

# Processing consequences of superfluous and missing prosodic breaks in auditory sentence comprehension



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## ABSTRACT

This ERP study investigates whether a superfluous prosodic break (i.e., a prosodic break that does not coincide with a syntactic break) has more severe processing consequences during auditory sentence comprehension than a missing prosodic break (i.e., the absence of a prosodic break at the position of a syntactic break). Participants listened to temporarily ambiguous sentences involving a prosody–syntax match or mismatch. The disambiguation of these sentences was always lexical in nature in the present experiment. This contrasts with a related study by Pauker, Itzhak, Baum, and Steinhauer (2011), where the disambiguation was of a lexical type for missing PBs and of a prosodic type for superfluous PBs. Our results converge with those of Pauker et al. (2011): superfluous prosodic breaks lead to more severe processing problems than missing prosodic breaks. Importantly, the present results extend those of Pauker et al. (2011) showing that this holds when the disambiguation is always lexical in nature. Furthermore, our results show that the way listeners use prosody can change over the course of the experiment which bears consequences for future studies.

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## 1. Introduction

To understand a sentence, listeners have to construct a representation of the syntactic and semantic structure of the sentence. To derive this representation, they need information about which words belong to the same syntactic constituent and which words belong to different syntactic constituents. In the auditory modality, a prosodic break (PB) or prosodic boundary can provide helpful information in this respect. A PB is usually realized as a pause in the speech signal, preceded by articulatory lengthening of the word preceding the pause and a boundary tone on this word. ERP research on the role of prosody in auditory sentence comprehension is still relatively scarce. The available ERP research has shown that listeners take a PB as an indication of a syntactic break in a sentence, that is, the position where a new syntactic constituent starts (e.g., Bögels, Schriefers, Vonk, & Chwilla, 2011a; Bögels, Schriefers, Vonk, Chwilla, & Kerkhofs, 2010; Steinhauer, Alter, & Friederici, 1999; see Bögels, Schriefers, Vonk, & Chwilla, 2011b, for a review of ERP studies on the role of PBs in sentence processing). Conversely, one could hypothesize that the absence of a PB can indicate the opposite, a possibility that has been studied much less. When no PB is present (i.e., no pause, lengthening,

or boundary tone, but rather normal pitch accents on the content words), listeners might infer that the syntactic constituent is not yet completed, that is, the absence of a PB would signal syntactic cohesion (see Cutler, Dahan, & van Donselaar, 1997, p. 169). The present study investigates the relative processing consequences of the presence versus absence of a PB, and is in this respect similar to a recent study by Pauker, Itzhak, Baum, and Steinhauer (2011).

Pauker et al. (2011) propose the Boundary Deletion Hypothesis. According to this hypothesis, the presence of a PB is a stronger cue than the absence of a PB. As Pauker et al. (2011) argue, it is costly to mentally delete a PB from the sentence when it turns out not to coincide with a syntactic break. By contrast, it should be less costly to mentally insert a PB into a certain position in the sentence, when this position turns out to correspond with a syntactic break. According to Pauker et al. (2011), this might be the case because a PB is a rather salient prosodic cue, and it would therefore be hard for a listener to imagine it to be produced 'by mistake'. Conversely, it would be more likely that a listener considers the absence of a PB as a potential PB that has not been produced to its full extent. The Boundary Deletion Hypothesis thereby assumes a prosodic repair of the sentence (mentally deleting or inserting a PB) after the prosody–syntax mismatch has been noticed. In the present paper we will stick to the term Boundary Deletion Hypothesis. However, we would like to stress that, with using this term, we do not imply any commitment as to the type of revision that is needed in the case of a superfluous (or missing) PB (i.e., whether

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the revision takes place at the prosodic level, as proposed by Pauker et al., 2011, or, for example, at the syntactic level).

Pauker et al. (2011) used sentences with a late versus early closure ambiguity, as in examples (1) and (2) (a PB is indicated by #).

- (1) When a bear is approaching the people # the dogs come running.
- (2) When a bear is approaching # the people come running.

These sentences are syntactically ambiguous up to *the people*. In (1), *the people* is the direct object of *approaching*. This is called a 'late closure' analysis because the current constituent (i.e., the verb phrase *is approaching*) is left open to incorporate *the people* as the verb's direct object. Reading studies have shown that this is the preferred syntactic analysis of these sentences (e.g., Kjelgaard & Speer, 1999). In contrast, in (2) the verb phrase is closed early ('early closure') and *the people* is the subject of a new clause, starting a new syntactic constituent. These different syntactic structures can be indicated by PBs at different places. In (1) and (2), the PB coincides with a syntactic break.

Via cross-splicing, Pauker et al. (2011) also created sentences like (3) and (4).

- (3) When a bear is approaching the people come running.
- (4) When a bear is approaching # the people # the dogs come running.

According to Pauker et al. (2011), sentences without PBs like (3), where a PB is missing after *approaching*, require listeners to mentally insert a PB in retrospect (i.e., when hearing *come*). Sentences with two PBs like (4), of which one is superfluous (the PB after *approaching*), require listeners to mentally delete this PB. Thus, sentences like (4) should lead to more severe processing difficulties than sentences like (3). Note that in (3) and (4) the late closure preference works against this prediction, since this preference is in accordance with the eventual disambiguation in (4) and not with the disambiguation in (3). Despite this fact, the results of Pauker et al. (2011) support the Boundary Deletion Hypothesis. In (4) as compared to (1), the ERPs yielded a biphasic N400/P600 pattern. These effects were observed at *the people*. In (3) as compared to (2), an apparently smaller P600 effect was elicited at the disambiguating verb (*come*) but no N400 effect was observed. Next to the ERP results, an acceptability judgment task administered during the EEG experiment, showed that sentences with a superfluous PB (like (4)) were judged less acceptable than sentences with a missing PB (like (3)); but both were judged less acceptable than (1) and (2)). From these results, the authors conclude that mentally deleting a PB is indeed more costly than mentally inserting one.

However, a potential confound of this study is that these effects are elicited by different types of events. The P600 effect in (3) is elicited by the lexical disambiguation of the sentence (*come*), which reveals the syntactic structure (*the people* starts a new clause). In contrast, the biphasic effect in (4) is not elicited by the lexical disambiguation of the sentence (*the dogs*), but earlier, by *the people*. Since *the people* contains information about the upcoming second PB (lengthening and a boundary tone), the biphasic effect in (4) appears to be elicited by a prosodic disambiguation. According to Pauker et al. (2011), at this point *the people* was prosodically separated from both the preceding verb and the subsequent clause and therefore could not receive a theta role, leading to the N400 effect (p. 2748). Alternatively, two PBs this close after each other might sound like a prosodic anomaly. In any case, sentences (3) and (4) are disambiguated by different types of information: lexical information in (3) and prosodic information

in (4). This might have had an influence on the strength and/or type of the processing difficulty.

Thus, it is an open issue whether these results also hold if the disambiguation in both cases is similar in nature. The present study addresses this question by using an early versus late closure ambiguity,<sup>1</sup> which is always disambiguated in a lexical way. The materials were adopted from an ERP study by Kerkhofs, Vonk, Schriefers, and Chwilla (2008) See sentences (5) to (7) for examples.

- (5) The traveler followed the carrier and the guide through the mountain-like area.
- (6) The model kissed the designer and the photographer took a bottle of champagne.
- (7) The model kissed the designer # and the photographer took a bottle of champagne.

In (5), the third NP *the guide* is coordinated by *and* with the preceding NP, *the carrier*. Together, the two NPs form a complex NP which is the direct object of *followed* (hereafter referred to as NP-coordination). This becomes clear when the listener encounters the prepositional phrase (*through...*). Sentences (6) and (7) contain words of the same syntactic categories as (5) up to and including the third NP. However, in (6) and (7) the third NP *the photographer* is the subject of a new sentence, coordinated with the preceding sentence by *and* (hereafter referred to as S-coordination). This becomes clear at the verb (*took*) following the third NP (*the photographer*). Reading studies (e.g., Hoeks, Vonk, & Schriefers, 2002) have shown that the NP-coordination analysis in (5) (late closure) is the preferred analysis. However, a PB between the second and third NP (as in (7), between *the designer* and *the photographer*) can indicate a syntactic break, acting against the late closure preference. Kerkhofs et al. (2008) focused on S-coordination sentences with a PB, like (7), and without a PB, like (6) (including NP-coordination sentences like (5), without a PB, only as filler sentences). S-coordination sentences with a missing PB (6) led to processing difficulties at the disambiguating verb (*took*) relative to the same sentences with a PB after the second NP (*the designer*) (7). These difficulties took a different form in the first and second half of the experiment; a Left Anterior Negativity (LAN) effect was found in the first half of the experiment and a P600 effect in the second half.

In the present study, we use the same locally ambiguous constructions as Kerkhofs et al. (2008). Like these authors, we compare S-coordination sentences with a missing PB as in (6), with S-coordination sentences with a PB as in (7). However, in the present study, we also compare NP-coordination sentences with a superfluous PB as in (8), with NP-coordination sentences without a PB as in (5).

- (8) The traveler followed the carrier # and the guide through the mountain-like area.

Put differently, in the present study, the presence or absence of a PB is fully crossed with the eventual disambiguation (as an NP-coordination or as an S-coordination). In our experiment, as in the examples given above, we used different sets of sentences for the NP-coordination and the S-coordination conditions. This made it easier (a) to create sentences that fit the NP- or S-coordination

<sup>1</sup> We believe the described ambiguity can be accounted for both by the late closure principle and the minimal attachment principle of the garden path model (Frazier, 1987). See also Pauker et al. (2011), note 3, for a similar account for a different type of locally ambiguous sentences. For simplicity, we refer to the ambiguities described here as late/early closure ambiguities.

frame in a natural way and (b) to avoid repetition of the same sentence in different conditions within a participant.

Sentences (5)–(8) are all disambiguated by the lexical item following the third NP. The Boundary Deletion Hypothesis (Pauker et al., 2011) makes the following predictions at the disambiguation. For NP-coordination sentences, a sentence like (8) with a superfluous PB, should lead to (substantial) processing difficulties as compared to (5) at the disambiguating prepositional phrase (*through the mountain-like area*). In contrast, in S-coordination sentences, a sentence like (6), with a missing PB, should show less severe processing difficulties at the disambiguating verb (*took*) as compared to (7). The specific ERP signatures of the processing difficulties are hard to predict, given the differences in the results of previous studies. Likely candidates are a biphasic N400/P600 effect (Pauker et al., 2011), only a P600 effect (Kerkhofs et al., 2008; Pauker et al., 2011), and/or a LAN effect (Kerkhofs et al., 2008). Because Kerkhofs et al. (2008) found different effects in the first and second half of their experiment, we ensured that the first and second half of the present experiment each contain a full design and can thus be analyzed separately.

In summary, the present study provides a test of the Boundary Deletion Hypothesis (Pauker et al., 2011) using a local early/late closure ambiguity. The preference for late closure may make processing easier at the disambiguation for sentences with a superfluous PB and harder for sentences with a missing PB. In this respect, the syntactic preference works against the predictions of the hypothesis (as in Pauker et al., 2011). In the present study, we test this hypothesis with a disambiguation that is always carried by lexical items (a prepositional phrase or a verb phrase). The main test of the hypothesis concerns the ERP data at the disambiguation. Within the ERP-study, we did not administer any explicit behavioral test (in contrast to Pauker et al., 2011), as we did not want to focus our listeners' attention too much on the prosodic anomalies. However, to be able to see whether the ERP results are backed up by behavioral data, we performed a behavioral pre-test of the materials (see Section 2).

In previous ERP studies investigating PBs, a very robust ERP response to the PB itself was found, the Closure Positive Shift (CPS; Steinhauer et al., 1999). In the present study, we expect to find a CPS in response to sentences with a PB, indicating that listeners process the PB during online sentence comprehension. However, as the CPS per se is not central to the present study, we will touch only briefly on this topic.

## 2. Methods

### 2.1. Participants

Thirty-six right-handed native speakers of Dutch, with no hearing problems, participated in the experiment. Eight participants were excluded from the analysis due to excessive artifacts. The remaining participants (5 male and 23 female) had a mean age of 21.7. The participants were paid or received course credit for their participation.

### 2.2. Materials

As a starting point, 60 NP-coordination and 60 S-coordination sentences were taken from an earlier experiment (Kerkhofs, Vonk, Schriefers, & Chwilla, 2007); see Table 1 for examples and Appendix A for the complete set of materials. These are hereafter referred to as the original NP- and S-coordination sentences. 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. 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. In the same way, an NP-coordination sentence was constructed for each original S-coordination sentence.

These 60 original NP-, 60 constructed S-, 60 original S-, and 60 constructed NP-coordination sentences were then recorded by a female native speaker of Dutch. She was instructed to first read each sentence silently for herself and then to read it out loud.

Each of the 60 original NP-coordination sentences was recorded twice without a PB. The corresponding constructed S-coordination sentences were recorded once with a PB between the second NP and *en* ('and'). To create the NP-coordination sentences with a PB (condition A in Table 1), the middle parts of the constructed S-coordination sentences with a PB (the first and second NP; *de drager # en de gids*) were cross-spliced over the corresponding parts of one token of the original NP-coordination sentences, the so-called template sentence. To create the NP-coordination sentences without a PB (condition B in Table 1), the middle parts of the other token of the recorded NP-coordination sentences without a PB (*de drager en de gids*) were cross-spliced over the corresponding parts of the template sentences. This resulted in 60 NP-coordination sentences with a (superfluous) PB (condition A) and 60 NP-coordination sentences without a PB (condition B), which were all cross-spliced. These two sets only differed in the middle part (*de drager # en de gids* versus *de drager en de gids*) and otherwise consisted of identical tokens.

The 60 original S-coordination sentences were recorded once without a PB, to serve as template sentences, and once with a PB. The corresponding 60 constructed NP-coordination sentences were recorded without a PB. The experimental S-coordination sentences with a PB (condition C in Table 1), were created by cross-splicing the middle parts of the S-coordination sentences with a PB (*de ontwerper # en de fotograaf*) over the corresponding parts of the template sentences. To create the S-coordination sentences without a PB (condition D in Table 1), the middle parts of the constructed NP-coordination sentences without a PB (*de ontwerper en de fotograaf*) were cross-spliced over the corresponding parts of the template sentences. This resulted in 60 S-coordination sentences without a PB (missing PB, condition C) and 60 S-coordination sentences with a PB (condition D), which were all cross-spliced. These two sets only differed in the middle part (*de ontwerper en de fotograaf* versus *de ontwerper # en de fotograaf*) and otherwise consisted of identical tokens.

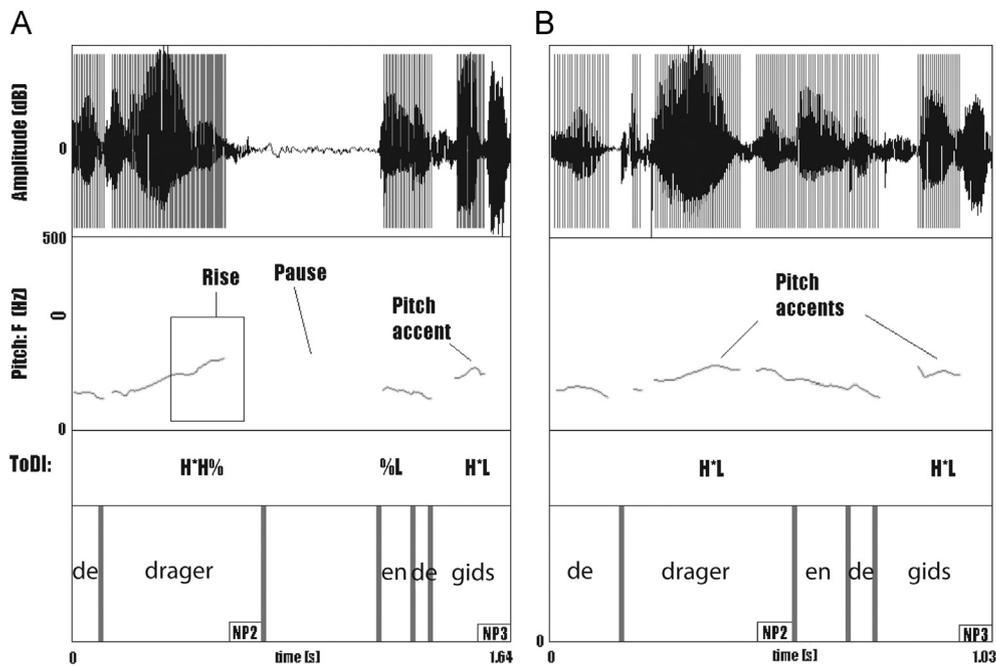
Acoustic analyses of the experimental sentences showed that the sentences with and without a PB clearly differed from each other. In Fig. 1, the features of the two types of sentence are indicated in the speech signal for the middle part of two example sentences. The prosodic structure of these sentence parts was transcribed using the ToDI system (Gussenhoven, 2004). Sentences without a PB did not contain a pause, but contained normal pitch accents on the second and third NP of the sentence (see Fig. 1, panel B). Sentences with a PB contained a pause between the second NP and *en* (and;  $M=312$  ms for NP-coordination sentences;  $M=326$  ms for S-coordination sentences), preceded by a pitch rise on the (last syllables of the) second NP (see Fig. 1, panel A). Furthermore, this second NP also contained prefinal lengthening. In NP-coordination sentences with a PB, it lasted 582 ms on average, compared to 477 ms in sentences without a PB ( $t(59)=11.71$ ,  $p<.001$ ). In S-coordination sentences with a PB, this second NP lasted 544 ms on average, compared to 450 ms in sentences without a PB ( $t(59)=18.5$ ,  $p<.01$ ).

For the behavioral pre-test of the materials, we asked 6 participants (1 male and 5 female) to rate the critical sentences on how natural they sounded on a scale from 1 to 5. We used two lists with the same order (3 participants per list), but the conditions were switched (see Section 2.3). Afterwards, all participants reported they had noticed that the sentences were different with respect to pauses and phrasing. The results replicate the behavioral results by Pauker et al. (2011). The sentences with a match of prosody and syntax were judged most natural

**Table 1**

Example of an experimental sentence in each of the four conditions. PBs are indicated by a #. Cross-spliced parts are underlined.

A	NP-coordination PB	De reiziger volgde <u>de drager # en de gids</u> door het bergachtige gebied waar ze doorheen moesten. <i>The traveler followed <u>the carrier # and the guide</u> through the mountain-like area which they had to cross.</i>
B	NP-coordination no PB	De reiziger volgde <u>de drager en de gids</u> door het bergachtige gebied waar ze doorheen moesten. <i>The traveler followed <u>the carrier and the guide</u> through the mountain-like area which they had to cross.</i>
C	S-coordination no PB	De mannequin kuste <u>de ontwerper en de fotograaf</u> pakte vrolijk een fles bruisende champagne en wat kaviaar. <i>The model kissed <u>the designer and the photographer</u> took merrily a bottle of bubbling champagne and some caviar.</i>
D	S-coordination PB	De mannequin kuste <u>de ontwerper # en de fotograaf</u> pakte vrolijk een fles bruisende champagne en wat kaviaar. <i>The model kissed <u>the designer # and the photographer</u> took merrily a bottle of bubbling champagne and some caviar.</i>



**Fig. 1.** Waveforms, intonation contours, and ToDI transcriptions of parts of two example sentences (see Table 1). Panel A shows a part of a sentence with a PB, with an H\* pitch accent on 'de drager', followed by a high boundary tone (H%) before the pause, a low boundary tone (%L) after the pause, and an H'L pitch accent on 'de gids'. Panel B shows a part of a sentence without a PB, without a pause and with H\*L pitch accents on 'de drager' and 'de gids'.

(NP without PB:  $M=4.23$ ,  $SD=.53$ ; S with PB:  $M=4.59$ ,  $SD=.21$ ) and these judgments did not differ from each other ( $t(5)=-1.70$ ,  $p=.15$ ). The prosody-syntax mismatch sentences with a missing PB (S-coordination) were judged less natural ( $M=3.33$ ,  $SD=1.00$ ) and those with a superfluous PB were judged least natural ( $M=2.18$ ,  $SD=.80$ ). The latter two conditions differed from each other ( $t(5)=-2.91$ ,  $p=.035$ ) and from the two prosody-syntax match conditions ( $ps < .05$ ).

### 2.3. Design

The experiment had a fully crossed two factor design with the factors PB (PB/no PB; within items) and Structure (S-/NP-coordination; between items), resulting in four conditions. Four lists of experimental items were created. Each of the four lists was used for one fourth of the participants. The first half of list 1 contained 15 of the 60 S-coordination and 15 of the 60 NP-coordination sentences with a PB, and 15 different S-coordination and NP-coordination sentences without a PB. The second half of list 1 contained another 15 of the 60 S-coordination and NP-coordination sentences with a PB and 15 S- and NP-coordination sentences without a PB. List 2 contained the same items in the same order as list 1, but sentences with a PB in list 1 appeared without a PB in list 2 and vice versa. As a result, the two lists together formed a complete design. Lists 3 and 4 were constructed to make sure that the two halves of the experiment also comprised a complete design. To that end, lists 3 and 4 were created by switching the two halves of lists 1 and 2, respectively. Thus, in both halves, across participants, every item occurred equally often in each condition. At the same time, each participant saw every item in only one condition. Within each list, we used a pseudorandom order, so that every condition on average occurred at the same position in each half of each list.

The 120 experimental sentences in each list were combined with 192 filler sentences with a different type of local ambiguity (see Bögels et al., 2010) to a total of 312 sentences. For each list, a pseudorandom order of the experimental and filler sentences was determined with the restriction that no more than two experimental trials appeared 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 had the same structure as the experimental sentences and one had the same structure as the filler sentences.

### 2.4. Procedure

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 ms. The sentence started 500 ms 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 end of each 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 a block of 54 sentences, participants were presented with a sentence recognition task. Two sentences were given on a piece of paper, and the participant had to decide which of these had appeared in the previous block. The sentences for this recognition task were constructed such that both had the same structure as the items in the experiment but only one had occurred in the previous block. This task was given to ensure that the participants paid attention to the experimental sentences. We did not use a behavioral acceptability judgment task during the EEG experiment, in order to avoid drawing our participants' attention to the prosodic manipulation.

### 2.5. Apparatus

The EEG was recorded from 25 tin electrodes. The electrode positions were a subset of the international 10% system, including 3 midline electrodes (Fz, Cz, and Pz) and 22 lateral electrodes (AF7/8, FT7/8, F7/8, F3/4, FC3/4, T7/8, C3/4, CP5/6, P7/8, P3/4, and PO7/8). This electrode montage has been used in earlier auditory ERP studies (e.g., Kerkhofs et al., 2007). 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 k $\Omega$  for the EOG-electrodes and below 3 k $\Omega$  for all other electrodes. EEG and EOG signals were amplified with a time constant of 8 s and a band pass filter of .05 to 100 Hz and digitized with a 16-bit A/D converter at a sampling frequency of 500 Hz.

### 2.6. 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 (PB), used to quantify the CPS, was the onset of the stressed syllable of the second NP, which was the word before the pause in the PB conditions (see Bögels et al., 2010 for a comparison of different time-locking points to quantify the CPS). The second critical position (disambiguating word) was the onset of the disambiguating element (verb in the S-coordination sentences, preposition in the NP-coordination sentences). A period of 150 ms before the critical position was used as a baseline. Trials with excessive EEG ( $> 100 \mu\text{V}$ ) and EOG amplitude ( $> 75 \mu\text{V}$ ) in the period from 150 ms before until 1000 ms after the critical position (or until 2000 ms for the time-locking point PB), were excluded from analysis. For the time-locking point at the disambiguating word, a mean of 1 item (of a total of 30 items) was removed per condition (range: 0–4 items). For the time-locking point PB, a mean of 8 items (of a total of 60 items) was removed per condition (range: 0–24 items). Within the

same time-locking point, the number of removed trials did not differ significantly between conditions.

On these preprocessed data, statistical analyses were performed. To analyze the CPS, we used an 800–1200 ms window as in an earlier study (Bögels et al., 2010). Since we did not have specific predictions for components at the disambiguation, we performed time-course analyses of consecutive 100-ms epochs for this time-locking point. Based on visual inspection, the analyses were conducted from 500 to 1000 ms.

For the time-locking point PB, we collapsed the NP- and S-coordination sentences. The critical factor for these analyses was PB (PB, no PB). At the disambiguating word, we instead used the factor Match, consisting of the levels match (NP-coordination without PB and S-coordination with PB) and mismatch (NP-coordination with PB and S-coordination without PB). We also included the factor Structure (S, NP) in the analyses, to be able to contrast the effect of the factor Match for S- and NP-coordination sentences. Since previous research has shown that ERP responses to prosodic manipulations can change over the course of an experiment (see Section 1: Kerkhofs et al., 2008; see Bögels et al., 2011b for a more extensive discussion), we argue that it is necessary to consider potential changes in the course of an experiment, presumably caused by changing strategies of participants. Especially when no specific task is used that could focus participants on the experimental prosodic manipulation and thus force them to process this information throughout the experiment, participants can adapt their strategies to the stimuli in the experiment. Therefore, we designed the experiment including two full designs for each of the two halves (see Section 2) and included the factor Half (first half, second half of experiment). Since we are only interested in effects of Match and how these effects differ with respect to the other variables, we only report effects including the critical factor Match (or PB in case of the CPS analyses).

The MANOVA for the midline electrodes included the factor Midline Electrode (Fz, Cz, Pz) next to the critical factor(s). The MANOVA for the lateral electrodes included the factors Hemisphere (left, right), Region of Interest or ROI (anterior, posterior), and Electrode next to the critical factor(s). 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, and FC4) and right posterior (P4, CP6, P8, and PO8). Three additional electrodes on either hemisphere (left: FT7, T7, and C3; right: FT8, T8, and C4) were not included in the overall analyses. For completeness, we include these electrodes in the figures and report significant effects for these electrodes, if present.

## 3. Results

### 3.1. Sentence recognition test

The results of the sentence recognition test showed that participants attentively listened to the sentences. Of the 28 participants, 26 participants identified the correct sentence in all cases and the other two participants made only one error.

### 3.2. Prosodic break

In Appendix B, we present the grand average waveforms for the sentences with and without a PB (Fig. B1) and the statistical analyses of the CPS (Table B1). A large and broadly distributed CPS was present for the sentences with a PB relative to the sentences without a PB. The CPS appeared to be somewhat larger over the right hemisphere. Furthermore, a hint of a small negativity preceding the CPS was found for a few electrodes on the right hemisphere.

### 3.3. Disambiguation

Figs. 2 and 3 present grand average waveforms time-locked to the onset of the disambiguating element, for the two halves of the experiment separately (first half in panels A and second half in panels B). Fig. 2 presents the NP-coordination sentences containing a prosody–syntax match (no PB, dotted line) and a mismatch (superfluous PB, solid line). Fig. 3 presents the S-coordination sentences with a match (with a PB, dotted line) and with a mismatch (missing PB, solid line). Visual inspection suggests differences between conditions starting around 500 ms, mostly positivities for the mismatch conditions. In the following, we will refer to these late positive effects as P600-like effects, given the time window of the effects and the fact that the waveforms are

more positive for mismatch sentences. However, one could argue that, for the NP-coordination sentences in the first half of the experiment (Fig. 2, panel A), the waveforms for match sentences appear to be going in the negative direction, showing an effect in the opposite direction as a P600. We will come back to this issue in Section 4.

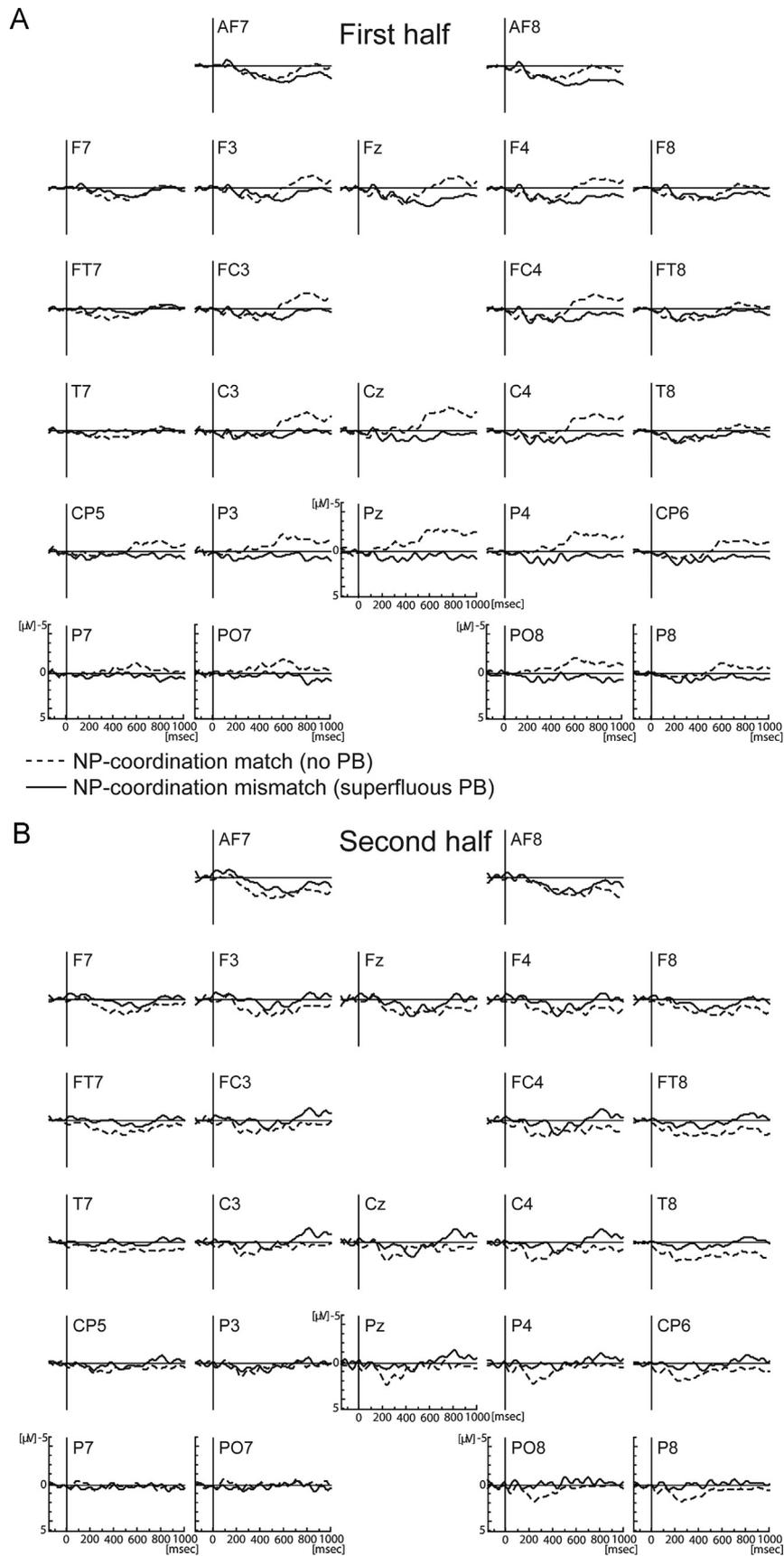
On the basis of this observation, we analyzed 5 consecutive 100 ms windows between 500 and 1000 ms. In Table 2, *F* and *p* values are reported for the analyses of the 5 time windows. For readability, we do not report *F* and *p* values in the text since they are reported in Table 2. We first performed overall analyses with the critical factors Match, Structure, and Half. For clarity, we report these and follow-up analyses separately for the 500–600 and the 600–1000 ms windows as the early 500–600 ms and the remaining time windows differ in the overall pattern of results.

#### 3.3.1. 500–600 ms window

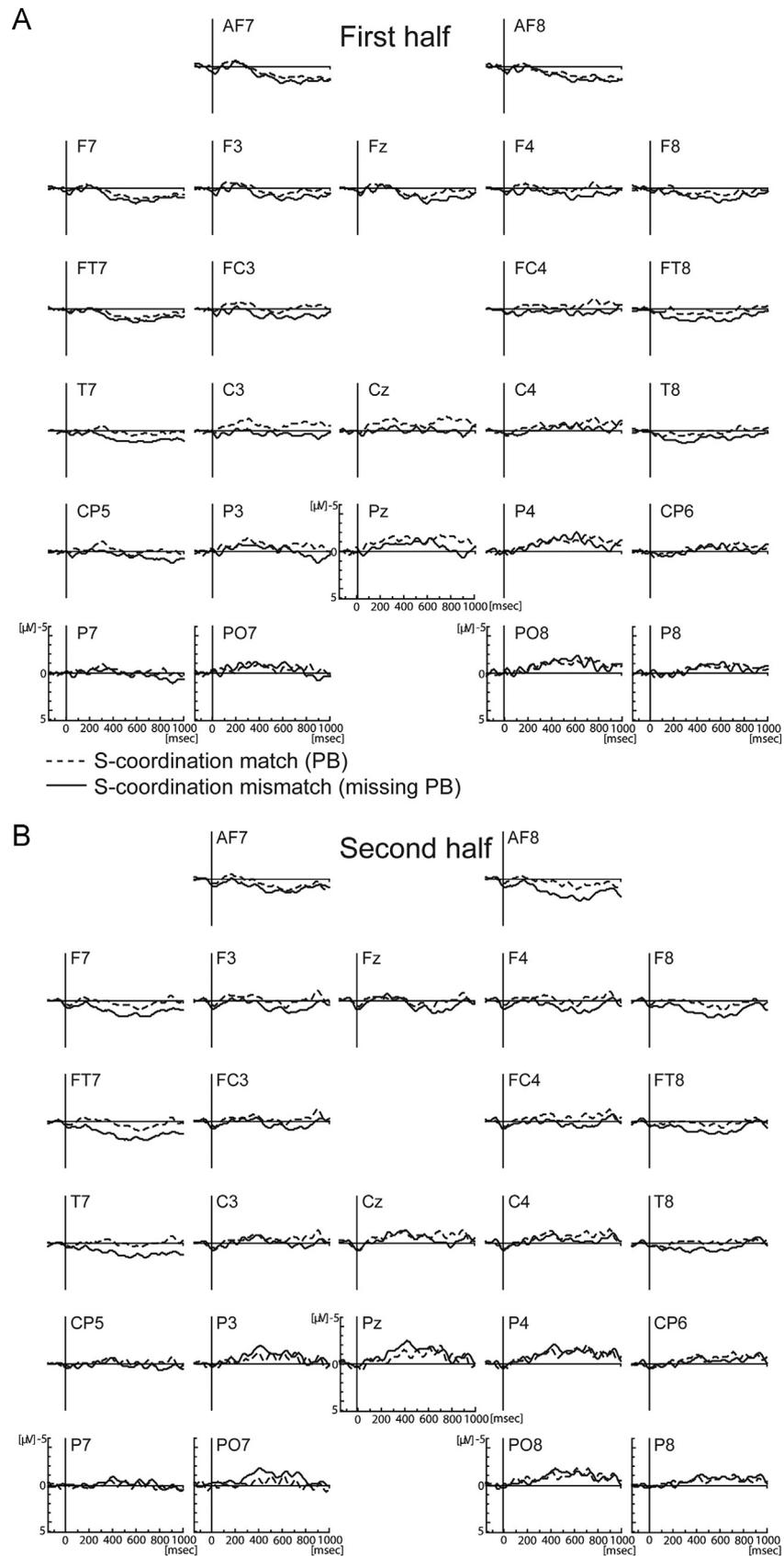
Between 500 and 600 ms, the overall lateral analysis yielded interactions between Match, Structure, and ROI and between Match, Structure, ROI, and Electrode. These interactions were qualified by another interaction including all three critical factors, an interaction between Match, Half, Structure, Hemisphere, ROI, and Electrode, which was just significant ( $p=.05$ ).<sup>2</sup> Since both the factors Hemisphere and ROI were involved, we followed-up this interaction by separate overall analyses (including all three critical factors) for the 4 separate quadrants. These showed a 3-way interaction between Match, Half, and Structure for the right posterior region only. Based on this interaction, we did separate analyses for the first and second half of the experiment for the right posterior region, including the factors Match and Structure. A Match by Structure interaction was found in the first half. Separate analyses in the right posterior quadrant for the two structures in the first half revealed more positive going waveforms for the mismatch as compared to the match condition for NP-coordination sentences, but no such effect for S-coordination sentences. The analysis for the right posterior region in the second half did not show any interactions between Match and Structure. Thus, in the first half of the experiment, a P600 like effect on the right posterior part of the scalp was already present between 500 and 600 ms for sentences with superfluous PBs but not for sentences with missing PBs.

One could argue that a long-lasting CPS (possibly still present in the baseline of the disambiguation time-locking point) might have influenced the P600-like effects in the NP- and S-coordination sentences differently, contributing to the difference found here in the 500–600 ms time window. To get a closer look at this possibility, we measured the time elapsing between the time-locking point used for the CPS (onset of the last stressed syllable before the pause) and the time locking point for the disambiguation. For sentences with a PB, this amounts to 1484 ms for the NP-coordination sentences and 1418 ms for the S-coordination sentences on average. Looking at Fig. B1 of the CPS (Appendix B), the CPS appears to be back to baseline around 1400 ms after the time-locking point for the CPS (zero point in Fig. B1). Moreover, even if the CPS would still be ongoing around the time of the baseline window of the disambiguation, it would be clearly past its peak (which lies around 1000 ms) and should go into the negative direction, returning back to baseline. Thus, for the NP-coordination sentences, the mismatch condition (with PB) would have a negative-going trend at the disambiguation, going against the P600-like effect found between 500 and 600 ms. In contrast, for the S-coordination sentences, the match condition (with PB)

<sup>2</sup> Following Loftus (1996) we consider *p*-values equal to and below .05 as significant.



**Fig. 2.** Grand average waveforms time-locked to the disambiguation point for NP-coordination sentences for the first half of the experiment (panel A) and the second half of the experiment (panel B). Solid lines represent the NP-coordination sentences with a superfluous PB (prosody–syntax mismatch) and dotted lines without a PB (prosody–syntax match).



**Fig. 3.** Grand average waveforms time-locked to the disambiguation point for S-coordination sentences for the first half (panel A) and the second half (panel B). Solid lines represent conditions with a missing PB (prosody–syntax mismatch) and dotted lines those with a PB (prosody–syntax match).

**Table 2**  
Results of the analyses of the P600-like effect in 5 consecutive 100 ms windows between 500 and 1000 ms. Nonsignificant F-values are not reported or indicated by n.s.

Critical factors (analysis)	Effect	500–600 ms	600–700 ms	700–800 ms	800–900 ms	900–1000 ms
Match, structure, half (midline)	Match			$F(1,27)=5.65^*$		
	Match × Half			$F(1,27)=4.64^*$	$F(1,27)=6.07^*$	$F(1,27)=7.14^*$
Match, Structure, Half (lateral)	Match × Half					$F(1,27)=4.45^*$
	Match × Half × Elec		$F(3,25)=4.07^*$	$F(3,25)=3.31^*$		$F(3,25)=3.20^*$
	Match × Half × Hem × Elec		$F(3,25)=3.02^*$	$F(3,25)=3.05^*$	$F(3,25)=4.32^*$	$F(3,25)=4.59^*$
	Match × Structure × ROI	$F(1,27)=7.90^{**}$				
	Match × Structure × ROI × Elec	$F(3,25)=5.03^{**}$				
	Match × Half × Struct × Hem × ROI × Electrode	$F(3,25)=2.97^*$				
Match, Structure, Half (right posterior)	Match × Half × Struct	$F(1,27)=4.51^*$				
<b>First half</b>						
Match (midline)	Match	$F(1,27)=4.81^*$	$F(1,27)=6.22^*$	$F(1,27)=10.35^{**}$	$F(1,27)=11.52^{**}$	$F(1,27)=7.65^*$
Match (lateral)	Match	$F(1,27)=4.41^*$	$F(1,27)=4.45^*$	$F(1,27)=7.42^*$	$F(1,27)=5.88^*$	$F(1,27)=4.32^*$
	Match × Elec		$F(3,25)=5.28^{**}$	$F(3,25)=5.75^{**}$	$F(3,25)=6.95^{**}$	$F(3,25)=4.47^*$
	Match × ROI × Elec		$F(3,25)=3.61^*$	$F(3,25)=4.59^*$	$F(3,25)=3.47^*$	$F(3,25)=3.71^*$
Match, Structure (right posterior)	Match × Structure	$F(1,27)=6.88^*$				
<b>NP-coordination</b>						
Match (right posterior)	Match	$F(1,27)=10.68^{**}$				
	Match × Elec	$F(3,25)=3.04^*$				
<b>S-coordination</b>						
Match (right posterior)		n.s.				
<b>Second Half</b>						
Match		n.s.	n.s.	n.s.	n.s.	n.s.
Match, Structure (right posterior)		n.s.				

\*  $p \leq .05$ .

\*\*  $p \leq .01$ .

would have a negative trend, possibly leading to a larger positive effect in the mismatch condition (without PB). Thus, if the CPS affects the baseline of the disambiguation at all, this would go against our findings of a P600-like effect for the NP-coordination, but not for the S-coordination sentences between 500 and 600 ms in the first half of the experiment.

### 3.3.2. 600–1000 ms windows

All time windows between 600 and 1000 ms showed an interaction including Match and Half, at least in the lateral analysis (see Table 1). Based on these interactions, follow-up analyses for the two halves were performed for all time-windows between 600 and 1000 ms, in which we regarded effects including only the critical factor Match. The analyses for the first half of the experiment showed a main effect of Match, both for the midline and the lateral analysis. The lateral analysis also yielded interactions between Match, ROI, and Electrode and between Match and Electrode. The analyses for the second half of the experiment yielded no significant effects. Thus, a solid P600-like effect between 600 and 1000 ms was present in the first half for the mismatch as compared to the match condition, collapsed over both structures, which disappeared in the second half of the experiment.

## 4. Discussion

The present study investigated whether a superfluous PB would lead to stronger processing problems (or more/deeper processing) than a missing PB. Pauker et al. (2011) tested this hypothesis using a prosodic disambiguation in the case of a superfluous PB and a lexical disambiguation in the case of a missing PB. In contrast, in the present study, the disambiguation following a superfluous or missing PB was always lexical in nature, making the two situations more comparable.

During the first half of the experiment, we found a clear difference between prosody–syntax mismatch sentences (with a superfluous or missing PB) and prosody–syntax match sentences at the disambiguation. For the sentences with a superfluous PB (NP-coordination; see Fig. 2, panel A) one could argue that the waveforms for NP-coordination sentences without a PB diverged in the negative direction (instead of a positive going deflection for NP-coordination sentences with a superfluous PB). However, there are good reasons to assume that the effect can be regarded as a P600-like effect for sentences with a superfluous PB. First, the effect had a centroparietal distribution (standard for P600 effects) which extended to frontal electrodes, which is not uncommon for auditory P600 effects (e.g., Balconi & Pozzoli, 2005). Second, also the timing of the effect is compatible with a P600 effect. It started after 500 ms, which is around the normal onset for a P600. The effect extended in time after 500 ms which has been found in several studies (e.g., Osterhout & Holcomb, 1993). Third, ERP studies on auditory sentence processing are characterized by more noise and stimulus variability than ERP studies on visual sentence processing. In such a noisy environment, many other processes might be going on, common to both conditions. Thus, the absolute movements of the waveforms might not be the most reliable source of information in auditory studies. Rather, it seems better to rely primarily on relative differences between conditions in these studies, as these relative differences can only be caused by the experimental manipulations. As an example, take the study by Kerkhofs et al. (2008), which looked both at written (in their Experiment 1) and spoken versions (in their Experiment 2) of very similar stimuli as in the present study. In their Experiment 1 (in the visual modality, p. 107, Figure 2) one can discern clear peaks and troughs in the ERP (N1, P2, N400...) which makes identification of the effect (within the ‘P600 trough’) and of its direction easy. In contrast, their Experiment 2 (in the auditory modality, p. 111, Figure 6) shows much noisier ERPs without clear peaks and troughs. Still, there is a difference between the

conditions in the P600 window (which they interpret as a P600 effect), similar to the effect we see (cf. Fig. 2, panel A, in the present paper). Fourth, it has been shown that a task that (implicitly and explicitly) focuses participants on the experimental manipulation can lead to a larger positivity (e.g., Astésano, Besson, & Alter, 2004; Kolk, Chwilla, Van Herten, & Oor, 2003). This might be another reason why a P600 effect in the present study, where no explicit task is used, might be smaller and less clearly have the characteristic 'P600 shape'. On the basis of this line of reasoning, we take the effect we found in the first half of the experiment to reflect a P600-like effect for the mismatch sentences.

For the S-coordination sentences with a missing PB (prosody–syntax mismatch), we also found a P600-like effect in the first half of the experiment, which disappeared in the second half of the experiment. Kerkhofs et al. (2008) used the same type of S-coordination sentences and found processing difficulties throughout the experiment. However, these were differently reflected in the first and second half of the experiment; a LAN effect was found in the first, and a P600 effect was found in the second half of the experiment. The differences in results between the two studies might be related to differences in the type of the other sentences that were included in the respective experiments. How precisely the composition of stimulus materials might influence the processing of the S-coordination sentences still remains to be clarified in future experiments.

Although a clear difference between prosody–syntax mismatch and match sentences was present in the first half, this effect disappeared in the second half of the experiment for both sentence structures. Apparently participants adapted to the fact that prosody (both the presence and absence of a PB) was an unreliable cue in many of the sentences presented in the experiment and did not help understanding the sentences. Listeners were asked, in the present experiment, to listen to the sentences for comprehension. When they fully commit to this task, it is probably best to start ignoring both the presence and the absence of the PB, since they were often misleading. It appears that this is what participants did in the second half of the experiment. Such adaptations to the use of prosodic cues in the course of an experiment might be less likely in the study by Pauker et al. (2011) (Pauker et al., 2011, do not report analyses for the halves), because a more explicit task was used (each sentence had to be judged on its acceptability). Because of this, participants will be more likely to keep attending to inappropriate prosodic cues (superfluous and missing PBs).

Both the present study and the study by Kerkhofs et al. (2008) suggest that listeners' processing of sentences can change in the course of an experiment as a function of the (un)reliability of prosodic cues. In order to have the possibility to test for such potential changes, experiments should be set up such that one can analyze the results as a function of the course of the experiment. The change in processing of prosody over the course of an experiment can be seen as a side effect of the experimental situation. On the other hand, it can also be a potentially interesting topic for future research. In everyday language processing, listeners might adjust to speaking styles of speakers with a more strict versus a more sloppy use of prosody as a marker of syntactic phrasing.

The main aim of this paper was to test the Boundary Deletion Hypothesis (Pauker et al., 2011). Since the first half of the experiment is least susceptible to listeners adapting to the specific use of prosody in the experiment, as argued above, we now focus on the results obtained in the first half of the present experiment.

It was predicted that superfluous PBs, that is, PBs in a position where no syntactic break is present, would lead to stronger processing difficulties at the disambiguation than missing PBs, that is, the absence of a PB at the position of a syntactic break. We investigated the

consequences of these two situations, at the point at which the sentence was lexically disambiguated, and found a P600-like effect in both cases. However, the comparison of these effects for NP- and S-coordination sentences showed that the effect started earlier in the case of a superfluous PB (in NP-coordination sentences) than in the case of a missing PB (in S-coordination sentences). A behavioral study (see Section 2.2) also showed that sentences with a superfluous PB (i.e., NP-coordination sentences with a PB) were judged as very unnatural, more so than sentences with a missing PB (i.e., S-coordination sentences without a PB). It should be noted in this context that these differences are found despite the fact that the late closure parsing preference for the type of sentences used in the present study (see Section 1) should work in the opposite direction. Thus, despite the counteracting influence of the late closure preference, superfluous PBs yield longer lasting processing problems than missing PBs.

The above results are consistent with the results by Pauker et al. (2011), although the difference in strength of the processing difficulty between superfluous and missing PBs appears larger in the Pauker et al. (2011) study than in the present study. Thus, the fact that we used a lexical disambiguation both for sentences with missing and with superfluous PBs, in contrast to Pauker et al. (2011), who used different types of disambiguation for the two cases, might have led to more subtle differences.

The present results also differed from those of Pauker et al. (2011) with respect to the type of ERP signatures. Next to the P600 effect, Pauker et al. (2011) found an N400 effect for sentences with a superfluous PB, which was absent in the present study. Two different types of functional interpretations of the N400 are currently held. The first one is based on memory retrieval of the critical word; the more priming this word has received from the preceding context, the less effortful retrieval of that word will be, and the smaller the N400 elicited by it (e.g., Kutas & Federmeier, 2000; Lau, Phillips, & Poeppel, 2008; Van Berkum, 2009). Since the lexical content of the compared sentences is identical, lexical priming cannot account for the N400 effect found by Pauker et al. (2011). However, it is possible that the prosody, together with the lexical (and syntactic) content of the sentence, leads to bottom-up anticipation for a certain next element. For example, the sentence fragment "When a bear is approaching # the people..." might lead to an anticipation of a verb and not another NP or another PB, as encountered in the Pauker et al. (2011) study. In the present study, the sentence: "The traveler followed the carrier # and the guide..." might lead to a similar anticipation for a verb. However, other options might be left open and the presence of a prepositional phrase, as in the present study, might receive more bottom-up support from the previous context than for example a second PB, as in the sentences from Pauker et al. (2011).

Pauker et al. (2011) explain the N400 effect in their study in terms of the second functional interpretation of the N400, as an index of sentence integration difficulties (e.g., Bornkessel and Schlesewsky, 2006; Chwilla, Hagoort, & Brown, 1998; Chwilla, Kolk, & Mulder, 2000). More specifically, the presence of an N400 is explained as the consequence of a lacking theta role for the NP following the verb (e.g., *the people* in "When a bear is approaching # the people # the dogs come running"); this NP cannot be coupled to any verb because of the two PBs. It appears that a similar situation occurs for sentences with a superfluous PB in the present study; NP3 (*the guide* in (8)) does not receive a theta role from the previous verb (*followed*) because of the preceding PB, but the presence of a PP (instead of a verb) following NP3 also does not provide a theta role, resulting in a lacking theta role for NP3 (*the guide*). Since no N400 effect is found in the present study, a lacking theta role for an NP appears not to be the full story for the presence versus absence of an N400 effect. In this context, a potentially important difference between the sentence structures

used by Pauker et al. (2011) and the present study should be noted. In the present study, no changes have to be made to the argument structure of the main verb (e.g., *followed* or *kissed*) in any of the critical sentences. The main verb is always transitive since NP2 (e.g., *the carrier*) is always its object. The revision process upon hearing the disambiguation only concerns the addition or removal of NP3 (e.g., *the guide*) from the already existing direct object. In contrast, in the materials of Pauker et al. (2011), the verb *approaching* has to change from an intransitive to a transitive interpretation for sentences with a superfluous PB (*the people* becomes its object) and from a transitive to an intransitive interpretation for sentences with a missing PB (*the people* turns out not to be its object). Thus, based on these observations, an N400 is elicited by the addition of an argument to the already established argument structure of a verb, but not by the removal of an argument from an argument structure of a verb. This explanation is also consistent with the results of earlier studies on the role of prosody in sentence processing (Bögels et al., 2010; Steinhauer et al., 1999).

Looking at the evidence so far, both the present study and the Pauker et al. (2011) study support the Boundary Deletion Hypothesis. Both studies report behavioral effects showing that sentences with superfluous PBs are judged as less natural than sentences with missing PBs. Also, both studies find more severe processing problems at the disambiguation for sentences with a superfluous PB than for sentences with a missing PB. Pauker et al. (2011) interpret this finding as follows. When encountering the disambiguation of a sentence with a prosody–syntax mismatch, participants have to either mentally delete a superfluous PB (NP-coordination with a PB in the present study), or mentally insert a missing PB (S-coordination without a PB in the present study), in order to repair the sentence. According to these authors, the former repair process is probably more costly than the latter. Such a prosodic revision is indeed one possible option for repairing a sentence that contains a prosody–syntax mismatch (see also Hwang & Steinhauer, 2011, for an indication that the same might be going on in reading, using implicit prosody). However, there are alternative options. A revision of the sentence might also take place on a non-prosodic level, reflecting, for example, a rearrangement of the arguments and verbs. Disconnecting two constituents that were connected before might be harder than the other way around. In the literature, different models on the functional significance of the P600 have been proposed. A division can be made between two types of models. Dual stream models (e.g., Bornkessel & Schleewsky, 2006; Kim & Osterhout, 2005; Kuperberg, 2007; Van de Meerendonk, Kolk, Chwilla, & Vissers 2009; see Brouwer, Fitz, & Hoeks, 2012, for a review) assume two processing streams (e.g., a semantic and a syntactic one) which, in case of a conflict, trigger reanalysis, which leads to a P600. In contrast, single stream models (e.g., Brouwer et al., 2012) assume that the P600 reflects increased processing when updating some kind of ‘mental representation’ of the sentence. As an example of a dual stream model, the Monitoring account (Van de Meerendonk et al., 2009), would assume that an NP following a PB (such as NP3, *the guide*, in (9)), is interpreted as starting a new clause (in our case, the subject of a new sentence).

(9) The traveler followed the carrier # and the guide through the mountain-like area.

This leads to a strong expectation that a verb will follow NP3 (*the guide*), which is not met in sentences like (9) with a superfluous PB. In contrast, two NPs connected by *and* without a PB (such as *the designer and the photographer* in (10)) will be interpreted as a coordination of the two NPs, which will lead to a strong expectation of a continuation of the main clause or a new clause, but not a verb, following NP3 (*the photographer*).

(10) The model kissed the designer and the photographer took a bottle of champagne.

This expectation is violated in sentences with a missing PB like (10) in which NP3 is followed by a verb. Both violations of expectations are apparently large enough to lead to a monitoring response, reflected by a P600. Since the P600 is larger in the former case, the expectation built up on the basis of the presence of a PB appears to be stronger than the expectation built up on the basis of the absence of a PB.

In contrast, according to a recent single stream account of the P600 (Brouwer et al., 2012) the size of the P600 reflects the amount of processing needed to update the current ‘mental representation of what is being communicated’ (including a possible reanalysis). According to this view, the mental representation after the PB in (9) should be a completed clause and thus the following NP3 (*the guide* in (9)) will be analyzed as the subject of a new sentence. In that case, a PP following this NP is hard to integrate and leads to a change in the current mental representation (i.e., *the guide* should be changed from a subject into part of an object). In the case of sentences like (10) with a missing PB, NP3 (*the photographer*) will be integrated with the mental representation of the current sentence as part of the direct object of *kissed*. The following verb (*took*) is hard to integrate with this representation, since it requires a subject. Thus, the mental representation should be changed such that the second NP becomes a subject instead of part of the object. In this view, the stronger P600 effect for sentences with superfluous PBs might be related to the way the current mental representation has to be changed. Changing a subject into an object might require more processing than changing an object into a subject. Note that this account can also be applied to the Pauker et al. (2011) materials. If this account is correct, the difference in size between the P600-like effects to superfluous and missing PBs (as found in the present study and by Pauker et al., 2011) reflects the way the current mental representation has to be changed given the available prosodic and lexical information.

## 5. Conclusion

The present study provides new and additional support for the Boundary Deletion Hypothesis (Pauker et al., 2011). First, superfluous and missing PBs lead to processing problems. Second, a prosody–syntax mismatch elicited by a superfluous PB leads to larger processing problems at the point of disambiguation than a prosody–syntax mismatch elicited by a missing PB. In previous research this was shown for sentences with different types of disambiguation (lexical versus prosodic; Pauker et al., 2011), whereas we showed this for a case in which both types of prosody–syntax mismatch were lexically disambiguated.

## Appendix A. Stimulus materials

Experimental materials, without prosodic annotation. All sentences were used with a PB in two of the four lists and without a PB in the other two lists. If a PB occurred in the sentence, it was always placed between the second NP and *en* (‘and’).

### 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 dienaars 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 rotpunt 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 geldschietster 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 schaatsster 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.

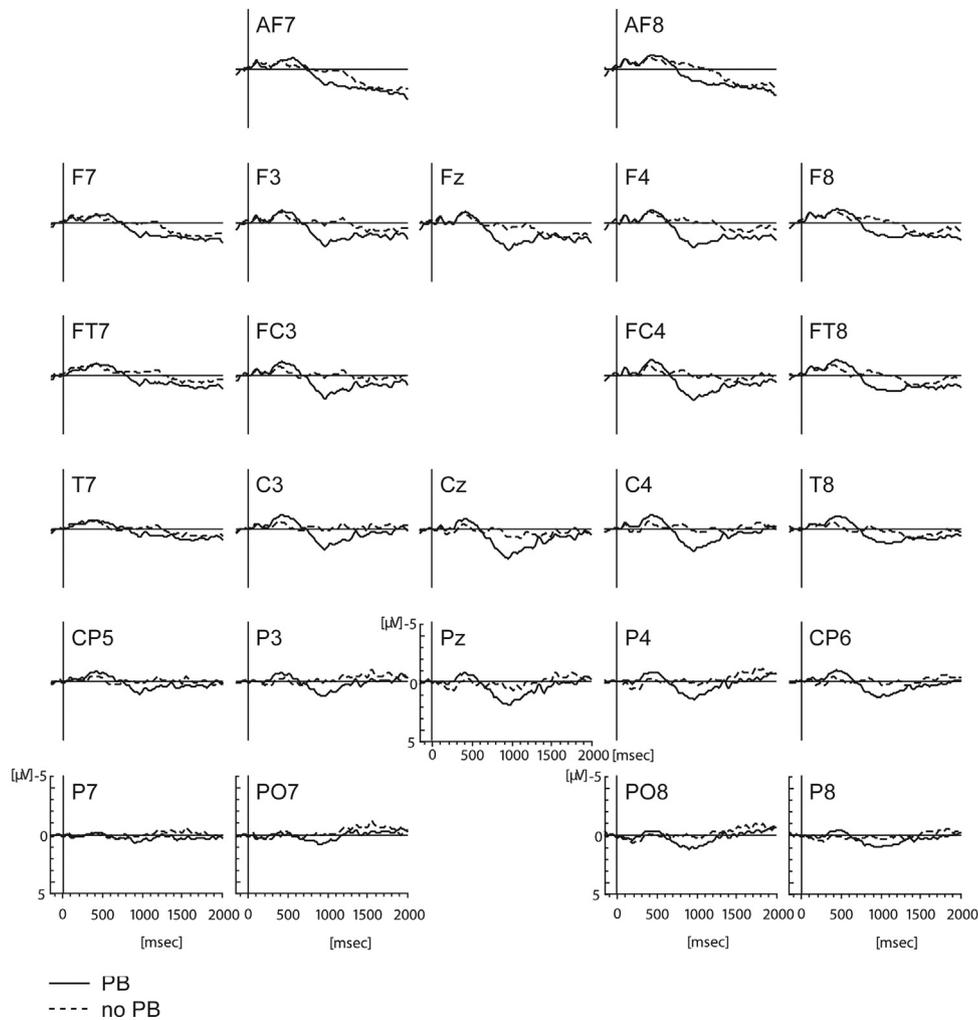
7. De redacteur prees de fotograaf en de journalist bekeek bewonderend de foto's van de vluchtelingenkampen.
8. De sheriff beschermde de boer en de knecht verdedigde wanhopig de boerderij tegen Johnsons bende.
9. De grimeur schminkte de schrijver en de interviewer besprak kort de vragen die hij wilde 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 smeedt 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 bespote 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 tovenaer 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 reisleader vertelde gedreven een verhaal over de visserij in de streek.
28. De dichter bezong de zwerfer 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 bespote 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 beloofde 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 behoeftzaam 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 koorleider 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

**Fig. B1** presents grand average waveforms for the PB and no PB conditions time-locked to the onset of the stressed syllable of NP2, corresponding to the word before the pause in sentences with a PB (see [Bögels et al., 2010](#) for a comparison of different time-locking points to quantify the CPS). Visual inspection of **Fig. B1** suggests a large and broadly distributed CPS, which at some electrodes appears to be preceded by an early negativity (see e.g., T8 and CP6). We chose an 800–1200 ms window to analyze the CPS and a 300–500 ms window to analyze the early negativity (e.g., [Bögels et al., 2010](#)). **Table B1** shows the results of the statistical analyses.

Follow-up analyses for the single electrodes showed that the CPS was broadly distributed and significant for all electrodes ( $ps < .05$ ) except for three left posterior electrodes (T7, CP5, P7;  $ps > .05$ ) and three anterior electrodes (F7, AF7, AF8;  $ps > .05$ ). Thus, in accordance with earlier research (e.g., [Bögels et al., 2010](#); [Steinhauer et al., 1999](#)) we found a widely distributed CPS, which was a bit more pronounced over the right hemisphere. The presence of this CPS clearly shows that listeners processed the PB.

The small negativity preceding the CPS was only significant for one electrode over the right hemisphere (T8,  $p < .05$ ) and



**Fig. B1.** Grand average waveforms time-locked to the last stressed syllable of NP2, collapsed over NP- and S-coordination sentences for the sentences with (solid line) and without a PB (dotted line).

**Table B1**

Results of the analyses of the CPS and the early negativity. Nonsignificant  $F$ -values are not reported.

Analysis	Effect	Negativity (300–500 ms)	CPS (800–1200 ms)
Midline	PB		$F(1,27) = 11.55^{***}$
Lateral	PB		$F(1,27) = 10.11^{**}$
	PB*ROI*Electrode	$F(3,25) = 2.89^1$	
	PB*Electrode		$F(3,25) = 3.04^*$
Anterior	PB*Electrode	$F(3,25) = 3.35^*$	

\*  $p < .05$ .

\*\*  $p < .01$ .

<sup>1</sup>  $p = .055$ .

approached significance for two additional electrodes over the same hemisphere (CP6, P8;  $ps < .09$ ). Such a (right-lateralized) small negativity preceding the CPS has been observed before (e.g., Bögels et al., 2010; Kerkhofs et al., 2008; Pauker et al., 2011). Since this effect clearly precedes pause onset, it might be elicited by early components of the PB such as prefinal lengthening and the boundary tone.

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