, as in the study by Steinhauer et al. (1999), an N400 was found although, technically, locally ambiguous sentences were used. This means that the prosodic break must have been a very strong cue for the syntactic parse that was made, because listeners apparently see the disambiguating verb as anomalous and find it hard to extract the message of the sentence.

A unique finding of the present study, that is also different from the results of Steinhauer et al. (1999), is that we found only an N400 and no P600. That would mean that no revision or repair processes took place after the detection of the mismatch. Because, technically, ambiguous and not violation sentences were used, *revision* was theoretically possible by ignoring the prosodic break in retrospect. However, this might be very difficult, if not impossible, if the prosodic break is a very strong cue. If so, the situation becomes more like the violation sentences in the studies that were mentioned before (Friederici & Frisch, 2000; Frisch, Hahne & Friederici, 2004; Osterhout et al., 1994). However, in those studies, next to the N400, a P600 was also found that reflected *repair* processes. That those were not present in the present experiment, either, would mean that the participants do not see (immediately) how the sentence could be repaired. Why would revision or repair of the sentence be absent in the present experiment, whereas it is present in the experiment of Steinhauer et al. (1999)? We can only speculate about the causes of this difference, but there are several factors that could play a role.

One difference between the present experiment and that of Steinhauer et al. lies in the NPs that were used. In German, case marking can already show the argument structure of a sentence before the verb is encountered, so Steinhauer et al. only used proper names (which are not case-marked in German) as NPs. Dutch does not have case marking on nouns, so we could use more varied and realistic sentences with real NPs in which a scenario was built up. Also the instruction to the participants may have played a role. In the present experiment, participants were explicitly asked to try to imagine what was happening in the sentences they would hear. This may promote that the participants really try to understand the sentence and process it semantically. In such a context, where listeners really try to understand the sentences and believe in the scenario, a 'wrong' word is more easily interpreted as not fitting into the semantic context than as a syntactic problem that can be repaired. An N400 is more likely in this case and it is less likely that participants immediately see how the structure can be repaired.

Furthermore, Steinhauer et al. (1999) only used a partial design, which means that all sentences without a prosodic break were sentences in which prosody and syntax matched and the sentences with a break could be matches or mismatches. In such a design, it is easier to see how mismatch sentences with a prosodic break can be reanalyzed in analogy to the match sentences without a break. In the present experiment, both types of sentences could be match or mismatch sentences, which made a more complex design and made it harder for the participants to see the proper way to reanalyze a mismatch sentence.

Another difference between the experiments was the task that was used. In the experiment of Steinhauer et al. the participants had to answer a comprehension question about the sentences in 20% of the cases. In the present experiment, they were only asked to pick out the sentence that appeared in the previous block, out of two presented sentences. The comprehension questions might have encouraged the participants to analyze the sentence and the relations that were present in the sentence very thoroughly. They were probably more pressed to extract a meaning out of the sentence at all costs and to actively try to reanalyze the sentence, because they might have to answer a question about the sentence.

To find out which of these factors, or a combination of them, caused the appearance of the P600 in one, but not the other experiment, further experiments have to be done. A possible first step would be to replicate the present study while presenting the participants with comprehension questions in 20% of the cases. First, it could be seen if this factor by itself has any effect. Second, if again only an N400 effect would appear, it would be interesting to see if the absence of repair (P600) would also be reflected in a poorer performance on the comprehension questions.

Transitive vs. intransitive verbs without prosodic break

In the comparison between the No Prosodic Break conditions, no effects were present in the N400 window. This means that the N400 effect found in the Mismatch condition with a prosodic break cannot be ascribed to the difference between the verbs. In the comparison between the No Prosodic Break conditions, however, a small anterior and slightly left effect was present between 300 and 400 ms, but only in the first half of the experiment. We assume this represents a LAN-effect.

For the condition without prosodic break and with a transitive verb, we expected processing difficulty because the default late closure strategy would not work here. We found only a small indication of processing difficulty (LAN-effect) that did not last over the whole experiment, but disappeared in the second half. In other cases of early/late closure ambiguities it has been shown that late closure is the default syntactic analysis (e.g. Frazier & Rayner, 1982). This suggests that the same will be the case in the sentences used in the present experiment. This was however never proven empirically before. So it is possible that no clear default exists and that therefore only minor processing difficulty was found. Moreover, the LAN-effect disappeared in the second half of the experiment. This indicates that if a default late closure analysis exists, it is subject to strategic influences and can be abandoned in the light of specific experience.

Another factor that could have caused the LAN-effect is the use of the absence of a prosodic break as a cue. If it is clear that a prosodic break signals early closure, the absence of a prosodic break could signal late closure. It is possible that the LAN effect reflects a reliance on this absence. However, if so, again this reliance is subject to strategic influences. Because so many sentences were encountered without a prosodic break that turned out to be early closure sentences, participants may have stopped using the absence of a prosodic break as a cue for late closure. The reason why they kept using the prosodic break itself (as indicated by the N400 over the whole experiment), might be that this is a much stronger cue that cannot be so easily ignored.

Conclusions

First of all, as in Experiment 1, a clear and broad Closure Positive Shift was found in response to a prosodic break, which replicates previous studies. Apparently, the CPS is a robust and reliable indicator of the processing of a prosodic break.

Second, this experiment clearly shows that a prosodic break can influence the syntactic analysis participants pursue when hearing a sentence. This can lead to semantic problems when the disambiguation depends on argument structure. In this experiment, apparently the prosodic break was such a strong cue for the pursued analysis, that participants were unable to revise or repair the sentence. Furthermore, we found some evidence that in the investigated sentence type, a preference for late closure exists and/or the absence of a prosodic break is used as a cue. However, it holds for both that, if they played a role at all, their influence disappeared in the course of the experiment. This could indicate that a prosodic break is a stronger cue that is more reliably used than the absence of a prosodic break.

General Discussion

Closure Positive Shift

The CPSs found in Experiment 1 and 2 were strikingly similar. This suggests that the appearance of the CPS does not depend much on the lexical elements around it or its place in the sentence. The specific experimental set-up, such as the speaker or the task may have an effect. The features (amplitude, onset, duration) and the distribution of the CPS were very similar in the two experiments. In the following these aspects will be discussed in turn.

Features of the CPS

As said, a large CPS was found in both Experiment 1 and Experiment 2. However, to see whether this is really different from earlier experiments, let us look at those experiments. Steinhauer (2003) presents an overview of some ERP-experiments in which a CPS was found (including Steinhauer et al. (1999)) and he provides a profile of the CPS. He mentions a mean amplitude of about 3.4 to 4.6 μV and a duration of about 500 ms. Furthermore, he states that the onset of the CPS precedes the onset of the pause. If we compare this to the present experiment we can see by visual inspection of Figures 4 and 10 that the peak amplitude of the CPS is around 3 to 4 μV in the electrodes with the largest CPS. That is quite similar to Steinhauer's profile. Apparently, the early onset we found here (100 or 200 ms) is not uncommon either. We cannot compare the onsets directly though, because Steinhauer (2003) does not align the CPS to the beginning of the break, but presents the ERPs over the whole sentence.

It could be said that the CPS has a long duration in the present experiment; in most electrodes it is present longer than 500 ms. In that regard, the CPS is larger than in Steinhauer's profile. Kerkhofs et al. (submitted-a) found a CPS in the 400-800 ms window. Most strikingly, this is later than the CPS found by

Steinhauer (1999) and the present study. Steinhauer (2003) explains the early onset by the hypothesis that the CPS is triggered by the first available acoustic marker. The early features of the prosodic break, such as the boundary tone (prefinal lengthening and pitch rise) signal its presence earlier than the pause. It is possible that our speaker (and the speaker of Steinhauer et al. (1999)) produced an earlier signaling of the prosodic break than the speaker in the study of Kerkhofs et al. (submitted-a).

The fact that the CPS lasted longer in the present experiments than in earlier studies, could be related to different factors. One possibility is that the prosodic break in the present experiments was realized more strongly than in earlier studies. One measure that could shed more light on this is the length of the pause in the prosodic break. In the experiment of Kerkhofs et al. (submitted-a) this was 343 ms on average and in Experiment 1 this was 319 ms. This fact makes it less likely that the realization of the prosodic break played an important role here. Steinhauer et al. (1999) do not report the average length of the break in their study (although they do report that it is significantly longer than in case no prosodic break is present), so we can not compare this with the lengths of the pauses in the Experiment 2. In summary, differences in the acoustic realization of a prosodic break might be responsible for variability in onset and duration of the CPS across different studies.

Another possible reason for the longer lasting CPS relates to the experiment as a whole. Experiments 1 and 2 reported here were both conducted in the same experiment, with the same participants. Experimental sentences in one experiment were used as filler sentences in the other experiment. As a consequence, the participants heard 324 sentences of which 81% contained at least one prosodic break. Moreover, in most of the cases this break was important for a correct understanding of the sentence. Under this scenario participants will probably start to pay more attention to these breaks. It might be that the CPS is sensitive to the amount of conscious attention that is paid to the prosodic break and becomes more extended if the break receives more attention. In Experiment 2 as compared to Experiment 1, this factor may have played an even larger role, because sentences are almost literally repeated in different conditions within the same participant. That means that in the second half of the experiment, participants have heard the start of a sentence at least two times already, so they might become even more alert. However, the CPS did not change in the course of the experiment, which argues against the idea that repetitions of the sentences have an effect. In future studies, influences of conscious processing on features of the CPS could be investigated by experiments in which instructions, tasks and proportions of different sentence types are manipulated.

Distribution

The typical distribution of the CPS is described by Kerkhofs et al. (submitted-a) as bilateral and centroparietal. In the present experiments the CPS was certainly present over both hemispheres, however more prominently over the right hemisphere. This is in accordance with Friederici (2001) who argues on the basis of fMRI experiments that prosody is likely to be processed mainly in the right hemisphere. The more anterior distribution is not new either. Isel, Alter and Friederici (2005) also found an anteriorly distributed CPS in response to a prosodic break. Furthermore, Pannekamp et al. (2005) systematically decreased the amount of semantic, syntactic and phonemic information in spoken sentences with a prosodic break. They found no specific scalp distribution for normal sentences, but for sentences in which some of the content was decreased, a more anterior and right distribution was found. It might be that listeners pay more attention to the prosody when not much other information is available. That could be related to the present experiments, since it was already indicated that participants might pay extra attention to the prosodic break here. It is possible that a more anterior (and possibly right) CPS distribution is found when participants pay much attention to the prosodic break.

Prosody-syntax interplay

In the following the results of Experiments 1 and 2 at the disambiguation point will be compared and discussed together. However, this is quite difficult, partly because different comparisons were made in the two experiments. In Experiment 1 we compared the same structure with and without prosodic break. If we had instead made comparisons between structures, we had to compare not only the ERPs at different items, but also at different syntactic categories, namely verbs (in the S-coordination sentences) and prepositions (in the NP-coordination sentences). It is not clear if the standard ERP to these categories is the same, so it would not be wise to compare them blindly. In Experiment 1, we therefore had no other choice than to compare the different structures with and without prosodic break, so that the critical position fell on the same word in both conditions. In Experiment 2 it would have been best to make the same within-item comparisons. However, the extension of the CPS into the disambiguating region made these comparisons impossible. Therefore we had to make the choice to compare the two structures with a prosodic break and the two structures without a prosodic break. For these reasons, the different comparisons in the two experiments were necessary and we are forced to deal with them here.

However, there are some similarities between the two structures that justify that we still try to compare the two sets of results and account for the differences between them. Next to the exact same experimental setup in which they were tested, there are important theoretical similarities between the two structures. The original garden path theory would entitle both as late closure sentences. However, this theory was expanded by the principle of Construal (Frazier & Clifton, 1996; 1997). This principle makes a division into primary and nonprimary phrases. Primary phrases are immediately attached to their position in the syntactic tree and if they have to be attached somewhere else later, processing costs occur. Therefore, these primary phrases are subject to garden path principles like late closure. Nonprimary phrases, on the other hand, are only associated to a certain domain in the sentence and can be attached anywhere in this domain later on, without processing cost. If we look at the structures used in the present study, we can say that NP/S-coordination ambiguities are categorized under the primary phrase ambiguities (Frazier & Clifton, 1997). For the structures in Experiment 2, we could not find any reports from Frazier and Clifton as to how they should be classified according to Construal theory. However, we assume that these also fall under primary phrase ambiguities, since the ambiguous element is either the indirect object of the verb or part of the direct object. Thus, both structures are primary phrase ambiguities according to Construal theory and they are both subject to the late closure principle. Moreover, a prosodic break can be placed between the ambiguous element and its preceding phrase that can reverse the preference to early closure.

In spite of these theoretical (and experimental) similarities, the results of the two experiments differ largely on two important aspects, namely the type of processing difficulty and the stability of the results over the experiment. These two aspects will be discussed in turn.

In both experiments processing difficulties were found, however, they were realized differently. In Experiment 1 processing difficulties were syntactic in nature; they appeared in the form of a P600. In Experiment 2 the main processing difficulty was realized as an N400, thus a semantic problem. This difference could be caused by the exact nature of the disambiguation of the sentences. In Experiment 2 the disambiguation is always made by a verb. In case of a prosody-syntax mismatch a transitive verb is expected, but an intransitive verb is encountered. This is a violation of argument structure, which has led to N400 effects in earlier studies, probably because it is inherently semantic. Moreover a verb is a content word, so it can be unexpected in a semantic way. In contrast, in the NP-coordination sentences in Experiment 1, the disambiguating word consisted of a preposition where a verb was expected. A preposition is a function word that carries no meaning so it cannot be unexpected in a semantic way. The disambiguation is purely syntactic, because a preposition is not allowed in this position syntactically, under the pursued syntactic analysis. Therefore, it will be easier to see that a syntactic revision of the sentence has to take place. Thus, superficially, the two structures seem similar and indeed, they both show a processing difficulty at a mismatch between a prosodic break and a disambiguation. This makes clear that the prosodic break can influence the syntactic analysis that is made of the sentence. However, the exact nature of the processing difficulty depends very much on the exact form of the disambiguation.

If we want to compare the stability of the results over the experiment, we have to regard the results for mismatch sentences with and without a prosodic break separately. For the mismatch condition without a prosodic break in Experiment 1, a stable P600 was found over the whole experiment, whereas for Experiment 2, a small LAN effect was found, and this LAN-effect occurred only in the first half of the experiment. One explanation for this difference in strength of the effects is that the late closure strategy is applied more reliably to the structures in Experiment 1 than to those in Experiment 2. Indeed, for NP/S-coordination structures, Hoeks (1999) has shown that a preference for NP-coordination exists. For the sentences in Experiment 2 this has not been explicitly shown, because not many earlier experiments have been done using these structures. If we look closely at the structures themselves, it can be argued that there is a greater difference between the two possible analyses in the NP/S-coordination sentences than in the transitive/intransitive sentences. An NP-conjunction is very local, to the last node available, whereas Sconjunction is very global, because in that case the NP has to be attached totally on top of the syntactic tree. In the sentences of Experiment 2, late closure implies that the NP becomes the indirect object of the preceding verb and early closure implies that it becomes part of the direct object of that verb. In any case, the NP stays beneath the VP node in the syntactic tree. In this regard, one could argue that the difference is smaller in the sentences of Experiment 2 than in those of Experiment 1. If that is true, less processing difficulty is expected for Experiment 2, based on the strength of the late closure strategy. However, it should be tested empirically whether the late closure strategy is indeed not reliably applied in the sentences of Experiment 2. This could be done with a reading experiment in the same vein as Hoeks (1999). It would then also be possible to test whether the use of the late closure strategy changes in the course of the experiment.

Furthermore, there are some reasons why the absence of a prosodic break will not be used as a cue so readily (or will be abandoned easily) in Experiment 2. In the sentences of Experiment 2 the first prosodic break occurs very early in the sentence, after only one NP and one verb. Such an early position is not very usual for a prosodic break because there is no need for taking a breath yet. The prosodic break might thus not be as frequent or expected in Experiment 2 as compared to Experiment 1. Therefore, the absence of a prosodic break does not give much new information and will not readily be used to predict something. Furthermore, in the sentences of Experiment 2 an option exists that is not present in Experiment 1. If one would want to stress that the sentence is meant to be a late closure sentence, one could produce a prosodic break at another point in the sentence, namely after the second NP (see sentence 33).

33. [De verpleegster hielp de zieke] [te lopen] [omdat hij na de behandeling nog te zwak was].

[De nurse helped the patient] [to walk] [because he was still too weak after the treatment].

Because thus both types of sentence can be disambiguated by 'their own' prosodic break, there is even less reason to see the absence of a prosodic break as a cue for one of them. These considerations are possible explanations for why the processing difficulty in Experiment 2 is weaker and less stable than that in Experiment 1.

For the mismatch condition with a prosodic break a stable N400 effect was found in Experiment 2, whereas a strong P600 effect was found in Experiment 1. However, this P600 effect was only present in the first half, and disappeared in the second. In the discussion of Experiment 1, we tried to explain the absence of this P600 in the second half. We ruled out the explanation that prosodic information was ignored overall in the second half of the experiment. The results of Experiment 2 provide more evidence that this explanation can not be true, since the N400, which provides evidence for the use of prosody, was present during the whole experiment. However, we did argue that a possible explanation of the results of Experiment 1 was that participants start to encounter the prosodic break in a very suspicious way and become less eager to make predictions on the basis of it. There are some reasons to suggest that this was not the case for the sentences of Experiment 2. First, as was suggested before, a prosodic break in this early place in the sentence may not be very frequent or expected. This suggests that it will definitely be noticed when a prosodic break is uttered anyway. Moreover it will be assumed that it was uttered for a special reason. Participants will thus be more likely to use the prosodic break as a cue here. Second, the clash at the disambiguation point is not syntactic, but semantic in nature in the sentences of Experiment 2. Therefore, this clash may be harder to ignore than in Experiment 1, because the main goal in sentence processing is after all to understand the message of the sentence.

In summary, 'late closure' is a very convenient term to cover different sorts of syntactic structures and to describe the similarities between them. However, these theoretical similarities do not guarantee that similar processes occur at the disambiguation point. The kind of processes that occur during processing of spoken late closure sentences and the stability of these processes also depend on the precise kind of late closure and on the disambiguation.

Methodological considerations

A methodological concern that one could raise about the present studies is the percentage of male participants. As described in the methods section, only 5 of the 28 participants (18%) were male. This is not a problem if one assumes that the investigated processes do not differ between men and women. Two fairly recent articles could possibly shed more light on the correctness of this assumption. Schirmer, Kotz and Friederici (2002) investigated sex differences in the role of emotional prosody during word processing. They presented participants with auditory sentences spoken with a positive or negative prosody. At the end of these sentences a word was presented visually that was sometimes related to the sentence and had a negative or positive valence. Participants had to perform a lexical decision task on this word. When the words were presented with an inter-stimulus interval (ISI) of 200 ms, women, but not men, were more primed with the sentences of which the prosody matched the valence of the words than with the sentences that did not match. Moreover, women, but not men, showed a larger N400 for mismatched words than for matched words. In a second experiment, an ISI of 750 ms was used. In this case, no behavioral effects of match were found, but the N400 for mismatched words was larger than that for matched words in *men*, but not in women. The authors concluded that men use emotional prosody later in the processing of language than women. In another study (Schirmer & Kotz, 2003) a version of the Stroop task was used. Spoken words were presented with a positive, negative or neutral prosody and with a positive, negative or neutral meaning. In one task, participants had to judge the prosody and in another task they had to judge the valence of the words. In the behavioral task, no differences were found between men and women. In the ERPs N400 effects for matched words were smaller than N400 effects for mismatched words. However, this only held for the semantic task and for women. This again suggests that women use emotional prosodic information faster. The authors argue that this information already plays a role in the semantic phase of language processing in women, but only comes into play in the response phase for men. These are very interesting studies but they do not apply directly to the present study for two reasons. First, only emotional prosody is investigated in these studies. In the present study, however, prosody is used for a completely different purpose than to convey emotion, namely to make the sentence easier to understand for the listener. It is not clear at all from these studies if women are really faster to understand prosody or only to understand emotion via prosody for example. Second, in the present study the main prosodic cue, namely the prosodic break, is presented several words before the mismatch with syntax comes into play. It might take longer for men to use prosodic cues in the language process, but in this study they have ample time to process it before they have to use it. Especially the first article (Schirmer, Kotz & Friederici, 2002) makes clear that men do eventually use prosody, but they take more time, which they have in the present experiments. Because of these considerations, it is not likely that there are differences between the results of men and women in the present study. In that case it is not such a problem that only 18% of the participants were male. To find out whether there where differences between men and women in our data, we looked at the grand averages of the CPS of only the five male participants. These grand averages look very much like the grand averages with all participants, especially in Experiment 1. For Experiment 2, it looked as if the male grand averages showed an even larger CPS than in the overall grand averages, which started even earlier. We could not statistically test these differences, because of the difference in number of participants, but visual inspection at least does not point to a slower processing of prosody by men. For the effects found at the disambiguation point, the data are too noisy too look at the grand average of only 5 participants.

Finally, we want to make clear that we do not wish to claim here to have showed that prosody has an immediate influence on sentence processing. We could only see processing difficulty, caused by the prosodic break, a few words downstream in the sentence. An interaction between prosody and syntax, immediately at the point where the prosodic information becomes available, has been shown by Kerkhofs et al. (submitted-b) by making use of the CPS. Future experiments could reveal whether such an immediate interaction is also present in the kind of structures used in Experiment 2.

Concluding remarks

The experiments reported here showed, by replicating previous research, that a prosodic break in a sentence very reliably elicits a unique ERP-component, the Closure Positive Shift. This is a very robust ERP-component that can be used to find out more about the role of prosody in sentence processing.

In the present study it was shown that listeners use a prosodic break to decide which syntactic analysis they will make of a sentence a few words downstream. The next step would be to investigate whether an *immediate* interaction between prosody and syntax exists.

Furthermore, by making use of two different kinds of locally ambiguous late closure sentences, it has become clear that the exact nature of language processes in the brain can depend very much on the exact nature of the syntactic structures themselves.

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References

Altmann, G., & Steedman, M. (1988). Interaction with context during human sentence processing. *Cognition, 30*, 191-238.

Beach, C. M. (1991). The interpretation of prosodic patterns at points of syntactic structure ambiguity: evidence for cue trading relations. *Journal of Memory and Language, 30*, 644-663.

Cutler, A., Dahan, D., & van Donselaar, W. (1997). Prosody in the comprehension of spoken language: A literature review. *Language and Speech, 40*, 141-201.

Ferreira, F., & Clifton, C. (1986). The independence of syntactic processing. *Journal of Memory and Language, 25*, 348-368.

Frazier, L., & Clifton, C., Jr. (1996). *Construal*. Cambridge, MA: MIT Press.

Frazier, L., & Clifton, C., Jr. (1997). Construal: Overview, motivation, and some new evidence. *Journal of Psycholinguistic Research, 26*, 277-295.

Frazier, L., & Fodor, J. D. (1978). The sausage machine: A new two-stage parsing model. *Cognition*, 6, 291-325.

Frazier, L., & Rayner, K. (1982) Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology, 14*, 178-210.

Friederici, A. (2001). Syntactic, prosodic and semantic processes in the brain: evidence from event-related neuroimaging. *Journal of Psycholinguistic Research, 30*, 237-250.

Friederici, A. D. (2002). Towards a neural basis of auditory sentence processing. *Trends in Cognitive Sciences, 6*, 78-84.

Friederici, A. D., & Frisch, S. (2000). Verb argument structure processing: The role of verb-specific and argument-specific information. *Journal of Memory and*

Language, 43, 476-507.

Frisch, S., Hahne A., & Friederici, A. D. (2004). Word category and verb-argument structure information in the dynamics of parsing. *Cognition, 91*, 191-219.

Garrett, M., Bever, T., & Fodor, J. (1965). The active use of grammar in speech perception. *Perception & Psychophysics, 1*, 30-32.

Geers, A. E. (1978). Intonation contour and syntactic structure as predictors of apparent segmentation. *Journal of the Acoustical Society of America, 4*, 273-283.

Grosjean, F. (1983). How long is the sentence? Prediction and prosody in the on-line processing of language. *Linguistics, 21*, 501-529.

Gussenhoven, C. (2004) Transcription of Dutch intonation. In: S. Jun (Ed.), *Prosodic typology and transcription: A unified approach*. Oxford: Oxford University Press.

Hagoort, P., & Brown, C. M. (2000). ERP effects of listening to speech compared to reading: the P600/SPS to syntactic violations in spoken sentences and rapid serial visual presentation. *Neuropsychologia, 38*, 1531-1549.

Hagoort, P. (2003). How the brain solves the binding problem for language: a neurocomputational model of syntactic processing. *Neuroimage, 20*, S18-S29.

Hagoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift (SPS) as an ERP measure of syntactic processing. *Language and Cognitive Processes, 8*, 439, 483.

Hahne, A., & Friederici, A. (1999). Rule-application during language comprehension in the adult and the child. In A. Friederici & R. Menzel (Eds.) *Learning Rule Extraction and Representation*. Berlin: Walter de Gruyter.

Hoeks, J. (1999). *The processing of coordination. Semantic and pragmatic constraints in ambiguity resolution*. Wageningen: Ponsen & Looijen.

Hoeks, J. C. J., Vonk, W., & Schriefers, H. (2002). Processing coordinated structures in context: The effect of topic-structure on ambiguity resolution. *Journal of Memory and Language, 46*, 99-119.

Isel, F., Alter, K., & Friederici, A. D. (2005). Influence of prosodic information on the processing of split particles: ERP evidence from spoken German. *Journal of Cognitive Neuroscience, 17,* 154-167.

Kaan, E., & Swaab, T. Y. (2003). Repair, revision and complexity in syntactic analysis: An electrophysiological differentiation. *Journal of Cognitive Neuroscience, 15*, 98-110.

Kerkhofs, R., Schriefers, H., Vonk, W., & Chwilla, D. J. (submitted-b). Discourse, syntax, and prosody: the brain reveals an immediate interaction. Ms.

Kerkhofs, R., Vonk, W., Schriefers, H., & Chwilla, D. J. (submitted-a). A comparison of sentence processing in the visual and auditory modality: do comma and prosodic break have parallel functions? Ms.

Kim, A., & Osterhout, L. (2004). The independence of combinatory semantic processing: evidence from event-related potentials. *Journal of Memory and Language, 52*, 205-225.

Kjelgaard, M. M., & Speer, S. R. (1999). Prosodic facilitation and interference in the resolution of temporary syntactic closure ambiguity. *Journal of Memory and Language, 40,* 153-194.

Kluender, R., & Kutas, M. (1993). Bridging the gap: Evidence from ERPs on the processing of unbounded dependencies. *Journal of Cognitive Neuroscience, 5*, 196-214.

Kolk, H. H. J., Chwilla, D. J., van Herten, M., & Oor, P. J. W. (2003). Structure and limited capacity in verbal working memory: A study with event related potentials. *Brain and Language, 85*, 1-36.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature, 307*, 161-163.

Ladd, D. R., & Cutler, A. (1983). Introduction. Models and measurements in the study of prosody. In A. Cutler & D.R. Ladd (Eds.) *Prosody: Models and Measurements.* Berlin: Springer-Verlag.

Mak, W. M., Vonk, W., & Schriefers, H. (2002). The influence of animacy on relative clause processing. *Journal of Memory and Language, 47*, 50-68.

Marslen-Wilson, W. D., Tyler, L. K., Warren, P., Grenier, P., & Lee, C. S. (1992). Prosodic effects in minimal attachment. *The Quarterly Journal of Experimental Psychology, 45*, 73-87.

McRae, K., Spivey-Knowlton, M. J., & Tanenhaus, M. K. (1998). Modeling the influence of thematic fit (and other constraints) in on-line sentence comprehension. *Journal of Memory and Language, 38*, 283-312.

Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language, 31*, 785-806.

Osterhout, L., Holcomb, P. J., & Swinney, D. A. (1994). Brain potentials elicited by garden-path sentences: Evidence of the application of verb information during parsing. *Journal of Experimental Psychology: Learning, Memory, Cognition, 20*, 785-803.

Pannekamp, A., Toepel, U., Alter, K., Hahne, A., & Friederici, A. D. (2005). Prosody-driven sentence processing: an event-related brain potential study. *Journal of Cognitive Neuroscience, 17*, 407-421.

Rösler, F., Friederici, A. D., Pütz, P., & Hahne, A. (1993). Event-related brain potentials while encountering semantic and syntactic constraint violations. *Journal of Cognitive Neuroscience, 5*, 345-362.

Schafer, A. (1995). The role of optional prosodic boundaries. *Paper presented to the Eight Annual CUNY Conference on Human Sentence Processing*. Tucson, Arizona. March 16-18.

Schafer, A., Carter, J., Clifton, C., & Frazier, L. (1996). Focus in relative clause control. *Language and Cognitive Processes, 11*, 135-163.

Schirmer, A., & Kotz, S. A. (2003). ERP evidence for a sex-specific stroop effect in emotional speech. *Journal of Cognitive Neuroscience, 15*, 1135-1148.

Schirmer, A., Kotz, S. A., & Friederici, A. D. (2002). Sex differentiates the role of emotional prosody during word processing. *Cognitive Brain Research, 14*, 228-233.

Spivey-Knowlton, M. J., Trueswell, J. C., & Tanenhaus, M. K. (1993). Context effects in syntactic ambiguity resolution: Discourse and semantic influences in parsing reduced relative clauses. *Canadian Journal of Experimental Psychology, 47*, 276-309.

Steinhauer, K. (2003). Electrophysiological correlates of prosody and punctuation. *Brain and Language, 86*, 142-164.

Steinhauer, K., Alter, K., & Friederici, A. D. (1999). Brain potentials indicate immediate use of prosodic cues in natural speech processing. *Nature Neuroscience, 2*, 191-196.

Stirling, L. & Wales, R. (1996). Does prosody support or direct sentence processing? *Language and Cognitive Processes, 11*, 193-212.

Streeter, L. A. (1978). Acoustic determinants of phrase boundary location. *Journal of the Acoustical Society of America, 64*, 1582-1592.

Tanenhaus, M. K., & Trueswell, J. C. (1995). Sentence comprehension. In J.L. Miller, P.D. Eimas (Eds.) *Speech, Language and Communication*. San Diego: Academic Press.

Townsend, D. J., & Bever, T. G. (2001). *Sentence Comprehension: The Integration of Habits and Rules*. Cambridge: The MIT Press.

Trueswell, J. C., Tanenhaus M. K., & Kello, C. (1993). Verb-specific constraints in sentence processing: Separating effects of lexical preference from garden-paths. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 528-553.

Trueswell, J. C., Tanenhaus, M. K., & Garnsey, S. M. (1994). Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language, 33*, 285-318.

Van Herten, M., Kolk, H. J., & Chwilla, D. J. (2005). An ERP study of P600 effects elicited by semantic anomalies. *Cognitive Brain Research, 22*, 241-255.

Warren, P., Grabe, E., & Nolan, F. (1995). Prosody, phonology and parsing in closure ambiguities. *Language and Cognitive Processes, 10*, 457-486.

Watt, S. M., & Murray, W. S. (1996). Prosodic form and parsing commitments. *Journal of Psycholinguistic Research, 25*, 291-318.

Wingfield, A., & Klein, J. F. (1971). Syntactic structure and acoustic pattern in speech perception. *Perception and Psychophysics, 9*, 23-25.

Appendix A. Stimulus materials of Experiment 1

All experimental materials of Experiment 1 are given below, without prosodic annotation. All sentences were used with a prosodic break in two of the four lists and without a prosodic break in the other two. If a prosodic break occurred in the sentence, it was always placed before *en*.

NP-coordination sentences

1. De schoonvader feliciteerde de bruid en de bruidegom in het middeleeuwse stadhuis met hun feestelijke bruiloft.
2. De journalist interviewde de kraker en de agent op de rumoerige Dam waar hevige rellen bezig waren.
3. De klant beledigde de bewaker en de verkoper in een hoogoplopende ruzie om een beschuldiging van diefstal
4. De brandweerman redde de conciërge en de leraar uit de brandende school voordat deze

instortte.

5. De dokter ondersteunde de notaris en de pastoor naar de verlichte uitgang van het café op de markt.

6. De moeder troostte de baby en het meisje met een lekker ijsje met nootjes.

7. De chirurg overtuigde de patiënt en de specialist in een lang gesprek over de noodzaak van een operatie

8. De stamgast loofde de leverancier en de kroegbaas met een theatraal gebaar en een uitbundig lied.

9. De winkelier betaalde de timmerman en de metselaar voor de nieuwe aanbouw die zij voor hem gebouwd hadden.

10. De ridder bevrijdde de jonkvrouw en de dienares uit het donkere hol van de gevaarlijke draak.

11. De boekhouder complimenteerde de stagiair en de telefoniste op het gezellige feestje omdat zij mooi gekleed waren.

12. De ambassadeur begroette de president en de tolk op het drukke vliegveld waar zij opgewacht werden.

13. De zieke raadpleegde de medicijnman en het stamhoofd uit het kleine dorp aan de rand van het bos.

14. Het meisje gehoorzaamde de imam en de dorpsoudste in het eenzijdige besluit dat zij met haar neef moest trouwen.

15. De hofnar feliciteerde de koning en de maarschalk in de grote troonzaal met de overwinning.

16. De scheidsrechter bestrafte de keeper en de aanvoerder met een gele kaart vanwege hun brutale gedrag.

17. De oppas zoende het jongetje en het meisje op hun warme hoofdjes en stopte ze in bed.

18. De quizmaster omhelsde de deelnemer en de assistente voor de draaiende camera's omdat hij de dure auto had gewonnen.

19. De directeur bewonderde de schilder en de beeldhouwer uit het pittoreske dorp in het zuiden van Frankrijk .

20. De student haatte de hospita en de huisgenoot van het akelige huis wat ook nog eens veel te duur was.

21. De sheriff zag de indiaan en de cowboy achter een grote rotspunt die scherp tegen de lucht afstak.

22. De dansleraar volgde de beheerder en de cursist in het nieuwe gebouw waar hij de weg niet kende.

23. De detective fotografeerde de directeur en de secretaresse in het donkere bedrijfspand omdat hij hun relatie wilde onthullen.

24. De getuige sloeg de tasjesdief en de straatrover in een woeste opwelling om hun respectloos gedrag.

25. De ambtenaar overtuigde de boer en de boerin met een goed bod voor het stuk grond.

26. De dokter begroette de patiënt en de verpleegster met een vriendelijke glimlach omdat hij goede zin had.

27. De regisseur kalmeerde de actrice en de cameraman op de koude set voordat er opnieuw gefilmd kon worden.

28. De uitgever bedankte de schrijver en de dichter voor het prachtige boek dat ze samen hadden geschreven.

29. De padvinder zag de stroper en de boswachter tijdens een woeste worsteling over de grond rollen.

30. De fraudeur sloeg de buurman en de beambte op het lokale politiebureau uit woedde over het verraad.

31. De conciërge riep de postbode en de melkman vanuit de lege kantine om hen wat koffie aan te bieden.

32. De paus verwelkomde de kardinaal en de bisschop in de mooie privé-vertrekken van zijn paleis. .

33. De ondernemer bezocht de geldschieter en de notaris met een goed humeur, omdat er veel van het gesprek afhing.

34. De toerist fotografeerde de straatmuzikant en de marktkoopman op het koude plein wat er zo schilderachtig uitzag.

35. De componist instrueerde de percussionist en de violist in de ruime repetitieruimte opdat de uitvoering perfect zou gaan.

36. De demonstrant bekogelde de minister en de ambtenaar bij de grote poort naar het Binnenhof.

37. De troubadour bezong de vorst en de maîtresse in de prachtige rozentuin waar zij zich hadden teruggetrokken.

38. De milieuwachter bekeurde de schilder en de loodgieter voor het illegaal dumpen van de verf.

39. De dictator wantrouwde de generaal en de adjudant van het machtige leger omdat hij nogal paranoïde was.

40. De reiziger volgde de drager en de gids door het bergachtige gebied waar ze doorheen moesten.

41. De makelaar ontving de koper en de verkoper op zijn luxe kantoor om het voorlopige koopcontract te tekenen.

42. De secretaris onderbrak de voorzitter en de penningmeester in de verhitte vergadering omdat hij

vond dat er een rekenfout in de begroting zat.

43. De bejaarde beschimpte de arts en de verzorgster in het schone verpleeghuis omdat hij meende dat zij hem kinderachtig behandelden.

44. De kleuter bewonderde de conducteur en de machinist in de oude trein vanwege hun mooie uniformen

45. De crimineel verlinkte de medeplichtige en de opdrachtgever tijdens het intensieve verhoor op het politiebureau.

46. De schipper vervloekte de stuurman en de bootwerker in een agressieve opwelling toen de lading opnieuw viel.

47. De veilingmeester ontmoette de curator en de antiquair in het mooie museum bij de onthulling van het schilderij.

48. De staker bekogelde de vakbondsman en de mijnwerker bij de oude mijn omdat hij zich bedrogen voelde.

49. De automobilist beschuldigde de monteur en de garagehouder in de smerige garage van het vernielen van zijn autolak.

50. De wielrenner riep de verzorger en de coach op het hoge erepodium omdat hen veel eer toekwam.

51. De econoom waarschuwde de belegger en de speculant in het verhitte gesprek over de naderende recessie.

52. De kapitein zag de bootsman en de piraat op het gladde dek gespannen vechten voor hun leven.

53. De aannemer riep de grondwerker en de chauffeur in de draaiende vrachtwagen omdat zij aan het werk moesten.

54. De titelverdediger sloeg de scheidsrechter en de tegenstander in de rumoerige ring waar ze hooglopende ruzie hadden.

55. De schaatser belde de haptonoom en de masseur in het geavanceerde sportcentrum waar hij voor de wedstrijd trainde.

56. De hertog bevocht de prins en de ridder in een hoogopgelopen geschil over een belangrijk landgoed.

57. De moeder schreef de mentor en de rector over het vervelende gedrag van haar zoon die geschorst was.

58. Het rotjoch schopte de dominee en de misdienaar in de kleine kerk omdat zij hem brutaal noemden.

59. De opziener berispte de jager en de drijver in het grote bos waar ze konijnen geschoten hadden.

60. De conducteur bekeurde de puber en de manager in de volle trein toen ze weigerden te betalen.

S-coordination sentences

1. De voorzitter bedankte de sponsor en de trainer bestelde lachend een biertje voor alle aanwezigen.

2. De mannequin kuste de ontwerper en de fotograaf pakte vrolijk een fles bruisende champagne en wat kaviaar.

3. De rector ondervroeg de leraar en de leerling volgde stiekem het verhitte gesprek vanaf de gang.

4. De gevangene gijzelde de priester en de bewaker riep geschrokken zijn collega's die meteen aan kwamen lopen.

5. De weduwe bedankte de organist en de predikant bekeek aandachtig de menigte mensen die was gekomen.

6. De bedrijfsleider kalmeerde de klant en de ober bracht mopperend het bord weer naar de keuken.

7. De redacteur prees de fotograaf en de journalist bekeek bewonderend de foto's van de vluchtelingenkampen.

8. De sheriff beschermde de boer en de knecht verdedigde wanhopig de boerderij tegen Johnsons bende.

9. De grimeur schminkte de schrijver en de interviewer besprak kort de vragen die hij wilde stellen.

10. De verdachte beledigde de rechter en de advocaat belde ontstemd het kantoor waar hij werkte.

11. De eigenaar prees de kok en de ober floot zachtjes een liedje met een vrolijke melodie.

12. De dirigent bekritiseerde de cellist en de pianist smeet boos zijn volledige partituur op de grond.

13. De portier bespioneerde de chef en de secretaresse belde heimelijk de politie om aangifte te doen.

14. De dief beschoot de juwelier en de agent riskeerde moedig zijn leven door de dief te ontwapenen.

15. De regisseur bespotte de nieuwslezer en de weerman vervloekte kwaad de opzet van het nieuwe programma.

16. De winnares omhelsde de sponsor en de trainer groette enthousiast het publiek op de tribune.

17. De rechter berispte de verdachte en de advocaat bedacht snel een reden om de zitting te verdagen.

18. De presentator introduceerde de schrijver en de criticus maakte grijnzend een buiging naar het publiek.

19. De stalker achtervolgde de danseres en de

manager opende vlug de deur van de gereedstaande limousine.

20. De politieman ondervroeg de koerier en de infiltrant achterhaalde later de naam van de opdrachtgever.

21. De gravin wenkte de koetsier en de lakei droeg zuchtend de koffers naar de gereedstaande koets.

22. De presentator omarmde de zanger en de zangeres zong huilend de beginregels van hun eerste hit.

23. De hulpverlener informeerde de arts en de brandweerman bevrijdde gehaast het slachtoffer uit de brandende auto.

24. De tovenaar bewaakte de koningin en de prinses haalde gauw het toverboek uit de magische bibliotheek.

25. De reddingswerker bevrijdde het kind en de vrouw schreeuwde hysterisch de longen uit haar lijf.

26. De boswachter berispte de padvinder en de hopman doofde gauw het vuurtje met wat scheppen zand.

27. De toerist fotografeerde de visser en de reisleider vertelde gedreven een verhaal over de visserij in de streek.

28. De dichter bezong de zwerver en de dronkaard prees luidkeels de schoonheid van de Amsterdamse grachten.

29. De professor belde de aannemer en de architect eiste direct een onderzoek door een onafhankelijk bureau.

30. De klant bedankte de bedrijfsleider en de verkoper vroeg meteen de kassabon om de trui te ruilen.

31. De lerares begroette de leerling en de moeder beschreef uitvoerig de thuissituatie van het problematische kind.

32. De pastoor zegende de stuurman en de kapitein bedankte lachend de geestelijke voor zijn goede zorgen.

33. De chauffeur vervoerde de baron en de butler bracht keurig de bagage naar het kasteel.

34. De actrice vervloekte de stuntman en de producent gooide woedend zijn dikke sigaar op de grond.

35. De burgemeester ondervroeg de leraar en de onderzoeker onderkende zakelijk de voordelen van het nieuwe onderwijsplan.

36. Het kamerlid bespotte de interviewer en de minister herhaalde minachtend de vragen die hem gesteld waren.

37. De lijfwacht beschermde de president en de generaal beval direct zijn troepen de omgeving te doorzoeken

38. De automobilist raakte de voetganger en de fietser verloor toen zijn evenwicht waardoor hij op straat viel.

39. De tuinman bespiedde het dienstmeisje en de butler pakte meteen een verrekijker om haar te bekijken.

40. De clown ontvluchtte de goochelaar en de acrobaat beklom de ladder naar de nok van de tent.

41. De suppoost waarschuwde de student en de studente stopte snel de camera in haar tas.

42. De psychiater observeerde de patiënt en de assistent noteerde zorgvuldig de medische gegevens in het dossier.

43. De huisvrouw zoende de kennis en het kind bekeek nieuwsgierig de mensen die langs hen heen liepen.

44. De directeur ontsloeg de werknemer en de chef riskeerde vervolgens zijn baan door hiertegen te protesteren.

45. De burgemeester loofde de wethouder en de ondernemer liet meteen een fles Franse cognac bezorgen.

46. De koningin beloonde de lakei en de hofdame kreeg meteen een rode kleur van opwinding.

47. De reiziger vervloekte de piloot en de stewardess opende haastig de nooduitgangen voor in het vliegtuig.

48. De chirurg troostte de man en de vrouw legde bezorgd haar hand op zijn warme voorhoofd.

49. De astronaut groette de technicus en de monteur opende behoedzaam de sluis van de gereedstaande raket.

50. De fan belaagde de drummer en de gitarist riep ontzet de beveiliging die al paraat stond.

51. De commissaris bedreigde de parkeerwacht en de rechercheur vertrok woedend waarbij hij de deur dichtsmeet.

52. De archeoloog betaalde de indiaan en de graver stopte netjes alle spullen in een grote koffer.

53. De dichter belaagde de criticus en de redacteur besloot meteen een uitvoerige rectificatie te plaatsen.

54. De verpleger verschoonde de junk en de zwerfster waste mopperend zijn gezicht met water en zeep.

55. De kapelaan vermaande de koorknaap en het hulpje wist nauwelijks zijn lachen te bedwingen.

56. De medicijnman besprenkelde de bezetene en het opperhoofd goot voorzichtig olie over het vreemde masker.

57. De priester offerde de slavin en de slaaf bewierookte dromerig het stenen beeld van de godheid.

58. De volgeling vereerde de goeroe en de

ingewijde luisterde ademloos naar zijn gepassioneerde toespraak.

59. De activist besmeurde de lijfwacht en de officier morste geschrokken koffie op zijn smetteloze uniform.

60. De fakir betoverde de toeschouwer en de danseres vertoonde geamuseerd haar sensuele buikdans.

Appendix B. CPS analyses for the separate blocks in Experiment 1

Table B.1
Overall analyses in the CPS window with the factor Block

Effect	Lateral	Midline	p
Prosodic Break*Block	**F(1,27) = 0.03**	**F(1,27) = 0.10**	**.75**
Prosodic Break*Block*Midline Electrode		**F(2,26) = 0.15**	**.86**
Prosodic Break*Block*Hemisphere (Hem)	**F(1,27) = 0.06**		**.81**
Prosodic Break*Block*ROI	**F(1,27) = 0.10**		**.76**
Prosodic Break*Block*Hem*ROI	**F(1,27) = 5.59***		**.03**
Prosodic Break*Block*Electrode (El)	**F(3,25) = 0.21**		**.89**
Prosodic Break*Block*Hem*El	**F(3,25) = 1.40**		**.27**
Prosodic Break*Block*ROI*El	**F(3,25) = 0.26**		**.85**
Prosodic Break*Block*Hem*ROI*El	**F(3,25) = 2.35**		**.10**

*** p < .001, ** p < .01, * p < .05

Table B.2
Separate analyses in the CPS window for the first block

Effect	Lateral	Midline	p
Prosodic Break	**F(1,27) = 39.64*****	**F(1,27) = 23.54*****	**.0**
Prosodic Break*Midline Electrode		**F(2,26) = 0.86**	**.44**
Prosodic Break*Hemisphere	**F(1,27) = 6.92***		**.0**
Prosodic Break*ROI	**F(1,27) = 5.52***		**.0**
Prosodic Break*Hem*ROI	**F(1,27) = 4.18**		**.0**
Prosodic Break*Electrode (El)	**F(3,25) = 9.31*****		**.0**
Prosodic Break*Hem*El	**F(3,25) = 1.96**		**.1**
Prosodic Break*ROI*El	**F(3,25) = 3.97***		**.0**
Prosodic Break*Hem*ROI*El	**F(3,25) = 3.45***		**.0**

*** $p < .001$, ** $p < .01$, * $p < .05$

Table B.3
Separate analyses in the CPS window for the second block

Effect	Lateral	Midline	p
Prosodic Break	**F(1,27) = 22.14*****	**F(1,27) = 23.51*****	**.0**
Prosodic Break*Midline Electrode		**F(2,26) = 2.96**	**.07**
Prosodic Break*Hemisphere	**F(1,27) = 6.00***		**.0**
Prosodic Break*ROI	**F(1,27) = 3.00**		**.0**
Prosodic Break*Hem*ROI	**F(1,27) = 2.38**		**.1**
Prosodic Break*Electrode (El)	**F(3,25) = 7.50*****		**.0**
Prosodic Break*Hem*El	**F(3,25) = 2.98**		**.0**
Prosodic Break*ROI*El	**F(3,25) = 7.49*****		**.0**
Prosodic Break*Hem*ROI*El	**F(3,25) = 0.50**		**.6**

*** $p < .001$, ** $p < .01$, * $p < .05$

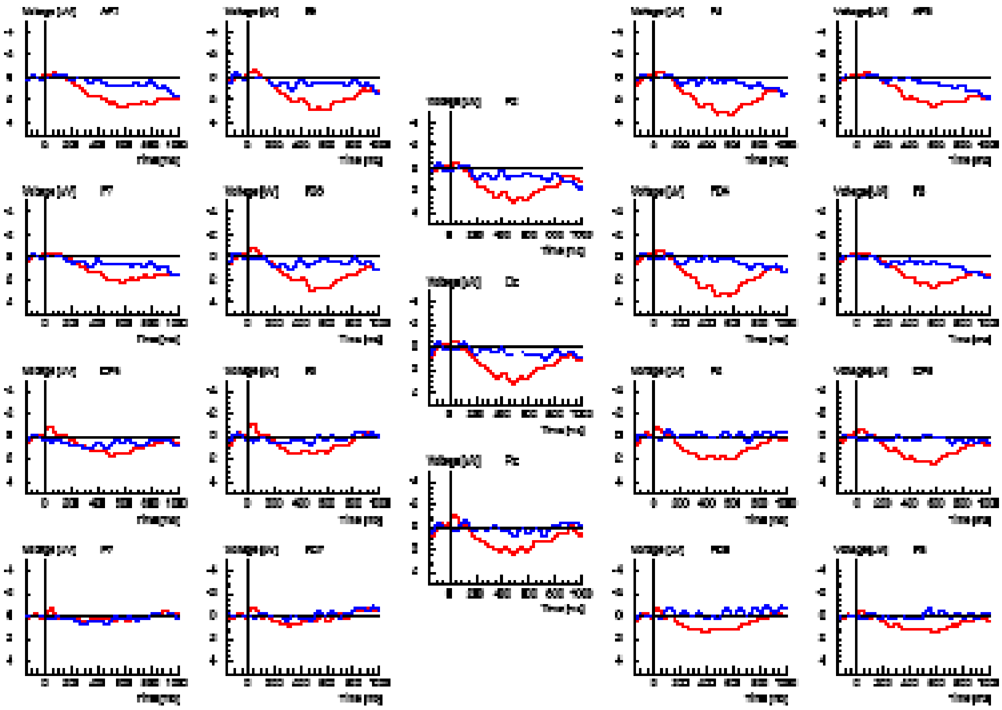

Figure B.1. Grand average waveforms time-locked to the position of the prosodic break for block 1. The red line represents the sentences with and the blue line those without a prosodic break.

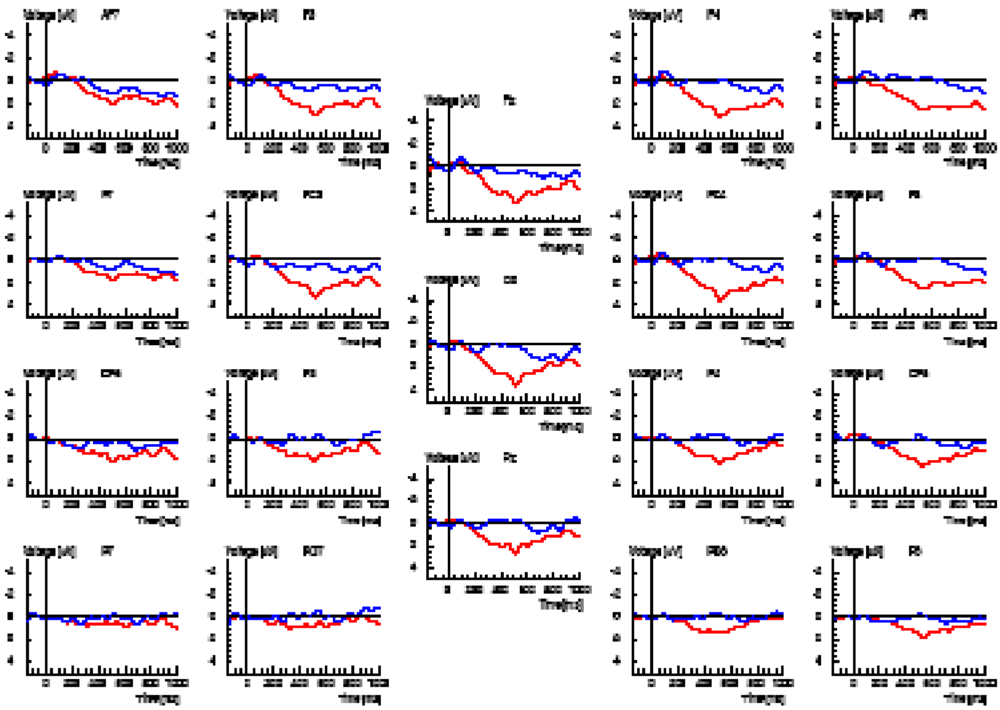

Figure B.2. Grand average waveforms time-locked to the position of the prosodic break for block 2. The red line represents the sentences with and the blue line those without a prosodic break.

Appendix C. Figures of the S-coordinations in the separate blocks

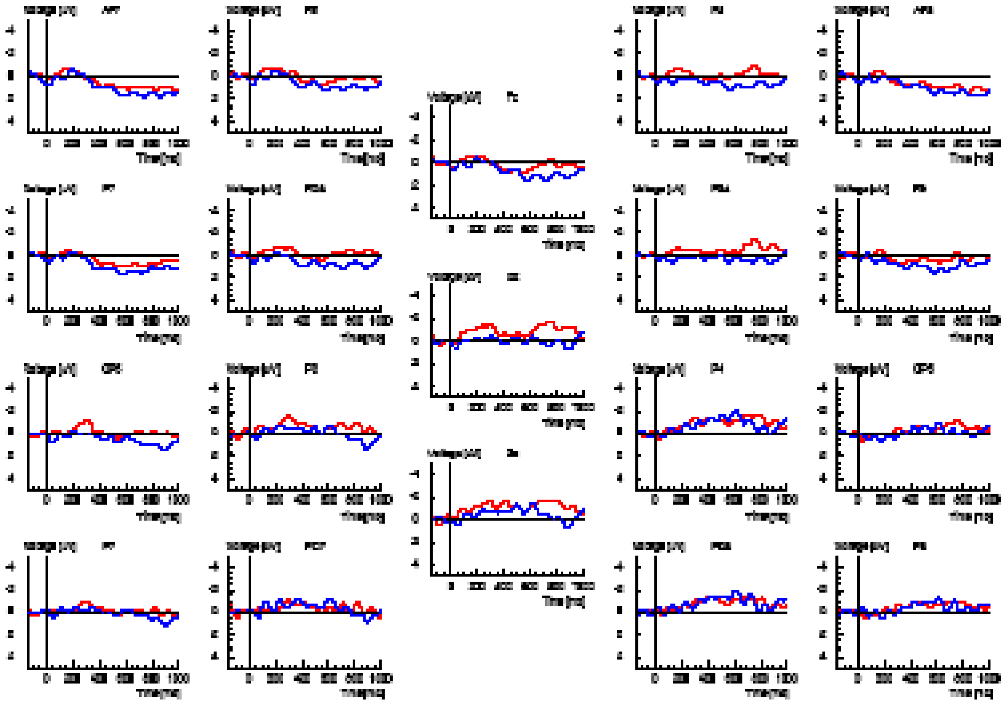

Figure C.1. Grand average waveforms time-locked to the disambiguation point for block 1. The red line represents the S-coordinations with (mismatch) and the blue line those without a prosodic break (match).

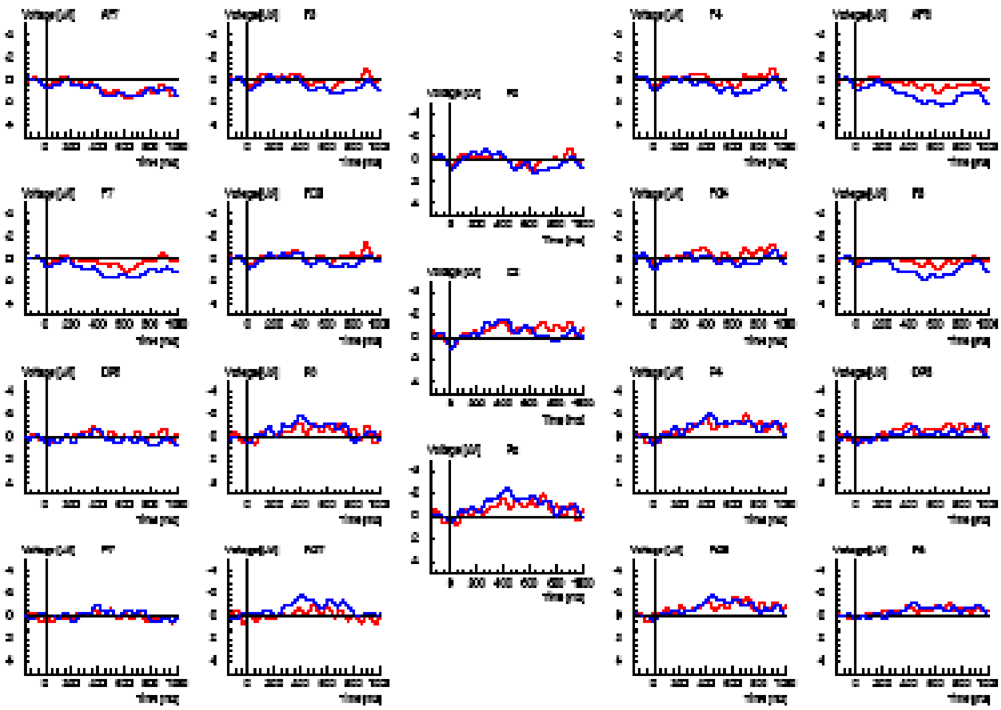

Figure C.2. Grand average waveforms time-locked to the disambiguation point for block 2. The red line represents the S-coordinations with (mismatch) and the blue line those without a prosodic break (match).

Appendix D. Stimulus materials of Experiment 2

All experimental materials of Experiment 2 are given below, without prosodic annotation. All sentences were used with and without a prosodic break in all lists. If a prosodic break occurred in the sentence, it was always placed after the first verb. The sentences are given in pairs. The sentences with an intransitive second verb are always given first and those with a transitive second verb are given second. The same first verb is always used in two sentence pairs. Pairs with the same first verb are placed after each other.

1. De huisarts adviseerde de vrouw te sporten om wat gewicht te verliezen.
2. De huisarts adviseerde de vrouw te motiveren om wat gewicht te verliezen.

3. De chirurg adviseerde de vrouw te slapen voor de ingrijpende operatie.
4. De chirurg adviseerde de vrouw te ondersteunen voor de ingrijpende operatie.

5. De wetenschapper antwoordt de interviewer te zullen triomferen als hij weer een nieuwe ontdekking heeft gedaan.
6. De wetenschapper antwoordt de interviewer te zullen inlichten als hij weer een nieuwe ontdekking heeft gedaan.

7. De secretaresse antwoordde de conciërge te komen om het probleem op te lossen.
8. De secretaresse antwoordde de conciërge te vragen om het probleem op te lossen.

9. De leerling bekende de leraar te hebben gespiekt tijdens het eerste uur.
10. De leerling bekende de leraar te hebben opgesloten tijdens het eerste uur.

11. De man bekende de vrouw te hebben geflirt met haar beste vriendin.
12. De man bekende de vrouw te hebben bedrogen met haar beste vriendin.

13. De voetballer belooft de trainer te excelleren en de beker te winnen.
14. De voetballer belooft de trainer te verblijden en de beker te winnen.

15. De vrouw beloofde de stervende te zullen rouwen en hem eerbiedig te zullen gedenken.
16. De vrouw beloofde de stervende te zullen begraven en hem eerbiedig te zullen gedenken.

17. De generaal bericht de koning te zullen capituleren en te zullen terugkeren naar het vaderland.
18. De generaal bericht de koning te zullen ondersteunen en te zullen terugkeren naar het vaderland.

19. De voorzitter bericht de leden te zullen vertrekken maar niet zonder een daverend afscheidsfeest.
20. De voorzitter bericht de leden te zullen verlaten maar niet zonder een daverend afscheidsfeest.

21. De commandant beval de soldaat te vuren en het lijk op te ruimen.
22. De commandant beval de soldaat te vermoorden en het lijk op te ruimen.

23. De commissaris beval de agent te spioneren om meer van de zaak te weten te komen.
24. De commissaris beval de agent te bespioneren om meer van de zaak te weten te komen.

25. De dief bezweert de handlanger te vechten en niet zomaar de gevangenis in te gaan.
26. De dief bezweert de handlanger te verraden en niet zomaar de gevangenis in te gaan.

27. De minister bezweert de staatssecretaris te zullen strijden tijdens het komende kamerdebat.
28. De minister bezweert de staatssecretaris te zullen benadelen tijdens het komende kamerdebat.

29. De dokter garandeerde de patiënt te zullen zwijgen en de familie niets te vertellen.
30. De dokter garandeerde de patiënt te zullen beschermen en de familie niets te vertellen.

31. De rector garandeerde de lerares te zullen standhouden tegen de boze ouders.
32. De rector garandeerde de lerares te zullen beschermen tegen de boze ouders.

33. De koning gebood de ridder te knielen tijdens het uitbundige overwinningsfeest.
34. De koning gebood de ridder te belonen tijdens het uitbundige overwinningsfeest.
35. De hertogin gebood de chauffeur te

claxonneren omdat er zich een noodgeval had voorgedaan.

36. De hertogin gebood de chauffeur te verwittigen omdat er zich een noodgeval had voorgedaan.

37. De minister gelaste de toehoorder te vertrekken van de publieke tribune.

38. De minister gelaste de toehoorder te verwijderen van de publieke tribune.

39. De rechter gelast de aanwezigen te zwijgen omdat ze de rechtsgang beletten.

40. De rechter gelast de aanwezigen te verwijderen omdat ze de rechtsgang beletten.

41. De verdachte getuigt de agent te hebben geslapen en dus onschuldig te zijn aan de misdaad.

42. De verdachte getuigt de agent te hebben beschermd en dus onschuldig te zijn aan de misdaad.

43. De gedaagde getuigt de rechter te hebben gelogen tijdens de vorige zitting.

44. De gedaagde getuigt de rechter te hebben beledigd tijdens de vorige zitting.

45. De verpleegster hielp de zieke te lopen omdat hij na de behandeling nog te zwak was.

46. De verpleegster hielp de zieke te vervoeren omdat hij na de behandeling nog te zwak was.

47. De bewaker hielp de crimineel te ontsnappen uit de beruchte gevangenis.

48. De bewaker hielp de crimineel te bevrijden uit de beruchte gevangenis.

49. De bankmedewerker ontraadde de klanten te beleggen in dit slechte economische klimaat.

50. De bankmedewerker ontraadde de klanten te benadelen in dit slechte economische klimaat.

51. De chirurg ontraadde de patiënte te ontbijten voor de zware operatie.

52. De chirurg ontraadde de patiënte te vermoeien voor de zware operatie.

53. De actrice smeekte de regisseur te volharden tot na de première van de film.

54. De actrice smeekte de regisseur te behouden tot na de première van de film.

55. De fan smeekte de zanger te komen om op het feest te zingen.

56. De fan smeekte de zanger te boeken om op het feest te zingen.

57. De dictator verbood de burger te liegen tijdens het belangrijke verhoor.

58. De dictator verbood de burger te pijnigen tijdens het belangrijke verhoor.

59. Het schoolhoofd verbood de kinderen te praten tijdens de rekentoets.

60. Het schoolhoofd verbood de kinderen te verontrusten tijdens de rekentoets.

61. De getuige verklaarde de rechter te zullen zwijgen tijdens het proces.

62. De getuige verklaarde de rechter te zullen verrassen tijdens het proces.

63. De minister verklaart de asielzoekers te zullen onderhandelen zodat ze in Nederland kunnen blijven.

64. De minister verklaart de asielzoekers te zullen naturaliseren zodat ze in Nederland kunnen blijven.

65. De directeur verplicht de werknemers te pauzeren als ze te veel fouten maken.

66. De directeur verplicht de werknemers te ontslaan als ze te veel fouten maken.

67. De arts verplicht de zieken te rusten voordat ze een grote ingreep ondergaan.

68. De arts verplicht de zieken te ontsmetten voordat ze een grote ingreep ondergaan.

69. De tennisser vertelde de trainer te hebben gefaald tijdens de vorige wedstrijd.

70. De tennisser vertelde de trainer te hebben geraakt tijdens de vorige wedstrijd.

71. De wielrenner vertelde de pers te rusten omdat hij erg moe was.

72. De wielrenner vertelde de pers te ontlopen omdat hij erg moe was.

73. De vrouw verzekerde de zieke te zullen overnachten in een zaaltje in het ziekenhuis.

74. De vrouw verzekerde de zieke te zullen bezoeken in een zaaltje in het ziekenhuis.

75. De studente verzekerde de docent te zullen feesten als ze haar tentamen zou halen.

76. De studente verzekerde de docent te zullen bedanken als ze haar tentamen zou halen.

77. De chef verzocht de werknemer te

vertrekken omdat het slecht ging met het bedrijf.

78. De chef verzocht de werknemer te ontslaan omdat het slecht ging met het bedrijf.

79. De brandweerman verzoekt de omstanders te wijken om de brandweerauto doorgang te geven.

80. De brandweerman verzoekt de omstanders te verwijderen om de brandweerauto doorgang te geven.

81. Het kind vraagt de oppas te mogen winkelen in de grote stad.

82. Het kind vraagt de oppas te mogen bezoeken in de grote stad.

83. De prinses vraagt de kroonprins te zingen op het publieke feest.

84. De prinses vraagt de kroonprins te inviteren op het publieke feest.

85. De bewoonster waarschuwde de inbreker te zullen schreeuwen als hij dichterbij zou komen.

86. De bewoonster waarschuwde de inbreker te zullen belagen als hij dichterbij zou komen.

87. De advocaat waarschuwde de officier te zullen dwarsliggen tijdens het belangrijke proces.

88. De advocaat waarschuwde de officier te zullen dwarsbomen tijdens het belangrijke proces.

89. De hooligan zei de agent te hebben gescholden tijdens de grote vechtpartij.

90. De hooligan zei de agent te hebben uitgescholden tijdens de grote vechtpartij.

91. De bezoeker zei de clown te hebben gelachen tijdens de circusvoorstelling.

92. De bezoeker zei de clown te hebben gewaardeerd tijdens de circusvoorstelling.

93. De studente zweert de professor te zullen blokken om het tentamen te halen.

94. De studente zweert de professor te zullen omkopen om het tentamen te halen.

95. De heks zweert de dwergen te zullen terugkeren als ze weer genoeg kracht heeft.

96. De heks zweert de dwergen te zullen betoveren als ze weer genoeg kracht heeft.

Appendix E. CPS analyses for the separate blocks in Experiment 2

Table E.1
Overall analyses in the CPS window with the factor Block

Effect	Lateral	Midline	p
Prosodic Break*Block	F(1,27) = 1.25	F(1,27) = 1.03	.86/
Prosodic Break*Block*Midline Electrode		F(2,26) = 1.47	.25
Prosodic Break*Block*Hemisphere (Hem)	F(1,27) = .02		.88
Prosodic Break*Block*ROI	F(1,27) = .48		.50
Prosodic Break*Block*Hem*ROI	F(1,27) = 1.72		.20
Prosodic Break*Block*Electrode (El)	F(3,25) = .36		.78
Prosodic Break*Block*Hem*El	F(3,25) = .23		.88
Prosodic Break*Block*ROI*El	F(3,25) = .65		.59
Prosodic Break*Block*Hem*ROI*El	F(3,25) = .39		.76

*** p < .001, ** p < .01, * p < .05

Table E.2
Separate analyses in the CPS window for the first block

Effect	Lateral	Midline	p
Prosodic Break	F(1,27) = 56.31***	F(1,27) = 32.39***	.0
Prosodic Break*Midline Electrode		F(2,26) = 2.31	.1 2
Prosodic Break*Hemisphere	F(1,27) = 15.78***		.0
Prosodic Break*ROI	F(1,27) = 9.98**		.0
Prosodic Break*Hem*ROI	F(1,27) = .01		.9
Prosodic Break*Electrode (El)	F(3,25) = 13.30***		.0
Prosodic Break*Hem*El	F(3,25) = 1.93		.1
Prosodic Break*ROI*El	F(3,25) = 6.74**		.0
Prosodic Break*Hem*ROI*El	F(3,25) = 1.55		.2

*** p < .001, ** p < .01, * p < .05

Table E.3
Separate analyses in the CPS window for the second block

Effect	Lateral	Midline	p
Prosodic Break	**F(1,27) = 49.20*****	**F(1,27) = 43.49*****	**.0**
Prosodic Break*Midline Electrode		**F(2,26) = 2.72***	**.09**
Prosodic Break*Hemisphere	**F(1,27) = 15.60*****		**.0**
Prosodic Break*ROI	**F(1,27) = 31.71*****		**.0**
Prosodic Break*Hem*ROI	**F(1,27) = 2.68**		**.1**
Prosodic Break*Electrode (El)	**F(3,25) = 9.49*****		**.0**
Prosodic Break*Hem*El	**F(3,25) = 1.60**		**.2**
Prosodic Break*ROI*El	**F(3,25) = 6.45****		**.0**
Prosodic Break*Hem*ROI*El	**F(3,25) = .72**		**.5**

*** p < .001, ** p < .01, * p < .05

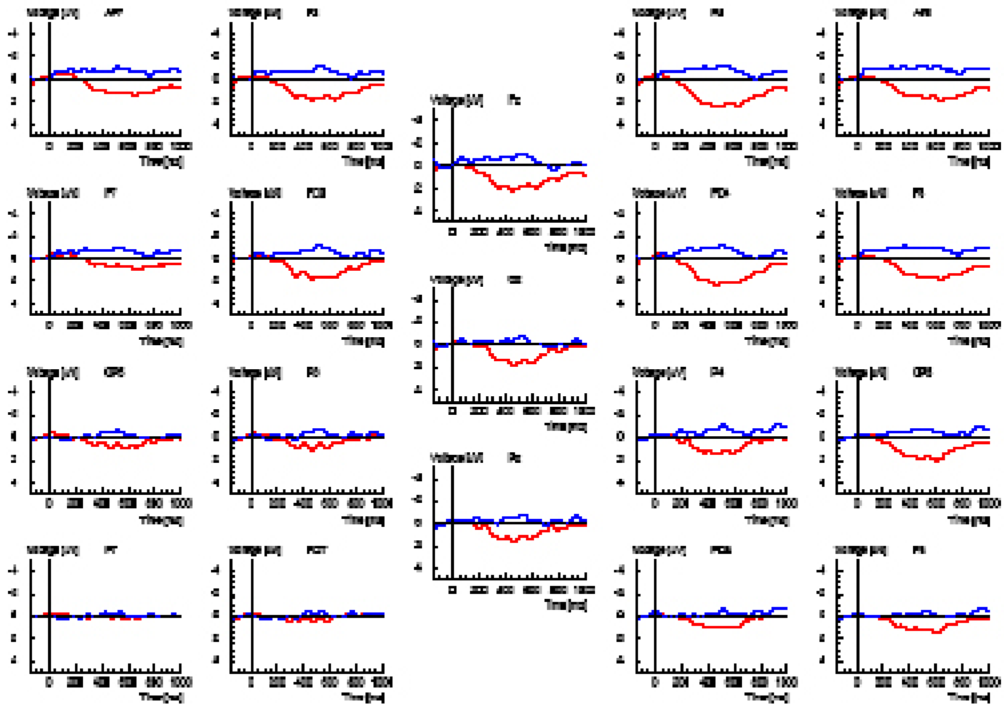

Figure E.1. Grand average waveforms time-locked to the position of the prosodic break for block 1. The red line represents the sentences with and the blue line those without a prosodic break.

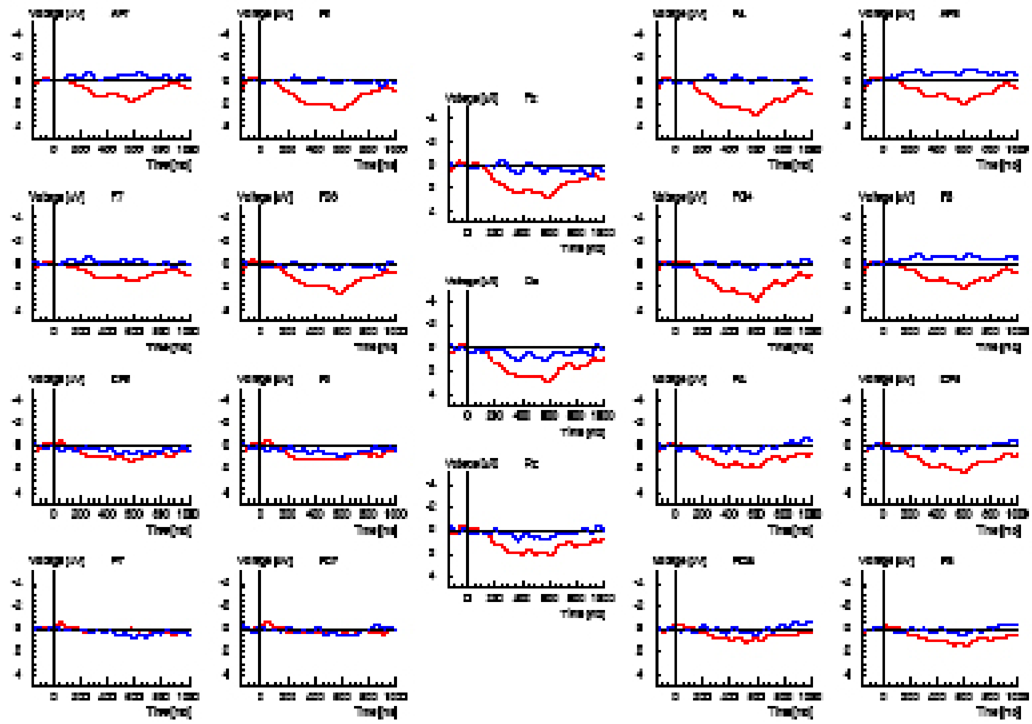

Figure E.2. Grand average waveforms time-locked to the position of the prosodic break for block 2. The red line represents the sentences with and the blue line those without a prosodic break.

Appendix F. Further justification for present comparisons

To gain more evidence for the assumption that the CPS is responsible for the differences between the conditions with and without a prosodic break at the disambiguating verb, we looked at the grand average waveforms at the disambiguating word for all four conditions, presented in Figure A. Visual inspection of this figure suggests that the two No Prosodic Break conditions cluster together as well as the two Prosodic Break conditions. This implies that the factor Prosodic Break is mainly responsible for the differences between the four conditions. To test this, time course analyses were done with the factors Prosodic Break and Structure in which all four conditions were included. The effects are shown in Table A (for the Midline analyses) and B (for the Lateral analyses). Only the effects that extend at least two adjacent time windows of 100 ms are reported.

Table F.1
p-values for the time course analyses of all four conditions: Midline.

Effect	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Prosodic Break (PB)	***	*		**	*	**	**	**		
PB*Structure*Electrode		*	*							

*** p < .001, ** p < .01, * p < .05

Table F.2
p-values for the time course analyses of all four conditions: Lateral.

Effect	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Prosodic Break (PB)	***	*		*		*	**	*		
PB*ROI*Electrode				***	*	**	**	**	**	***
Structure*ROI*Electrode					*	*				
PB*Structure*Item*ROI*Electrode							**	**		

*** p < .001, ** p < .01, * p < .05

As is clear from these tables, the factor Prosodic Break is mainly responsible for the differences between the four conditions at the disambiguating verb and definitely for the very early effects. Furthermore, there was one interaction between Structure, ROI and Electrode from 400 to 600 ms.

Follow-up analyses revealed that an interaction between Structure and Electrode was present in the anterior ($p < .01$), but not in the posterior ROI ($p > .95$). Analyses for the single sites revealed no reliable effects ($ps > .05$). Two effects were found that pointed to an interaction between Prosodic Break and Structure. However, follow-up analyses revealed no interaction effects between Prosodic Break and Structure in any of the electrodes ($ps > .08$).

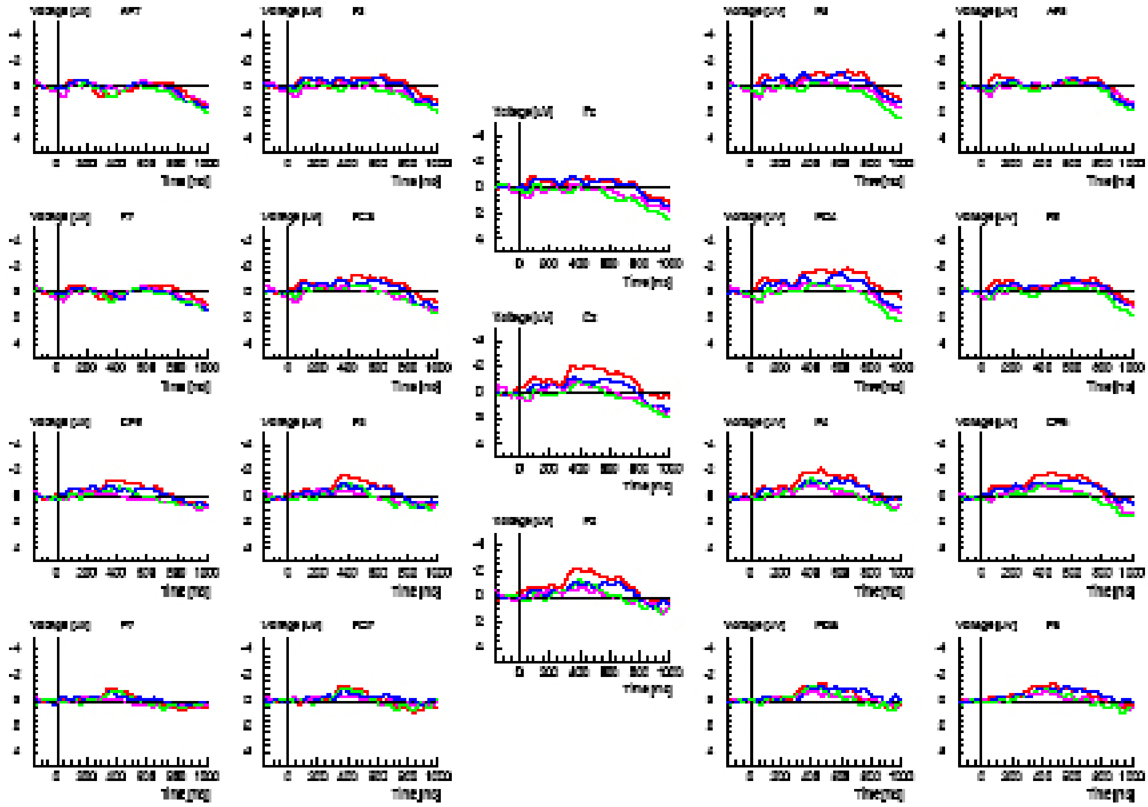

Figure F.1. Grand average waveforms time-locked to the disambiguation point for all conditions in Experiment 2: intransitive sentences with (red line) and without prosodic break (purple line) and transitive sentences with (blue line) and without prosodic break (green line).

Appendix G. Figures of the N400 in the separate blocks

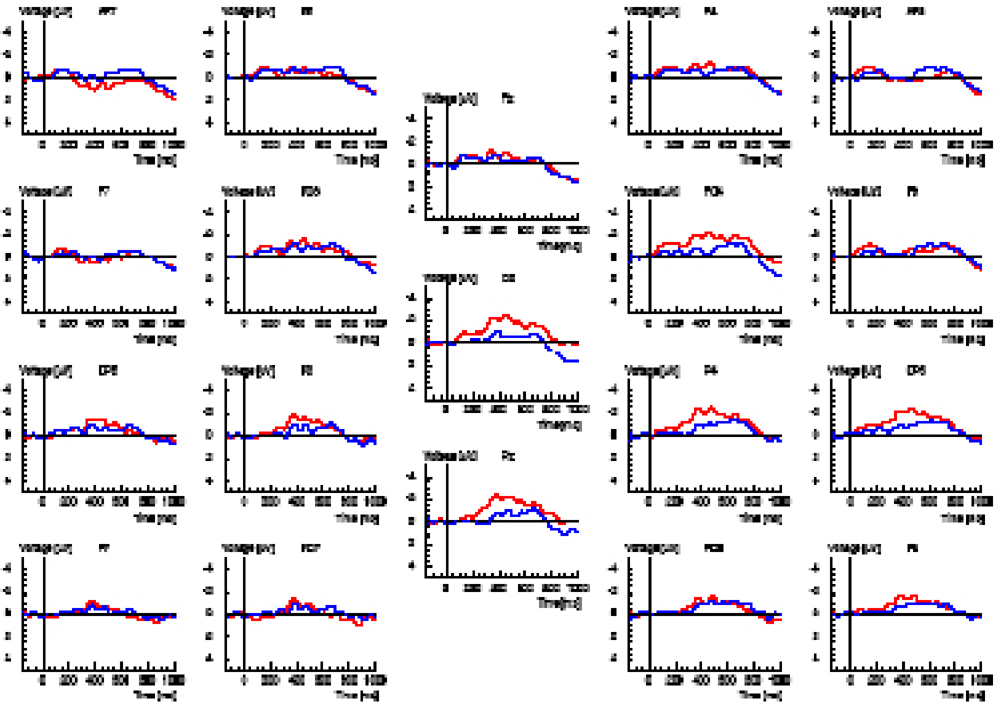

Figure G.1. Grand average waveforms time-locked to the disambiguation point for block 1. The red line represents the intransitive sentences (mismatch) and the blue line the transitive sentences with a prosodic break (match).

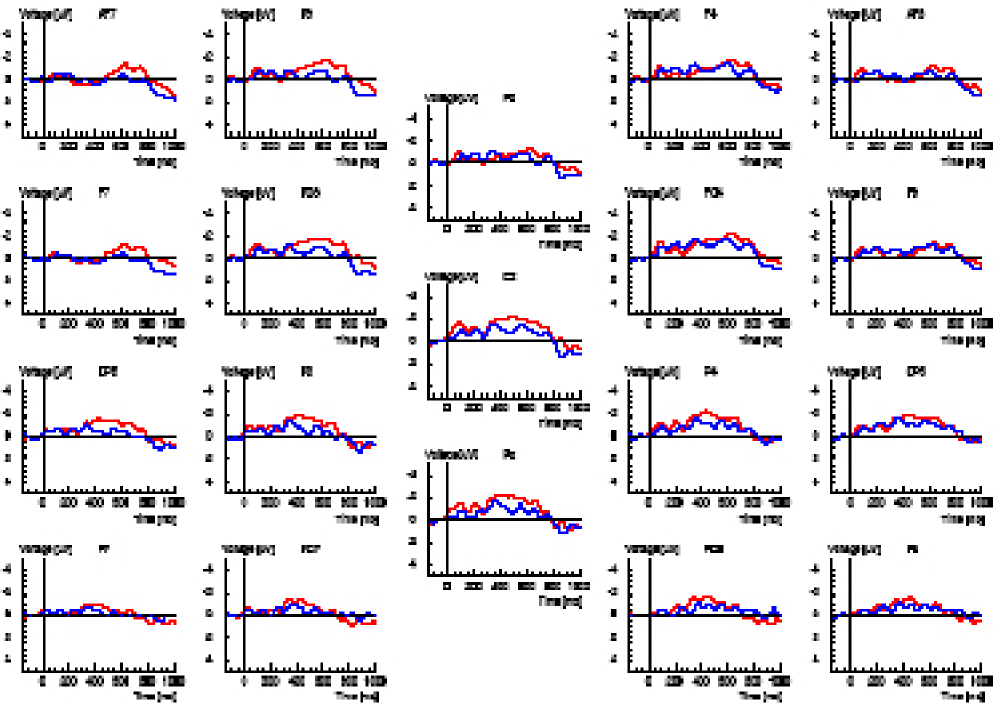

Figure G.2. Grand average waveforms time-locked to the disambiguation point for block 2. The red line represents the intransitive sentences (mismatch) and the blue line the transitive sentences with a prosodic break (match).