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## The Syntactic Positive Shift (SPS) as an ERP Measure of Syntactic Processing

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This paper presents event-related brain potential (ERP) data from an experiment on syntactic processing. Subjects read individual sentences containing one of three different kinds of violations of the syntactic constraints of Dutch. The ERP results provide evidence for an electrophysiological response to syntactic processing that is qualitatively different from established ERP responses to semantic processing. We refer to this electrophysiological manifestation of parsing as the Syntactic Positive Shift (SPS).

The SPS was observed in an experiment in which no task demands, other than to read the input, were imposed on the subjects. The pattern of responses to the different kinds of syntactic violations suggests that the SPS indicates the impossibility for the parser to assign the preferred structure to an incoming string of words, irrespective of the specific syntactic nature of this preferred structure. The implications of these findings for further research on parsing are discussed.

### INTRODUCTION

Most psycholinguistic models of language comprehension assume that in constructing a full interpretation of the linguistic input, listeners or readers automatically exploit their knowledge of grammar, next to their semantic and pragmatic knowledge (cf. Flores d'Arcais, 1990; Frazier, 1979; 1987a; Norris, 1987; Pulman, 1987). That is, unlike claims made in the early

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artificial intelligence tradition of models of language comprehension (e.g. Schank, 1972; Wilks, 1978), the cognitive architecture of the comprehension system is thought to include a parser, which assigns syntactic structure to spoken or written strings of words (Caplan & Hildebrandt, 1988; Frazier, 1987a).

In this paper, we present some event-related brain potential (ERP) data that we believe provide part of the basis for a future psycholinguistic research programme on a central issue in parsing research, namely the debate concerning the autonomous or interactive processing nature of the parser. The data we discuss here do not provide the answer, but they do open the way for a novel empirical investigation of this long-standing question.

Advocates of an autonomous parser claim that lexical, semantic and pragmatic information have their influence only after an initial syntactic parse is delivered, which is computed solely on the basis of syntactic principles in combination with a limited number of parsing preferences (e.g. Ferreira & Clifton, 1986; Frazier, 1979; 1987a; 1987b; 1990; Frazier & Rayner, 1982; Rayner & Frazier, 1987; Rayner, Carlson, & Frazier, 1983; Rayner, Garrod, & Perfetti, 1992). Proponents of interactive approaches to parsing claim that non-syntactic sources of information are used either to direct the parser's initial analysis (e.g. Altmann, Garnham, & Dennis, 1992; Bates et al., 1982; Ford, Bresnan, & Kaplan, 1982; Holmes, 1987; McClelland, St John, & Taraban, 1989; Mitchell & Holmes, 1985; Taraban & McClelland, 1988; 1990) or to evaluate immediately the outcome of the syntactic analysis on a (more or less) word-by-word basis during the construction of a semantic representation of the input (e.g. Altmann & Steedman, 1988; Crain & Steedman, 1985).

According to the autonomous position, the computation of a separate intermediate level of representation for the syntactic structure of a sentence is required. According to the interactive position, syntactic information is directly integrated with lexical and semantic/pragmatic information in a continuous process of mapping sounds or letters onto a meaning representation of the whole sentence. Such an account of parsing does not need to appeal to a separate level of syntactic representation.

It can be argued that the available empirical evidence does not suffice to settle the debate between proponents of autonomous or interactive parsing models. For instance, some researchers claim that measures such as preference judgements and reading times involve introspective conscious evaluation by the subjects, and so do not tap the on-line automatic parsing process (e.g. Tanenhaus, Carlson, & Seidenberg, 1985). A further problem that has been noted is that the existing chronometric techniques may not pick up on the presumably small effects of the rapid parsing process (cf. Mitchell & Holmes, 1985). Frazier (1990) points out that for

certain syntactic constructions (e.g. PP-attachments in V-NP-PP structures), re-analysis could be so fast and easy that it will be difficult to observe. In general, the processing claims of the different parsing models have become so subtle that it is hard to think of a sufficiently sensitive empirical test based only on latency data.

To test the claims of autonomous and interactive parsing models, studies applying the ERP method might provide us with additional information over and above the empirical evidence from reaction times and eye-tracking studies. The multidimensional nature of ERPs allows, at least in principle, qualitatively different cognitive processes to show up in qualitatively different ways in the ERP waveform. This is what Osterhout and Holcomb (1992) refer to as the sensitivity of ERPs to representational level. So, if the processing of semantic and syntactic aspects of an utterance is subserved by separate processing components which produce output at different levels of representation, one might expect their brain correlates to be distinct too. If this expectation is upheld, distinct brain correlates for the computation of semantic and syntactic representations might be used to answer some of the harder questions in research on parsing, such as whether or not the computation of an initial syntactic structure is influenced by lexical and semantic/pragmatic factors, or what the consequences are of an unsuccessful first parse for the semantic integration of sentence elements into a coherent interpretation of the utterance (cf. Flores d'Arcais, 1982; 1987).

However, before the ERP method can be exploited to test the more subtle claims of different parsing models, more information is needed about the basic ERP responses to aspects of syntactic processing. Compared to ERP studies on semantic processing (for an overview, see Kutas & Van Petten, 1988), until recently ERP research with a focus on parsing has been scarce (Garnsey, Tanenhaus, & Chapman, 1989; Kluender, 1991; Kutas & Hillyard, 1983; Kutas & Kluender, 1993; Neville et al., 1991; Osterhout & Holcomb, 1992; Osterhout & Swinney, 1989). Moreover, these studies have not resulted in one specific ERP component that can be claimed to be sensitive to different types of syntactic violations, or to different kinds of parsing operations. That is, compared to the robustness of the N400 as a manifestation of the integration of different kinds of semantic information, a global ERP index of parsing operations has not yet been established. A short overview of the literature on ERPs and parsing makes this clear.

The first study in which ERP responses to syntactic errors were investigated was reported by Kutas and Hillyard (1983). They had subjects read sentences containing violations of the contextually appropriate tense and number morphemes. These violations induced a small enhanced negativity in the 300–500 msec latency range relative to the control sentences.

However, this negativity did not have the same amplitude and scalp distribution as the N400 obtained for semantic violations. In addition to this negativity, a positive peak with a latency of about 300 msec was observed to words following the syntactic violation.

Garnsey et al. (1989) used the ERP method to study the assignment of a filler to a gap in constructions such as "The businessman knew which customer/article the secretary called \_\_\_\_\_ at home" (the empty position is the gap, "customer" is the plausible filler, "article" the implausible one). Filler-gap constructions play a central role in studies on the processing of long-distance structural dependencies (cf. Frazier, 1987a). Garnsey et al. obtained an increased N400 amplitude when the parser made an implausible filler-gap assignment, resulting in a semantic incongruity. However, the N400 effect obtained is not so much a direct reflection of the filler-gap assignment by the parser, but more a reflection of the consequences of the assignment for the semantic interpretation of the filler-gap construction. Although this study provides clear evidence for early filler-gap assignment, it does not address the issue of direct manifestations of parsing operations.

Osterhout and Holcomb (1992) examined ERPs to violations of verb subcategorisation and phrase structure constraints. In their first experiment, they presented subjects with active sentences where the finite verb was followed by a clausal complement. Some of the verbs they used easily take a clausal complement (e.g. "The broker hoped to sell the stock"). Other verbs, however, required an NP-complement. Clausal complement sentences with these kinds of verbs were therefore labelled ungrammatical (e.g. \*"The broker persuaded to sell the stock"). At the first point in the ungrammatical sentences at which the parser was unable to construct the preferred syntactic representation (i.e. at the word "to"), a positive shift occurred, starting between 400 and 500 msec after the presentation of the infinitival marker, with a duration in the order of 400 msec. The authors labelled this effect the P600. The same positivities were seen in a second experiment using sentences with reduced relative clauses with verbs that do not take direct objects, and hence cannot undergo passivisation (e.g. \*"The broker hoped to sell the stock was sent to jail"). In these kinds of sentences, an additional P600 effect in response to the presentation of the auxiliary (i.e. "was") was obtained in a comparison of the grammatically incorrect sentences with their grammatically correct counterparts (e.g. "The broker persuaded to sell the stock was sent to jail"). The P600 elicited by the auxiliary is presumably related to the violation of the phrase structure constraints. In addition, in both experiments, increased N400 amplitudes were obtained for the final words in the ungrammatical sentences. The authors suggest that this N400 effect might indicate the difficulty subjects have with the ungrammatical sentences to integrate the sentence elements into a coherent overall sentential-semantic representa-

tion (for a similar view of the processing nature of the N400, see Brown & Hagoort, 1993).

Neville et al. (1991) studied violations of phrase-structure constraints and violations of constraints on the movement of wh-phrases, within the framework of Government and Binding Theory. The first kind of violation was realised by changing the obligatory word order of the head noun and the preposition in an NP (e.g. \**"Ted's about films America"*). The movement constraints were violated by either the illegal extraction of wh-phrases from within a subject-NP (violation of subjacency, e.g. \**"What<sub>i</sub> was a picture of t<sub>i</sub> printed by the newspaper?"*), or by the movement of a wh-phrase out of an NP with specific reference (violation of specificity, e.g. \**"What<sub>i</sub> did the scientist criticise Max's proof of t<sub>i</sub>?"*) (extraction sites are marked by the symbol *t*, coindexed with the wh-phrase by the subscript *i*). A complex and heterogeneous pattern of ERP effects was obtained for the different syntactic violations. ERP responses to the violating lexical item were compared to those for its control in the grammatically correct sentences. For the phrase-structure violations, the authors report a pattern of early negativities over anterior sites of the left hemisphere with a latency of 125 msec (the "N125"), a later more posterior negativity over the left hemisphere in the latency range of the N400, and a positive effect that is reminiscent of the P600 reported by Osterhout and Holcomb (1992). The violation of the subjacency constraint evoked a broadly distributed late positivity, and an early positivity that the authors interpret as an enhancement of the P2. Finally, the violation of the specificity constraint resulted in a slow negative wave with an early onset (around 125 msec) over the anterior regions of the left hemisphere.

In summary, studies focusing on parsing have shown that syntactic violations do not show the N400 effects seen for semantic anomalies (Kutas & Hillyard, 1983; Neville et al., 1991). In the cases where N400 effects were obtained, they most likely were not induced by syntactic processes *per se*, but were a consequence of the semantic incongruities resulting from a specific parse (Garnsey et al., 1989). On a number of occasions, positive shifts in the ERP waveform have resulted from syntactic violations (Kutas & Hillyard, 1983; Neville et al., 1991; Osterhout & Holcomb, 1992). These positivities might belong to the P300 family. If so, it could be the case that these effects were induced or enhanced by the specific task demands (i.e. acceptability judgements) of some of these studies (Neville et al., 1991; Osterhout & Holcomb, 1992). In addition to positivities, some studies obtained evidence for an early negative component with a left anterior distribution that is claimed to be related to parsing (Kluender & Kutas, this issue; Neville et al., 1991). All in all, the few ERP studies on parsing show a fairly complicated picture, at least suggesting that different syntactic violations do not unequivocally lead to one and the same ERP response. However, the number of ERP studies on parsing is too limited to draw

firm conclusions as to the existence and nature of "syntactic" ERP responses. This uncertain situation with respect to ERP manifestations of parsing in our view requires a step-by-step approach, in which the central issues in the research on parsing can only be fruitfully addressed after the basic ERP effects of syntactic processing have been firmly established.

In addition to the small number of studies, another handicap of the current literature is that to date all ERP studies on parsing have been done in one language only, namely English. It is unclear whether ERP responses to specific syntactic violations generalise across different languages. Certain syntactic specifications for the assignment of structure to the incoming string of words (e.g. word order) have different weights in different languages (cf. Bates et al., 1982; Bates & MacWhinney, 1987). Thus, even if the syntactic violations are the same across languages according to their formal linguistic description, it does not necessarily mean that they have the same consequences for parsing in these languages. So, it remains to be seen whether a specific syntactic violation of English (e.g. a phrase-structure violation) results in similar ERP effects as the same type of violation in, for instance, Dutch.

To further investigate ERP manifestations of syntactic processing, we investigated the ERP correlates of three different types of syntactic violations in Dutch. Because positive effects (such as the P600) might either be a consequence of the syntactic violation or be induced by the task demands (e.g. grammaticality judgements), we decided only to require the subjects to read the sentences carefully, without imposing any additional task demands. Requiring subjects to respond explicitly to the essentially rare event of an ungrammaticality in the context of a legally structured string of words, could result in a P300 effect to the ungrammatical words. In this way, direct effects of the syntactic violation might be masked or contaminated by the ERP effects related to the additional task.

The first type of violation in our study consists of sentences in which the subject-NP and the finite verb do not agree in number (e.g. \*"On a rainy day the old man *buy* a life insurance"). The first word at which the parser can detect the violation is italicised.

Next to agreement violations we constructed sentences with violations of subcategorisation. In these sentences, verbs that do not take an object-NP are followed by a noun that according to the syntactic properties of Dutch unambiguously has to be assigned the role of grammatical object (e.g. \*"The tired young man elapsed the *book* on the floor").

Finally, in the third type of violation, the constraints on the construction of phrase structures are not met. In Dutch noun phrases that consist of a noun, an adjective and an adverb, the adverb has to precede the adjective. We reversed the obligatory local word order between adjective and adverb, thereby making the phrase structure ungrammatical (e.g. \*"Most of the visitors like the colourful very *tulips* in Holland"). Note that



following the adverb there is still the alternative but less frequent and more complex possibility in Dutch of an additional adjective preceding the noun (e.g. "the colourful very expensive tulips"). If the parser takes the frequency and/or the structural complexity of constructions such as adverb–adjective–noun and adjective–adverb–adjective–noun into consideration, ERP effects of structural misassignment may become evident before the actual point of violation (i.e. at the adverb; cf. Osterhout & Holcomb, 1992).

In the choice of syntactic violations and in the construction of the materials, we tried to optimise the likelihood that the subjects actually detect the violations. Unlike in ungrammatical *wh*-constructions, tag questions, etc., the size of the parsing buffer required for detecting the three types of violations we used is kept to a minimum. All violations could be locally processed by detecting a mismatch between syntactic specifications of immediately adjacent elements, or of elements separated by a determiner. However, the three types of violations are clearly different at the level of the grammar. Whereas agreement violations are violations across major phrasal boundaries (NP and VP) outside the scope of maximal projection, both the phrase structure and the subcategorisation violation are violations in the relation between the head of a phrase and its arguments. Moreover, both the agreement violation and the phrase-structure violation violate structural constraints on the combination of lexical items, whereas the subcategorisation violation results from the violation of a syntactic specification in the lexical entry of the verb. The three types of violations also differ with respect to their consequences for the semantic interpretation of the sentence. Subcategorisation and phrase-structure violations are less easily reinterpreted semantically in comparison to the agreement violation, which does not seriously affect the way in which the content words in the sentence are ordered and combined into a coherent interpretation of the sentence.

Without relying on one specific linguistic theory, we therefore believe that our choice of syntactic violations does not tax the processing constraints of the parser too much, and at the same time covers a broad enough range of syntactic structures in Dutch to investigate the specificity of ERP responses to different kinds of syntactic information.

## METHOD

### Materials

A total of 360 sentences was constructed (see the Appendix for the entire set). Half of these are grammatically correct, half contain a grammatical violation. Each sentence in the violated set is derived from a sentence in the correct set, such that the words preceding and following the word string

that makes the sentence ungrammatical are the same as in the companion correct sentence, and such that the sets of incorrect and correct sentences are matched on the number of words they contain. So, other than the specific violation in the incorrect sentences, the sets of 180 correct and 180 incorrect sentences are closely matched. Three kinds of grammatical violations are used: (1) violation of verb–noun number agreement, (2) violation of verb subcategorisation and (3) violation of phrase structure.

The agreement violations all consist of number violations between verbs and nouns within SVO and VSO sentences. Violations occur on either finite verbs or subject nouns within the same sentence. For instance, in an SVO sentence, the subject noun could be singular, in combination with a plural verb form. The following example gives both the grammatically correct and incorrect versions of an SVO and a VSO agreement violation [literal translations in English between brackets; the word that makes the sentence ungrammatical (i.e. the critical word, CW) and its correct counterpart are italicised].

1. Het verwende kind *gooit* het speelgoed op de grond.  
(The spoilt child *throws* the toys on the floor.)
2. \*Het verwende kind *gooien* het speelgoed op de grond.  
(The spoilt child *throw* the toys on the floor.)
3. Na afloop van het feest bestellen de *gasten* een taxi.  
(After ending of the party order the *guests* a taxi.)
4. \*Na afloop van het feest bestelt de *gasten* een taxi.  
(After ending of the party orders the *guests* a taxi.)

Singular verbs in combination with plural subject nouns are used for all ungrammatical versions of the VSO sentences. We chose this construction for this subset of the stimuli because the morphosyntactic properties of Dutch easily allow for expansion of the noun phrase to a complex plural NP containing a succession of singular nouns with connectives, which implies that in the case of plural verbs and singular nouns, a grammatical continuation could have been readily constructed.

The subcategorisation violations involve obligatory intransitive verbs. Such verbs cannot take a noun as direct object, and this was the constraint that we violated. For example:

5. De zoon van de rijke industrieel leent de *auto* van zijn vader.  
(The son of the rich industrialist borrows the *car* of his father.)
6. \*De zoon van de rijke industrieel pocht de *auto* van zijn vader.  
(The son of the rich industrialist boasts the *car* of his father.)

The determiner following the intransitive verb does not violate syntactic properties of Dutch; it is always possible to continue with an adverbial

phrase of duration (e.g. “boasts the whole day”). However, unlike some instances of English, no grammatical continuation is possible following the noun in object position. Although it is difficult to exclude all impact from semantics in these kinds of subcategorisation violations (an issue that we will expand on in the Discussion), we have attempted to minimise any such possibility. In particular, we ensured that the meaning of the intransitive verb was fully compatible with the overall meaning of the sentence. So, in sentence (6), the obligatory intransitive verb “boast” is semantically entirely compatible with the theme of the sentence. This can be readily verified by inserting a preposition following the intransitive verb, thereby creating a grammatically correct sentence in Dutch. In all of the subcategorisation violations used in this experiment, such a minimal grammatical “repair” leads to a syntactically and semantically well-formed sentence, as can be seen in sentence (7), the “repaired” version of sentence (6):

7. De zoon van de rijke industrieel pocht op de auto van zijn vader.  
(The son of the rich industrialist boasts about the car of his father.)

The phrase structure violations all consist of nouns preceded by transpositions of adverbs and adjectives. In Dutch, it is a violation of phrase structure constraints to have an adjective–adverb–noun sequence. For example (the adjective, adverb and noun are italicised):

8. De echtgenoot schrikt van de *nogal emotionele reactie* van zijn vrouw.  
(The husband [is startled] by the *rather emotional response* of his wife.)  
9. \*De echtgenoot schrikt van de *emotionele nogal reactie* van zijn vrouw.  
(The husband [is startled] by the *emotional rather response* of his wife.)

In this example, as in all of the phrase-structure violation sentences, the actual violation occurs on the noun following the adverb (i.e. on “reactie”). It is only at this point that the sentence can no longer be continued in a grammatically correct manner. This is because, in Dutch, adjective–adverb combinations can be part of adjective–adverb–adjective–noun sequences (e.g. “the emotional rather violent response”). However, it is the case that such sequences are relatively infrequent and complex structures compared to the adverb–adjective–noun sequences. It is therefore possible that in terms of actual performance, readers of Dutch will already experience parsing difficulties before the noun in sequences beginning with an adjective followed by an adverb. We will pick up on this point again when we present the data analysis of the ERP waveforms. For present purposes, it is important to note that in terms of the syntactic properties of Dutch, it is only at the presentation of the italicised noun that the parser is confronted with a syntactic violation.

In addition to the specific issues concerning the construction of the three kinds of incorrect sentences, the following criteria apply to all the materials:

1. All violations are "immediate" violations in the sense that the syntactic constraint being violated is restricted to the syntactic information carried by either two adjacent words within a clause, or by a triplet of words.

2. The critical word of an incorrect sentence has a counterpart in its companion correct sentence. This counterpart is always the same word (with the exception of the different inflections of the verbs in the agreement VSO sentences), in the same position (in terms of number of words from sentence onset) as in the incorrect sentence.

3. The critical word is a verb or a noun. The maximum length in number of letters of the critical word is 9, the minimum length 4. The range in number of letters of the words immediately preceding the critical word is 2–10. The maximum length of all other words is 12. These restrictions are used to minimise differential processing effects due to length in number of letters, to ensure that each word can be read in one fixation and, thereby, to avoid successive eye fixations during the reading of a single word (which can severely contaminate the ERP waveform).

4. There are at least three words preceding the critical word, and at least two following it (with the exception of one subcategorisation violation and three agreement violation sentences, which have only one word following the critical word). This is because we want subjects to be fully engaged in the parsing process before probing the state of the parser, and because we want to avoid contamination from closure effects at sentence-final position. Such effects can manifest themselves as positivities in the ERP waveform (cf. Friedman, Simson, Ritter, & Rapin, 1975), and/or as an enhanced N400 to sentence-final words in syntactically anomalous sentences (cf. Osterhout & Holcomb, 1992). These closure effects create the problem of disentangling possible effects of the syntactic violation from the effects of overlapping components.

5. All sentences are between 8 and 12 words long. The position of the critical word in the sentence varies between position 4 and position 10.

## Design

Two experimental lists of 180 sentences each were made. The separate lists contain 90 correct and 90 incorrect sentences. The 90 incorrect sentences are made up of three sets of 30 sentences from each violation type. The 90 correct sentences are made up of three sets of 30 companion sentences for each of the violation types. The members of a pair of incorrect and

correct companion sentences are assigned to different lists. The same set of 30 practice sentences (15 grammatically correct and 15 incorrect, evenly divided over the three violation types) precedes the two lists. Each list is presented to a separate group of subjects.

The same pseudo-randomised sequence of sentences is used for each list. The sequence is such that, in immediate succession, no more than three incorrect sentences from the same violation type occur, no more than three incorrect or correct sentences occur, and no more than three sentences occur in which the critical word is at the same position (in terms of the number of words from sentence onset).

The sequence of 180 test sentences is divided into three blocks of 60. After the practice session, and after the first and second block, the testing session is interrupted to give the subjects a pause. After each of these pauses, four filler sentences (two grammatically correct and two incorrect) are presented before the first test sentence. This is done to ensure that the subjects are performing the reading task smoothly before being confronted with a test sentence.

### Grammaticality Judgement Pre-test

Following the first construction phase of the materials, the test sentences were pretested in a grammaticality judgement experiment, using a Go/NoGo task, in which subjects were instructed to respond whenever they detected a grammatical violation. The purpose of this pre-test was to ascertain whether the violations we had created are indeed perceived as such, and, if so, on which word in the ungrammatical sentences subjects give a response.

*Procedure.* The two experimental lists as described in the Design section were used. Each list was presented to a separate group of university students (all native speakers of Dutch, paid for their participation), 14 in one group and 16 in the other. We will report a combined analysis of the data (i.e. a group size of 30). The subjects were tested individually in a sound-attenuating booth with dimmed background lighting. The sentences were displayed word by word in white lower-case letters against a dark grey background, in the centre of a high-resolution computer screen (Nec Multisync 3D, 640 × 350 pixels, 14.3 msec frame time). Each word replaced the preceding one. A proportional Triplex font was used, with a letter width of 18 pixels and a letter height of 25 pixels. The subjects sat at a distance of 70–80 cm from the screen. The words subtended a vertical visual angle of approximately 3°. Presentation duration was 200 msec, with an inter-stimulus interval of 500 msec and an inter-trial interval of 4000 msec. The first word of each sentence began with a capital letter. The last

word was presented together with a period sign, to indicate that the sentence had ended. The subjects were instructed to read each sentence for comprehension, and to press a button whenever they encountered a grammatical error. Speed of response was not emphasised, but correctness was. No information was given concerning the kinds of errors that would be presented. The position in the sentence at which the subjects pressed the button, or the fact that they did not respond, was stored by computer for off-line analysis.

*Results.* The grammaticality judgements were analysed by sentence. Correct sentences were screened for false alarms; that is, the subjects pushed the button to indicate an ungrammaticality despite the fact that these sentences are well-formed. For the set of 60 correct companion sentences for the agreement violations, there were five sentences where three or four subjects gave a false alarm. For the set of 60 companion sentences for the subcategorisation violations, there were four sentences with three or more false alarms. For the set of 60 companion sentences for the phrase-structure violations, there was one sentence that scored three false alarms. All other correct sentences had either no or at most two false alarms. The correct sentences that scored three or more false alarms were analysed for the possible cause of these erroneous responses. In all cases, it was in retrospect clear why a local parsing problem could have occurred, and the sentences were adapted accordingly.

The incorrect sentences were analysed for misses (i.e. the subjects did not give a response) or, if the subjects did respond, for the position in the sentence at which the response occurred. Table 1 lists the percentage of responses averaged over subjects and sentences for each kind of violation, as a function of position in the sentence relative to the critical word (CW). It also lists the percentage of non-responses.

As can be seen from the numbers in Table 1, other than some sporadic misses and incorrect early responses, the subjects are picking up on the

TABLE 1  
Percentage of Responses by Violation Type, Relative to the Position of the Critical Word (CW)

<i>Violation</i>	<i>Before the CW</i>	<i>On the CW</i>	<i>One Word after CW</i>	<i>Two or More Words after CW</i>	<i>Miss (No Response)</i>
Agreement	1.5	35.0	55.0	7.0	1.5
Subcategorisation	4.0	40.0	34.0	17.0	5.0
Phrase structure	12.0	77.0	9.0	1.0	1.0

ungrammaticalities in the sentences. It is also clear that the majority of responses are either to the critical word (i.e. the point in the sentence at which it becomes grammatically incorrect), or to the word immediately following the critical word. We take this as evidence for the validity of the critical word as the point of ungrammaticality in the sentence. The fact that many of the subjects' responses to the violations are distributed over the critical word and the following word position, is in our opinion a reflection of the relative saliency of these kinds of ungrammaticalities.

Those sentences on which three or more subjects responded before the critical word, more than one word after the critical word, or on which they did not respond at all, were again scrutinised and subsequently adapted. No further pre-testing was performed on the adapted sentences.

### The ERP Experiment

*Subjects.* A total of 34 university students (20 females) participated in the experiment, 17 on each list (all native speakers of Dutch, mean age = 23 years, range 18–28 years). All but two of the subjects were right-handed according to their responses on an abridged, adapted Dutch version of the Oldfield Handedness Inventory (Oldfield, 1971). Eleven subjects reported familial left-handedness, in each case restricted to one member of the direct family. All the subjects had normal or corrected-to-normal vision. None of the subjects had any neurological impairment or had experienced any neurological trauma according to their responses on a questionnaire. The subjects were paid for their participation.

*Procedure.* The stimuli were displayed using the same font and letter size, the same centralised word-by-word presentation, and the same visual display unit as used for the grammaticality pre-test. The display unit was covered by a non-reflecting black shield, in which a rectangular window was cut out for the presentation of the stimuli. Viewing distance was between 70 and 80 cm, and the words subtended a vertical visual angle of approximately 3°. Each word was presented for 300 msec, with an ISI of 300 msec. The length of the inter-trial interval (ITI) was variable, and depended on the number of words in each sentence. For the longest sentences (i.e. those with 12 words), the ITI was 4500 msec, made up of the following sequence. After the presentation of the last word, there was a 1500 msec blank frame, followed by the presentation of an asterisk for 2000 msec. This was used as a signal for the subjects that they could blink their eyes. After the asterisk had been displayed, a 1000 msec blank frame preceded the onset of the first word of the next sentence. For the shorter sentences, the time between the presentation of the last word and the onset

of the asterisk was longer, depending on how many words less than 12 the sentences contained. For these sentences, the timing conditions after the onset of the asterisk were the same as for the 12-word sentences.

EEG activity was recorded using an Electrocap with seven scalp tin electrodes, each referred to the left mastoid. Three electrodes were placed according to the International 10–20 system (Jasper, 1958) at frontal (Fz), central (Cz) and parietal (Pz) sites. Symmetrical anterior temporal electrodes were placed half-way between the F7 and T3 (anterior left: AL) and F8 and T4 sites (anterior right: AR), respectively. Symmetrical posterior temporal electrodes were placed lateral (by 30% of the interaural distance) and 12.5% posterior to the vertex (posterior left: PL; posterior right: PR). Vertical eye movements and blinks were monitored via a supra- to sub-orbital bipolar montage. A right-to-left canthal bipolar montage was used to monitor for horizontal eye movements.

The EEG and EOG recordings were amplified with Nihon Kohden AB-601G bioelectric amplifiers, using a Hi-Cut of 30 Hz and a time constant of 8 sec. The EEG and EOG were digitised on-line with a sampling frequency of 200 Hz. Sampling started 150 msec before the presentation of the first word of each sentence, with a total sampling epoch of 8550 msec.

The subjects were tested in a sound-attenuating booth, seated in a comfortable reclining chair. They were informed that they would see sentences presented one word at a time. They were asked to pay attention to each word, and to focus on comprehending the whole sentence. No additional task demands were imposed. The subjects were told that some sentences would be grammatically incorrect, but they were given no information concerning the kinds of grammatical errors that would occur. There was a pause following the practice sequence, and following the first two blocks of the experimental sequence. Each experimental block lasted about 15 min. The entire session, including electrode application and removal, lasted at most 2½ h.

## RESULTS

### EEG Analysis

Prior to off-line averaging, all single-trial waveforms were screened for eye movements, electrode drifting, amplifier blocking and EMG artifacts. Trials containing such artifacts were rejected. For the two time-locked latency windows that we will be reporting analyses on (more details below), the overall rejection rate was 6.9% and 5.3%.

Average waveforms were computed by subject over the correct and incorrect sentences for each of the three violation types. Statistical analyses are performed on the basis of calculations of the mean amplitudes in



restricted time ranges preceding and/or following the critical word (the specific time ranges are given below in the separate sections on each of the violation types). Calculations are done separately for each of the seven active electrodes. The baseline for the critical word and its preceding positions was chosen so that it preceded a word position at which the sentences in the grammatical and ungrammatical conditions were still completely identical (see the sections below for a specification of the baseline for each violation type). The resulting values are entered into repeated-measures analyses of variance for each violation type separately—agreement, subcategorisation and phrase structure. In these analyses, the subjects are nested within experimental lists, and crossed with grammaticality (two levels: correct, incorrect) and electrode site (seven levels: Fz, Cz, Pz, AL, AR, PL, PR). We will report statistics for each violation type on time ranges of (1) the critical word, (2) the two or three word positions preceding the critical word, and (3) the penultimate and sentence-final word positions. The analyses on the positions preceding the critical word serve primarily to demonstrate that the effects found on the critical word are not spurious, but these analyses also serve to assess the impact of different words in different conditions. The analyses on the penultimate and sentence-final positions served to demonstrate the (possible) persistence and ramifications of the effects observed on the critical word.

Other than a few exceptions that will be explicitly mentioned, in all of the following results the list  $\times$  grammaticality interaction did not reach significance. Therefore, the factor list was collapsed prior to the analyses of variance that are reported here. Furthermore, all overall analyses with violation type as an additional factor did not result in any significant three-way interactions of violation type  $\times$  grammaticality  $\times$  electrode site on the critical word, penultimate or sentence-final positions. This demonstrates that between the three violation types, there are no topographical differences in the ERP effects obtained. Therefore, we will not report the effects of the factor electrode.

We will give the results for each of the violation types separately. Each section on a violation type starts with a general description of the waveforms, followed by three subsections. The first subsection reports the results for the critical word waveforms, the second for word positions preceding the critical word, and the third gives results for the penultimate and sentence-final positions.

## Agreement

Figures 1 and 2 show the grand average waveforms by electrode site for the critical word in the correct and incorrect agreement conditions. The critical word is preceded by two, and followed by three words. Figure 1

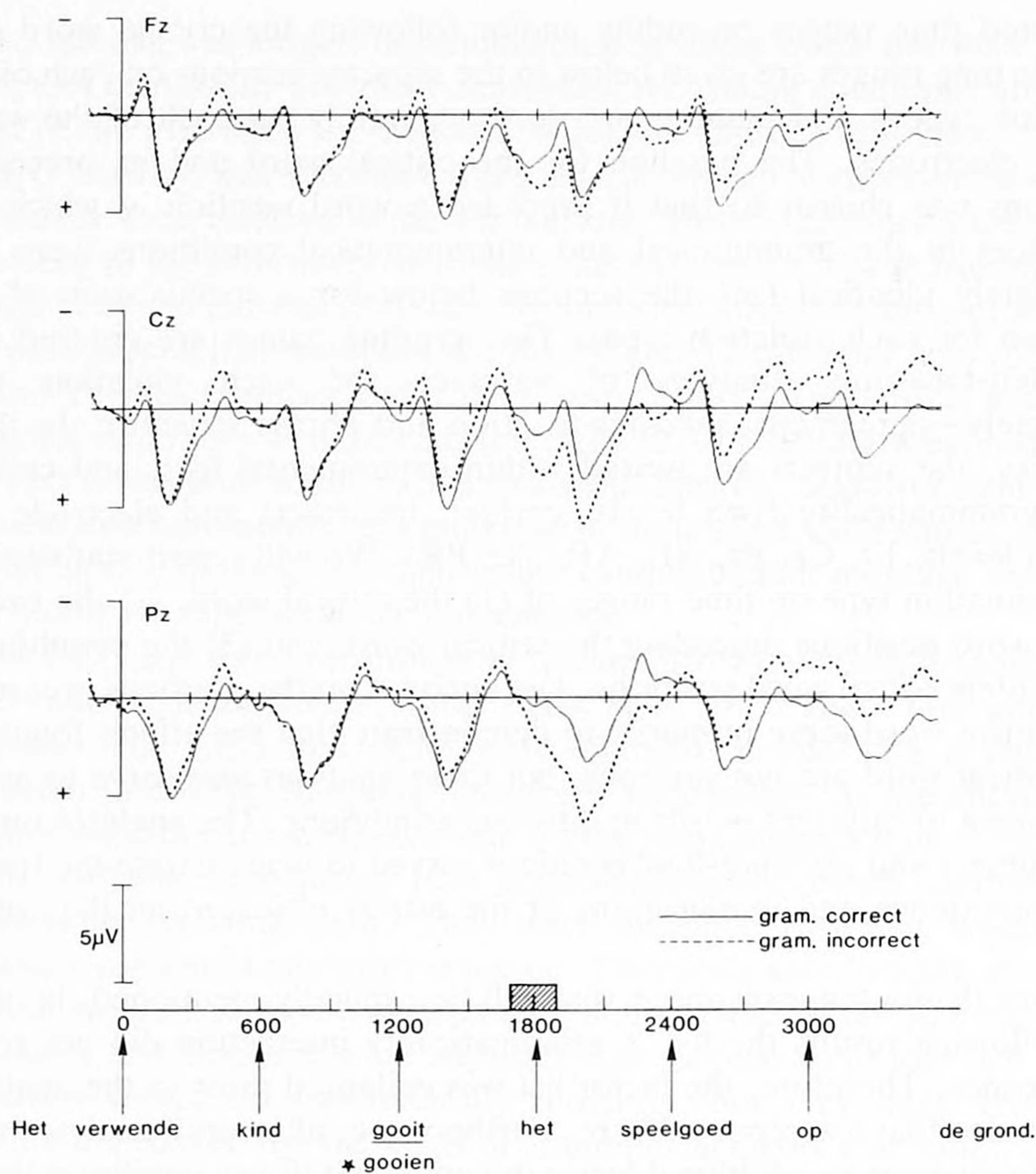


FIG. 1 Agreement condition. Grand average waveform for each of the three midline electrode sites, for the grammatically correct (average of  $n = 966$  waveforms) and incorrect (average of  $n = 985$  waveforms) critical words (CW). The CW is preceded by two and followed by three words. The area for statistical analysis is indicated on the time axis. The translation of the example sentence is "The spoiled child throws/throw the toy on the ground" (the zero alignment point is on "spoilt").

shows the three midline electrode sites; Fig. 2 shows the four lateral electrodes. In these figures, and in all of the following figures, the baseline used for normalisation is the first 150 msec of the depicted waveform.

The waveforms for the incorrect critical words have a widely distributed positive shift in comparison to the correct words. The positivity has a centro-parietal maximum, of similar size over both hemispheres. The positive shift starts at around 500 msec following the onset of the critical word, and continues throughout the following word.

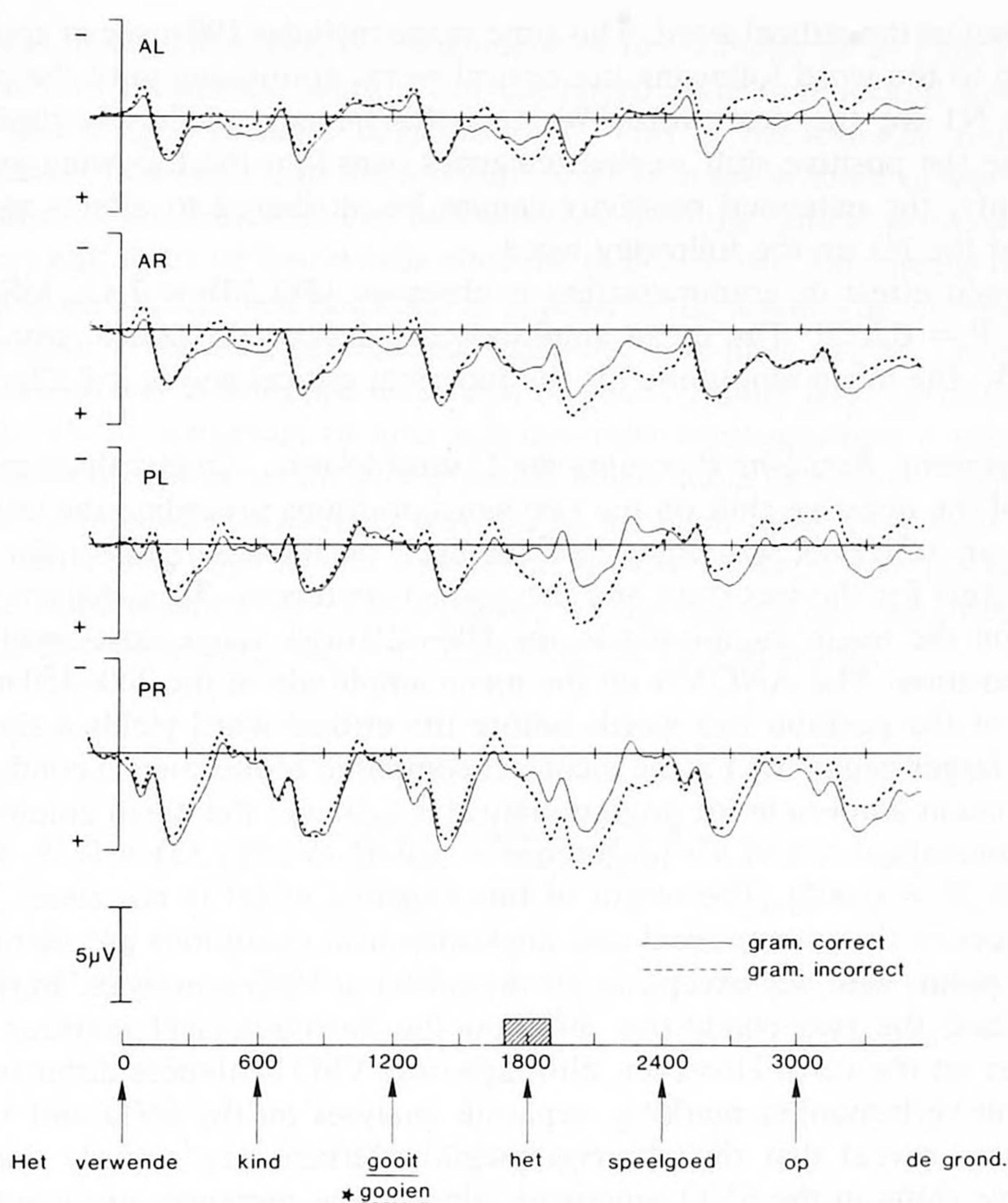


FIG. 2 Agreement condition. Grand average waveform for each of the four lateral electrode sites, for the grammatically correct and incorrect critical words (CW). The CW is preceded by two and followed by three words. The area for statistical analysis is indicated on the time axis. Same example sentence as in Fig. 1.

On the second word following the critical word, the positive shift for the incorrect condition is replaced by a sustained, broadly distributed negativity, already manifest at 200 msec post-onset and continuing throughout the following, third word position.

*Agreement: Critical Word Position.* To test the positive shift on the incorrect critical words, an ANOVA was computed by subjects for the waveforms for the incorrect and the correct sentences. The analysis was performed on the mean amplitudes in the 500–700 msec range following

the onset of the critical word. This time range includes 100 msec of activity related to the word following the critical word, continuing until the peak of the N1 for the next word. We feel this latency window is justified because the positive shift so clearly carries over into the following word. Certainly, the extended positivity cannot be attributed to effects at the level of the N1 on the following word.

A main effect of grammaticality is observed [ $F(1,33) = 7.12$ ,  $MSe = 19.06$ ,  $P = 0.012$ ]. The mean amplitude for the correct critical words is  $1.15 \mu V$ ; the mean amplitude for the incorrect critical words is  $2.22 \mu V$ .

*Agreement: Positions Preceding the Critical Word.* To test the significance of the negative shift on the two word positions preceding the critical word, an ANOVA was computed for each position by subject for the waveforms for the incorrect and the correct sentences. This analysis was done on the mean amplitudes in the 200–450 msec range post-onset for each position. The ANOVA on the mean amplitude in the 200–450 msec range of the position two words before the critical word yields a significantly larger negativity for the incorrect compared to the correct condition—the mean amplitude for ungrammatical is  $1.30 \mu V$ , the mean amplitude for grammatical is  $1.92 \mu V$  [difference =  $-0.62 \mu V$ ;  $F(1,33) = 9.28$ ,  $MSe = 4.93$ ,  $P = 0.005$ ]. The origin of this negative effect is not clear. The sentences in the grammatical and ungrammatical conditions are identical at this point, with one exception for the subset of VSO sentences. In these sentences, the two conditions differ in the morphological marking for number on the verb. However, although only VSO sentences differ minimally in verb-number marking, separate analyses on the SVO and VSO sentences reveal that the observed negative effects are entirely due to negative shifts in the SVO sentences. Since these sentences are identical at all word positions preceding the critical word, the observed effects seem to be of spurious origin.

The negative shift at two positions before the critical word does not, however, modulate the ERP profile for the critical word. This is revealed by an ANOVA on the 200–450 msec range for the position immediately preceding the critical word, which shows no effect of the factor grammaticality.

To demonstrate that the significant positive shift in the 500–700 msec range on the incorrect critical words is not some spurious effect, we performed ANOVAs within the same time range for the two words preceding the critical word. No significant grammaticality effects emerge.

*Agreement: Penultimate and Sentence-final Positions.* The negative shift on the second word position following the critical word looks quite different compared to the waveform observed immediately following the

critical word. However, the alignment of the waveforms in Figs 1 and 2 relative to the critical word is not the appropriate time-locked waveform for assessing a possible negative shift. This is because the individual sentences that enter into the waveforms differ in the number of words they contain. Some sentences end two words beyond the critical word, whereas others end three or four words after the critical word. This means that the second and third word positions as aligned in the waveforms in Figs 1 and 2 contain a mixture of sentence-final and non-final words. Given that closure effects at sentence-final positions can be quite large (cf. Friedman et al., 1975), a mixture of final and non-final word positions is possibly a too heterogeneous set on which to base any reliable assertions. Therefore, we re-computed the average waveforms for each subject on each condition, after first aligning the waveforms for each sentence on the penultimate word position (for this analysis, we did not include the three sentences that have only one word following the critical word).

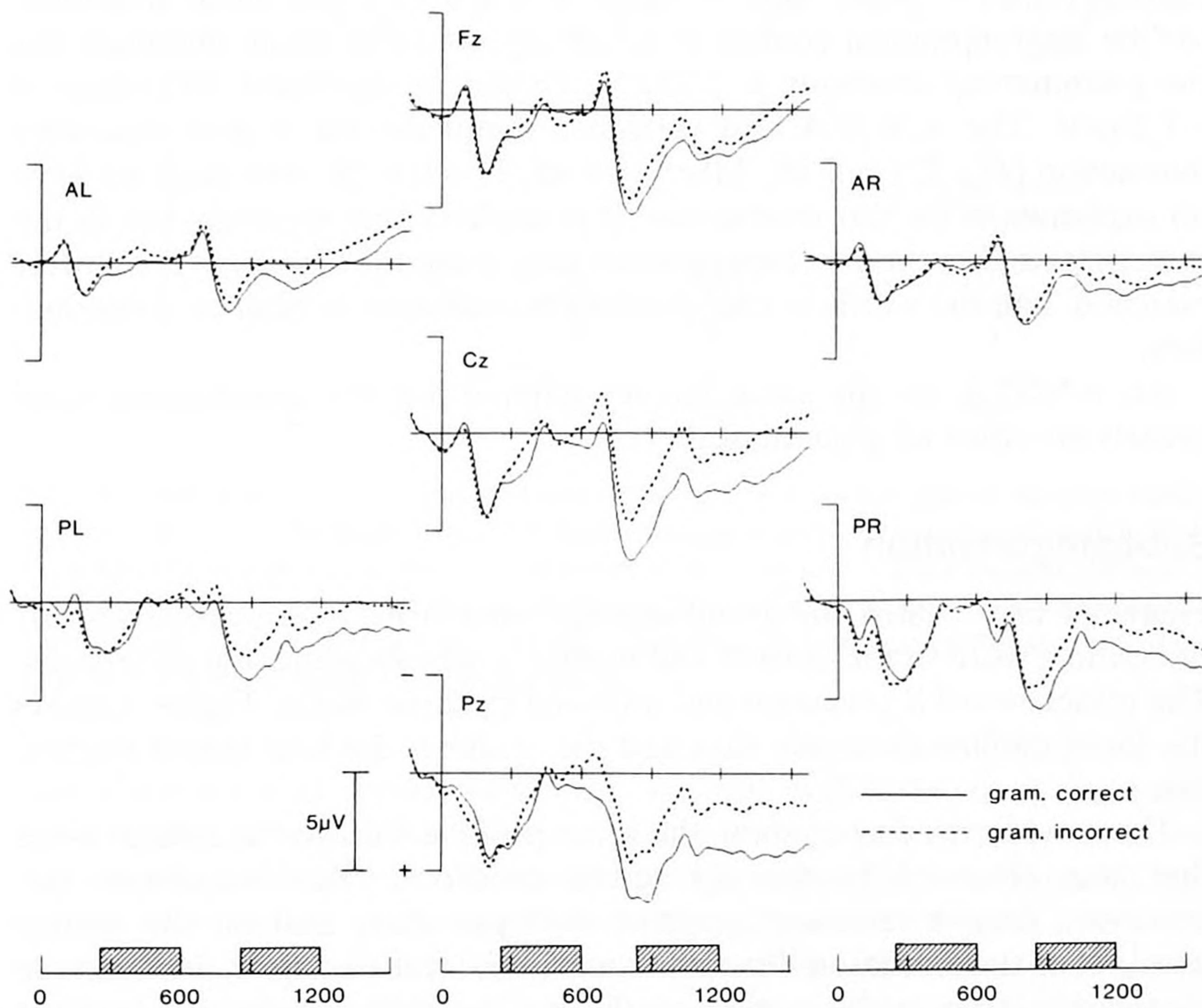


FIG. 3 Agreement condition. Grand average waveform by electrode site for the penultimate and sentence-final word positions in the correct (average of  $n = 911$  waveforms) and incorrect (average of  $n = 928$  waveforms) conditions. The areas for statistical analysis are indicated on the time axis.

Figure 3 depicts the grand average waveforms by electrode site for the penultimate and final word positions in the correct and incorrect agreement conditions. Inspection of the waveforms shows a broad and sustained negative shift for the final word in the incorrect compared to the correct condition. The negativity is larger at posterior than anterior electrode sites, equally so over both hemispheres, with a centro-parietal maximum. The shift is clearly manifest at 200 msec post-onset, and continues throughout the remaining epoch. The negativity fits closely with the morphology and time-course that is characteristic of the N400 (cf. Kutas & Van Petten, 1988). We interpret the negativity as a manifestation of semantic processing problems resulting from the syntactic violation on the critical word (we will expand on this point in the Discussion).

To test the significance of the sentence-final negativity, an ANOVA was computed for the waveforms for the incorrect and the correct sentences, on the mean amplitudes in the 250–600 msec range following the onset of the final word. This ANOVA shows a significant main effect of grammaticality [ $F(1,32) = 14.02$ ,  $MSe = 14.45$ ,  $P = 0.0007$ ]. The mean amplitude for the ungrammatical condition is  $1.45 \mu V$ , and the mean amplitude for the grammatical condition is  $2.75 \mu V$ , yielding a significant difference of  $-1.30 \mu V$ . The ANOVA also yielded a significant list  $\times$  grammaticality interaction [ $F(1,32) = 7.06$ ,  $MSe = 14.45$ ,  $P = 0.012$ ]. Although we have no explanation for this interaction, it is unlikely that its origin lies in the materials used in the two experimental lists, since the sentences are closely matched, and the words in final position are identical in both experimental lists.

An ANOVA on the same latency window for the penultimate word reveals no effect of grammaticality.

### Subcategorisation

Figures 4 and 5 show the grand average waveforms by electrode site for the critical word in the correct and incorrect subcategorisation conditions. The critical word is preceded and followed by three words. Figure 4 shows the three midline electrode sites and Fig. 5 shows the four lateral electrodes.

The waveforms do not show the same positive shift to the critical word that was observed in the agreement condition. The waveforms do, however, show a sustained positive shift preceding and on the critical word, over the frontal midline and anterior lateral electrode sites, for the incorrect relative to the correct condition. This shift is most prominent at the Fz and right anterior sites, where it continues into the position following the critical word. However, because the shift is already apparent at word positions before the critical word (i.e. at a moment in time at which

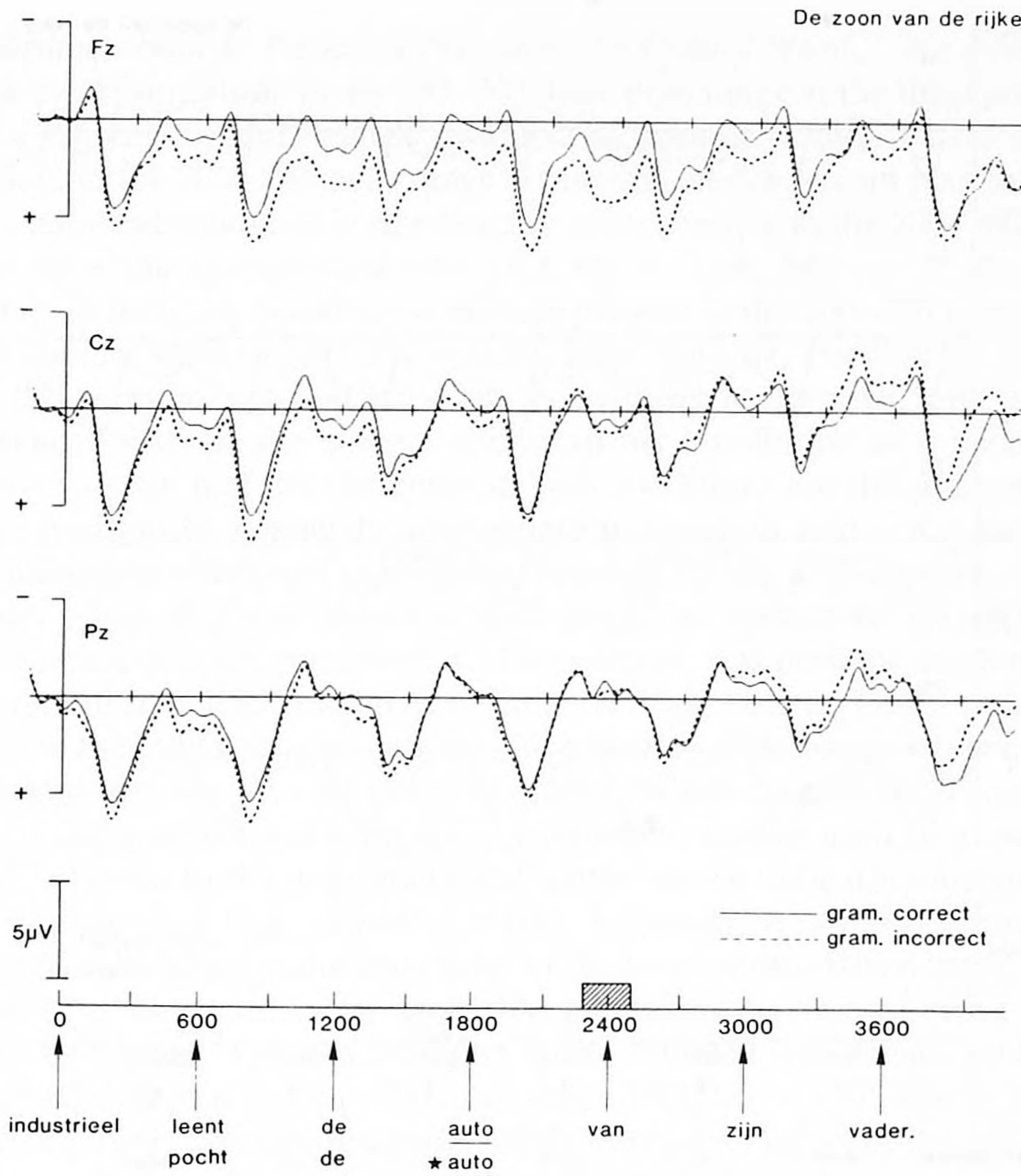


FIG. 4 Subcategorisation condition. Grand average waveform for each of the three midline electrode sites, for the grammatically correct (average of  $n = 946$  waveforms) and incorrect (average of  $n = 939$  waveforms) critical words (CW). The CW is preceded and followed by three words. The area for statistical analysis is indicated on the time axis. The translation of the example sentence is "The son of the rich industrialist borrows/boasts the car of his father" (the zero alignment point is on "industrialist").

the incorrect and correct sentences are still well-formed), it cannot be reliably linked to possible effects of the subcategorisation violation on the critical word. Moreover, the waveforms show that the frontal positivity is absent or marginal at the centro-parietal and posterior lateral sites.

At word positions following the critical word, the waveform for the incorrect condition develops into a negativity, compared to the correct condition, much like is observed for the incorrect agreement sentences. With the exception of Fz, the negative shift is apparent at the first or second position after the critical word.

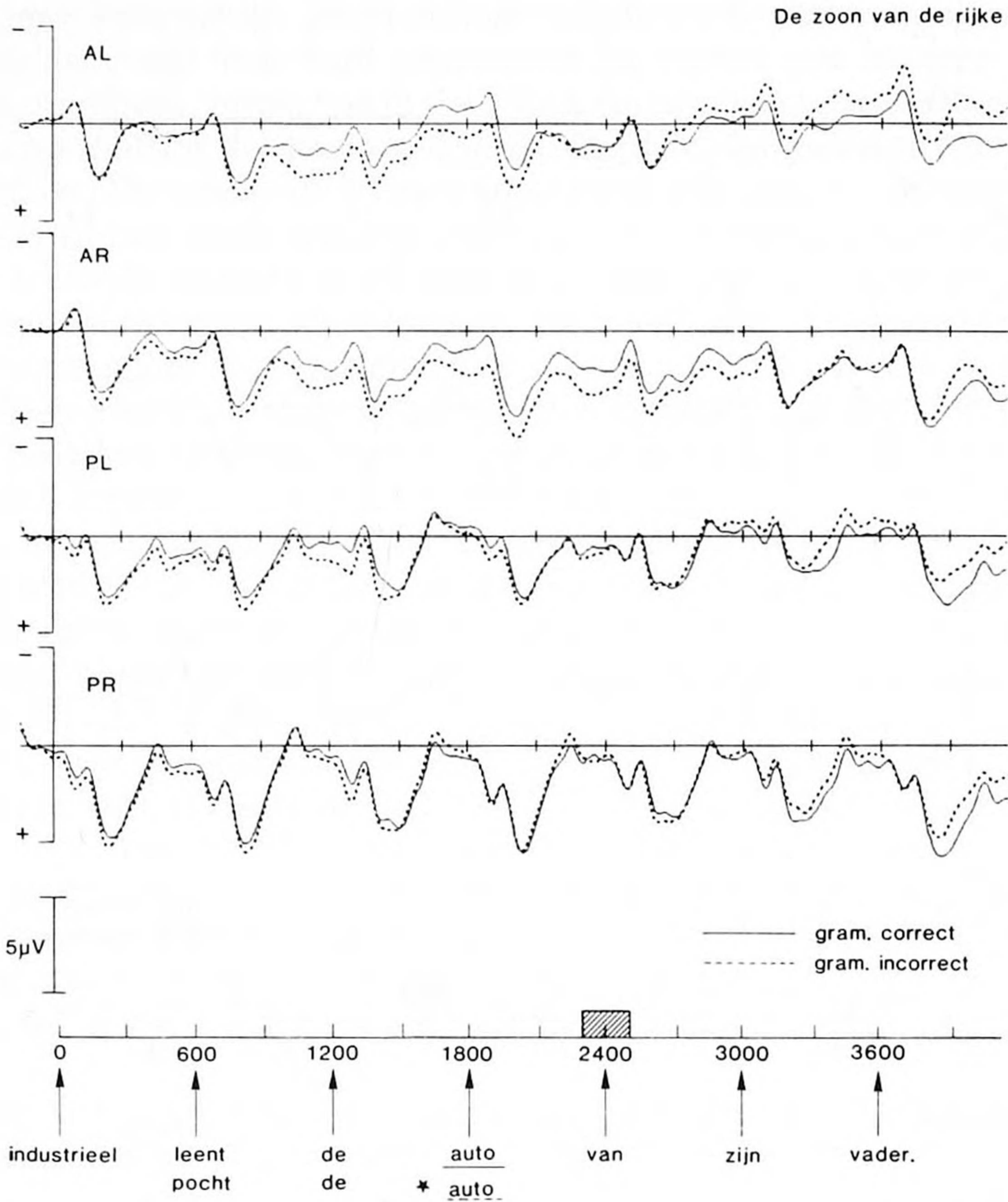


FIG. 5 Subcategorisation condition. Grand average waveform for each of the four lateral electrode sites, for the grammatically correct and incorrect critical words (CW). The CW is preceded and followed by three words. The area for statistical analysis is indicated on the time axis. Same example sentence as in Fig. 4.

*Subcategorisation: Critical Word Position.* To test for differences for the critical word in the incorrect condition, an ANOVA was computed by subjects for the waveforms for the incorrect and the correct sentences, in the same time range as used for the agreement analysis (i.e. 500–700 msec post-onset of the critical word). In this latency window, the mean amplitude for the correct condition is  $0.89 \mu\text{V}$ ; the incorrect condition has a mean amplitude of  $1.45 \mu\text{V}$ . This difference of  $0.56 \mu\text{V}$  is not significant. So, the positive shift observed on the critical word for the agreement violation condition is not found for the subcategorisation violations.



*Subcategorisation: Positions Preceding the Critical Word.* An ANOVA on the mean amplitude in the 500–700 msec time range at the third position before the critical word shows no effect of grammaticality. There is also no effect in the 200–450 msec range. However, at the second position, the ungrammatical condition is significantly more positive in the 500–700 msec range than the grammatical one [ $F(1,33) = 7.59$ ,  $MSe = 15.85$ ,  $P = 0.0095$ ]. In fact, this positivity is already present in the 200–450 msec post-onset latency window [ $F(1,33) = 6.36$ ,  $MSe = 11.09$ ,  $P = 0.017$ ]. In line with the terminology that we have been using so far, we refer to the difference between the correct and incorrect conditions as a positivity. However, given that the sentences in both conditions are still grammatical at this position, it is equally appropriate to speak in terms of a negative shift for the grammatical condition compared to the ungrammatical one. In fact, given that the observed shift might be related to the different lexical items that are presented at this position, it is perhaps more in line with established ERP effects (cf. Kutas & Van Petten, 1988) to indeed think of this shift as a negativity. The lexical differences between the conditions concern the verbs used to realise the subcategorisation comparison. In the grammatical sentences, a transitive verb is used (e.g. *reads* a book), whereas in the ungrammatical sentences, an obligatory intransitive verb is presented (e.g. *elapses* a book). However, it is unlikely that the observed shift affected the waveform at the level of the critical word, since the shift at the position immediately preceding the critical word is no longer significant. There is no effect in the 200–450 msec range, and only a marginal effect in the 500–700 msec range [ $F(1,33) = 3.77$ ,  $MSe = 17.45$ ,  $P = 0.06$ ], reflecting the dissipation of the carry-over effect of the positivity on the second word position preceding the critical word.

*Subcategorisation: Penultimate and Sentence-final Positions.* To test for sentence-final effects, the waveforms for each sentence were aligned on the penultimate word position, and subsequently averaged by subjects for each condition (leaving out the one sentence that has only one word following the critical word). Figure 6 shows the grand average waveforms by electrode site for the penultimate and final word positions in the correct and incorrect subcategorisation conditions.

An ANOVA was performed on the mean amplitude within the 250–600 msec post-onset latency window for the penultimate and final word position separately. The mean amplitude for the penultimate word of the grammatical condition is  $0.89 \mu V$ ; the mean amplitude for the ungrammatical condition is  $-0.10 \mu V$ . This difference of  $-0.99 \mu V$  is significant [ $F(1,33) = 11.01$ ,  $MSe = 10.47$ ,  $P = 0.0022$ ].

The ANOVA for the final word position also revealed a significant main effect of grammaticality [ $F(1,32) = 17.9$ ,  $MSe = 14.16$ ,  $P = 0.0002$ ]. The

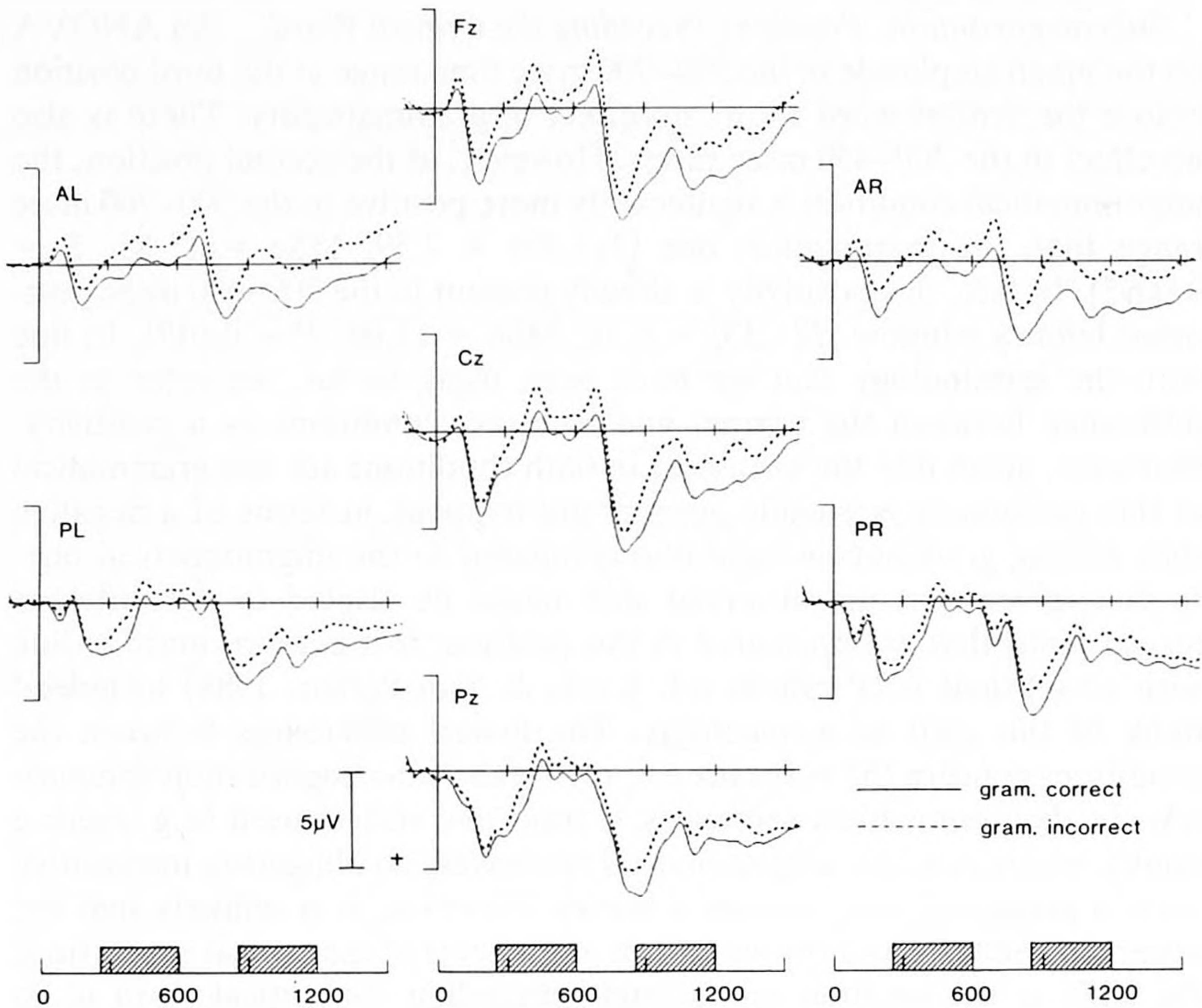


FIG. 6 Subcategorisation condition. Grand average waveform by electrode site for the penultimate and sentence-final word positions in the correct (average of  $n = 962$  waveforms) and incorrect (average of  $n = 950$  waveforms) conditions. The areas for statistical analysis are indicated on the time axis.

mean amplitude for the ungrammatical condition is  $1.67 \mu\text{V}$  and the mean amplitude for the grammatical condition is  $3.31 \mu\text{V}$ , yielding a significant difference of  $-1.64 \mu\text{V}$ . In addition, a significant list  $\times$  grammaticality interaction was found [ $F(1,32) = 7.06$ ,  $MSe = 14.45$ ,  $P = 0.012$ ], indicating that the two subject groups differ in the relative size of their grammaticality effects. It is unlikely that this group difference is due to the assignment of the grammatical and ungrammatical versions of the sentences to the specific experimental lists. The sets of grammatical and ungrammatical sentences are closely matched, and only differ in the transitive and intransitive verbs used.

### Phrase Structure

Figures 7 and 8 show the grand average waveforms by electrode site for the critical word in the correct and incorrect phrase-structure conditions. The critical word is preceded and followed by three words. Figure 7 shows

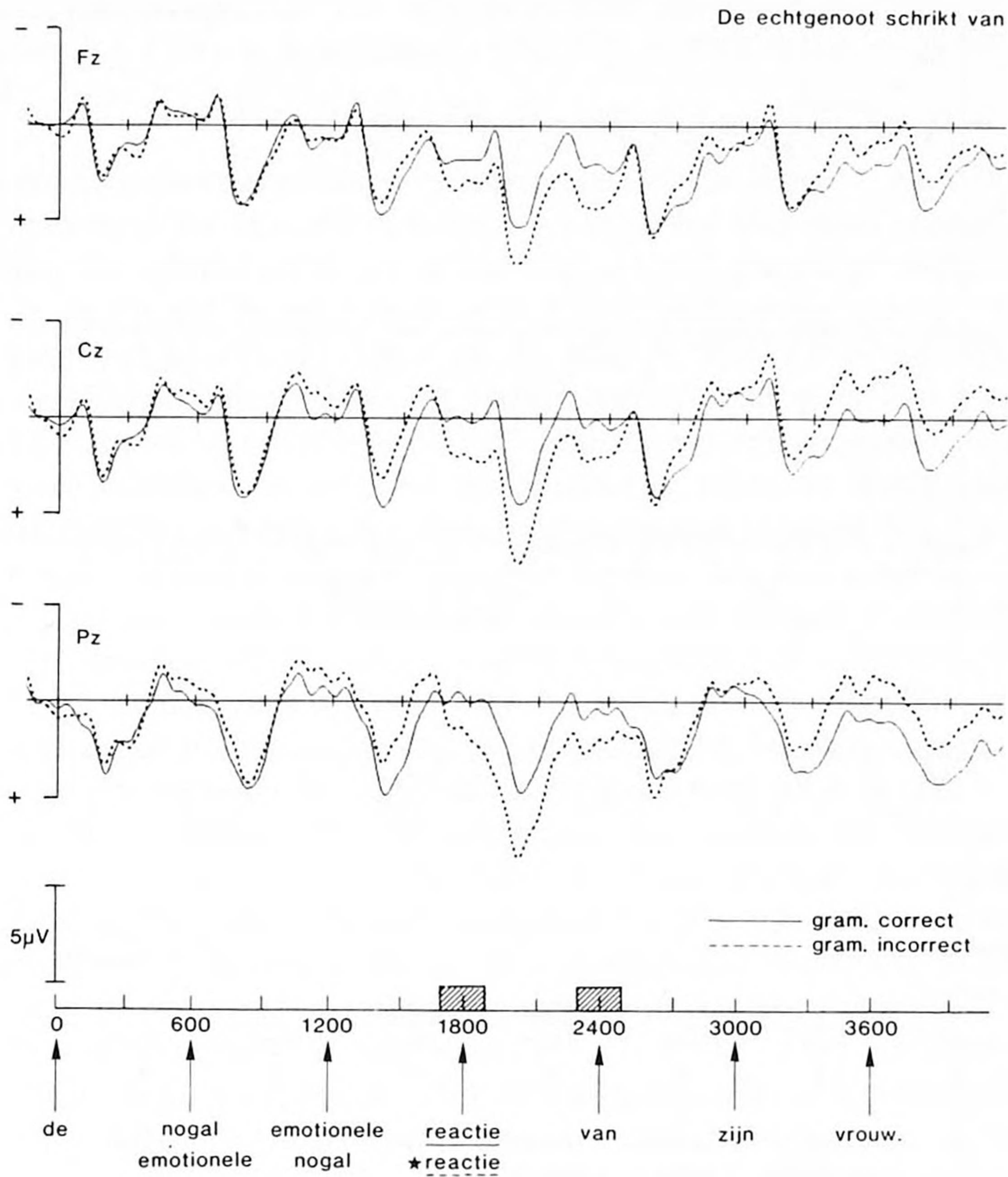


FIG. 7 Phrase-structure condition. Grand average waveform for each of the three midline electrode sites, for the grammatically correct (average of  $n = 966$  waveforms) and incorrect (average of  $n = 970$  waveforms) critical words (CW). The CW is preceded and followed by three words. The areas for statistical analysis are indicated on the time axis. The translation of the example sentence is "The husband [is startled] by the rather emotional/emotional rather response of his wife" (the zero alignment point is on the second "the").

the three midline electrode sites and Fig. 8 shows the four lateral electrodes.

The waveforms at the critical word position in Figs 7 and 8 are characterised by a positive shift with a broad scalp distribution for the incorrect critical words in the latency window between 500 and 700 msec post-onset. In fact, the positivity is present from the immediate onset of the critical word. This very early positive shift is a carry-over effect from a similar shift in the incorrect condition in the time range from 500 to 700 msec on the word position directly preceding the critical word. This preceding word position is further characterised by an earlier negative shift for the incor-

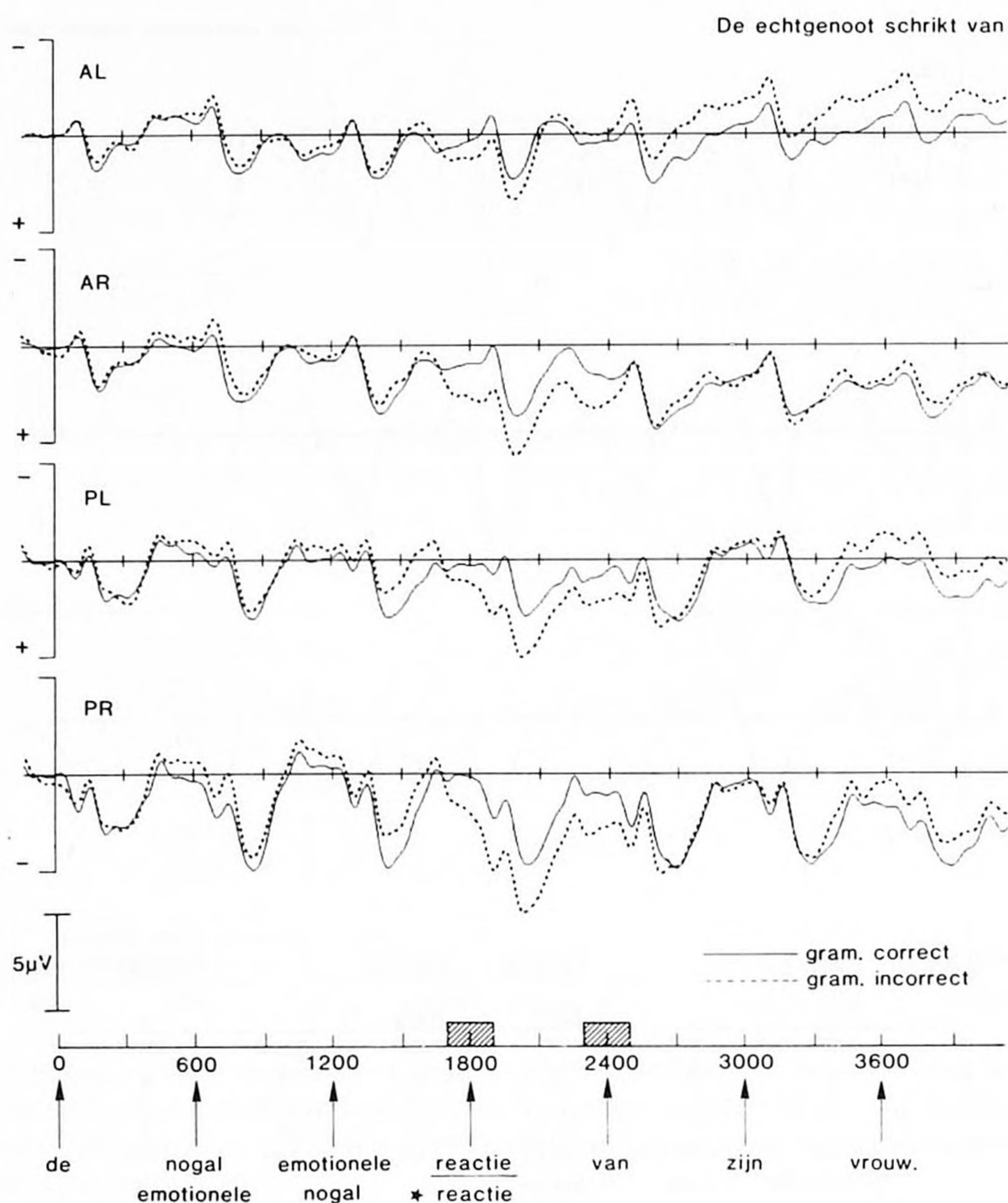


FIG. 8 Phrase-structure condition. Grand average waveform for each of the four lateral electrode sites, for the grammatically correct and incorrect critical words (CW). The CW is preceded and followed by three words. The areas for statistical analysis are indicated on the time axis. Same example sentence as in Fig. 7.

rect condition, with a posterior maximum. Following the critical word, the waveforms come together on the next word position, and then show a broadly distributed negative shift for the incorrect condition on the second and third positions, very similar to the negative shifts observed for the agreement and subcategorisation conditions.

*Phrase Structure: Critical Word Position.* The positive shift for the incorrect critical words was tested in an ANOVA by subjects for the waveforms for the incorrect and the correct sentences, in the 500–700 msec range. The mean amplitude for the grammatical condition is  $1.00\ \mu\text{V}$  and

the mean amplitude for the ungrammatical condition is  $2.10\ \mu\text{V}$ . This difference of  $1.10\ \mu\text{V}$  is significant [ $F(1,33) = 5.44$ ,  $\text{MSe} = 26.67$ ,  $P = 0.026$ ].

*Phrase Structure: Positions Preceding the Critical Word.* An ANOVA was performed for the 500–700 msec window for the word immediately preceding the critical word. As on the critical word, the effect of grammaticality is significant [grammatical =  $0.50\ \mu\text{V}$ , ungrammatical =  $2.13\ \mu\text{V}$ , difference =  $1.63\ \mu\text{V}$ ;  $F(1,33) = 10.41$ ,  $\text{MSe} = 30.11$ ,  $P = 0.0028$ ]. This effect most likely results from the requirement for the parser to entertain the possibility of an adjective–adverb–adjective–noun sequence, which is both more complex (in terms of the number of syntactic nodes) and less frequent than the adverb–adjective–noun sequence (a point that we raised earlier in the Materials section). Despite the fact that at this word position the incorrect sentences are still grammatically well-formed, it could be the case that because of the rarity and/or complexity of adjective–adverb sequences, the presence of the adverb following the adjective goes against the syntactic structure expected and/or preferred by the subjects. This parsing problem then manifests itself as the same positive shift that is found for syntactic violations. We will pick up on this point in the Discussion.

To test the early negative shift for the word position preceding the critical word, an ANOVA was computed for the 200–450 msec latency window. The mean amplitude for the grammatical condition is  $2.03\ \mu\text{V}$  and the mean amplitude for the ungrammatical condition is  $0.97\ \mu\text{V}$ . This difference of  $-1.06\ \mu\text{V}$  is significant [ $F(1,33) = 7.7$ ,  $\text{MSe} = 17.49$ ,  $P = 0.009$ ]. Although it is possible that this negative shift is a reflection of a processing difficulty related to adjective–adverb sequences, it is also possible that the shift is due to the presence of different words (i.e. adjectives and adverbs) in the correct and incorrect conditions.

To assess whether the observed negative and positive shifts for the critical word and for its immediately preceding position are restricted to these positions, separate ANOVAs were computed in the 200–450 msec and the 500–700 msec range for the second and third positions before the critical word. None of these analyses yielded significant effects of grammaticality.

*Phrase Structure: Penultimate and Sentence-final Positions.* To test the sentence-final negative shift, an ANOVA was performed on the mean amplitude within the 250–600 msec post-onset latency window for the penultimate and final word position separately, after alignment on the penultimate position. Figure 9 shows the grand average waveforms by electrode site for the penultimate and final word positions in the correct and incorrect phrase structure conditions.

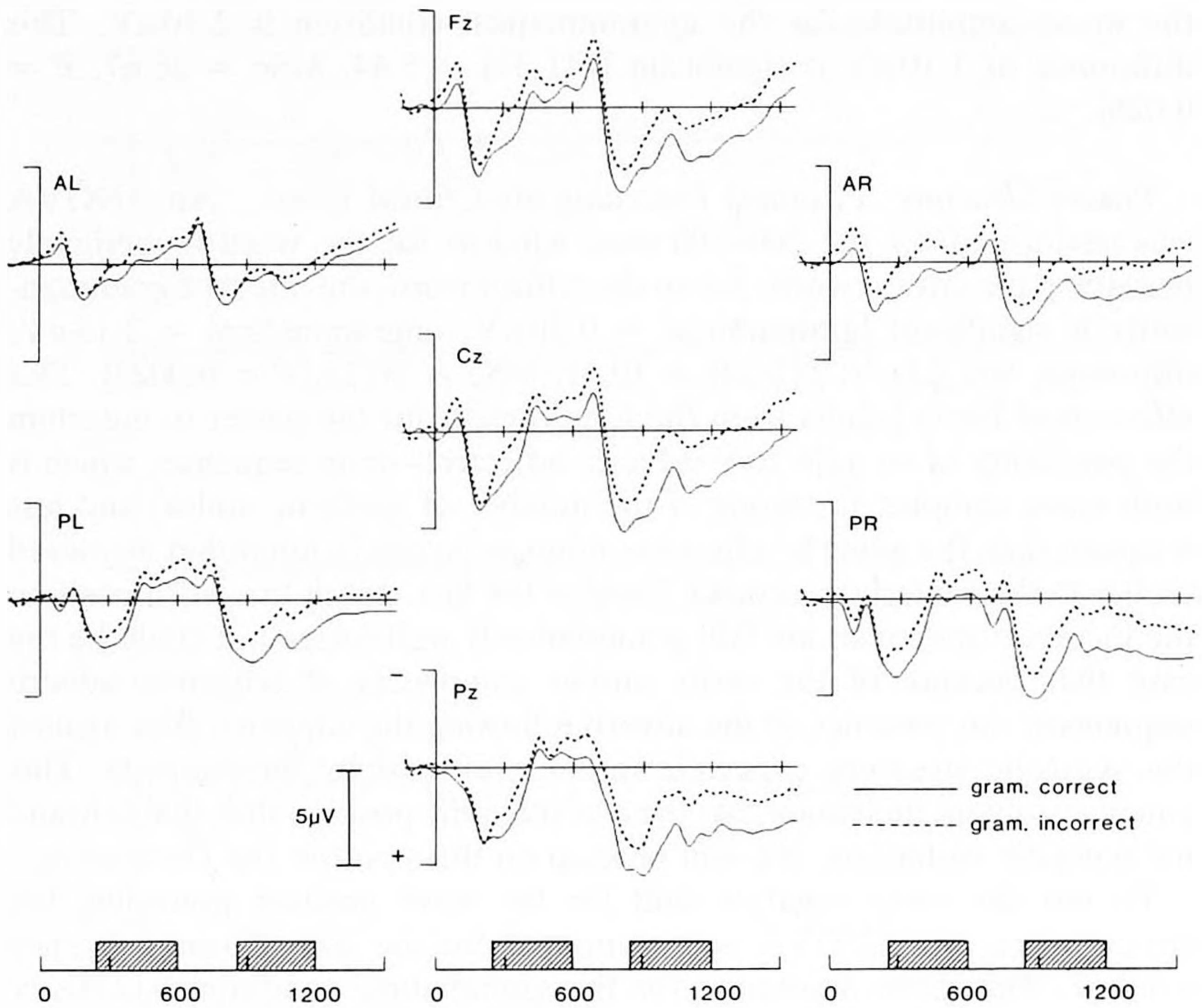


FIG. 9 Phrase-structure condition. Grand average waveform by electrode site for the penultimate and sentence-final word positions in the correct (average of  $n = 962$  waveforms) and incorrect (average of  $n = 965$  waveforms) conditions. The areas for statistical analysis are indicated on the time axis.

The mean amplitude for the penultimate word of the grammatical condition is  $0.67 \mu\text{V}$  and the mean amplitude for the ungrammatical condition is  $-0.23 \mu\text{V}$ . This difference of  $-0.90 \mu\text{V}$  is significant [ $F(1,33) = 8.83$ ,  $\text{MSe} = 11.01$ ,  $P = 0.0055$ ]. A similar significant effect is present for the sentence-final position [grammatical =  $2.65 \mu\text{V}$ , ungrammatical =  $1.21 \mu\text{V}$ , difference =  $-1.44 \mu\text{V}$ ;  $F(1,33) = 16.31$ ,  $\text{MSe} = 15.08$ ,  $P = 0.0003$ ].

### Summary of the Main Results

The critical words in the incorrect agreement and phrase-structure conditions have a positive shift compared to the correct conditions. This shift most probably results from the syntactic violation on the critical word. There is no significant positive shift in the subcategorisation condition.

This could be due to aspects of the materials used (we will expand on this possibility in the Discussion).

All three violation types have a significant negative shift for the incorrect condition on the sentence-final position. In addition, the incorrect subcategorisation and phrase structure conditions have a significant negative shift on the penultimate position. The negativity is most likely reflecting semantic analysis problems originating from the syntactic violations.

The waveforms preceding the critical word in all three violation types show some sporadic significant effects of the factor grammaticality, despite the fact that all of the sentences are well-formed up to the critical word. Other than one spurious effect in the ungrammatical agreement condition, these effects only occur when different words are present in the grammatical and ungrammatical conditions. Therefore, lexical differences seem the most likely explanation for the origin of these effects. A possible exception here concerns the differences observed for the word preceding the critical word in the phrase structure condition. These differences could be reflecting the fact that adjective-adverb sequences go against the structural analysis preferred by the subjects.

## DISCUSSION

The major result of this study is the widely distributed positivity that is elicited by two of the three types of syntactic violations. This positive effect starts at about 500 msec, with a centro-parietal maximum. The effect is very similar to the P600 reported by Osterhout and Holcomb (1992). From our data, a number of conclusions follow about the nature of the "syntactic" positivity we have obtained.

First, the positive shift to different syntactic violations is clearly different from the negative shift (the N400) which arises as a result of semantic violations, such as violations of selectional restrictions (Kutas & Hillyard, 1980a). That is, the brain responses to violations of different kinds of linguistic constraints (i.e. syntactic and semantic) seem to honour distinctions made in most models of language comprehension between the processing of syntactic and semantic information. Although the results do not allow conclusions concerning autonomous or interactive parsing, they suggest that in the process of language understanding either some intermediate level of syntactic representation is computed, or a process of syntactic re-analysis is initiated upon encountering a structural misassignment. We will return to this point later.

Second, the positive shift is not an ERP response to violations only. This is shown by the results for the phrase-structure condition. In this condition, the positive shift already occurred one word before the syntactic violation. It is on this word (i.e. the adverb) that the parser can no longer assign the

more frequent and less complex NP-structure in Dutch (i.e. determiner–adjective–noun) to the incoming string. Instead, the adverb forces the parser to entertain the possibility of a less frequent and more complex NP-structure (i.e. determiner–adjective–adverb–adjective–noun). Note that at the adverb the less frequent, more complex, but syntactically legal structure in Dutch was still possible (for a slightly different, alternative account of this result in terms of predicting phrasal heads, see Wright and Garrett, 1984). Only the noun following the adverb excluded the less frequent and more complex alternative, and rendered the sentence ungrammatical. This result is consistent with other empirical evidence suggesting that the parser is designed to avoid keeping all structural options open until final disambiguating information is encountered (e.g. Frazier & Rayner, 1982; Garnsey et al., 1989; Rayner et al., 1983). That is, the parser does not assign and maintain all possible structures until disambiguating information excludes the inappropriate alternatives. Instead, a preferred structure is assigned on the basis of some computational economy principle (see Frazier, 1987a), or on the basis of the frequency of alternative syntactic constructions. This preferred structure gets revised if it is made untenable by further incoming words. In general, then, the positive shift seems to be elicited by words which indicate that the preferred structural assignment is an incorrect syntactic analysis for the processed string of words.<sup>1</sup>

Third, the positive shift occurs in the absence of any task other than the requirement for the subjects to attentively read the sentences for understanding. This in itself is a distinct advantage for studies on language processing, which are often confronted with the problem of task interfer-

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<sup>1</sup>This conclusion is further supported by a subset of the sentences in the agreement condition. In this condition, a substantial number of the SVO sentences (11 of the 25) can be claimed to be structurally legal at the critical word position in the ungrammatical condition. These are sentences with transitive verbs in NPsg-Vpl sequences, with the verb morphologically marked for present-tense plural. In Dutch, the morphological marker for present-tense plural is also the infinitival marker. The combination of a singular NP with a present-tense plural verb form in the ungrammatical version of these 11 sentences can, therefore, be analysed as an infinitival phrase. This infinitival construction might be assigned the role of grammatical subject of the sentence (e.g. “[De goed opgeleide technicus *vervangen*], is moeilijk”; the critical word is italicised; the plural/infinitival marker is in bold; the infinitival subject construction is within square brackets). These 11 cases differ from the remaining 49 sentences in the agreement condition, in that the critical word renders the preferred assignment impossible instead of rendering the sentence structurally illegal. However, the positivity to the critical word in the SVO sentences does not differ in size or latency from that in the VSO sentences. This further substantiates the claim that the positive shift to syntactic violations is similar to the positivity elicited by words that render a preferred assignment impossible.



ence effects. Much of the psycholinguistic processing literature can be read as an extended attempt to rid real-time performance of the contamination brought about by the task used to observe that performance. The fact that differential ERP effects can be obtained without imposing irrelevant and interfering task demands on the subjects, demonstrates one of the most appealing characteristics of the ERP method for language research.

The fact that we have observed the positive shift in the absence of irrelevant task demands also makes a "surprise" account of the observed positivity less likely. One could argue that the observed positivity is not directly related to the processing of syntactic information, but is mediated by a surprise reaction to the rare event of a syntactic violation. This would be the case if the observed positivity is a member of the P300 family, an ensemble of positive components with an amplitude that is proportional to the rarity of a task-relevant stimulus (e.g. Donchin, 1979; 1981; Fabiani, Gratton, Karis, & Donchin, 1987; see also Osterhout & Holcomb, 1992). The possibility that the observed positivity belongs to a family of P300-like waves has, however, become less likely in the light of the present study. The reason is that the unexpected syntactic violations are not the task-relevant stimuli. This contrasts with studies where subjects were required to judge the acceptability or grammaticality of the sentences, and to overtly indicate their judgement (e.g. Neville et al., 1991; Osterhout & Holcomb, 1992). In such situations, it could be claimed that the coincidence of a task-relevant stimulus and an essentially rare event (i.e. an ungrammaticality) combines to bring about a classical oddball stimulus, resulting in a positivity. As we just mentioned, this line of reasoning does not apply to the experiment we have reported here, because we have not required a decision and an overt response from our subjects, and because we have not instantiated a task-relevant dimension with respect to the grammaticality variable used in the experiment. Nevertheless, even in the absence of an overt response, it could still be claimed that the syntactic violations are relevant to the task of reading. This leaves open the possibility that the positivity is still being driven by the rarity of an ungrammatical event. However, in this case, it remains to be explained why the rare event of a semantic incongruity elicits an N400, whereas the rare event of a syntactic violation elicits a positive shift. That is, by attributing the positive shift to an aspecific surprise reaction, one can no longer explain why the brain responses to different kinds of rare events honour the linguistic distinction between syntax and semantics so well. As long as the ERP responses can be differentiated in terms of psycholinguistically motivated categories, the answer to the question whether they are direct or mediated responses to the underlying language processing events leaves the functional relevance and interpretation of the results largely unaffected. For the data obtained in this study, this clearly is the case.

Fourth, unlike the study by Osterhout and Holcomb (1992), the syntactic anomalies in our study elicited a positivity to open-class words (i.e. nouns and verbs) and to words with closed-class characteristics (i.e. adverbs). In the study by Osterhout and Holcomb, positivities were observed to closed-class words (i.e. infinitival markers and auxiliaries). Taken together, the present study and the one by Osterhout and Holcomb rule out the possibility that the positivity might be elicited as a function of word class. Both open- and closed-class words bring about a "syntactic" positivity, under the assumption that these are the words that render the preferred structural assignment impossible.

As in Osterhout and Holcomb's study, for all violation types significant N400 effects were obtained on the sentence-final words. But in addition to the findings by Osterhout and Holcomb, these N400 effects were also significant on the penultimate word in the subcategorisation and the phrase structure violations. Since in most sentences (71%) the penultimate word followed the critical word either immediately or with one intervening word, the results indicate that the N400 effects emerge closely after the occurrence of the parsing problem. The suggestion of a tight coupling between parsing problems and N400 effects is enforced by the observation that the morphology of the waveforms for the agreement violation and the phrase structure violation indicates that the positivity elicited by the critical word carries over to the following word, thereby probably masking a negative shift in the waveform elicited by the word following the critical word in the ungrammatical sentences. This might result in an underestimation of the onset latency of the N400 effects. In all, then, the results show N400 effects more or less immediately after, and certainly on, the second word following the presentation of the critical word that renders the sentence ungrammatical. According to recent claims, the N400 is especially sensitive to the integration of lexical meaning into an overall representation of the word or sentence context (Brown & Hagoort, 1993; Osterhout & Holcomb, 1992). The N400 effects to words following the critical word in the ungrammatical sentences suggest that the semantic integration process is affected by the syntactic violation not only at sentence closure (as suggested by Osterhout & Holcomb, 1992), but more or less immediately after the failure of the first parse. That is, the syntactic violations have immediate consequences for the semantic integration of following words into a coherent message-level representation of the whole sentence. The integration of words following a syntactic violation becomes more difficult, as is indicated by an increase in the amplitude of the N400 to words following the critical word.

It is clear that in this respect not all syntactic violations have an equally strong disruptive effect on the integration of following words. The agreement violation, for instance, is realised by an incorrect suffix on the noun

or verb, which in itself does not seriously affect the semantic relations between the individual open-class words in the sentence. For this reason, the agreement violation might have relatively restricted consequences for the semantic integration of open-class words following the item that renders the sentence ungrammatical. This might explain why in sentences with an agreement violation, N400 effects were restricted to the sentence-final word. Much stronger effects on semantic integration were seen for the two other types of violation, in which either a strong syntactic cue in Dutch for the interpretation of a phrase was violated (i.e. word order), or in which the structural violation was associated with different verbs in the grammatical and ungrammatical conditions. With respect to the latter violation, in addition to differences in their subcategorisation frame, these different verbs involve differences in the semantic constraints for the remaining part of the sentence. For the phrase structure and subcategorisation violations, therefore, significant N400 effects were also obtained in pre-final word positions, which in the majority of the sentences was only one or two words after the critical word.

The combination of positivities and negativities obtained for the agreement violation and the phrase structure violation provides some clues to explain the *prima facie* unexpected absence of an effect on the critical word in the subcategorisation violation condition. The subcategorisation violation differs from the other two violations in that already two words before the critical word expectations are set up on the basis of the subcategorisation frame associated with the transitive (in the grammatical sentences) and intransitive (in the ungrammatical sentences) verbs. These lexically specified structural constraints on whether an object-NP can or cannot follow most likely translate into a matrix for what fits semantically. That is, given the context there might be a difference in cloze probability for the critical word in the grammatical and the ungrammatical conditions. The N400 amplitude is known to be inversely related to the cloze probability of open-class words (Kutas & Hillyard, 1984). For this reason, one could expect a larger N400 to the critical word in the ungrammatical compared to the grammatical condition. In addition to the possible difference in cloze probability, it is only in the subcategorisation condition that the critical word renders the sentence ungrammatical via its semantic properties. Although the intransitive verb cannot take an object-NP, in Dutch it could have taken a noun at the critical word position as part of an adverbial phrase of duration (e.g. "laughs an *hour* long"). However, this analysis is rendered untenable due to the semantic properties of the actual noun in the critical word position, which cannot occur as part of an adverbial phrase of duration (e.g. "laughs a *car* . . .").

Most importantly, recent empirical evidence indicates that part of the verb's semantic specifications is encoded in the subcategorisation frames

(Fisher, Gleitman, & Gleitman, 1991). This is in line with several linguistic accounts claiming that subcategorisation frames are relatively straightforward projections from certain semantic features (Bresnan, 1979; Chomsky, 1981; Jackendoff, 1978). This implies that verb meaning and the syntactic aspects of the verb that are specified on the subcategorisation frames are tightly intertwined. Therefore, subcategorisation violations as used in this study are not only syntactic violations, but by necessity also semantic violations.

The intricate relationship between the violation of semantic expectations and the rejection of the preferred structural assignment might have led to a "semantic" negativity and a "syntactic" positivity to the very same word, which for the subcategorisation violation is the critical noun in the ungrammatical condition. Given the opposite polarity of these two effects and given their overlap in time, they might have cancelled each other out, with as a net result the absence of a significant difference on the critical word itself.

One could say that a similar cancellation of "syntactic" positivity and "semantic" negativity should have been likely for the phrase structure violation. However, for the phrase structure violation, we already obtained a positivity to the adverb, where a semantically legal and normal continuation was still possible (e.g. "the colourful very expensive tulips"). The adverb thus did not exclude the structurally more frequent, less complex and, therefore, probably preferred assignment on the basis of its semantic specifications, but on the basis of its word class. In other words, the rejection of the preferred assignment was a consequence of structural and not of semantic constraints. This is the probable cause of the sustained positivity elicited to the adverb and carried through into the critical word.

The absence of an effect on the critical word in the subcategorisation condition leads us to a methodological worry. In cases where a first parse is rejected on the basis of a semantic evaluation, or in cases where strong and immediate consequences of a syntactic violation for the semantic integration of the violating word are to be expected, one might be confronted with the problem of overlapping positive and negative components in ERP studies on parsing. One way to reduce the chance of N400s masking "syntactic" positivities is by using a closed-class word to render the sentence ungrammatical, as in Osterhout and Holcomb's (1992) study. In contrast to open-class words, closed-class words primarily serve a syntactic function. This implies that their occurrence is not, or only weakly, determined by purely semantic constraints, such as selectional restrictions. Given the relative weakness of the semantic matrix for closed-class words, these words might be more suited than open-class words to pick up the consequences of a syntactic violation or misassignment. A second possibility to minimise this particular problem of overlapping components is to

reduce the semantic constraints of the context altogether. One way of doing this is to use so-called "syntactic prose", in which sentences are semantically incoherent but syntactically legal. In these kinds of sentences, one can again test the effect of specific syntactic violations, with probably only minor consequences for semantic integration processes. In a syntactic prose version of the current experiment, we recently obtained the same positivities to the same syntactic violations. However, in contrast to the current experiment, these positivities were not followed by N400 effects to the words following the critical word. The effects of grammaticality in syntactic prose support the validity of the positive-shift effects that we have reported in this paper. In addition, the absence of N400 effects fits well with our interpretation in terms of semantic integration processes concerning the significant N400 effects in the normal prose sentences of the present experiment.

For those syntactic violations which are at the same time inherently semantic violations, however, most likely neither the above nor other methodological approaches will avoid the cancellation of a "syntactic" positivity and a "semantic" negativity. That is, for our subcategorisation violations, it might be impossible altogether to separate "syntactic" positivities from "semantic" negativities.

Finally, on the basis of these results, we cannot make strong claims about the temporal relation between parsing operations and semantic integration processes. Although in general the onset of the negative shift (the N400) seems to be earlier than the onset of the "syntactic" positive shift, this in itself does not provide us with conclusive evidence about the time-course of the underlying processes. The reason here is that not enough is known about the temporal origin of processes resulting in endogenous ERP components with specific latency characteristics, such as time of onset and time of maximum amplitude. More detailed knowledge is required about the time-locking parameters of the endogenous ERP components with respect to their underlying cognitive processes before specific inferences can be made about the temporal relation between these processes.

In addition, it is as yet unknown whether the "syntactic" positive shift is time-locked to the initial structural assignment, or to the processor's rejection of this first assignment. This makes it difficult to draw conclusions from the onset latency of the obtained "syntactic" positive shift about the time-course of the initial structural assignments by the parser. No firm statements can therefore be made as yet about the temporal co-ordination of parsing and semantic integration.

In conclusion, we believe that at the level of language processing there seems to be a relation (direct or indirect) between syntactic processing and a "syntactic" positivity in the ERP waveform. Combining the various

points that we have made in the preceding paragraphs, leads us to believe that the positive shift we have observed for violations of syntactic constraints and preferences is a manifestation of a functionally distinct process concerning the computation of syntactic structures. We therefore feel that within the context of language processing, it is justified to assign a functional label to this ERP response, and we will from now on refer to this effect as the Syntactic Positive Shift (SPS). With this functional label we explicitly do not claim that similar positivities cannot be obtained outside of the domain of language processing. What we do want to claim, though, is that with respect to the cognitive architecture of language processing, the obtained positivity can be fruitfully related to the domain of parsing.

The SPS that we have obtained is a common brain response to very different types of syntactic violations. With respect to language processing, the SPS seems to indicate the impossibility for the parser to assign the preferred structure to an incoming string of words, whatever the specific syntactic nature of this preferred structure is. In this respect, the SPS might have a robustness in the domain of syntactic computations that is comparable to that of the N400 in the domain of semantic computations. Whether the sensitivity of the SPS to rejected preferred structural assignments is mediated by awareness of the misassignment, or whether it is a direct consequence of a failing automatic first parse, is still an open issue.

What are the consequences of these results for models of parsing? The present study was exploratory, and therefore not designed to directly test claims of one or other specific proposal on parsing operations. So, the results do not bear directly on such hotly debated issues in the parsing literature as the informational encapsulation of parsing operations with respect to lexical and discourse information. However, at a more global level, certain general notions of parsing are more compatible with the results of the present study than others. The present study suggests the existence of different brain states for parsing and for semantic integration. To the degree to which the SPS and the N400 individuate different sets of neural generators, and to the degree to which different sets of neural generators correspond to different cognitive states, it can be concluded that the results of the present study provide evidence for dedicated processing events underlying the computation of syntactic structures. This result is, therefore, at odds with early proposals on language processing in which the role of syntactic analysis in understanding language is ignored (e.g. Bever, 1970; Schank, 1972; Wilks, 1978).

One way of interpreting the data is that the SPS reflects the computation of a separate level of syntactic representation during the process of language understanding. Under this interpretation, the difference in ERP responses to semantic and syntactic processing goes against the spirit of models that deny an independent status for intermediate products of

syntactic computation (e.g. Bates et al., 1982; McClelland et al., 1989). For example, McClelland et al. (1989) propose in their PDP model of sentence comprehension that "... there is but a single integrated system in which syntactic and other constraints are combined in the connection weights, to influence the construction of a single representation reflecting the influences of syntactic, semantic, and lexical constraints" (p. 329). This single system approach needs to explain how the different constraints embodied in the same connection weights, and therefore indistinguishable at the representational level, can nevertheless lead to ERP responses that are qualitatively differentiated according to the very nature of the constraints (i.e. syntactic and semantic).

Alternatively, one could interpret the data as indicating the initiation of a syntactic reanalysis after a first-pass structural assignment has failed to provide a well-formed structure. That is, the incoming word that cannot be attached to the preferred structure signals the need for the revision of this structure. The SPS might be related to this process of syntactic reanalysis. However, given that the SPS is qualitatively different from ERP responses to the processing of semantic information, under this interpretation one has to conclude that the process of syntactic reanalysis is at least partly separate from the process of deriving a final semantic interpretation. Further research is needed to establish which functional account of the SPS is the most adequate one.

At a more specific level, the results of the present study, in combination with the results of Osterhout and Holcomb (1992), open perspectives for fruitfully applying the ERP method to more intricate issues in the parsing literature. If further ERP studies on parsing confirm the existence of a "syntactic" ERP component such as the SPS, one can investigate what kinds of information influence the morphology of this component, such as its amplitude or latency (cf. Osterhout & Swinney, 1989). In this way, relevant information can be obtained about the principles that guide the human parser in assigning structure to incoming strings of words. For instance, it might enable additional empirical tests of the hypothesis that a first parse is done on the basis of structural principles only, as embodied in the garden-path model (Frazier, 1987a). According to the garden-path model, lexical and discourse information should not influence the morphology of first-pass "syntactic" ERP responses. We are currently implementing a research programme to test these more specific claims.

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## APPENDIX

*All the experimental sentences are listed below. The critical words are in boldface. The text between parentheses is part of the grammatically correct or incorrect version of each sentence, respectively.*

### Agreement condition

#### SVO sentences

1. Alleen de ervaren zwemmers (**duiken/duikt**) vanaf de hoge duikplank.
2. De baldadige jongeren (**zorgen/zorgt**) voor overlast in hun woonplaats.
3. Het kleine verwende kind (**gooit/gooien**) het speelgoed op de grond.
4. Het buiten de stad wonende rijke echtpaar (**handelt/handelen**) in antiek.
5. Mijn leergierige broer (**zoekt/zoeken**) paddestoelen in het grote bos.
6. De gruwelijk verwende meisjes (**kopen/koopt**) een ketting van goud.
7. De prachtig versierde wagens (**rijden/rijdt**) weer door het dorp.
8. Zowel de ouders als hun sportieve kinderen (**doen/doet**) mee aan het toernooi.
9. Het zwaar beladen schip (**arriveert/arriveren**) in de haven.

10. De langdurig werkeloze psycholoog (**behaalt/behalen**) een diploma informatica aan de open universiteit.
11. Zowel de leerlingen als de leraren (**bidden/bidt**) voor de doodzieke rector.
12. De tamelijk agressieve Afrikaanse olifanten (**stappen/stapt**) vaak in kolonnes door de savanne.
13. Neushoorns en vele andere uitheemse soorten (**leven/leeft**) voornamelijk in dierentuinen.
14. Het onlangs geopende theater (**trekt/trekken**) bezoekers uit heel de wereld.
15. De nieuwe democratisch gekozen directeur (**neemt/nemen**) harde maatregelen.
16. De pas aangelegde snelwegen (**kosten/kost**) meer geld dan was verwacht.
17. De in lompen gehulde bedelaar (**steelt/stelen**) fruit van de groenteboer.
18. De goed opgeleide technicus (**vervangt/vervangen**) de machine door een beter systeem.
19. De toch al angstige kinderen (**schrokken/schrok**) erg van het bericht.
20. De zieke soldaat vraagt verlof maar de sergeant (**negeert/negeren**) zijn verzoek.
21. De voetballer scoort gemakkelijk maar de arbiter (**keurt/keuren**) het doelpunt af.
22. De kostbare gouden ring (**ligt/liggen**) zorgvuldig opgeborgen in een kluis.
23. Mijn zus breide een das en mijn broer (**kocht/kochten**) bloemen voor oma.
24. De meeste gasten drinken thee maar mijn vader (**bestelt/bestellen**) koffie met slagroom.
25. De geheel uitgeputte hardloper (**drinkt/drinken**) gulzig een glas water leeg.

*VSO sentences*

26. Met een oorverdovend lawaai (vallen/valt) de **takken** op het tuinhuisje.
27. Bij mooi weer (dragen/draagt) de **kinderen** fleurige jurkjes.
28. Ondanks het verbod van moeder (plagen/plaagt) de **kinderen** de debiele jongen.
29. Na afloop van het gezellige feest (bestellen/bestelt) de **gasten** een taxi.
30. Vanwege het stormachtige weer (spelen/speelt) de **teams** in een sporthal.
31. Met de buitenlandse werknemers in de fabriek (zoeken/zoekt) de **vakbonden** nauwelijks contact.
32. Halverwege de spannende wedstrijd (arresteren/arresteert) de **agenten** een aantal vechtende supporters.
33. Aan het maken van reclame (besteden/besteedt) de **bedrijven** veel geld.
34. In de verre toekomst (reizen/reist) de **mensen** wellicht per vliegende schotel.
35. Voor de aankoop van een auto (sluiten/sluit) mijn **ouders** een lening af.
36. Naar aanleiding van het artikel over toenemend vandalisme (leveren/levert) de **studenten** commentaar.
37. Vrolijk spelend op hun instrumenten (liepen/liep) de **leden** van de fanfare voorbij.
38. Vanwege de massale stakingen in het slachthuis (stijgen/stijgt) de **prijzen** van vlees.
39. Vanwege de intense rust in het reservaat (broeden/broedt) de **vogels** er graag.
40. Na een wachttijd van ruim een uur (vertrekken/vertrekt) de **gasten** zeer boos.
41. Tijdens de zeer gevaarlijke oefening (droegen/droeg) de **soldaten** een gasmasker.
42. Bij de aankoop van twaalf flessen wijn (krijgen/krijgt) de **klanten** korting.
43. Bij het zebrapad op de hoek (wachten/wacht) de **kinderen** vaak zeer lang.
44. Aan het einde van ieder schooljaar (logeren/logeert) de **meisjes** bij hun oma.
45. Met in iedere hand een verse boterham (liepen/liep) de **zusjes** naar school.
46. In dit vrijstaande woonhuis met garage (wonen/woont) de **kennissen** van mijn ouders.
47. Onder de eeuwenoude eik in de tuin (bloeien/bloeit) de **tulpen** volop.
48. Om de lekkages in huis te verhelpen (bellen/belt) de **buren** een loodgieter.
49. Over de voornaamste resultaten van het onderzoek (schrijven/schrijft) de **kranten** kritische commentaren.
50. Tijdens een tocht door de jungle (zien/ziet) de **toeristen** een groep apen.
51. Bij de opening van de nieuwe sporthal (kregen/kreeg) de **bezoekers** een consumptie.
52. Bij het zien van de dikke muis (raken/raakt) de **vrouwen** helemaal overstuur.

53. In de kleine zaal van het hotel (vieren/viert) onze **buren** hun bruiloft.
54. Na een vermoeiende reis door de bergen (bereiken/bereikt) de **toeristen** de camping.
55. Mede dankzij de uitstekende organisatie (komen/komt) de **bezoekers** in groten getale.
56. Tijdens de openbare zitting (stellen/stelt) de **advocaten** lastige vragen.
57. Vanwege de onlangs behaalde overwinning (trakteren/trakteert) mijn **vrienden** op gebak.
58. Tijdens de rumoerige vergadering (besloten/besloot) de **leden** de staking voort te zetten.
59. Alvorens de zojuist geschrobde vloer te betreden (vegen/veegt) de **kinderen** hun voeten.
60. Na de feestdagen in december (liggen/ligt) de **winkels** vol met afgeprijsde artikelen.

#### Subcategorisation condition

1. De tijdens de storm ingestorte kerktoren (vernielde/belandde) het **huis** van de pastoor.
2. De altijd behulpzame vrouw (troost/zorgt) de **kinderen** van haar overleden vriendin.
3. De vrouw die onlangs werd mishandeld (verdringt/beeft) de **gedachte** aan die gebeurtenis.
4. De op hol geslagen ezel (draagt/verdwijnt) de **voorraad** eten op zijn rug.
5. De ongehoorzame jongen (verstopt/ravot) de **hond** in zijn slaapkamer.
6. Enkele leerlingen uit de vierde klas (schrijven/geeuwen) een **verhaal** over de oorlog.
7. De bemanning van het stoomschip (redt/treurt) de **matroos** die overboord geslagen is.
8. Mijn pas getrouwde broer (boekt/mijmert) een **vakantie** naar het zonnige zuiden.
9. De bewaker in de gevangenis (vernedert/walgt) de **gevangene** die een kind vermoordde.
10. Het kleine magere ventje (spitst/bloedt) zijn **oren** en begint te schreeuwen.
11. De aan drank verslaafde vrouw (verwerpt/huivert) het **idee** om minder te drinken.
12. De trotse ouders (betalen/glunderen) de **bruiloft** van hun dochter.
13. Mijn zus opent de tuindeuren en (ziet/hurkt) een **egel** in de tuin.
14. De politicus van de oppositie (bespreekt/debatteert) het **voorstel** met de minister.
15. De automobilist lette niet op en (raakte/botste) de **auto** van zijn collega.
16. De zeer jonge muzikant (wint/schittert) de **wedstrijd** en oogst veel bewondering.
17. De ballerina uit Rusland (verneemt/verbleekt) het **bericht** over de dood van Stalin.
18. De grote zwarte kraaien (bevuilen/nestelen) de **toren** van het kasteel.
19. De jongen met de nieuwe schaatsen (trotseert/bibbert) de **poolwind** op het meer.
20. De buitenlandse toeristen (bezoeken/verdwalen) de **stad** met de vele nieuwe woonwijken.
21. De zoon van de rijke industrieel (leent/pocht) de **auto** van zijn vader.
22. De oude man doet open en (begroet/keuvelt) het **meisje** met rood haar.
23. De eerlijke ambtenaar op het ministerie (bestrijdt/strijdt) de **corruptie** van zijn collega.
24. Een beroemd schrijver uit Nederland (ontmoet/vertoeft) de **minister** in het dure hotel.
25. De jonge ijverige tuinman (vervangt/baalt) de **struiken** die verdroogd zijn.
26. Het meisje is erg ontroerd en (sluit/knippert) haar **ogen** tijdens de plechtigheid.
27. De zeer religieuze man (kuste/knielde) het **beeld** van Maria.
28. De ongeoefende wandelaar uit Gelderland (behandelt/kreunt) een **blaar** onder zijn voet.
29. De schilder en zijn knecht (verven/leunen) de **kast** in de bijkeuken.
30. Mijn oude opa van tachtig (ontloopt/roddelt) de **buren** tijdens het carnaval.
31. Een vreemd uitgedoste kerel (filmt/kibbelt) de **vrouw** met de gebloemde jurk.
32. De vrouw van de miljonair (verzamelt/pronkt) **sieraden** van beroemde kunstenaars.
33. De goed geklede man (gebruikt/schuilt) zijn **paraplu** tijdens de regenbui.
34. De trotse moeder (bewondert/glimlacht) de **prestatie** van haar zoon.
35. De student uit het eerste jaar (geeft/blundert) een **lezing** over emancipatie.
36. De spreker op het congres (draagt/verschijnt) een **broek** die versleten is.
37. De jongen die vorig jaar is gezakt (haat/spijbelt) het **practicum** biologie.
38. De oude man en zijn metgezel (drinken/gruwelen) een **borrel** met suiker.
39. De vermoeide vrouw (eet/snakt) een **boterham** met kaas.

40. Mijn kleine verlegen zusje (ontwijkt/bloost) de **vragen** van de leraar.
41. De kippen op het erf (mijden/kakelen) de **voederbak** van de hond.
42. Het dienblad met glaswerk (vult/klettert) het **aanrecht** in de keuken.
43. De kletsnatte wandelaar (reserveert/overnacht) een **kamer** in een klein pension.
44. De hond van de bureu (bijt/gromt) de **postbode** die een telegram afgeeft.
45. Een leerlinge uit onze klas (bezoekt/poseert) de **schilder** in zijn atelier.
46. De verslaafde Duitser (ziet/grinnikt) een **agent** en rent snel weg.
47. De veel te grote trui (bedekt/floddert) de **benen** van het meisje.
48. De doodzieke en verzwakte man (ondergaat/sterft) een **operatie** aan zijn nieren.
49. Mijn ouders huren een appartement maar wij (lenen/kamperen) een **tent** van vrienden.
50. De van achteren aangereden man (beschrijft/kermt) de **pijn** in zijn nek.
51. De in gedachten verzonken boer (beschadigt/buitelt) een **melkbus** op het erf.
52. De dappere soldaten van de twaalfde compagnie (herdachten/sneuvelden) de **oorlog** in Vietnam.
53. De Griekse veldheren bij Troje (verzonnen/pekerden) en **list** bij het kampvuur.
54. De vriendelijke serveerster (poetst/pauzeert) de **keuken** van het restaurant.
55. De jonge talentvolle kunstenaar (bewondert/arriveert) de **stad** met de fraaie architectuur.
56. Het meisje op de voorste rij (omhelst/lonkt) de **gitarist** van de popgroep.
57. De oude kalende bouwvakker (vermijdt/bezwijkt) het **werken** in de felle zon.
58. Het kleine aapje in de dierentuin (amuseert/profiteert) het **publiek** dat nootjes gooit.
59. De onlangs aangenomen werkster (verzorgt/struikelt) de **planten** in de woonkamer.
60. De spion in de lange regenjas (forceert/gluurt) een **deur** in de ambassade.

#### Phrase-structure condition

1. Het meisje zit zeer voldaan naar het (netjes gestreken/gestreken netjes) **wasgoed** te kijken.
2. De onderwijzer betreft ongemerkt de (enigszins verlegen/verlegen enigszins) **leerling** bij de discussie.
3. Het publiek moet lachen om de (omlaag zakkende/zakkende omlaag) **broek** van de clown.
4. De dokter vertelt de vrouw over haar (uitermate geringe/geringe uitermate) **kans** op herstel.
5. De echtgenoot schrikt van de (nogal emotionele/emotionele nogal) **reactie** van zijn vrouw.
6. De jongen kijkt beteuterd naar de (dunnetjes belegde/belegde dunnetjes) **boterham** in zijn broodtrommel.
7. De verpleegster troost het (zachtjes huilende/huilende zachtjes) **kind** en veegt zijn tranen weg.
8. De oppas kijkt tevreden naar de (stilletjes spelende/spelende stilletjes) **kinderen** in de box.
9. De uitgebreide samenvatting van het (zojuist afgeronde/afgeronde zojuist) **onderzoek** zal binnenkort gepubliceerd worden.
10. De man aan de balie kan de (zachtjes sprekende/sprekende zachtjes) **klant** nauwelijks verstaan.
11. De vallende balk miste de (opzij springende/springende opzij) **metselaar** op een haar na.
12. De pyromaan kijkt zeer tevreden naar de (nagenoeg afgebrande/afgebrande nagenoeg) **huizen** achter hem.
13. Na de aardbeving vond men in de (nagenoeg verwoeste/verwoeste nagenoeg) **dorpen** nauwelijks overlevenden.
14. Het orkest speelde gisteravond voor een (vrijwel lege/lege vrijwel) **zaal** in Nijmegen.

15. De onderwijzer kan zijn ergernis over de (dikwijls rumoerige/rumoerige dikwijls) **leerling** amper verbergen.
16. De kranten berichten over de (nogal kritieke/kritieke nogal) **situatie** in het verre oosten.
17. De verkoopster vertelt over haar (uitermate slechte/slechte uitermate) **ervaring** met het goedkope wasmiddel.
18. De verloren gewaande erfgenaam rakelt de (nagenoeg vergeten/vergeten nagenoeg) **vete** opnieuw op.
19. De journalist wordt ontslagen vanwege zijn (nogal indiscrete/indiscrete nogal) **manier** van informatie verzamelen.
20. Mijn tante ontfermt zich over het (enigszins schuwe/schuwe enigszins) **zoontje** van haar bureu.
21. De kapitein geeft via de mobilfoon het (langsij varende/varende langsij) **schip** een waarschuwing.
22. De kinderen willen de voorstelling van het (alom bekende/bekende alom) **circus** graag bijwonen.
23. De jager richt zijn geweer op de (omhoog rennende/rennende omhoog) **geit** en schiet.
24. Het meisje kent alle rivieren en de (daaraan liggende/liggende daaraan) **steden** van Nederland.
25. Legerartsen besluiten de gewonde officier en zijn (eveneens gewonde/gewonde eveneens) **chauffeur** te opereren.
26. De leraar leest de antwoorden van de (zojuist gemaakte/gemaakte zojuist) **toets** hardop voor.
27. De leraar gebiedt het (achteraan huppelende/huppelende achteraan) **meisje** een beetje op te schieten.
28. De kraamvisite kijkt vertederd naar het (zoetjes slapende/slapende zoetjes) **kind** in de wieg.
29. Zowel de spannende film als het (daarna gehouden/gehouden daarna) **feest** waren een succes.
30. De man repareert fietsen met de (daartoe benodigde/benodigde daartoe) **spullen** van de fietsenmaker.
31. Een supporter hindert de (voorop rennende/rennende voorop) **atleet** waardoor deze de wedstrijd verliest.
32. De verkoopster bekijkt de kandelaar en de (daarbij geleverde/geleverde daarbij) **kaarsen** zeer nauwkeurig.
33. Onze agressieve waakhond bijt de (achterom kijkende/kijkende achterom) **wandelaar** in zijn been.
34. De loodgieter repareert de (buitenom lopende/lopende buitenom) **buis** van de installatie.
35. De kranten schrijven lovend over het (vooralsnog geweldloze/geweldloze vooralsnog) **optreden** van de politie.
36. De gasten bestellen het dagmenu en de (daarbij aanbevolen/aanbevolen daarbij) **huiswijn** uit Portugal.
37. De oude bunker wordt vanwege de (daarheen gevluchte/gevluchte daarheen) **dief** omsingeld door politie.
38. De sterk vervuilde kelder wordt vanwege de (daarin levende/levende daarin) **ratten** hermetisch afgesloten.
39. Mijn broer at soep maar liet de (daarna opgediende/opgediende daarna) **gerechten** koud worden.
40. De man besluit zijn (aldoor blaffende/blaffende aldoor) **hond** naar het asiel te brengen.
41. De loodgieter vervangt de (aldoor lekkende/lekkende aldoor) **kranen** door een aantal nieuwe exemplaren.
42. Het publiek moedigt de (achteraan fietsende/fietsende achteraan) **ploeg** in de rode truien aan.

43. De zwangere vrouw kon gelukkig het (rechtsom kerende/kerende rechtsom) **voertuig** nog net ontwijken.
44. Diverse landelijke acties zijn gestart om het (alom getroffen/getroffen alom) **Afrika** te helpen.
45. De afrastering beschermt het verkeer tegen (omlaag vallend/vallend omlaag) **puin** tijdens de verbouwing.
46. Mijn oude tante uit Groningen kan de (alsmaar toenemende/toenemende alsmaar) **herrie** niet verdragen.
47. Het jonge stel vraagt het (vooraan zittende/zittende vooraan) **echtpaar** om op te schuiven.
48. De secretaresse raakt overspannen van de (alsmaar groeiende/groeiende alsmaar) **stapel** brieven met klachten.
49. De minister bestrijdt de (lichtelijk overdreven/overdreven lichtelijk) **kritiek** van de oppositie.
50. De therapeut reageert nauwelijks op de (lichtelijk panische/panische lichtelijk) **reactie** van de vrouw.
51. De centrale computer is defect waardoor de (daarmee verbonden/verbonden daarmee) **apparaten** niet functioneren.
52. De huismeester draagt de kapstok met de (daaraan opgehangen/opgehangen daaraan) **jassen** naar boven.
53. De grimeur test de haarlak en de (daarmee opgemaakte/opgemaakte daarmee) **pruiken** zeer grondig.
54. Ondanks de geringe opkomst werd het een (hartstikke gezellige/gezellige hartstikke) **avond** voor iedereen.
55. De verliefde jongen wil zijn vriendin een (hartstikke duur/duur hartstikke) **horloge** cadeau geven.
56. Mijn oma legt elke morgen een (netjes opgevouwen/opgevouwen netjes) **servet** naast haar ontbijtbord.
57. Bij de finish geeft het publiek de (vrijwel uitgeputte/uitgeputte vrijwel) **schaatser** een applaus.
58. De naaister heeft beloofd mijn (vrijwel versleten/versleten vrijwel) **blouse** nog eenmaal te maken.
59. De Amsterdamse politie hoopt dat de (vooralsnog verschoven/verschoven vooralsnog) **wedstrijd** niet zal doorgaan.
60. De docent vermoedt dat de (voorover gebogen/gebogen voorover) **student** zit te spieken.