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# Temporal Structure of Syntactic Parsing: Early and Late Event-Related Brain Potential Effects

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Event-related brain potentials (ERPs) were recorded from participants listening to or reading sentences that were correct, contained a violation of the required syntactic category, or contained a syntactic-category ambiguity. When sentences were presented auditorily (Experiment 1), there was an early left anterior negativity for syntactic-category violations, but not for syntactic-category ambiguities. Both anomaly types elicited a late centroparietally distributed positivity. When sentences were presented visually word by word (Experiment 2), again an early left anterior negativity was found only for syntactic-category violations, and both types of anomalies elicited a late positivity. The combined data are taken to be consistent with a 2-stage model of parsing, including a 1st stage, during which an initial phrase structure is built and a 2nd stage, during which thematic role assignment and, if necessary, reanalysis takes place. Disruptions to the 1st stage of syntactic parsing appear to be correlated with an early left anterior negativity, whereas disruptions to the 2nd stage might be correlated with a late posterior distributed positivity.



The modeling of language comprehension processes is mainly based on reaction-time measurements taken during the listening to or reading of words or sentences. The results of these measurements have lead to two different views of language comprehension: One assumes different independent processing components responsible for phonological, syntactic, lexical–semantic, and interpretative processes (Forster, 1979; Frazier, 1978; Swinney, 1979), whereas the other takes these different aspects to interact continuously during comprehension (Marslen-Wilson, 1980; McClelland, St. John, & Taraban, 1989). The former view is known as the serial approach to language comprehension, the latter as the interactive approach. Critical for the difference between these two approaches is not whether the different types of linguistic information interact at all, but rather when during comprehension interaction takes place.

Another way of getting insight into the mental structure of the language comprehension system and its temporal parameters is to evaluate the language behavior–brain relationship. The description of the relation between brain structure and language behavior is traditionally based on correlations of particular brain lesions with the resulting associated behavior. Although early studies had to rely on the premortem observation of a patient's language behavior and the postmortem autopsy information of the lesion site (e.g., Broca, 1865; Marie, 1926/1906; Wernicke, 1874), studies during the last four decades were able to specify this brain lesion–behavior relation in vivo by using structural imaging techniques, such as the computerized tomography and the structural magnetic resonance imaging techniques (Basso, Roch Lecours, Moraschini, & Vanier, 1985; Damasio & Damasio, 1989; Kertesz, 1983; Poeck, De Bleser, & Keyserlingk, 1984). Functional imaging techniques that allow correlation of the brain's activity with specific language behavior, such as positron emission tomography or single positron emission computerized tomography, so far, have mainly been used to investigate the neural substrate of single-word processing (Démonet et al., 1992; Frith, Friston, Liddle, & Frackowiak, 1991; Petersen, Fox, Posner, Mintun, & Raichle, 1988; Petersen, Fox, Snyder, & Raichle, 1990) and only in rare exceptions to study sentence-level processes (Mazoyer et al., 1993). These latter techniques, however, are invasive and therefore cannot be applied routinely with normal participants. Moreover, the time resolution these techniques provide keeps them from registering language processes on-line (i.e., as they take place on a subsecond time scale).

## Electrophysiology of Language Processes

A measurement that is noninvasive and allows the registration of brain activity during on-line language processing is the electrophysiological measurement of event-related brain potentials (ERPs).[1] Its temporal resolution is in the millisecond

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[1] Magnetoencephalography provides the same time resolution, but so far has only rarely been used to study language processes (e.g., Mäkelä et al., 1994).

domain and its topographic resolution depends on other factors (e.g., spatial interpolation methods depend on the number of electrodes used for registration). ERP experiments evaluating the processing of semantic aspects during comprehension consistently report a broadly distributed parietotemporal negative component peaking around 400 ms after the critical lexical event, the so-called N400 component. The amplitude of this component varies as a function of the semantic suitability of a critical word with respect to prior context, being larger the more effort is required to integrate the critical word into the preceding context (for a review, see Kutas & Hillyard, 1984; Kutas & Van Petten, 1988; Van Petten & Kutas, 1991). The processing of syntactic information, in contrast, has been shown to be correlated with either a left anterior negativity or a centroparietal positivity or a biphasic ERP pattern including a negativity and a positivity.

### *Left Anterior Negativities*

In several studies an early negativity with left anterior maximum was found to covary with the processing of word-category information in phrasal context. In experiments by Brown and colleagues (Brown, Lehmann, & Marsh, 1980; Brown, Marsh, & Smith, 1973, 1976, 1979), participants listened to ambiguous word forms requiring either a noun or a verb reading depending on the phrasal context (e.g., *sit by the fire* vs. *ready, aim, fire*). A principle component analysis of the brain potentials revealed an early negativity around 150 ms over the anterior part of the left hemisphere with a larger amplitude for the noun than for the verb reading. A similarly distributed early left anterior negativity around 120 ms during reading was also reported by Neville, Nicol, Barss, Forster, and Garrett (1991) coincident with a word-category error (e.g., . . . **Max's of proof the theorem*), but not, however, coincident with other syntactic violations, such as subjacency violations. Friederici, Pfeifer, and Hahne (1993) examined word-category errors such as **Der Freund wurde im besucht* [The friend was in visited] in an auditory task. They found an early negativity peaking around 180 ms with a left anterior maximum. This was followed by a negativity around 400 ms again with a maximum over the left anterior parts of the brain that was specifically correlated with this type of violation. Moreover, an early left anterior negativity was observed for the reading of function words (N280) compared with the reading of content words when these were presented in correct sentences (Neville, Mills, & Lawson, 1992) or when presented in word lists (Nobres & McCarthy, 1994), suggesting that the early left anterior negativity might reflect syntactic processes associated with function words.[2] Osterhout and Holcomb (1992) found a left anterior negativity between 300 and 500 ms during sentence reading for the first word marking the sentences' incorrectness. In a sentence such as **The persuaded hoped to sell the stock was* (as compared to a correct sentence such as *The broker persuaded to sell the stock was*), they found a left anterior negativity between 300 and 500 ms when participants encountered the word *was* (indicating the structural incorrectness), but a late positivity when participants encountered the word *to* (violating the structural preference; for discussion of this effect see below). Although these authors reported the left anterior negativity in their article, they did not discuss its functional significance in relation to syntactic processes.

Studies investigating other types of syntactic violations also report left anterior negativities around 400 ms. The processing of a verb's subcategorization information (i.e., transitivity information; Rösler, Friederici, Pütz, & Hahne, 1993) and the information about a verb's potential syntactic arguments (Münte, Heinze, & Prevedel, 1990) as well as verb agreement information (Coulson, King, & Kutas, 1995; Gunter, Vos, & Mulder, 1995; Münte, Heinze, & Mangun, 1993) have been shown to correlate with a left anterior negativity between 300 and 500 ms. However, other studies reported a late centroparietal positivity associated with verb subcategorization violations (e.g., Osterhout & Holcomb, 1992, 1993) or no effect at all (e.g., Hagoort, Brown, & Groothusen, 1993; see below).

### *Late Centroparietal Positivities*

Late centroparietally distributed positivities were observed with the processing of a number of different syntactic anomalies including violations of obligatory syntactic structures and violations of syntactic preferences requiring syntactic reanalyses. Osterhout and Holcomb (1992, 1993) investigated sentences that at a given point required a complete structural reanalysis of the preceding sentence (i.e., deriving a reduced relative clause analysis from an initial analysis as a simple declarative sentence) and found a positivity around 600 ms after the disambiguating lexical element. When examining noun phrase–sentential complement ambiguities (Osterhout, Holcomb, & Swinney, 1995), they found a late positivity around 600 ms when the critical word (e.g., *was*) violated syntactic constraints (e.g., . . . **forced the patient was lying*) or syntactic preferences (e.g., . . . *charged the patient was lying*).[3] The positivity (labeled P600) was larger for the violation of syntactic constraints than for the violation of the syntactic preferences and only the former condition was preceded by a negativity. Mecklinger, Schriefers, Steinhauer, and Friederici (1995) observed a similarly distributed positivity, however, peaking at 345 ms in correlation with a revision of an initial filler–gap relation during the processing of German syntactically correct relative clauses. In these sentences the ultimate interpretation depends on the phrase-final auxiliary, which

[2] A difference between the processing of function words and content words has been shown in behavioral studies when words were presented in sentential context (e.g., Friederici, 1985; Rosenberg et al., 1985), not, however, when they were presented in word lists (e.g., Gordon & Caramazza, 1982; Kolk & Blomert, 1985). This finding was taken to suggest that a differential pattern between content words and function words during perception is most likely to be observed when function words serve their particular syntactic function, namely to structure the incoming information.

[3] For the violation condition, they observed a negativity that preceded the P600 and whose distribution resembled that of an N400. The authors do not discuss this finding with respect to their own study using sentences including subcategorization violations (Osterhout & Holcomb, 1992) or that of others (Rösler et al., 1993).

either indicates a subject-relative clause reading (e.g., *Das ist die Managerin, die die Arbeiterinnen gesehen hat* [This is the manager that the workers seen has]) or an object-relative clause reading (e.g., *Das ist die Managerin, die die Arbeiterinnen gesehen haben* [This is the manager that the workers seen have]). When revising the initial filler–gap assignment of such a sentence, the parser only has to determine which noun phrase in a given sentence is the subject and which is the object of the sentence, while the hierarchical phrase structure of the given sentence is preserved. Hagoort et al. (1993) found a similarly distributed late positive shift for subject–verb agreement violation involving verb morphology (singular vs. plural) and for a particular phrase structure violation involving word order (correct adverb–adjective noun vs. incorrect adjective–adverb noun constructions), but not for subcategorization violations in Dutch.[4]

## ERP Data and Models of Language Parsing

Can the temporal structure of the ERP components observed in correlation with different syntactic and/or lexical processes be connected to recent models of language comprehension? One of the few models considering the temporal structure of syntactic processes explicitly is that of Frazier and colleagues (Frazier, 1987, 1990; Frazier & Fodor, 1978; Frazier & Rayner, 1982; for a more recent two-stage model, see also Gorrell, 1995). This model assumes two separate stages of syntactic processes: a first stage, during which a structure-driven parser assigns an initial structure to the input on the basis of major category information, and a second stage, during which thematic role assignment takes place. Because major category information vastly underdetermines the structural analysis of many sentences, the model assumes additional principles for an ad hoc resolution of possible ambiguities. These principles, though successful in most cases, may sometimes lead to an initial analysis that cannot be confirmed by the thematic analysis during the second stage. In these cases reanalysis of the initial structure becomes necessary. Recent variations of this model assume that in case of ambiguities the parser does not dismiss the nonpreferred structure altogether, but keeps both structures active although setting a clear preference for one of the two possible structures (Hickok, 1993; Inoue & Fodor, 1995). According to this view, the system in the case of a mismatch between the preferred structure and the thematic role assignment would only have to reactivate the less preferred structure and would not have to compute a full reanalysis.

The following picture seems to emerge from an attempt to connect the temporal structure of the observed ERP data to the models discussed. An assumed first stage during which initial syntactic structure is built up on the basis of word-category information may to some extent be reflected in the early negativity peaking around 200 ms, most prominent over the anterior parts of the left hemisphere as this negativity is observed in correlation with the detection of word-category errors (Friederici et al., 1993; Neville et al., 1991). The entire information encoded in a lexical element, including the information about a word's meaning and its selectional restrictions, but also additional syntactic information such as a verb's subcategorization information, may become available immediately after this initial stage.[5] The processing of lexical–semantic information (i.e., meaning and selectional restrictions), in contrast, appears to correlate with a specific negative component present around 400 ms that is broadly distributed over the parietotemporal parts of both hemispheres (the so-called N400 component). The processing of syntactically relevant lexically encoded information (i.e., subcategorization and inflectional information), also seems to correlate with a negativity at about 400 ms, whose distribution, however, differs from the N400 in that it is focused over left anterior brain regions (Coulson et al., 1995; Gunter et al., 1995; but see Hagoort et al., 1993; Osterhout & Holcomb, 1992, 1993; Rösler et al., 1993).[6]

The second stage of syntactic parsing assumed by Frazier (1987, 1990) represents the stage of thematic role assignment during which syntactic and semantic analyses are mapped onto each other. When the initial analysis and the thematic information retrieved from the lexical elements do not map, reanalysis becomes necessary. This second stage has not yet been described in all details. Even at the theoretical level it has received its definition mainly in contrast to the first-pass processes that are hypothesized to be involuntary and automatic. Caplan and Waters (1990) distinguished first-pass syntactic processes from second-pass syntactic processes by stating "being garden-pathed . . . reflects the operation of first-pass processing of syntax . . ., recovery from a garden-path is a second-pass process" (p. 344). They took these second-pass processes to often involve controlled processes. Gorrell (1995) similarily interpreted the structure-building process as a highly automatic one and contrasted this early process to

[4] It has repeatedly been questioned whether this late positivity is a language-specific component. The centroparietal scalp distribution of the positivity in some studies is quite similar to that of the domain general P300 component, usually elicited by attended and unexpected stimuli requiring context updating processes (Donchin, 1979, 1981; Dunca-Johnson & Donchin, 1977; Hillyard & Picton, 1987). This view seems to find support in recent reports (Coulson et al., 1995; Gunter et al., 1995) showing the ampitude of the late positivity elicited by subject–verb agreement errors to be sensitive to the probability of incorrect sentences in a given set. These findings challenge the notion that the late positivity is specifically tied to syntactic processes.

[5] Note that this idea requires the assumption that syntactic information encoded in a lexical element may become available or may be used serially with word category information preceding subcategorization information (e.g., Frazier, 1987). We are well aware of alternative models that assumed that subcategorization information along with word-category information is used during initial parsing (e.g., Gorrell, 1995) as well as models assuming that this information becomes available in parallel with meaning information. (e.g., MacDonald, 1993), but we use the Frazier model as a working hypothesis.

[6] It should be mentioned that a left anterior negative component was also observed with the processing of filler–gap dependencies (King & Kutas, 1995; Kluender & Kutas, 1993). These authors view the left anterior negativity to reflect processes of working memory. It is open for discussion whether this interpretation is the only possible one. It may well be that the negativity reflects aspects of structure building involved in filler–gap assignment.

secondary processes of interpretation. This second stage of processing seems to be associated with a late positive ERP component with a centroparietal distribution observed in relation with the processing of a number of syntactic and morphosyntactic violations as well as with processing structures requiring recovery. In some studies this late positive shift was preceded by a left anterior negative component. From a systematic review it is not entirely clear under which circumstances this negativity is present. Violations of the expected word category, subcategorization, or agreement information carrying consequences for thematic assignments may trigger a biphasic response, whereas the recovery from garden-path sentences may elicit an isolated positive component. Osterhout and Holcomb (1993) took the amplitude of the late positivities to indicate the processing demands imposed by recovering from garden-path sentences. It is not unlikely that the latency of this late positivity is related to the complexity of the required reanalysis showing an earlier peak with less complex types of reanalysis (Mecklinger et al., 1995) than with processes involving a complete structural reanalysis of the sentence (Osterhout & Holcomb, 1992, 1993). It must remain a speculation whether the temporal order of the detection of a particular type of violation indeed reflects processing stages, but given the on-line nature of language processing such an assumption seems not unlikely.

## The Present Study

As the early left-anterior negativity peaking between 150 and 280 ms was observed in some of the studies investigating syntactic processes but not in others, we decided to evaluate this issue further by considering the most obvious differences between those studies that found this early negativity and those that did not. The first difference to be considered is the presentation mode. Some studies used auditory language input, others used a visual word-by-word presentation mode with different interword intervals. Early negativities were observed in studies using on-line auditory presentation (Friederici et al., 1993; Osterhout & Holcomb, 1993), as well as those studies using a visual word-by-word presentation with fast interword intervals (Neville et al., 1991; Osterhout & Holcomb, 1992). Neville et al. (1991), however, reported an early left anterior negativity only for one of the three syntactic violation conditions tested, namely for word-category violations. Thus, the next factor to be considered is the type of syntactic violation investigated in the different studies. The early negativity was observed for phrase structure violations realized as word-category errors (Friederici et al., 1993, but see Hagoort et al., 1993; Neville et al., 1991; Osterhout & Holcomb, 1993).

This study was designed to evaluate the hypothesis that a violation of an obligatory phrase structure should elicit an early left anterior negativity, possibly followed by a late positivity both in the auditory and the visual domain when presented with relatively short interword intervals. The phrase-structure violation was realized as a violation of a phrasally required syntactic category, hereafter called the syntactic-category violation condition. This violation condition was contrasted with a condition in which several different syntactic categories would form a correct continuation, however, with one syntactic category being the most likely. This condition was called the syntactic-category ambiguity condition. It was predicted that a violation of the preference of several possible syntactic categories should not elicit an early negativity if this component is an index for the detection of syntactic incorrectness. The syntactic-category ambiguity condition may, however, evoke a late positivity under the assumption that processes of reanalysis become necessary and that the late positivity can be taken to reflect those.

### *Syntactic-Category Violation Condition*

This condition consisted of sentences containing an obligatory noun phrase context (i.e., a prepositional form (e.g., *zur* [for] or *trotz* [despite]) in sentences like *Das Metall wurde zur* ... [The metal was for] or an appositional form (*als* [as]). These forms require a noun phrase as continuation. Thus, in these sentences, past participles create a violation of the phrasally required syntactic category (e.g., *Das Metall wurde zur veredelt* [*The metal was for refined]) compared with sentences without a preposition or an appositional form in which the past participle is a correct continuation after the auxiliary *wurde* (e.g., *Das Metall wurde veredelt* [The metal was refined]).

### *Syntactic-Category Ambiguity Condition*

In this condition the critical element is a noun that in the correct condition follows a prepositional form. In the anomalous counterpart, the noun is either a semantically anomalous or a syntactically anomalous continuation dependent on the reading of the ambiguous context word *wurde*. The word *wurde* can either be read as an auxiliary [*was*] in passive constructions requiring a past participle to follow or it can be read as a main verb [*become*] allowing a noun or an adjective as a grammatical continuation. Although both readings are possible, normative results (see the *Method* section) from a sentence completion test showed that the auxiliary reading is more frequent than the main verb reading.

Examples of correct and anomalous conditions are given in Figure 1. Note that the word-category distinction (noun vs. verb) in these sentences is marked only by the suffix, either being an inflectional element marking the verb (i.e., past participle form) or a derivational element marking the noun, whereas the word stem remains identical for both forms. This allows semantic aspects (of the word stem) to be kept as comparable as possible in the different sentence conditions.

The predictions for ERPs elicited by the violation and the ambiguity condition are quite different. For the syntactic-category violation condition, we predicted an early left anterior negativity possibly followed by a late positivity, for both the auditory and the visual domain. The prediction for the syntactic-category ambiguity condition directly depended on the particular processing model and assumptions for processing lexical and syntactic ambiguities. There are basically two different approaches to the issue of syntactic-category ambiguity resolution: the constraint-based model (MacDonald, 1993) and the delay model (Frazier & Rayner, 1987). The delay

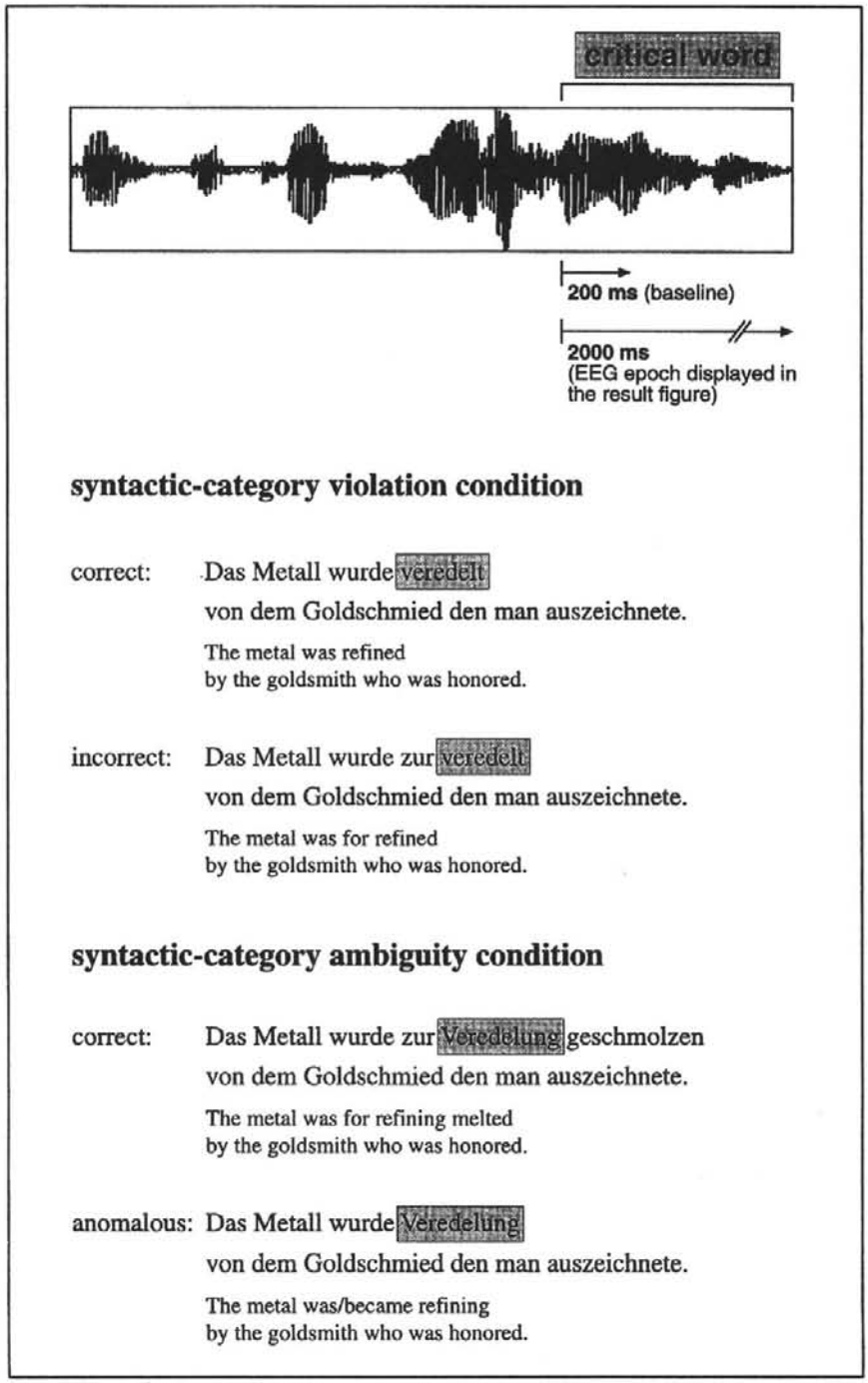


*Figure 1.* Temporal sequence of stimulus presentation in the four experimental conditions. Note that the same baseline (i.e., the first 200 ms of the critical word) was used for the event-related brain potentials in all conditions. EEG = electroencephalogram.

model assumes that both readings of a syntactically ambiguous item are active, just like the two meanings of an ambiguous word are (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979), but that the activation of a syntactically ambiguous item, unlike a lexically ambiguous item, is upheld until disambiguating information is encountered. Frazier and Rayner (1987) argued that this parallel activation should be very local, as the disambiguating information is usually given within the next one or two words. For the experimental sentences used in our syntactic-category ambiguity condition this would mean that both the auxiliary and the main verb reading of the word *wurde* are activated and that disambigua-

tion takes place when encountering the target word, which is either a past participle or a noun. Because both syntactic categories are syntactically possible continuations, we expect no left anterior negativity for the processing of the critical word (past participle or noun) in this condition. However, because in our sentence material the particular nouns following the word *wurde* are semantically anomalous, we predicted an N400 to be elicited by the nouns. The constraint-based approach (MacDonald, 1993), in contrast, assumes that the frequency of occurrence of a given structure or lexical element influences the amount to which the one or the other reading of a syntactic ambiguity is activated. On the basis of this approach, one would predict a different pattern under the condition that one of the readings of *wurde* is less frequent than the other one. Empirical measures (see the *Method* section), suggested that the main verb reading in German is indeed less frequent than the auxiliary reading. Thus, there should be a primary activation of the auxiliary reading, in which case the noun continuation in our sentence would be syntactically incorrect. Thus, if the participants primarily read the word *wurde* as an auxiliary, and if the left anterior negativity reflects the detection of phrase-structure violations, then a left anterior negativity for the processing of the noun in the syntactic-category ambiguity condition would be expected.

Moreover, we predicted a late positivity for both conditions. Reanalysis or repair may take place in both conditions, though for different reasons, at different points in the sentences, or both. Syntactic-category violations could be reanalyzed by omitting the preposition as the head of the phrase, resulting in a verb phrase instead. For the syntactic-category ambiguity condition, two reanalysis or repair processes are conceivable depending on the reading of the ambiguous context word. When reading or listening to the ambiguous word as an auxiliary, the parser may detect a mismatch between the expected and the actual word category, and because the meaning of the word stem is compatible with a possible interpretation of a verb reading of the phrase, reanalysis may involve a change in the word-category-marking suffix and the phrase under construction. When reading the ambiguous word as being compatible with two possible structures (verb and noun), the parser will detect no word-category violation when encountering the noun, but will detect a lexical–semantic violation, as the meaning of the noun is not compatible with the preceding context. Under this circumstance, structural reanalysis may only be triggered at the onset of the by-phrase, obligatorily requiring the preceding word to be a verb form and not a noun predicate. Because the positivity associated with the reanalysis processes is likely to vary in latency with the type of reanalysis required, we expected that the latency of the positivity may be shorter for the syntactic-category violation condition compared with the syntactic-category ambiguity condition either because the reanalysis processes assumed for the former might require less processing capacity than the latter or because the former processes can be accomplished earlier than the latter.

## Experiment 1

In Experiment 1 we used connected speech as the stimulus material.

### *Method*

*Participants.* Sixteen young adults (7 men and 9 women; mean age = 27 years) participated in the experiment. They were students of the Free University of Berlin and they were paid DM10 per hour to serve as participants. All were right handed, as evaluated by the Edinburgh Inventory (Oldfield, 1971). They were all native speakers of German with no known hearing deficit.

*Materials.* A set of 240 sentences was constructed. There were 60 base sentence beginnings, out of which 4 sentences each were constructed (see Appendix A) leading to 120 correct sentences and 120 sentences carrying an anomaly. Syntactically anomalous sentences contained either a mismatch between the phrasally required category and the word's actual syntactic category (syntactic-category violation; $N = 60$) or a mismatch between the word's actual syntactic category and the one expected on the most frequent reading of a syntactically ambiguous context word (syntactic-category ambiguity; $N = 60$). To gather empirical data on the issue of how the ambiguous word *wurde* is read in the material used in the experiment, we conducted two tests: a sentence completion test and a grammaticality judgement test. The sentence completion test contained the 60 base sentence beginnings (*determines + noun + wurde*) used in the experiment in each of the four conditions. This test conducted with 10 participants revealed a clear preference for the auxiliary reading (96.30% past participle continuations, 1.5% adverb + past participle, 0.33% adjective, and 1.83% preposition + noun + past participle). The grammaticality judgement test was conducted to demonstrate that although there is a strong preference for the auxiliary reading of *wurde*, the main verb reading is clearly grammatical in German. The grammaticality judgement test consisted of the 60 sentences used in the syntactic-ambiguity anomalous condition and 60 sentences made up of the sentence beginning of the 60 sets used in the ERP experiment continued with semantically coherent noun phrases (see Appendix B). This test was conducted with 18 participants, all native speakers of German. They judged these sentences as being grammatically correct (e.g., *Das Metall wurde Bestandteil der Legierung* [The metal became part of the alloying]) at a rate of 88.67%.

All sentences used in the ERP experiment were constructed according to the structural schema presented in Figure 1, resulting in 60 sets of four sentences each. Appendix A lists the entire set of sentence material. The critical words in all sentences were either a verb or a noun derived from the same word stem (e.g., *veredel-* [refine-]) only differing in their suffix, that is, an inflectional suffix indicating a verb tense (e.g., [-ed]) or a derivational ending indicating a noun (e.g., *-ung*[-ing]). In using verb and noun forms derived from a common stem, we aimed toward the most precise identification of the word category uniqueness point, that is, the point at which one can unambiguously decide whether the current element is a verb or a noun. The mean duration of critical words was 588 ms, $SD = 78$ ms (for verbs, 551 ms, $SD = 76$ ms; for nouns, 625 ms, $SD = 80$ ms).[7] The mean word-category uniqueness point for the 240 auditory stimuli used in this experiment was determined theoretically by identifying the last common sound of the target word. To determine this last common sound, we classified the last vowel in the word stem common to both word types, that is, nouns and verbs. This vowel was identified in a visual display of the sound and its midpoint was taken as the point of measurement. With this procedure, the word-category uniqueness point was calculated to be 328 ms ($SD = 97$ ms) in the correct context and 329 ms ($SD = 99$ ms) in the anomalous context. Thus, no

[7] Word onset was determined by careful visual and oral inspection of the digitized speech wave display. We listened to that part of the speech signal following the presumed word onset and made sure that no parts of the preceding word would be audible in that signal.

systematic difference was found between the tokens in the correct and the incorrect context conditions.[8]

The frequencies of the members of the different word categories were held comparable. According to the lexical database CELEX (Baayen, Piepenbrock, & van Rijn, 1993), the mean lemma frequency using the combined index for spoken and written language was 20.56 per million for nouns and 35.82 per million for verb infinitives. The mean word-form frequency was 16.04 per million for the nouns and 14.57 per million for the past participle forms. Other aspects of the sentence material controlled for were the following: (a) The first noun was always inanimate and marked first person singular, (b) the prepositions used were monosyllabic and were forms that cannot be used as verb prefixes, and (c) the relative clauses all referred to the second noun of the main clause.

Sentences used in the ERP experiment were spoken by a woman. She was trained to produce correct and incorrect sentences with normal intonation or a best approach.[9] Sentences were first recorded and were then digitized (20 kHz, 12-bit resolution).

Because the experiment used a probe verification paradigm, each sentence was followed by a probe word presented auditorily. The probe word appeared 800 ms after sentence offset. Half of the probe words were so-called true probes, that is, words that had occurred in the sentence immediately preceding the probe. Words from four different word positions could serve as a probe: the noun in the first noun phrase, the critical word, the noun in the by phrase, and the sentence-final word. Probe positions were equally distributed over the entire set of the true probes for the correct and the incorrect sentences. The other half of the probes were so-called false probes, as they had not occurred in the previously heard sentence. False probes were morphological variants of words that had occurred in the sentence, such as a noun with a different number marking (e.g., *Goldschmied* [dative, singular]/*goldsmith* vs. *Goldschmieden* [dative, plural]/*goldsmiths*) or a verb with a different number or tense marking (e.g., *veredelt* [past participle]/*refined* vs. *veredele* [first person, singular]/*refine*). We chose to use morphological variants as probes in order to keep the auditory attention at a high level. Previous experiments (Friederici et al., 1993) had shown the present procedure to be successful. Again the different categories of morphological deviation were equally distributed over the false probe set for the correct and incorrect sentences.

These probe words were spoken as individual words by the same woman who had spoken the sentence material. They were spoken on analogue tape and digitized and stored in separate files. Using this technique, trials with a standard interstimulus interval of 800 ms between sentence offset and probe onset were constructed. All sentences and their probe words were analog/digital (A/D) converted and recorded onto an analog audiotape. Ten practice trials together with the 240 experimental trials were presented from a tape, blocking the experimental items into five blocks of 48 sentences each and two block-initial fillers, respectively. All blocks were separated by short pauses. Before each new block a warning tone indicated the start of the new block. The blocks were constructed in such a way that not more than one variant of a base sentence appeared in one block. Each block contained 24 correct and 24 incorrect sentences. False and true probes were also distributed equally in each block. The sequence of trials within each block was random except for the following two constraints: (a) No more than four identical probe conditions (true or false) were presented in adjacent trials, and (b) no more than two correct or incorrect sentences were presented in succession.

Each participant received the practice block followed by the five experimental blocks. To avoid serial-order effects, the five experimental blocks were distributed over five different tapes following a Latin-square design. The sentences within each block remained the same. They were, however, newly quasirandomized. These different tapes were approximately equally distributed across participants. Thus, each participant heard all four versions of each sentence.[10]

*Procedure.* The probe verification paradigm required participants to listen to the auditorily presented sentence and to a probe following a pause of 800 ms. They were asked to indicate whether the probe word had appeared in the preceding sentence. This response was delayed by the introduction of an interstimulus interval of 800 ms between the offset of the sentence and the onset of the probe word preventing the motor response from contaminating the ERP to the final word. Participants were instructed to give their response as fast and as accurately as possible. After a silent pause of 2,000 ms, the next trial began. The participants were seated in a dimly lit room and were asked to fixate their eyes on a small red square on a wall approximately 1.5 m in front of them.

*ERP recording.* The electroencephalogram (EEG) was recorded by means of an elastic cap (Electro Cap International, Inc., Eaton, Ohio) containing 25 tin electrodes: 19 according to the standard international 10–20 system (Jaspers, 1958) and 6 nonstandard locations, that is, Broca's region (BL [Broca left] was defined in the front-temporal region as the crossing point between T3–Fz and F7–Cz) and the right hemisphere homologue (BR [Broca right], defined as the crossing point between T4–Fz and F8–Cz), the Wernicke's region (WL [Wernicke left] was defined in the posterior-temporal region as the crossing point between T3–P3 and C3–T5) and the right hemisphere homologue (WR [Wernicke right], i.e., the crossing point between T4–P4 and C4–T6). Moreover, an anterior temporal left (AL) and an anterior temporal right (AR) location was defined as half the distance between F7 and T3 and between F8 and T4. All scalp electrodes were referenced to linked mastoids. Eye movements and blink artifacts were monitored by the electrooculograph (EOG). Vertical EOG was recorded from electrodes placed above and below the right eye and horizontal EOG was recorded from electrodes placed beside the left and right eye. The EOG electrodes used were silver–silver chloride electrodes. All impedances were maintained below 5 kΩ. The EEG and EOG channels were amplified by ESmed (ESmed Mediziutechnik GmbH, Berlin, Germany) amplifiers with a 1.6-s time constant and a low-pass filter at 70 Hz, (−3 dB/octave roll-off). The EEG and EOG were recorded continuously for each block and were A/D converted with 12-bit resolution at a rate of 256 Hz. The EEG was

[8] In order to ensure that the different tokens in the different experimental conditions were indeed comparable, we specified the word-category uniqueness point of the critical tokens empirically by using a gating paradigm (Grosjean, 1980). This paradigm provides information about the word isolation point. This gating experiment used the tokens of the critical words cut out of the connected speech samples used in the main experiment. Thus, each critical word was represented by two tokens, that is, one cut out of the correct context and one cut out of the incorrect context starting at 100 ms (Segment 1). Consecutive segments of 50 ms were presented in isolation. The mean word isolation point lay between 400 and 450 ms for all tokens. Thus, a first identification was possible for all tokens between Segment 7 (400 ms) and Segment 8 (450 ms) with a nonsignificant variation between different types (i.e., verb out of correct context with a mean of 7.44, verb out of incorrect context with a mean of 7.37, noun out of correct context with a mean of 7.43, and noun out of incorrect context with a mean of 7.58).

[9] Attempts were made to splice the auditory material of correct sentences and use these parts for the incorrect sentences. This procedure, however, resulted in unnatural sounding transitions between the context and the critical word. We therefore decided to use the procedure described in the *Method* section.

[10] The repetition of a critical element could reduce ERP differences between two conditions as compared with a multiple-list design in which each participant sees only one version of each critical element.

digitized on-line and stored for later analysis. Data collection was controlled by an IBM-compatible 386 computer.

For each sentence, the onset of the critical word was marked to allow time locking of EEG averages. As any prestimulus baseline calculated from the onset of the critical word would cover different word types (i.e., auxiliaries and prepositions), we chose to use a poststimulus-onset baseline (e.g., the beginning of the critical word that was the same for the four conditions of a given token). Thus, the first 200 ms of the critical word were used to calculate the baseline. The average voltage in the 200 ms following the onset of the critical word was examined for significant differences as a function of experimental condition. Because no systematic effects were found in an analysis of variance (ANOVA), this interval was used as a baseline for all further ERP amplitude measures. To cover ERP activity elicited by the critical word as well as the following words, ERPs were calculated from the onset of the critical word until 2,000 ms thereafter.

Epochs containing ocular artifacts (criterion ± 50 microvolts) or other movement artifacts were excluded from further analysis. The rejected trials due to artifacts were distributed equally over the different conditions with a mean of 29.58% ($SD$ = 13.41) for the correct sentences of the syntactic-category violation condition, a mean of 31.46% ($SD$ = 14.67) for the incorrect sentences of the syntactic-category violation condition, a mean of 30.73% ($SD$ = 13.23) for the correct sentences of the syntactic-category ambiguity condition, and a mean of 32.29% ($SD$ = 13.98) for the incorrect sentences of the syntactic-category ambiguity condition.[11] Prior to the estimation of ERP components, the participant averages were digitally filtered using a phase-true digital low-pass filter (−3 dB at 10 Hz, −45 dB at 23 Hz). ERP components were quantified as the mean voltage in two different time windows (400–600 ms and 800–1,200 ms) relative to the onset of the critical word. These latency windows were defined after visual inspection of the grand averages of the different conditions and the visual identification of the main differences in amplitudes.

*ERP analysis.* The ERP data were first analyzed in repeated measures ANOVAs separately for each time window and violation type. The target item in the syntactic-category violation condition was a past participle form and the target item in the syntactic-category ambiguity condition was a noun. Thus, the target items in the incorrect condition were compared with the identical target items in the correct condition. To examine the topographic distribution of the different ERP measures, three variables relevant for topographic information were included in the ANOVA designs, namely hemisphere (left or right), region (anterior or posterior), and electrode. For the two levels of the region variable, eight anterior (F7, F3, AL, BL, F8, F4, AR, and BR) and eight posterior electrodes (T5, WL, P3, O1, T6, WR, P4, and O2) were selected. Thus, four electrode sites remained in each of the four quadrants (i.e., left anterior, right anterior, left posterior, and right posterior) resulting from a complete crossing of the hemisphere and the region variables. To protect against excessive Type I error, resulting from violations of the assumption of equal variances of differences between conditions of within-subject variables, the Geisser–Greenhouse correction (Geisser & Greenhouse, 1959) was applied when evaluating effects with more than one degree of freedom in the numerator. Post hoc comparisons at single electrode sites were performed using a modified Bonferroni procedure with $\alpha$ set to .04 (Keppel, 1991).

## Results

Because this was behavioral data, error rates were computed separately for each condition and probe type (true vs. false). Descriptive analyses showed that overall error rates amounted to 4.2% and were distributed equally over all conditions.

Visual inspection of the wave forms plotted separately for the syntactic-category violation condition in Figure 2 and the syntactic-category ambiguity condition in Figure 3 revealed the following similarities and dissimilarities. The syntactic-category violation condition showed a left anterior negativity apparent at all four electrodes of this quadrant starting as early as 370 ms after word onset (i.e., 50 ms after the word category uniqueness point). For the syntactic-category ambiguity condition, a similar negativity was absent in this time period. In this condition, however, a frontal negativity more pronounced over the left hemisphere emerged at about 800 ms and extended to 1,350 ms.[12]

For both conditions, a late centroparietal positivity was found. This positivity had its maximum earlier for the syntactic-category violation condition than for the syntactic-category ambiguity condition. Note that for the syntactic-category ambiguity condition the left frontal negativity and the posterior positivity were present in the same time interval. These observations were confirmed by statistical analysis. The statistical results of the four-way ANOVAs for the syntactic-category violation and the syntactic-category ambiguity condition with the variables Region (anterior or posterior) × Hemisphere (left or right) × Correctness (correct or incorrect or anomalous, respectively) × Electrode (four in each quadrant) calculated for two time epochs (400–600 ms and 800–1,200 ms) are shown in Table 1.[13]

In the first time epoch (400–600 ms), there were marginally significant Correctness × Region and Correctness × Region × Hemisphere interactions for the syntactic-category violation condition, reflecting the larger negativities for incorrect than for correct sentences in the left anterior quadrant. Separate tests for each anterior quadrant, as displayed in Table 2, revealed a marginally significant correctness effect for the left but not for the right anterior quadrant. At the single-electrode level, more negative-going waveforms were found at the F7 recording site ($p < .04$). For the syntactic-category ambiguity condition, no such effects were obtained.

The analysis for the second time window (800–1,200 ms) with the same variables covered the observed posterior positivity and the frontal negativity. Table 1 displays the results of the ANOVAs calculated separately for each condition. Both conditions showed a Correctness × Region interaction plus interactions involving either the variable hemisphere or the variable electrode. Moreover, a main effect of hemisphere was

[11] The relatively large number of trials rejected presumably results from long recording epochs (i.e., 2,000 ms) used for ERP averaging.

[12] Visual inspection of Figure 3 might suggest the presence of a negative component elicited by anomalous sentences in the syntactic-category ambiguity condition peaking at about 400 ms at the posterior recording sites (e.g., P3, Pz). However, statistical analysis revealed no reliable differences between the mean amplitude measures in the 300–500-ms time window for correct and anomalous sentences at the posterior electrodes ($p > .20$).

[13] ANOVAs were also performed for the three midline electrodes with the variables correctness and electrode. The results of this analysis were very similar to those obtained from the ANOVAs including the lateral electrodes. Because this ANOVA design additionally allows the examination of hemispheric differences, only the results of the ANOVAs including the lateral electrodes are reported.

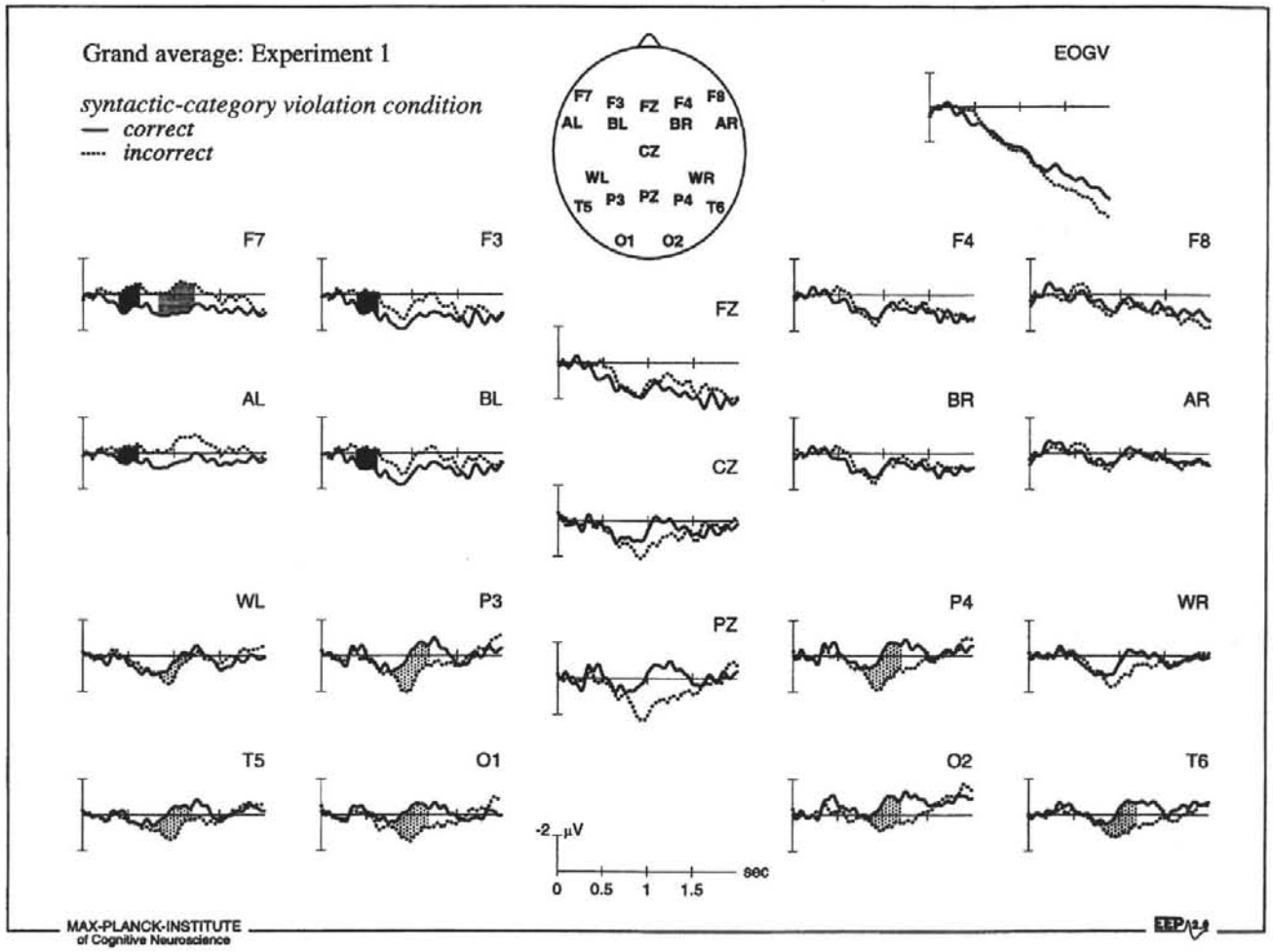


*Figure 2.* Grand average event-related brain potentials at the electrode sites in the four quadrants and three midline positions elicited by the critical word in the syntactic-category violation condition in Experiment 1. The waveforms are superimposed for correct and incorrect sentences. The ordinate indicates the onset of the critical word. The black shaded area indicates the early left anterior negativity, the gray shaded area a left frontal negativity and the dotted area the posterior positivity. Midline electrodes are excluded from shading as these electrodes were not included in the analyses of variance calculated separately for each quadrant.

obtained for the syntactic-category ambiguity condition, indicating the more negative-going waveforms for the left as compared with the right hemisphere recordings. A separate analysis for each quadrant (see Table 2) revealed main effects of correctness for both conditions at the posterior recordings, reflecting the larger positivities elicited by the incorrect or anomalous sentences than by the correct sentences. For the anterior recordings, a Correctness × Electrode interaction was obtained for the left anterior quadrant in the syntactic-category violation condition. Post hoc tests indicated more negative-going waveforms for the incorrect sentences than for the correct sentences at the F7 recording site ($p < .04$). For the syntactic-category ambiguity condition there was a main effect of correctness and a Correctness × Electrode interaction for the left and right anterior quadrant, respectively, indicating that the negativities in this time window were larger for the anomalous sentences than for the correct sentences at all left anterior recordings but only for the F8 electrode site in the right anterior quadrant ($p < .02$).

The peak latencies of the positivities obtained for the incorrect or anomalous sentences in the violation condition and the ambiguity condition were quantified as the maximum positive deflection in a time window starting 800 ms after the critical word relative to the baseline at the electrode site where the positivities were largest (i.e., at Pz). The mean latencies were 1,037 ms ($SD = 181$ ms) and 1,105 ms ($SD = 164$ ms) for the syntactic-category violation and the syntactic-category ambiguity condition, respectively, and thus were significantly shorter for syntactic-category violations than for syntactic-category ambiguities, $t(15) = 2.48, p < .02$.

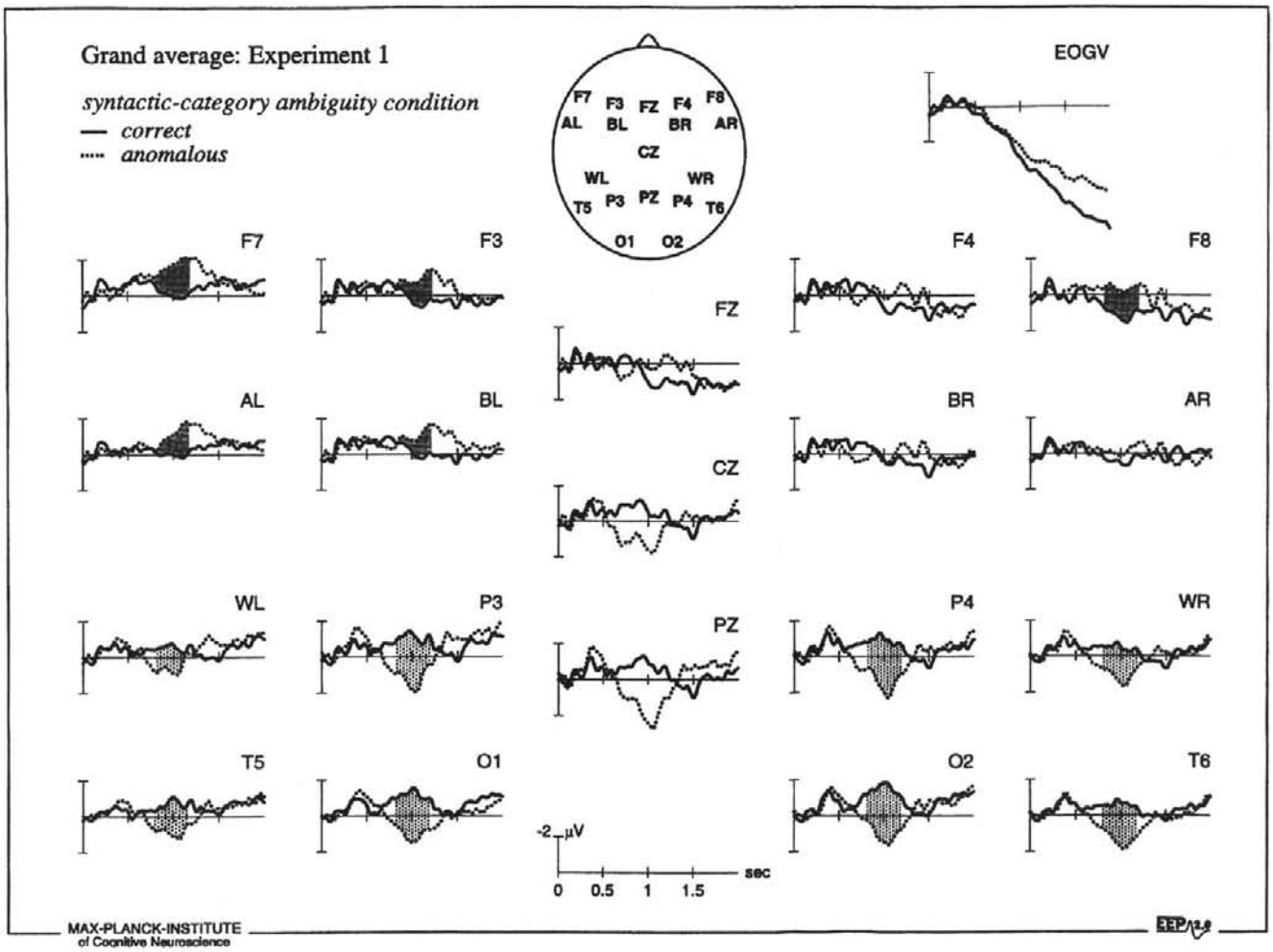


*Figure 3.* Grand average event-related brain potentials at the electrode sites in the four quadrants and three midline positions elicited by the critical word in the syntactic-category ambiguity condition in Experiment 1 (for details see legend of Figure 2).

## *Discussion*

The experiment compared the processing of two types of anomalies concerning syntactic-category information in auditorily presented sentences. One anomaly was a violation of a phrasally required syntactic category, whereas the other was a violation of the preferred of several possible syntactic categories. The syntactic-category violation condition was correlated with an early left anterior negativity present shortly after the theoretically determined mean word-category uniqueness point (330 ms after word onset) in a time window between 400 and 600 ms after word onset. In this time window, no effect was observed for the syntactic-category ambiguity condition. In the second time window, between 800 and 1,200 ms, a frontal negativity somewhat more pronounced over the left hemisphere was seen for both types of anomalies. Moreover, in the same time window both types of anomalies elicited a late centroparietal distributed positivity.

The observed early left anterior negativity for the syntactic-category violation condition replicated earlier findings of studies reporting a similar negativity in correlation with a phrase-structure error in language comprehension (Friederici et al., 1993; Neville et al., 1991). The phrase-structure violation in the Friederici et al. (1993) study was realized by an obligatory noun phrase context (i.e., a preposition indicating a prepositional phrase requiring a noun) and the actual word category of the upcoming word (i.e., verb) mismatching the phrasal context. The early left anterior negativity reported by Neville et al. (1991) could also be classified as a word-category error (i.e., after the genitive marker in *Max's* the closed class element *of* cannot occur). Thus, these violations can be detected as soon as the word-category information of the critical word is available. The processing of this type of information as well as an initial check between the current phrase structure and the word category of the incoming item seems to be related to electrocortical negative activity over the anterior parts of the left hemisphere shortly after detecting the mismatch. Other studies finding a left anterior negativity between 300 and 500 ms used other types of grammatical

violations, such as verb agreement violations (Coulson et al., 1995; Gunter et al., 1995) or verb subcategorization violations (Rösler et al., 1993). Kluender and Kutas (1993) found a left anterior negativity in the time window between 300 and 500 ms to be correlated with aspects of filler–gap assignment. These authors took their data to index "the processing cost involved in holding a filler in working memory" (p. 610). This interpretation, however, is challenged by data from reaction time studies (e.g., Nicol & Swinney, 1989) showing that antecedents (fillers) are reactivated at the gap position, but not kept active between their first appearance and their gap position (see also McKoon & Ratcliff, 1994; McKoon, Ratcliff, & Ward, 1994; Nicol, Fodor, & Swinney, 1994). Thus, a cautious interpretation of the combined data is that the left anterior negativity reflects disruptions to syntactic processes of structure building.

The finding that the left anterior negativity was absent in the syntactic-category ambiguity condition suggests that the word *wurde* was not read only as an auxiliary, as in this case a noun would have been a syntactically incorrect continuation. For a syntactically incorrect continuation, one would have expected a left anterior negativity, which we did not find. For an ambiguous reading of the word *wurde,* one would have expected an N400 component, as the nouns in this condition were semantically anomalous. The data show a tendency toward such an N400 pattern that, however, was not statistically reliable. The absence of the left anterior negativity and the tendency toward an N400 pattern seems to suggest that there is no immediate disambiguation of a syntactically ambiguous word. The finding that both types of anomalies elicited a centroparietal positivity between 800 and 1,200 ms seems to indicate that disambiguation is delayed. When measuring the peaks of these positivites with respect to the word-category uniqueness point, which was 328 ms after the word onset at the offset of the suffix indicating a noun (derivational suffix) or a verb (inflectional suffix), it becomes obvious that the obvious latencies are in the range usually found for the P600. This can be taken as evidence for the notion that the observed positivity was elicited by the critical word rather than by the words following it.

The positivity elicited by both types of anomalies was similar in latency and distribution to positivities observed in correlation with the processing of garden-path sentences (e.g., Osterhout & Holcomb, 1992, 1993), as well as in correlation with the processing of different types of grammatical anomaly (e.g., Hagoort et al., 1993). A positivity with a similar distribution pattern, but a shorter latency, was found to correlate with garden-path sentences requiring a particular type of reanalysis, namely the process of re-coindexation required when transforming an initial subject-relative structure into an object-relative structure in German (Mecklinger et al., 1995). It is likely that the late positivity reflects processes of reanalysis and that its latency is correlated with the type of reanalysis required.

The frontal negativity observed in the time window between 800 and 1,200 ms (i.e., 470–870 ms after the word-category uniqueness point) is similar in latency and distribution to components seen in correlation with other cognitive phenomena. Similar components have been found in correlation with working-memory tasks involving aspects of language (e.g., Ruchkin, Johnson, Grafman, Canounce, & Ritter, 1992). From

Table 1
*Event-Related Potential Analysis of Variance (ANOVA) Results for Experiment 1*

| Source | *df* | Category violation *F* | Category violation *MSE* | Category ambiguity *F* | Category ambiguity *MSE* |
|---|---|---|---|---|---|
| Latency range 400–600 ms | | | | | |
| He | 1, 15 | 3.19* | 4.12 | 0.00 | 4.00 |
| Co | 1, 15 | 0.93 | 12.63 | 0.23 | 16.15 |
| Co × Re | 1, 15 | 3.04* | 8.99 | 0.88 | 2.59 |
| Co × He | 1, 15 | 1.05 | 4.17 | 0.25 | 1.07 |
| Co × El | 3, 45 | 1.29 | 0.55 | 0.17 | 0.53 |
| Co × Re × He | 1, 15 | 3.16* | 0.51 | 0.47 | 0.99 |
| Co × Re × El | 3, 45 | 0.32 | 0.86 | 0.45 | 0.39 |
| Co × He × El | 3, 45 | 0.59 | 0.15 | 1.19 | 0.18 |
| Co × Re × He × El | 3, 45 | 0.58 | 0.17 | 2.14 | 0.38 |
| Latency range 800–1,200 ms | | | | | |
| He | 1, 15 | 0.03 | 7.77 | 8.61*** | 3.41 |
| Co | 1, 15 | 0.94 | 14.64 | 2.01 | 17.63 |
| Co × Re | 1, 15 | 6.88*** | 10.93 | 22.84*** | 11.00 |
| Co × He | 1, 15 | 2.93 | 4.11 | 2.07 | 2.40 |
| Co × El | 3, 45 | 1.28 | 0.64 | 5.14*** | 1.01 |
| Co × Re × He | 1, 15 | 13.16*** | 0.75 | 0.08 | 1.69 |
| Co × Re × El | 3, 45 | 2.29 | 0.50 | 4.65*** | 0.52 |
| Co × He × El | 3, 45 | 1.72 | 0.19 | 0.45 | 0.68 |
| Co × Re × He × El | 3, 45 | 0.79 | 0.33 | 1.24 | 0.25 |

*Note.* He = hemisphere; Co = correctness; Re = region; El = electrode. ANOVA effects that did not involve the variables hemisphere or correctness are of no theoretical interest in this study and are not listed in the table.
*$p < .10$. ***$p < .01$.

Table 2
*Event-Related Potentials Analysis of Variance (ANOVA) Results in Each of the Four Quadrants for Experiment 1*

| Source | *df* | Category violation *F* | Category violation *MSE* | Category ambiguity *F* | Category ambiguity *MSE* |
|---|---|---|---|---|---|
| Latency range 400–600 ms | | | | | |
| Left anterior | | | | | |
| Co | 1, 15 | 4.17* | 8.66 | 0.00 | 8.35 |
| Co × El | 3, 45 | 0.63 | 0.28 | 1.35 | 0.27 |
| Right anterior | | | | | |
| Co | 1, 15 | 0.98 | 7.16 | 0.02 | 5.03 |
| Co × El | 3, 45 | 0.20 | 0.31 | 1.40 | 0.34 |
| Latency range 800–1,200 ms | | | | | |
| Left anterior | | | | | |
| Co | 1, 15 | 2.45 | 13.69 | 4.82** | 8.12 |
| Co × El | 3, 45 | 3.06** | 0.23 | 2.15* | 0.53 |
| Right anterior | | | | | |
| Co | 1, 15 | 0.11 | 6.40 | 1.63 | 8.18 |
| Co × El | 3, 45 | 0.02 | 0.35 | 8.05*** | 0.35 |
| Left posterior | | | | | |
| Co | 1, 15 | 7.16*** | 5.08 | 14.12*** | 7.04 |
| Co × El | 3, 45 | 2.00 | 0.64 | 3.38** | 0.53 |
| Right posterior | | | | | |
| Co | 1, 15 | 7.66*** | 5.27 | 14.90*** | 9.39 |
| Co × El | 3, 45 | 1.28 | 0.34 | 4.02*** | 0.35 |

*Note.* Co = correctness; El = electrode.
*$p < .10$. **$p < .05$. ***$p < .01$.

the present data, it is not clear whether the observed negativity between 800 and 1,200 ms is elicited by the critical word itself or by the word following it. As we have used connected speech as input, we cannot be sure of whether this negativity was elicited by the critical word alone. Because the mean word length was 588 ms for the critical word, we cannot exclude that the effect observed in the time window of 800–1,200 ms originates from the word following the critical word, which is the word *von* [by] in three of the four conditions. The fact that we used connected speech in this experiment did not allow us to study this issue post hoc. A second experiment using a visual word-by-word presentation mode allowed for an investigation of the processing of each individual word in the sentence.

## Experiment 2

Experiment 2 used the same sentence material as Experiment 1. The presentation mode in this experiment was visual, with an interword interval of 200 ms and a stimulus onset asynchrony of 500 ms.

### Method

*Participants.* Sixteen young adults (6 men and 10 women; mean age = 26 years) participated in Experiment 2. They were students of the Free University of Berlin and they were paid DM10 per hour to serve as participants. All were right handed, as evaluated by the Edinburgh Inventory (Oldfield, 1971). They were all native speakers of German. All participants had normal or corrected-to-normal vision.

*Materials.* The stimulus material (sentences and probes) used was the same as in Experiment 1.

*Procedure.* The sentences were presented visually, word-by-word, on a 17 in. computer screen, with words being presented for 300 ms each and with an interword interval of 200 ms. The words were presented in black letters against a light gray background in the center of the computer screen. Proportional fonts with a vertical letter size of 0.4 cm were used. The small letter size was used to minimize saccadic eye movements during EEG recording. The use of lower case and capital letters conformed to the rules of German orthography. Participants sat at a distance of 80 cm from the screen, which yielded a visual angle of 3.0° horizontally and 0.3° vertically. Probes were presented visually 800 ms after the offset of the last word of the sentence. Participants were asked to indicate whether the probe word had appeared in the sentence. Participants were instructed to give their response as fast and as accurately as possible. After a pause of 2,700 ms the next trial began.

*ERP recording.* The procedures were the same as in Experiment 1. Off-line separated ERPs were averaged for each participant at each electrode site from trials free of EOG artifacts in each condition. The rejected trials due to artifacts were equally distributed over the different conditions with a mean of 22.92% ($SD$ = 10.14) for the correct sentences of the syntactic-category violation condition, a mean of 23.33% ($SD$ = 10.50) for the incorrect sentences of the syntactic-category violation condition, a mean of 22.29% ($SD$ = 9.39) for the correct sentences of the syntactic-category ambiguity condition, and a mean of 22.08% ($SD$ = 10.29) for the anomalous sentences of the syntactic-category ambiguity condition. ERPs were time-locked to the onset of the critical word. The 100 ms preceding the critical word were taken as the baseline because the interword interval was only 200 ms. By choosing this baseline we wanted to make sure that no "spillover" effects from the previous word confounded the baseline. ERPs were time locked to the onset of the critical word and quantified in two different time windows (a first time window between 350 and 500 ms and a second time window between 500 and 1,000 ms and 700 and 1,200 ms for the positivity and the negativity, respectively) on the basis of a visual inspection of the grand averages for the different conditions.

*ERP analysis.* The procedures were the same as in Experiment 1.

### Results

The waveforms evoked in the syntactic-category violation and syntactic-category ambiguity conditions are displayed in Figures 4 and 5, respectively. The waveforms cover the presentation of the critical word and the three words following it. In all four conditions, they depict an ensemble of sharp negative and positive components related to the onset and offset of the rapidly presented stimuli. The following pattern of results was obtained: For the syntactic-category violation condition, we observed a left anterior negativity between 350 and 500 ms. For the syntactic-category ambiguity condition, there was a negativity present in this time interval at the posterior electrode sites, most pronounced at right central and parietal sites, around 350–500 ms after the presentation of the critical word, suggesting an N400 pattern. Moreover, for both anomaly types there was a posterior positivity spanning from 500 to 1,000 ms. For the syntactic-category violation condition, this positivity peaked slightly earlier and was most pronounced at the right posterior recordings, whereas in the ambiguity condition it was visible at all posterior electrodes.

In addition, we observed for all four conditions a frontal negativity in correlation with the presentation of the word *von* [by], which marks the beginning of the by phrase. In Figure 6 the waveforms for all four conditions at the F3 recording site are aligned to the onset of the word *von* [by] and overlayed. The observed negativity was more pronounced over the left hemisphere between 300 and 600 ms after the onset of the presentation of *von* [by]. Note that for three out of the four conditions this word followed the critical word immediately, and for one condition (syntactic-category ambiguity correct condition), the word *von* [by] was the second word after the critical word (see examples in Figure 1). This difference in the word position is reflected in a later onset of the frontal negativity in the syntactic-category ambiguity correct condition as compared with the three other conditions in the Figures 4 and 5. Figure 6 displays the ERPs for the word *von* [by] for all four conditions superimposed independent of its position in the sentences.

Results of the ANOVAs calculated for each condition and time epoch are displayed in Table 3. The statistical results of ANOVAs with the variables Region × Hemisphere × Correctness × Electrode for the first time epoch (350–500 ms) revealed several interactions. Similar to the results of the auditory experiment, there was a marginally significant Correctness × Region interaction that was present for the syntactic-category violation, but absent for the syntactic-category ambiguity condition. Separate analyses for the four quadrants (cf. Table 4) showed that this correctness effect was significant for the syntactic-category violation condition at the left anterior recordings. However, these analyses also revealed a Correctness × Electrode interaction for the syntactic-category ambiguity condition for the left anterior quadrant, which was not observed in the auditory experiment, as well as a main effect of correctness at the right anterior recordings. At the posterior

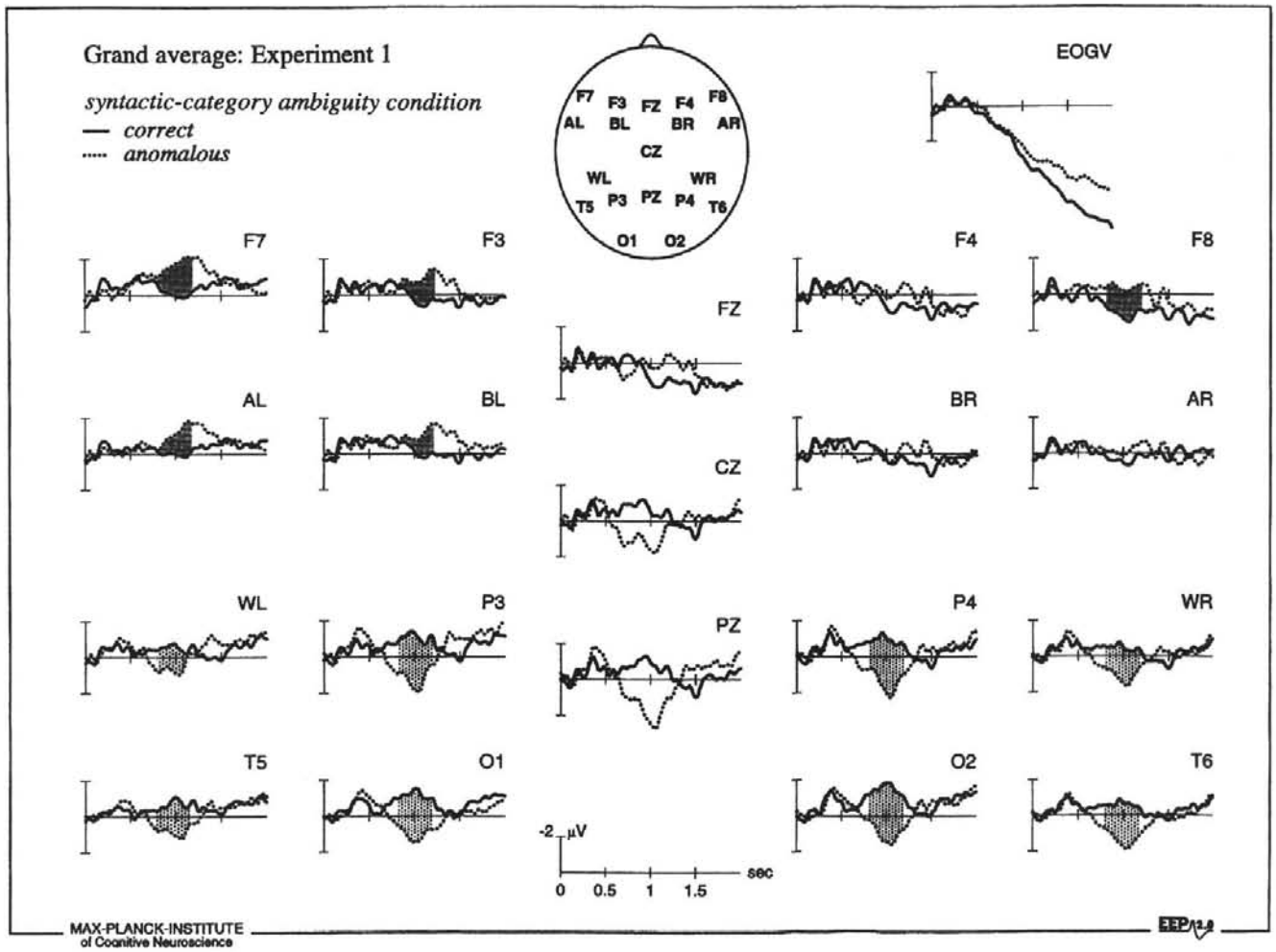


*Figure 4.* Grand average event-related potentials at the electrode sites in the four quadrants and three midline positions elicited by the critical word in the syntactic-category violation condition of Experiment 2 (for details see legend of Figure 2).

electrode sites, we found for the ambiguity condition a more negative-going component for the incorrect condition compared with the correct condition. The topographic distribution of this posterior negativity resembles the N400 pattern. For the syntactic-category violation condition, we observed the following pattern at the posterior electrodes. At the left posterior electrodes, a Correctness × Electrode interaction was obtained that reflected larger negativities in the incorrect condition than in the correct condition at the T5 recording site ($p < .01$), but not at the other left posterior electrodes. At the right posterior recording, the Correctness × Electrode interaction suggests more negative-going waveforms in the correct condition than in the incorrect condition. However, post hoc comparisons performed for single-electrode sites did not reveal reliable differences between the two conditions ($p > .05$).

As apparent from Figures 4 and 5, there were differences in the timing of the anterior and posterior effects in the later portions of the waveforms in both violation conditions. We therefore selected different time windows to quantify anterior and posterior effects in the second time epoch, namely a 700–1,200-ms time window for the anterior effects and a 500–1,000-ms window for the posterior effects. The statistical results of the ANOVAs calculated for these time epochs are displayed in Tables 3 and 4. The frontal negativity lateralized to the left-hemisphere recordings in the time epoch 700–1,200 ms revealed main effects of hemisphere for both conditions. Moreover, a significant Correctness × Hemisphere interaction for the syntactic-category violation and (marginally significant) for the ambiguity condition as well as a main effect of correctness for the latter condition were obtained. Separate analyses for the two anterior quadrants revealed a main effect of correctness for the left-hemisphere recordings that was marginally significant for the violation condition and highly significant for the ambiguity condition.

The posterior positivity in the time epoch 500–1,000 ms was lateralized to the right electrodes for the syntactic-category violation, but not for the syntactic-category ambiguity condition. This observation translates into a significant correctness effect at the right posterior recordings for the violation condition

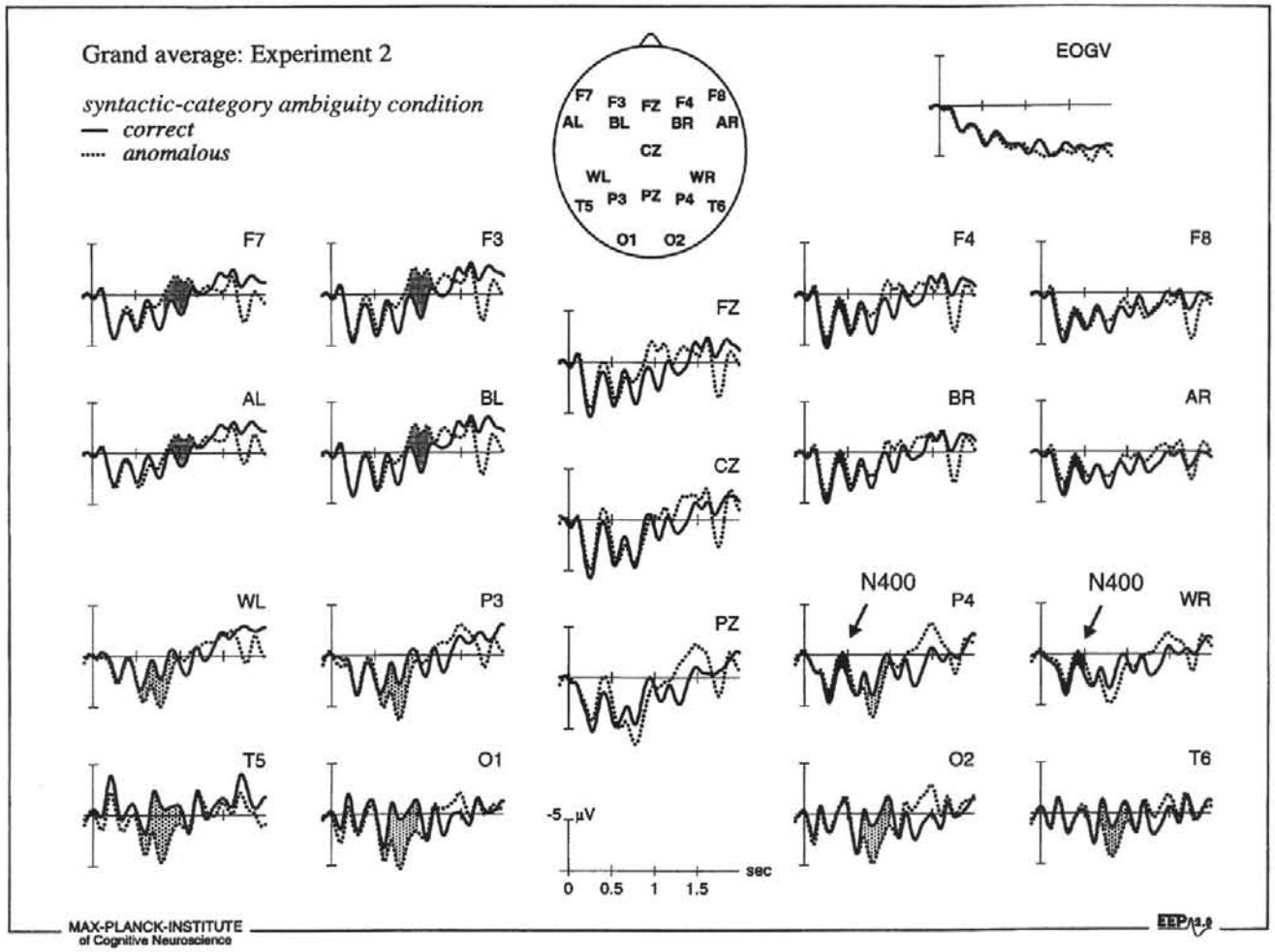


*Figure 5.* Grand average event-related potentials at the electrode sites in the four quadrants and three midline positions elicited by the critical words in the syntactic-category ambiguity condition in Experiment 2. Details are outlined in the legend of Figure 2. The arrow at the electrode sites P4 and WR indicates the N400.

and in correctness effects for both hemispheres in the syntactic-category ambiguity condition (cf. Table 4). In parallel to the auditory experiment, we examined differences in peak latency of the positivities elicited by the anomalies in both conditions by means of base-to-peak measures at the Pz electrode site. The mean values were 764 ms ($SD$ = 84 ms) and 790 ms ($SD$ = 79 ms) for the violation and the ambiguity condition, respectively. This difference was marginally significant, $t(15) = 2.12, p < .051$.

### *Discussion*

The results of the present experiment comparing the processing of the two types of anomalies during reading replicated the major results of Experiment 1, namely the left anterior negativity for the syntactic-category violation condition and the late posterior positivity for both types of anomalies and, furthermore, shed some light on the functional origin of the late frontal distributed negativity. In addition, we obtained an N400-like negativity for the syntactic-category ambiguity condition, which was not realizable in the auditory Experiment 1.

For the syntactic-category violation condition, we observed a left anterior negativity in the time window between 350 and 500 ms whose distribution was somewhat more lateral than in the auditory domain. This left anterior negativity seems to reflect the detection of a syntactic mismatch between the actual and the required word category, as a similar negativity was absent in the syntactic-category ambiguity condition.

For the syntactic-category ambiguity condition, we found a right posterior negativity between 300 and 500 ms. The distribution of this negativity was similar to the classical N400 (Kutas & Hillyard, 1980) and, therefore, suggests that the anomaly flagged in this condition also includes lexical–semantic aspects. Remember, this condition contained the ambiguous word *wurde* ([was] and [became]). Therefore, the noun following this word can be viewed as a violation of lexical–semantic aspects if both readings are activated. The

observed N400 pattern suggests that this is indeed the case. This N400-like negativity, although present in the same time epoch as the left anterior negativity, appears to peak later than the left anterior negativity. A base-to-peak measurement conducted at the two electrode sites where the components were largest, namely BL (left anterior) and P4 (right parietal) revealed that the left anterior negativity peaked about 50 ms earlier (at 390 ms; $SD$ = 41.9 ms) than the N400 (437 ms; $SD$ = 43.9 ms). This difference was significant, $t(15) = 2.62$, $p < .01$. This finding might be taken to suggest that word-category information, although only available in the suffix, was processed somewhat earlier than lexical–semantic information. Such a temporal order of the availability of different types of information would be in agreement with the claim that syntactic-category information is retrieved prior to lexical–semantic information (Frazier & Fodor, 1978).

In the second time epoch, both types of anomalies elicited a late positivity. For the syntactic-category violation condition this positivity was lateralized to the right hemisphere and was most pronounced at the parietal recordings. This lateralization of the positivity was most likely due to the sustained negativity over the left hemisphere. For the syntactic-category ambiguity condition the positivity was broadly distributed over the posterior scalp. This latter positivity is similar in its distribution and timing to other late positive components reported in correlation with the critical word inducing the grammatical anomaly in visual language comprehension tasks (Hagoort et al., 1993; Neville et al., 1991; Osterhout & Holcomb, 1992) and in auditory comprehension tasks (Osterhout & Holcomb, 1993). The late positivity may be taken to reflect processes involved in syntactic repair. In the case of anomalous but correct sentences, these processes most likely are those of structural reanalysis. In the case of incorrect sentences, such as those including agreement violations (Coulson et al., 1995; Gunter et al., 1995; Hagoort et al., 1993), the late positivity may reflect processes of syntactic repair with the attempt to achieve a possible interpretation of the sentences.[14]

Moreover, in this second time epoch we found a frontal distributed negativity, which was more prominent over the left than the right hemisphere. The late onset of this negativity suggests that it was correlated with the end of the phrase or beginning of the next phrase, independent of whether the ending phrase was correct or not. This negativity was present between 300 ms and 600 ms after the onset of the word *von* [by] heading the by phrase. A comparison between those three conditions in which *von* [by] followed the critical word immediately and the one condition in which it was the second word

Table 3
*Event-Related Potentials Analysis of Variance (ANOVA) Results for Experiment 2*

| Source | *df* | Category violation *F* | Category violation *MSE* | Category ambiguity *F* | Category ambiguity *MSE* |
|---|---|---|---|---|---|
| Latency range 350–500 ms | | | | | |
| He | 1, 15 | 0.06 | 7.21 | 0.08 | 8.60 |
| Co | 1, 15 | 0.49 | 18.42 | 1.78 | 17.21 |
| Co × Re | 1, 15 | 3.40* | 5.29 | 1.30 | 6.33 |
| Co × He | 1, 15 | 26.78*** | 2.74 | 6.83*** | 2.69 |
| Co × El | 3, 45 | 3.10** | 0.72 | 7.97*** | 0.58 |
| Co × Re × He | 1, 15 | 1.56 | 2.10 | 2.47 | 1.15 |
| Co × Re × El | 3, 45 | 3.10** | 0.58 | 3.27** | 0.67 |
| Co × He × El | 3, 45 | 7.69*** | 0.24 | 3.85** | 0.29 |
| Co × Re × He × El | 3, 45 | 4.46*** | 0.20 | 3.07 | 0.11 |
| Latency range 700–1,200 ms (anterior recordings) | | | | | |
| He | 1, 15 | 10.73*** | 11.36 | 9.38*** | 9.81 |
| Co | 1, 15 | 0.43 | 21.90 | 6.56** | 18.49 |
| Co × He | 1, 15 | 14.06*** | 3.58 | 3.31* | 6.23 |
| Co × El | 3, 45 | 0.33 | 0.59 | 2.69* | 0.79 |
| Co × He × El | 3, 45 | 2.61 | 0.36 | 1.29 | 0.64 |
| Latency range 500–1,000 ms (posterior recordings) | | | | | |
| He | 1, 15 | 2.65 | 5.18 | 0.56 | 5.09 |
| Co | 1, 15 | 3.91* | 9.89 | 8.91*** | 27.14 |
| Co × He | 1, 15 | 13.84*** | 1.72 | 8.02*** | 2.05 |
| Co × El | 3, 45 | 7.32*** | 0.45 | 4.69*** | 0.99 |
| Co × He × El | 3, 45 | 5.52*** | 0.54 | 0.38 | 0.54 |

*Note.* He = hemisphere; Co = correctness; Re = region; El = electrode. ANOVA effects that did not involve the variables hemisphere or correctness are of no theoretical interest in this study and are not listed in the table.
*$p < .10$. **$p < .05$. ***$p < .01$.

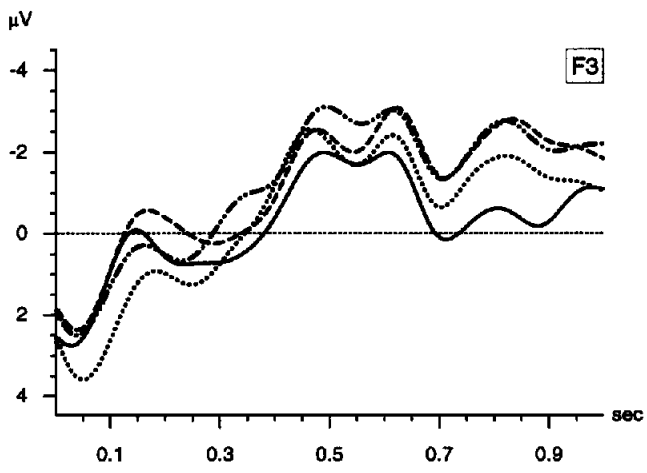


*Figure 6.* Grand average event-related potentials for the word *von* [by] in the four different conditions at electrode F3. The ordinate is identical with the onset of *von* [by].

[14] Whether the late positivities observed with these two aspects of syntactic repair, namely structurally licensed reanalysis on the one hand and post hoc repair mechanisms on the other hand, are of a different kind is currently under investigation. For the time being, we can only state that late positivities around 600 ms were observed for both types of syntactically anomalous sentences.

Table 4
*Event-Related Potentials Analysis of Variance (ANOVA) Results in Each of the Four Quadrants for Experiment 2*

| Source | *df* | Category violation *F* | Category violation *MSE* | Category ambiguity *F* | Category ambiguity *MSE* |
|---|---|---|---|---|---|
| Latency range 350–500 ms | | | | | |
| Left anterior | | | | | |
| Co | 1, 15 | 6.62** | 11.74 | 1.81 | 4.64 |
| Co × El | 3, 45 | 1.93 | 0.51 | 5.12** | 0.34 |
| Right anterior | | | | | |
| Co | 1, 15 | 0.35 | 7.08 | 4.60** | 6.59 |
| Co × El | 3, 45 | 1.68 | 0.34 | 0.88 | 0.34 |
| Left posterior | | | | | |
| Co | 1, 15 | 1.81 | 4.20 | 0.28 | 9.86 |
| Co × El | 3, 45 | 7.54*** | 0.50 | 6.82*** | 0.52 |
| Right posterior | | | | | |
| Co | 1, 15 | 2.90 | 5.52 | 2.97 | 6.29 |
| Co × El | 3, 45 | 3.74** | 0.38 | 5.90*** | 0.46 |
| Latency range 700–1,200 ms (anterior recordings) | | | | | |
| Left anterior | | | | | |
| Co | 1, 15 | 3.29* | 15.68 | 13.44*** | 9.00 |
| Co × El | 3, 45 | 1.55 | 0.47 | 2.20* | 0.71 |
| Right anterior | | | | | |
| Co | 1, 15 | 0.83 | 9.80 | 1.33 | 15.72 |
| Co × El | 3, 45 | 0.86 | 0.48 | 1.84 | 0.72 |
| Latency range 500–1,000 ms (posterior recordings) | | | | | |
| Left posterior | | | | | |
| Co | 1, 15 | 0.12 | 7.18 | 12.17*** | 15.79 |
| Co × El | 3, 45 | 7.85*** | 0.54 | 3.23** | 0.83 |
| Right posterior | | | | | |
| Co | 1, 15 | 13.92*** | 4.43 | 4.93** | 13.40 |
| Co × El | 3, 45 | 4.65*** | 0.47 | 3.07** | 0.70 |

*Note.* Co = correctness; El = electrode.
*$p < .10$. **$p < .05$. ***$p < .01$.

after the critical word suggests that this negativity was primarily a function of the detection of the beginning of a new phrase and thereby the need for a closure of the preceding phrase. This frontal negativity seems to be enhanced by grammatical anomaly, as it was slightly more pronounced in the case of both types of the anomalous conditions as compared with the correct conditions. A similar sustained negativity explicitly was discussed only in a few other studies investigating the processing of grammatical anomalies. Neville et al. (1991), for example, observed a sustained negativity over frontal and anterior parts of the left hemisphere with violations of specificity constraints. A left lateralized frontal negativity was also found in a study investigating the processing of subject- and object-relative clause sentence comprehension (Mecklinger et al., 1995). In the former study, these negativities were not given an explicit interpretation; the second study tentatively related this negativity to working-memory processes. Frontal negativities similar in distribution to the one observed in the present study have indeed been reported in relation to verbal memory (Lang et al., 1988; Ruchkin et al., 1992). Thus, it is likely that the present left frontal negativity reflects aspects of verbal memory. The finding that the left frontally distributed negativity in all four conditions was related in time to the beginning of the by phrase suggests that this negativity might reflect aspects of the working-memory operation involved in closing and opening major phrases.

## General Discussion

In two experiments we recorded ERPs while participants were listening to sentences presented as connected speech or reading sentences presented one word at a time. These sentences were either correct or contained a word indicating a violation of the phrasally required syntactic category or a violation of the most frequent of several possible syntactic categories.

Specific components were found to correlate with these two different types of anomalies. Whereas the syntactic-category violation elicited an early left anterior negativity followed by a late centroparietal positivity, the early left anterior negativity was absent when the violation concerned the most frequent of several possible syntactic categories, although the late positivity was present. The discussion that follows details the picture that emerged.

### *Left Anterior Negativity and N400*

Independent of whether sentences were presented auditorily or visually, the critical word in the syntactic-category violation condition elicited an early left anterior negativity. This negativity was absent in the syntactic-category ambiguity condition. Because the presence and absence of the early left anterior negativity were observed as a function of the correctness of a phrasally required syntactic category, we take this negativity to reflect the parsing system's sensitivity to phrase-structure errors. Note that in the syntactic-category ambiguity condition no phrase structure error was present, as the ambiguity of the word *wurde* (auxiliary reading vs. main verb reading) allows for two structures, a verb phrase structure indicated by the auxiliary [was] reading and a noun predicate structure indicated by the main verb [became] reading. Although the former is preferred over the latter in terms of frequency of usage, the parsing system seems to activate both readings and thereby tolerates both structures. The observed N400 pattern in the visual Experiment 2 suggests that the parser had activated both readings of the word *wurde,* as a semantic anomaly could only be detected under the condition in which the less frequent main verb reading was activated. A similar pattern observed for the auditory Experiment 1 failed to reach significance. One possible explanation for this difference between the two presentation modes may consider additional cues in the auditory domain as compared with the visual domain indicating whether the word *wurde* should be read as an auxiliary (function word) or a main verb (content word). This is not unlikely, as a recent study by Cutler (1993) has shown that the spontaneous production of word-class ambiguous word forms differs as a function of their assigned class membership, with a shorter duration when produced as a closed-class element (function word) than when produced as an open-class element (content word). However, post hoc measurements of the realization of the word *wurde* in the four conditions suggest that the speaker read all instances as

belonging to one category (syntactic-category violation, correct $M$ = 214 ms, range = 164–262 ms; incorrect $M$ = 224 ms, range = 191–265 ms; syntactic ambiguity, correct $M$ = 213 ms, range = 149–262 ms; anomalous $M$ = 211 ms, range = 148–258 ms). Given that the realizations in the correct sentence appear to be auxiliary readings and given the absence of a difference between the syntactic ambiguity anomalous realization and the two former realizations, it is likely that the syntactic ambiguity anomalous realization is not a typical open-class reading of the word *wurde.* The absence of a left anterior negativity in the syntactic-category ambiguity condition, however, must be taken as an indication that the parser did not devote itself to the function word reading either. In the face of the absence of a significant N400 pattern in the auditory domain, it is difficult to conclude what the parser's processes in this domain were. The finding, however, that a significant N400 pattern was observed when the sentences were presented visually suggests that in the absence of phonetic–prosodic cues, the parser indeed considered the two readings during its first parse.

Left anterior negativities have now been found in different studies using different stimulus material, although in different time windows (Friederici et al., 1993; Kluender & Kutas, 1993; Münte et al., 1993; Neville et al., 1991; Rösler et al., 1993). With the data at hand, we are not able to decide whether these negativities are of a similar kind. They all reflect the processing of syntactic aspects although at functionally different levels. The latency may vary as a function of the type of information relevant (e.g., with word-category information ranging higher in a hierachically organized lexicon, and therefore being available earlier than verb-argument information), as a function of at which point during word processing the relevant information within the syntactic domain becomes available (e.g., with syntactic information encoded in the prefix becoming available earlier than syntactic information encoded in the suffix), or both. Future research will have to clarify this point. What the present study indicates, however, is that the processing of syntactic word-category information precedes the processing of lexical–semantic information even when the former is encoded in the suffix and the latter is encoded in the word stem.

### *Late Positivity*

A late centroparietal positivity was observed for both the syntactic-category violation and the ambiguity condition independent of whether sentences were presented as connected speech or visually. For the sentences used in the present study, this positivity seems to correlate with processes of reanalysis possible in both conditions. A possible reanalysis in the syntactic-category violation condition (e.g., *Das Metall wurde zur veredelt* . . . [The metal was for refined . . .]) would be to eliminate the one node in the syntactic tree, namely the prepositional phrase node when encounting the past participle. For the syntactic-category ambiguity condition, two possible reanalyses were considered. In sentences such as *Das Metall wurde Veredelung von* . . . [The metal was/became refining by . . .] one may carry out an immediate reanalysis of the ambiguous word *wurde* when encountering the particular noun that is semantically implausible, but whose word stem points towards a plausible verb interpretation. In such a case, the derivational suffix would have to be changed into a verb inflection, thereby changing the noun predicate into a main verb requiring an auxiliary reading for the word *wurde.* The other possibility is to postpone the reanalysis until the beginning of the by phrase as it is only at this point where the sentence becomes syntactically incorrect. The latency of the positivity for the syntactic-category ambiguity condition in both experiments as well as the N400 in Experiment 2 suggests that the parser does not postpone the reanalysis, but initiates the reanalysis when processing the noun. Statements about the actual types of reanalyses conducted in the two conditions must remain a speculation. The finding, however, that this late positivity is not only correlated with syntactic-category violations (Hagoort et al., 1993; Osterhout & Holcomb, 1992, 1993), but also with syntactic-category ambiguities (Mecklinger et al., 1995; Osterhout et al., 1995; and the results from present study) strongly suggests that the late positivity cannot be taken to reflect the system's sensitivity to syntactic errors alone.

### *Sustained Frontal Negativity*

The third component observed in the present study in relation to syntactic processes was present in the auditory and visual modality but could best be observed in the visual condition, as it allowed separate analysis for the word following the critical word. This component concerned the processing of words marking a phrase boundary. The word under discussion is the word *von* [by] signalling the beginning of the next phrase and thereby the need for phrase closure of the preceding phrase. The processing of this word was analyzed separately in the visual presentation mode, as in this mode the exact temporal sequence of lexical elements was available. Processing of this word elicited a frontal sustained negativity starting around 200 ms after word onset distributed over both hemispheres, but more pronounced over the left hemisphere. This frontally distributed negativity was present in all sentences between 300 and 600 ms after onset of the word *von* [by]. As mentioned above, a similar frontal negative component is only discussed in a few other reports of studies of language parsing. These studies, however, as well as the review of studies investigating verbal memory, suggest that this component may be related to verbal memory processes involved during phrase-structure building and retention.

### *Psycholinguistic Modeling*

When discussing the temporal structure of the ERP data from the present and other parsing studies in connection with psycholinguistic models of language parsing, a model proposing two consecutive stages of syntactic parsing may be considered (Frazier, 1987). This model assumes an early stage of parsing during which initial structural assignment is made on the basis of word-category information and a late stage during which structural and lexical–semantic information becomes available, which will either lead to a successful interpretation

or a reanalysis of the initial structure. The early stage involving syntactic processes of initial structural assignment could be taken to be correlated with an early left anterior negativity, whereas the later stage might be reflected by the centroparietally distributed positive component. The present finding that the left anterior negativity was present only in the syntactic-category violation condition, but not in the ambiguity condition, whereas the late positivity was observed in both anomaly conditions, seems to support the assumption of two separate stages of syntactic parsing. It seems that the failure to build up the syntactic structure on-line during an initial parse, in particular, is reflected by a left anterior negative component. The second stage involving thematic role assignment as well as processes of reanalysis or repair seem to be associated with a late centroparietal positivity. Further research specifying these different subprocesses is clearly needed before an adequate description of the language comprehension process can be provided, but it seems that the temporal resolution and the topographical pattern can help to specify the functional architecture of the language comprehension process.

## References


Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database* [CD-ROM]. Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania.

Basso, A., Roch Lecours, A., Moraschini, S., & Vanier, M. (1985). Anatomo-clinical correlations of the aphasias as defined through computerized tomography: Exceptions. *Brain and Language, 26,* 201–229.

Broca, P. (1865). Sur la faculté du langage articulé [On the faculty of spoken language]. *Bulletins de la Société Anthropologique de Paris,* 493–494.

Brown, W. S., Lehmann, D., & Marsh, J. T. (1980). Linguistic meaning-related differences in evoked potential topography: English, Swiss-German and imagined. *Brain and Language, 11,* 340–353.

Brown, W. S., Marsh, R. E., & Smith, J. C. (1973). Contextual meaning effects on speech-evoked potentials. *Behavioral Biology, 9,* 755–761.

Brown, W. S., Marsh, R. E., & Smith, J. C. (1976). Evoked potential wave-form differences produced by the perception of different meanings of an ambiguous phrase. *Electroencephalography and Clinical Neurophysiology, 41,* 113–123.

Brown, W. S., Marsh, R. E., & Smith, J. C. (1979). Principal component analysis of ERP differences related to the meaning of an ambiguous word. *Electroencephalography and Clinical Neurophysiology, 46,* 709–761.

Caplan, D., & Waters, G. S. (1990). Short-term memory and language comprehension: A critical review of the neuropsychological literature. In G. Vallar (Ed.), *Neuropsychological impairments of short-term memory* (pp. 337–389). Cambridge, England: Cambridge University Press.

Coulson, S., King, J., & Kutas, M. (1995, March). *The late show: The syntactic positive shift meets the late positive component.* Paper presented at the Eighth Annual CUNY Conference on Human Sentence Processing, Tucson, Arizona.

Cutler, A. (1993). Phonological cues to open- and closed-class words in the processing of spoken sentences. *Journal of Psycholinguistic Research, 22,* 109–131.

Damasio, H., & Damasio, A. R. (1989). *Lesion analysis in neuropsychology.* New York: Oxford University Press.

Démonet, J.-F., Chollet, F., Ramsay, S., Cardebat, D., Nespoulous, J.-L., Wise, R., Rascol, A., & Frackowiak, R. (1992). The anatomy of phonological and semantic processing in normal subjects. *Brain, 115,* 1753–1768.

Donchin, E. (1979). Event-related brain potentials: A tool in the study of human information processing. In H. Begleiter (Ed.), *Evoked brain potentials and behavior* (pp. 13–18). New York: Plenum.

Donchin, E. (1981). Surprise! ... Surprise! *Psychophysiology, 18,* 493–513.

Duncan-Johnson, C. C., & Donchin, E. (1977). On quantifying surprise: The variation of event-related potentials with subjective probability. *Psychophysiology, 14,* 456–467.

Forster, K. I. (1979). Levels of processing and the structure of the language processor. In W. E. Coopers & E. C. T. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett* (pp. 27–85). Hillsdale, NJ: Erlbaum.

Frazier, L. (1978). *On comprehending sentences: Syntactic parsing strategies.* Unpublished doctoral dissertation, University of Connecticut.

Frazier, L. (1987). Sentence processing: A tutorial review. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 559–586). Hillsdale, NJ: Erlbaum.

Frazier, L. (1990). Exploring the architecture of the language-processing system. In G. T. M. Altmann (Ed.), *Cognitive models of speech processing* (pp. 409–433). Cambridge, MA: MIT Press.

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

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

Friederici, A. D. (1985). Levels of processing and vocabulary types: Evidence from on-line comprehension in normals and agrammatics. *Cognition, 19,* 133–166.

Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: Effects of semantic, morphological, and syntactic violations. *Cognitive Brain Research, 1,* 183–192.

Frith, C. D., Friston, K. J., Liddle, P. F., & Frackowiak, R. S. J. (1991). A PET study of word finding. *Neuropsychologia, 29,* 1137–1148.

Geisser, S., & Greenhouse, S. (1959). On methods in the analysis of profile data. *Psychometrica, 24,* 95–112.

Gordon, B., & Caramazza, A. (1982). Lexical decision for open and closed class items: Failure to replicate differential frequency sensitivity. *Brain and Language, 15,* 143–180.

Gorrell, P. (1995). *Syntax and parsing.* Cambridge, England: Cambridge University Press.

Grosjean, F. (1980). Spoken word recognition processes and the gating paradigm. *Perception and Psychophysics, 28,* 267–283.

Gunter, T. C., Vos, S. H., & Mulder, G. (1995, March). *Syntactic violations and ERPs: P600 or P3b?* Paper presented at the Eighth Annual CUNY Conference on Human Sentence Processing, Tucson, Arizona.

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

Hickok, G. (1993). Parallel parsing: Evidence from reactivation in garden-path sentences. *Journal of Psycholinguistic Research, 22,* 239–250.

Hillyard, S. A., & Picton, T. W. (1987). Electrophysiology of cognition. In F. Plum (Ed.), *Handbook of physiology: Higher functions of the nervous system: Section 1. The nervous system: Vol. 5. Higher functions*

*of the brain: Part 2* (pp. 519–584). Bethesda, MD: American Physiological Society.

Inoue, A., & Fodor, J. D. (1995). Information-paced parsing of Japanese. In R. Mazuka & N. Nagai (Eds.), *Japanese sentence processing* (pp. 9–63). Hillsdale, NJ: Erlbaum.

Jaspers, H. H. v. (1958). Report of the committee of methods of clinical examination in electroencephalography. *Electroencephalography and Clinical Neurophysiology, 10,* 370–375.

Kertesz, A. (Ed.). (1983). *Localization in neuropsychology.* New York: Academic Press.

King, J. W., & Kutas, M. (1995). When parsing along time: Slower and slower ERP components related to sentence processing. *Journal of Cognitive Neuroscience, 7,* 376–395.

Kluender, R., & Kutas, M. (1993). Bridging the gap: Evidence from ERPs on the processing of unbounded dependencies. *Journal of Cognitive Neuroscience, 2,* 196–214.

Kolk, H., & Blomert, L. (1985). On the Bradley hypothesis concerning agrammatism: The nonword-interference effect. *Brain and Language, 26,* 94–105.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Event-related brain potentials during natural sentence processing. *Brain and Language, 11,* 354–373.

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

Kutas, M., & van Petten, C. (1988). Event-related potential studies of language. In P. K. Ackles, J. R. Jennings, & M. G. H. Coles (Eds.), *Advances in psychophysiology* (Vol. 3, pp. 135–181). Greenwich, CT: JAI Press.

Lang, M., Lang, W., Uhl, F., Kornhuber, A., Deeke, L., & Kornhuber, H. H. (1988). Left frontal lobe in verbal associative learning: A slow potential study. *Experimental Brain Research, 70,* 99–108.

MacDonald, M. C. (1993). The interaction of lexical and syntactic ambiguity. *Journal of Memory and Language, 32,* 692–715.

Mäkelä, J. P., Ahonen, A., Hämäläinen, M., Hari, R., Ilmoniemi, R., Kajola, M., Knuutila, J., Lounasmaa, O. V., McEvoy, L., Salmelin, R., Salonen, O., Sams, M., Simola, J., Tesche, C., & Vasama, J.-P. (1993). Functional differences between auditory cortices of the two hemispheres revealed by whole-head neuromagnetic recordings. *Human Brain Mapping, 1,* 48–56.

Marie, P. (1926). La troisème cironvolution frontale gauche ne joue aucun rôle spécial dans la function du language [The third frontal convolution does not play a special role for language functions]. In P. Marie (Ed.), *Travaux et memoires, tome 1* [Works and memories, Vol. 1] (pp. 3–30). Paris: Masson. (Original work published 1906; for translation, see M. F. Cole & M. Cole (Eds.). (1971). *Pierre Marie's papers on speech disorders.* New York: Hafner.

Marslen-Wilson, W. D. (1980). Speech understanding as a psychological process. In J. C. Simon (Ed.), *Spoken language generation and understanding* (pp. 39–67). Dordrecht, The Netherlands: Riedel.

Mazoyer, B. M., Tzourio, N., Frak, V., Syrota, A., Murayama, N., Levrier, O., Salamon, G., Dehaene, S., Cohen, L., & Mehler, J. (1993). The cortical representation of speech. *Journal of Cognitive Neuroscience, 5,* 467–479.

McClelland, J. L., St. John, M., & Taraban, R. (1989). Sentence comprehension: A parallel distributed processing approach. *Language and Cognitive Processes, 4,* 287–336.

McKoon, G., & Ratcliff, R. (1994). Sentential context and on-line lexical decision. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1239–1243.

McKoon, G., Ratcliff, R., & Ward, G. (1994). Testing theories of language processing: An empirical investigation of the on-line lexical-decision task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1219–1228.

Mecklinger, A., Schriefers, H., Steinhauer, K., & Friederici, A. D. (1995). The processing of relative clauses varying on syntactic and semantic dimensions: An analysis with event-related potentials. *Memory & Cognition, 23,* 477–494.

Münte, T. F., Heinze, H.-J., & Mangun, G. R. (1993). Dissociation of brain activity related to syntactic and semantic aspects of language. *Journal of Cognitive Neuroscience, 5,* 335–344.

Münte, T. F., Heinze, H.-J., & Prevedel, H. (1990). Ereigniskorrelierte Hirnpotentiale reflektieren semantische und syntaktische Fehler bei Sprachverarbeitung [Event-related potentials reflect semantic and syntactic violations during language processing]. *Zeitschrift für EEG und EMG und verwandte Gebiete, 21,* 75–81.

Neville, H. J., Mills, D. L., & Lawson, D. L. (1992). Fractionating language: Different neural subsystems with different sensitive periods. *Cerebral Cortex, 2,* 244–258.

Neville, H. J., Nicol, J., Barss, A., Forster, K., & Garrett, M. (1991). Syntactically based sentence processing classes: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience, 3,* 155–170.

Nicol, J. L., Fodor, J. D., & Swinney, D. (1994). Using cross-modal lexical-decision tasks to investigate sentence processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1229–1238.

Nicol, J., & Swinney, D. (1989). The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistic Research, 18,* 5–19.

Nobres, A. C., & McCarthy, G. (1994). Language-related ERPs: Scalp distributions and modulations by word type and semantic priming. *Journal of Cognitive Neuroscience, 6,* 233–255.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9,* 97–113.

Osterhout, L., & Holcomb, P. J. (1992). Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language, 31,* 785–804.

Osterhout, L., & Holcomb, P. J. (1993). Event-related potentials and syntactic anomaly: Evidence of anomaly detection during the perception of continuous speech. *Language and Cognitive Processes, 8,* 413–437.

Osterhout, L., Holcomb, Ph.J., & Swinney, D. A. (1995). Brain potentials elicited by garden-path sentences: Evidence of the application of verb information during parsing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 786–803.

Petersen, S. E., Fox, P. T., Posner, M. I., Mintun, M. A., & Raichle, M. E. (1988). Positron emission tomographic studies of the cortical anatomy of single-word processing. *Nature, 331,* 585–589.

Petersen, S. E., Fox, P. T., Snyder, A. Z., & Raichle, M. E. (1990). Activation of extrastriate and frontal cortical areas by visual words and word-like stimuli. *Science, 249,* 1041–1044.

Poeck, K., De Bleser, R., & Keyserlingk (1984). CT-localization of standard aphasic syndrome. In F. C. Rose (Ed.), *Advances in neurology, Vol. 42: Progress in aphasiology* (pp. 71–89). New York: Raven Press.

Rosenberg, B., Zurif, I., Brownell, H., Garrett, M., & Bradley, D. (1985). Grammatical class effects in relation to normal and aphasic sentence processing. *Brain and Language, 26,* 287–303.

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

Ruchkin, D. S., Johnson, R., Jr., Grafman, J., Canounce, H., & Ritter, W. (1992). Distinctions and similarities among working memory

processes: An event-related potential study. *Cognitive Brain Research, 1,* 53–66.

Seidenberg, M. S., Tanenhaus, M. K., Leiman, J. M., & Bienkowski, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge based processing. *Cognitive Psychology, 14,* 489–537.

Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior, 18,* 645–659.

Van Petten, C., & Kutas, M. (1991). Influences of semantic and syntactic context on open and closed class words. *Memory & Cognition, 19,* 95–112.

Wernicke, C. (1874). *Der aphasische symptomenkomplex* [The aphasic symptom]. Breslau, Germany: Cohn & Weigert.

## Appendix A

### Sentence Material and Probe Words

| Noun phrase | Auxiliary | Critical word | By-phrase | Probe word |
|---|---|---|---|---|
| Die Sauce | wurde | *verfeinert/Verfeinerung* | von dem Wirt den wenige begrüßten | Sauce/verfeinert |
| [The sauce | is being | *refined/refinement* | by the host who few greeted] | sauce/refined |
| Die Sauce | wurde als | *Verfeinerung hinzugegeben/verfeinert* | von dem Wirt den wenige begrüßten | Wirt/begrüßen |
| [The sauce | is being as | *refinement added/refined* | by the host who few greeted] | host/greet |
| Der Computer | wurde | *verpackt/Verpackung* | von dem Mann den viele verspotteten | verpacke/Mann |
| [The computer | is being | *wrapped/wrapping* | by the man who many scoffed] | wrap/man |
| Der Computer | wurde trotz | *Verpackung beschädigt/verpackt* | von dem Mann den viele verspotteten | verspottete/Computer |
| [The computer | is being despite | *wrapping damaged/wrapped* | by the man who many scoffed] | scoffed/computer |
| Die Note | wurde | *bestätigt/Bestätigung* | von der Lehrerin die man versetzte | Lehrerinnen/versetzte |
| [The note | is being | *confirmed/confirmation* | by the teacher who was transferred] | teacher/transferred |
| Die Note | wurde als | *Bestätigung verstanden/bestätigt* | von der Lehrerin die man versetzte | Noten/bestätigt |
| [The note | is being as | *confirmation understood/confirmed* | by the teacher who was transferred] | note/confirmed |
| Das Inventar | wurde | *erfaßt/Erfassung* | von der Angestellten die alle kritisierten | kritisierten/Inventaren |
| [The inventory | is being | *included/inclusion* | by the employee who all criticized] | criticized/inventories |
| Das Inventar | wurde zur | *Erfassung numeriert/erfaßt* | von der Angestellten die alle kritisierten | Erfassung/Angestellter |
| [The inventory | is being to the | *inclusion numbered/included* | by the employee who all criticized] | inclusion/employee |
| Die Instruktion | wurde | *erklärt/Eklärung* | von einem Forscher den keiner kannte | Instruktionen/Erklärung |
| [The instruction | is being | *explained/explanation* | by the scientist who nobody knew] | instruction/explanation |
| Die Instruktion | wurde als | *Erklärung verwendet/erklärt* | von einem Forscher den keiner kannte | Forschern/kannte |
| [The instruction | is being as | *explanation used/explained* | by the scientist who nobody knew] | scientist/knew |
| Der Strauch | wurde | *verpflanzt/Verpflanzung* | von einem Gärtner den wenige empfahlen | verpflanzt/Gärtnerin |
| [The bush | is being | *transplanted/transplantation* | by a gardener who few recommended] | transplanted/gardener |
| Der Strauch | wurde trotz | *Verpflanzung vernachlässigt/verpflanzt* | von einem Gärtner den wenige empfahlen | empfahlen/Sträuchern |
| [The bush | is being despite | *transplantation neglected/transplanted* | by a gardener who few recommended] | recommended/bushes |
| Die Summe | wurde | *verrechnet/Verrechnung* | von einem Lehrling den wenige achteten | Lehrling/achten |
| [The sum | is being | *miscalculated/calculation* | by an apprentice who few respected] | apprentice/respect |
| Die Summe | wurde zur | *Verrechnung überwiesen/verrechnet* | von einem Lehrling den wenige achteten | Summe/Verrechnung |
| [The sum | is being to the | *calculation transferred/calculated* | by an apprentice who few respected] | sum/calculation |

(*appendix continues*)

## Appendix A (*continued*)

### Sentence Material and Probe Words

| Noun phrase | Auxiliary | Critical word | By-phrase | Probe word |
|---|---|---|---|---|
| Die Stadtmauer | wurde | *befestigt/Befestigung* | von dem Volk das man bedrohte | bedrohten/Stadtmauer |
| [The town-wall | is being | *stabilized/stabilization* | by the people who was threatened] | threatened/town-wall |
| Die Stadtmauer | wurde als | *Befestigung gebaut/befestigt* | von dem Volk das man bedrohte | befestige/Volk |
| [The town-wall | is being as | *stabilization built/stabilized* | by the people who was threatened] | stabilize/people |
| Der Müll | wurde | *beseitigt/Beseitigung* | von dem Unternehmen das alle bedrängten | Müll/beseitige |
| [The rubbish | is being | *removed/removal* | by the firm which all distressed] | rubbish/remove |
| Der Müll | wurde zur | *Beseitigung gestapelt/beseitigt* | von dem Unternehmen das alle bedrängten | Unternehmen/bedrängte |
| [The rubbish | is being to the | *removal piled up/removed* | by the firm which all distressed] | firm/distressed |
| Die Wunde | wurde | *untersucht/Untersuchung* | von einem Chirurgen den viele verkannten | Untersuchung/Chirurgen |
| [The wound | is being | *examined/examination* | by the surgeon who many misjudged] | examination/surgeon |
| Die Wunde | wurde zur | *Untersuchung gesäubert/untersucht* | von einem Chirurgen den viele verkannten | verkennen/Wunde |
| [The wound | is being to the | *examination cleaned/examined* | by the surgeon who many misjudged] | misjudge/wound |
| Das Material | wurde | *erprobt/Erprobung* | von dem Techniker den viele befragten | Technikerin/befragten |
| [The material | is being | *tested/test* | by the technician who many questioned] | technician/consulted |
| Das Material | wurde zur | *Erprobung angeschafft/erprobt* | von dem Techniker den viele befragten | Materialien/erprobt |
| [The material | is being to the | *test obtained/tested* | by the technician who many questioned] | materials/tested |
| Das Werkzeug | wurde | *benutzt/Benutzung* | von dem Handwerker den keiner beriet | beriet/Werkzeuges |
| [The tool | is being | *used/use* | by the craftsman who nobody advised] | advised/tools |
| Das Werkzeug | wurde zur | *Benutzung bereitgestellt/benutzt* | von dem Handwerker den keiner beriet | Benutzung/Handwerkern |
| [The tool | is being to the | *use provided/used* | by the craftsman who nobody advised] | use/craftsman |
| Die Diskussion | wurde | *vertieft/Vertiefung* | von dem Politiker den man einflog | Diskussionen/Vertiefung |
| [The discussion | is being | *deepened/deepening* | by the politician who was flown in] | discussion/deepening |
| Die Diskussion | wurde zur | *Vertiefung angeboten/vertieft* | von dem Politiker den man einflog | Politikerin/einflog |
| [The discussion | is being to the | *deepening offered/deepened* | by the politician who was flown in] | politician/flew in |
| Das Metall | wurde | *veredelt/Veredelung* | von dem Goldschmied den man auszeichnete | veredelt/Goldschmieden |
| [The metal | is being | *refined/refinement* | by the goldsmith who was honored] | refined/goldsmith |
| Das Metall | wurde zur | *Veredelung geschmolzen/veredelt* | von dem Goldschmied den man auszeichnete | auszeichnete/Metalls |
| [The metal | is being to the | *refinement melted/refined* | by the goldsmith who was honored] | honored/metals |
| Die Milch | wurde | *verdünnt/Verdünnung* | von einem Jungen den keiner tadelte | Jungen/tadelten |
| [The milk | is being | *diluted/dilution* | by a boy who nobody accused] | boy/accused |
| Die Milch | wurde als | *Verdünnung benutzt/verdünnt* | von einem Jungen den keiner tadelte | Milch/verdünne |
| [The milk | is being as | *dilution used/diluted* | by a boy who nobody accused] | milk/dilute |

## Appendix A (*continued*)

### Sentence Material and Probe Words

| Noun phrase | Auxiliary | Critical word | By-phrase | Probe word |
|---|---|---|---|---|
| Der Termin | wurde | *vereinbart/Vereinbarung* | von einer Gruppe die keiner erwartete | erwarten/Termin |
| [The appointment | is being | *arranged/arrangement* | by a group who nobody expected] | expect/appointment |
| Der Termin | wurde als | *Vereinbarung notiert/vereinbart* | von einer Gruppe die keiner erwartete | vereinbart/Gruppe |
| [The appointment | is being as | *arrangement quoted/arranged* | by a group who nobody expected] | arranged/group |
| Das Gesetz | wurde | *erneuert/Erneuerung* | von einem Richter dem wenige vertrauten | Gesetz/Erneuerung |
| [The law | is being | *renewed/renewal* | by a judge who few trusted] | law/renewal |
| Das Gesetz | wurde zur | *Erneuerung vorgelegt/erneuert* | von einem Richter dem wenige vertrauten | Richtern/vertrauen |
| [The law | is being to the | *renewal presented/renewed* | by a judge who few trusted] | judge/trust |
| Die Verletzung | wurde | *versorgt/Versorgung* | von einem Pfleger den wenige liebten | versorge/Pflegerin |
| [The injury | is being | *attended/attention* | by a nurse who few loved] | attend/nurse |
| Die Verletzung | wurde zur | *Versorgung vorbereitet/versorgt* | von einem Pfleger den wenige liebten | liebten/Verletzung |
| [The injury | is being to the | *attention prepared/attended* | by a nurse who few loved] | loved/injury |
| Die Spende | wurde | *verteilt/Verteilung* | von dem Land das viele bereisten | Ländern/bereisen |
| [The donation | is being | *distributed/distribution* | by a country that many travelled] | countries/travel |
| Die Spende | wurde zur | *Verteilung vorgesehen/verteilt* | von dem Land das viele bereisten | Spende/verteilt |
| [The donation | is being to the | *distribution provided/distributed* | by a country that many travelled] | donation/distributed |
| Das Ziel | wurde | *verfehlt/Verfehlung* | von dem Sportler den keiner ausbildete | ausbildete/Ziel |
| [The finish | is being | *failed/failure* | by the athlete who nobody instructed] | instructed/finish |
| Das Ziel | wurde trotz | *Verfehlung beibehalten/verfehlt* | von dem Sportler den keiner ausbildete | verfehle/Sportlerin |
| [The finish | is being despite | *failure maintained/failed* | by the athlete who nobody instructed] | fail/athlete |
| Der Unterschied | wurde | *verdeutlicht/Verdeutlichung* | von der Dozentin der wenige zuhörten | Unterschiedes/verdeutlicht |
| [The difference | is being | *elucidated/elucidate* | by the assistant professor who few listened to] | differences/elucidated |
| Der Unterschied | wurde trotz | *Verdeutlichung mißverstanden/verdeutlicht* | von der Dozentin der wenige zuhörten | Dozentin/zuhörten |
| [The difference | is being despite | *elucidate misunderstood/elucidated* | by the assistant professor who few listened to] | assistant professor/listened to |
| Der Vorschlag | wurde | *ergänzt/Ergänzung* | von einer Studentin die keiner verpflichtete | ergänzt/Studentin |
| [The proposition | is being | *completed/completion* | by a student who nobody engaged] | completed/student |
| Der Vorschlag | wurde als | *Ergänzung verstanden/ergänzt* | von einer Studentin die keiner verpflichtete | verpflichteten/Vorschlägen |
| [The proposition | is being as | *completion understood/completed* | by a student who nobody engaged] | engaged/propositions |
| Das Denkmal | wurde | *bewacht/Bewachung* | von dem Soldaten dem viele mißtrauten | Soldaten/mißtrauten |
| [The memorial | is being | *guarded/guard* | by the soldier who many distrusted] | soldier/distrusted |
| Das Denkmal | wurde trotz | *Bewachung erklommen/bewacht* | von dem Soldaten dem viele mißtrauten | Denkmals/Bewachung |
| [The memorial | is being despite | *guard climbed up/guarded* | by the soldier who many distrusted] | memorials/guard |

(*appendix continues*)

## Appendix A (*continued*)

### Sentence Material and Probe Words

| Noun phrase | Auxiliary | Critical word | By-phrase | Probe word |
|---|---|---|---|---|
| Der Plan | wurde | *verändert/Veränderung* | von der Abgeordneten die man delegierte | delegierten/Plänen |
| [The conception | is being | *changed/change* | by the parliamentary who was delegated] | delegated/conceptions |
| Der Plan | wurde als | *Veränderung angepriesen/verändert* | von der Abgeordneten die man delegierte | Veränderung/Abgeordneten |
| [The conception | is being as | *change praised/changed* | by the parliamentary who was delegated] | change/parliamentary |
| Das Bild | wurde | *verschönert/Verschönerung* | von einem Künstler den keiner engagierte | Bild/Verschönerung |
| [The picture | is being | *embellished/embellishment* | by an artist who nobody engaged] | picture/embellishment |
| Das Bild | wurde als | *Verschönerung empfunden/verschönert* | von einem Künstler den keiner engagierte | Künstlerin/engagierten |
| [The picture | is being as | *embellishment perceived/embellished* | by an artist who nobody engaged] | artist/engaged |
| Das Beet | wurde | *bepflanzt/Bepflanzung* | von einem Rentner den alle beneideten | Bepflanzung/Rentnern |
| [The patch of land | is being | *planted/plant* | by a pensioner who all envied] | plant/pensioner |
| Das Beet | wurde trotz | *Bepflanzung betreten/bepflanzt* | von einem Rentner den alle beneideten | beneideten/Beet |
| [The patch of land | is being despite | *plant stepped on/planted* | by a pensioner who all envied] | envied/patch of land |
| Der Name | wurde | *verwechselt/Verwechselung* | von einem Redner den alle auslachten | Rednerin/auslachte |
| [The name | is being | *confused/confusion* | by a speaker who all laughed at] | speaker/laughed at |
| Der Name | wurde trotz | *Verwechselung erwähnt/verwechselt* | von einem Redner den alle auslachten | Name/verwechselt |
| [The name | is being despite | *confusion mentioned/confused* | by a speaker who all laughed at] | name/confused |
| Der Auftrag | wurde | *erteilt/Erteilung* | von der Kommission die man einberief | einberief/Auftrag |
| [The order | is being | *granted/grant* | by the commission who was convoked] | convoked/order |
| Der Auftrag | wurde trotz | *Erteilung blockiert/erteilt* | von der Kommission die man einberief | erteilt/Kommissionen |
| [The order | is being despite | *grant blocked/granted* | by the commission who was convoked] | granted/commission |
| Das Zeugnis | wurde | *beurteilt/Beurteilung* | von dem Chef den alle ablehnten | Zeugnissen/beurteile |
| [The testimony | is being | *judged/judgment* | by the director who all declined] | testimonials/judge |
| Das Zeugnis | wurde als | *Beurteilung herangezogen/beurteilt* | von dem Chef den alle ablehnten | Chef/ablehnten |
| [The testimony | is being as | *judgment referred to/judged* | by the director who all declined] | director/declined |
| Der Artikel | wurde | *verfaßt/Verfassung* | von einem Autor den wenige verehrten | Artikeln/Verfassung |
| [The article | is being | *composed/composition* | by an author who few honored] | article/composition |
| Der Artikel | wurde trotz | *Verfassung geheimgehalten/verfaßt* | von einem Autor den wenige verehrten | Autorin/verehrten |
| [The article | is being despite | *composition kept secret/composed* | by an author who few honored] | author/honored |
| Das Gemälde | wurde | *versichert/Versicherung* | von dem Museum das wenige besuchten | Museum/besuchten |
| [The painting | is being | *insured/insurance* | by the museum which few visited] | museum/visited |
| Das Gemälde | wurde trotz | *Versicherung bewacht/versichert* | von dem Museum das wenige besuchten | Gemälden/versichere |
| [The painting | is being despite | *insurance guarded/insured* | by the museum which few visited] | paintings/insure |

## Appendix A (*continued*)

### Sentence Material and Probe Words

| Noun phrase | Auxiliary | Critical word | By-phrase | Probe word |
|---|---|---|---|---|
| Das Fenster | wurde | *vergittert/Vergitterung* | von dem Maurer den keiner erkannte | erkennen/Fensters |
| [The window | is being | *barred/bars* | by the mason who nobody recognized] | recognize/windows |
| Das Fenster | wurde trotz | *Vergitterung aufgebrochen/vergittert* | von dem Maurer den keiner erkannte | Vergitterung/Maurer |
| [The window | is being despite | *bars broken up/barred* | by the mason who nobody recognized] | bars/mason |
| Die Rechnung | wurde | *bezahlt/Bezahlung* | von dem Schuldner den viele anmahnten | Rechnungen/Bezahlung |
| [The bill | is being | *paid/payment* | by the debtor who many reminded] | bills/payment |
| Die Rechnung | wurde zur | *Bezahlung vorgelegt/bezahlt* | von dem Schuldner den viele anmahnten | Schuldner/anmahnen |
| [The bill | is being to the | *payment submitted/paid* | by the debtor who many reminded] | debtor/remind |
| Der Auftrag | wurde | *erledigt/Erledigung* | von der Mitarbeiterin die keiner förderte | erledigt/Mitarbeiter |
| [The order | is being | *attended/attention* | by the coworker who nobody promoted] | attended/coworker |
| Der Auftrag | wurde zur | *Erledigung angenommen/erledigt* | von der Mitarbeiterin die keiner förderte | förderten/Auftrag |
| [The order | is being to the | *attention accepted/attended* | by the coworker who nobody promoted] | promoted/order |
| Das Problem | wurde | *erörtert/Erörterung* | von der Referentin die viele interviewten | Referentin/interviewen |
| [The problem | is being | *considered/consideration* | by the lecturer who many interviewed] | lecturer/interviewed |
| Das Problem | wurde trotz | *Erörterung mißachtet/erörtert* | von der Referentin die viele interviewten | Problems/erörtert |
| [The problem | is being despite | *consideration neglected/considered* | by the lecturer who many interviewed] | problems/considered |
| Der Hinweis | wurde | *erläutert/Erläuterung* | von einem Anwalt den alle provozierten | provozierte/Hinweis |
| [The indication | is being | *explained/explanation* | by a lawyer who all provoked] | provoked/indication |
| Der Hinweis | wurde als | *Erläuterung gegeben/erläutert* | von einem Anwalt den alle provozierten | Erläuterung/Anwältin |
| [The indication | is being as | *explanation given/explained* | by a lawyer who all provoked] | explanation/lawyer |
| Der Kaffee | wurde | *erwärmt/Erwärmung* | von einem Koch den viele beschimpften | Kaffee/erwärmt |
| [The coffee | is being | *warmed up/warming* | by a cook who many insulted] | coffee/warmed up |
| Der Kaffee | wurde zur | *Erwärmung bereitgestellt/erwärmt* | von einem Koch den viele beschimpften | Köchen/beschimpften |
| [The coffee | is being to the | *warming provided/warmed* | by a cook who many insulted] | cooks/insulted |
| Das Dorf | wurde | *erobert/Eroberung* | von einem Heer das alle fürchteten | erobere/Heer |
| [The village | is being | *conquered/conquest* | by an army which all feared] | conquer/army |
| Das Dorf | wurde trotz | *Eroberung angezündet/erobert* | von einem Heer das alle fürchteten | fürchteten/Dörfern |
| [The village | is being despite | *conquest inflamed/conquered* | by an army which all feared] | feared/village |
| Die Quote | wurde | *beziffert/Bezifferung* | von einem Institut das alle anriefen | Instituten/anriefen |
| [The quota | is being | *numbered/numbering* | by an institute which all called] | institutes/called |
| Die Quote | wurde trotz | *Bezifferung verschwiegen/beziffert* | von einem Institut das alle anriefen | Quote/Bezifferung |
| [The quota | is being despite | *numbering discreted/numbered* | by an institute which all called] | quota/numbering |

(*appendix continues*)

## Appendix A (*continued*)

### Sentence Material and Probe Words

| Noun phrase | Auxiliary | Critical word | By-phrase | Probe word |
|---|---|---|---|---|
| Das Resultat | wurde | *verfälscht/Verfälschung* | von einem Team dem keiner traute | traute/Resultaten |
| [The result | is being | *falsified/falsification* | by a team which nobody trusted] | trusted/results |
| Das Resultat | wurde trotz | *Verfälschung akzeptiert/verfälscht* | von einem Team dem keiner traute | verfälsche/Team |
| [The result | is being despite | *falsification accepted/falsified* | by a team which nobody trusted] | falsify/team |
| Das Medikament | wurde | *bestellt/Bestellung* | von dem Apotheker den viele haßten | Apotheker/haßten |
| [The medicine | is being | *ordered/order* | by the chemist who many hated] | chemist/hated |
| Das Medikament | wurde als | *Bestellung aufgegeben/bestellt* | von dem Apotheker den viele haßten | Medikamenten/bestelle |
| [The medicine | is being as | *order assigned/ordered* | by the chemist who many hated] | medicine/order |
| Die Idee | wurde | *verfilmt/Verfilmung* | von einem Regisseur den alle anpriesen | verfilmt/Regisseuren |
| [The idea | is being | *screened/screening* | by a producer who all recommended] | screened/producer |
| Die Idee | wurde als | *Verfilmung realisiert/verfilmt* | von einem Regisseur den alle anpriesen | anpreisen/Idee |
| [The idea | is being as | *screening realized/screened* | by a producer who all recommended] | recommend/idea |
| Die Aussage | wurde | *verharmlost/Verharmlosung* | von dem Arzt den wenige mochten | Arzt/mochte |
| [The statement | is being | *made innocent/innocency* | by the doctor who few liked] | doctor/liked |
| Die Aussage | wurde als | *Verharmlosung eingestuft/verharmlost* | von dem Arzt den wenige mochten | Aussagen/verharmlost |
| [The statement | is being as | *innocency classified/innocent* | by the doctor who few liked] | statements/innocent |
| Der Vorbau | wurde | *vergrößert/Vergrößerung* | von einer Firma die alle bekämpften | bekämpfen/Vorbau |
| [The front | is being | *enlarged/enlargement* | by a firm which all opposed] | opposed/front |
| Der Vorbau | wurde als | *Vergrößerung geplant/vergrößert* | von einer Firma die alle bekämpften | Vergrößerung/Firmen |
| [The front | is being as | *enlargement planned/enlarged* | by a firm which all opposed] | enlargement/firms |
| Das Modell | wurde | *erweitert/Erweiterung* | von einem Physiker den wenige bewunderten | Modell/erweitere |
| [The model | is being | *extended/extension* | by a physician who few admired] | model/extend |
| Das Modell | wurde als | *Erweiterung verstanden/erweitert* | von einem Physiker den wenige bewunderten | Physikerin/bewunderten |
| [The model | is being as | *extension understood/extended* | by a physician who few admired] | physician/admired |
| Das Gas | wurde | *verflüssigt/Verflüssigung* | von einem Chemiker den keiner beobachtete | Verflüssigung/Chemiker |
| [The gas | is being | *liquefied/liquefaction* | by a chemist who nobody observed] | liquefaction/chemist |
| Das Gas | wurde zur | *Verflüssigung abgekühlt/verflüssigt* | von einem Chemiker den keiner beobachtete | beobachtete/Gases |
| [The gas | is being | *liquefaction cooled/liquefied* | by a chemist who nobody observed] | observed/gas |
| Das Datum | wurde | *erinnert/Erinnerung* | von dem Reiseleiter den alle fragten | Reiseleiterin/fragten |
| [The date | is being | *reminded/remembrance* | by the guide who all asked] | guide/asked |
| Das Datum | wurde zur | *Erinnerung wiederholt/erinnert* | von dem Reiseleiter den alle fragten | Datum/erinnere |
| [The date | is being | *remembrance repeated/reminded* | by the guide who all asked] | date/remind |

## Appendix A (*continued*)

### Sentence Material and Probe Words

| Noun phrase | Auxiliary | Critical word | By-phrase | Probe word |
|---|---|---|---|---|
| Das Verfahren | wurde | *beschleunigt/Beschleunigung* | von dem Ausschuß den viele würdigten | würdigten/Verfahrens |
| [The proceeding | is being | *accelerated/acceleration* | by the committee which many appreciated] | appreciated/proceedings |
| Das Verfahren | wurde zur | *Beschleunigung kritisiert/beschleunigt* | von dem Ausschuß den viele würdigten | beschleunigt/Ausschuß |
| [The proceeding | is being despite | *acceleration criticized/accelerated* | by the committee which many appreciated] | accelerated/committee |
| Die Statue | wurde | *beschädigt/Beschädigung* | von einem Restaurateur den keiner bemerkte | Statue/beschädigt |
| [The statue | is being | *damaged/damage* | by the restorer who nobody noticed] | statue/damaged |
| Die Statue | wurde trotz | *Beschädigung transportiert/beschädigt* | von einem Restaurateur den keiner bemerkte | Restaurateur/bemerken |
| [The statue | is being | *damage transported/damaged* | by the restorer who nobody noticed] | restorer/notice |
| Die Berechnung | wurde | *überprüft/Überprüfung* | von einem Experten den viele verständigten | überprüfe/Experten |
| [The calculation | is being | *examined/examination* | by an expert who many notified] | examine/expert |
| Die Berechnung | wurde zur | *Überprüfung erstellt/überprüft* | von einem Experten den viele verständigten | verständigte/Berechnung |
| [The calculation | is being to the | *examination available/examined* | by an expert who many notified] | notified/calculation |
| Der Urlaub | wurde | *verkürzt/Verkürzung* | von der Familie die man vermißte | Familie/vermißte |
| [The holiday | is being | *shortened/shortening* | by the family who was missed] | family/missed |
| Der Urlaub | wurde trotz | *Verkürzung genossen/verkürzt* | von der Familie die man vermißte | Urlaubs/Verkürzung |
| [The holiday | is being despite | *shortening enjoyed/shortened* | by the family who was missed] | holiday/shortening |
| Die Urkunde | wurde | *beglaubigt/Beglaubigung* | von einer Beamtin die man beförderte | beförderten/Urkunden |
| [The document | is being | *verified/verification* | by an official who was promoted] | promoted/documents |
| Die Urkunde | wurde als | *Beglaubigung hinzugefügt/beglaubigt* | von einer Beamtin die man beförderte | Beglaubigung/Beamtin |
| [The document | is being as | *verification appended/verified* | by an official who was promoted] | verification/official |
| Der Aufsatz | wurde | *veröffentlicht/Veröffentlichung* | von der Zeitschrift die viele lasen | Aufsatzes/Veröffentlichung |
| [The assay | is being | *published/publication* | by a newspaper which many read] | assay/publication |
| Der Aufsatz | wurde zur | *Veröffentlichung überarbeitet/veröffentlicht* | von der Zeitschrift die viele lasen | Zeitschrift/lesen |
| [The assay | is being to the | *publication rewritten/published* | by a newspaper which many read] | newspaper/read |
| Die Theorie | wurde | *verbessert/Verbesserung* | von einer Professorin die man respektierte | verbessert/respektierten |
| [The theory | is being | *improved/improvement* | by a professor who was respected] | improved/respected |
| Die Theorie | wurde als | *Verbesserung angesehen/verbessert* | von einer Professorin die man respektierte | respektierten/Theorie |
| [The theory | is being as | *improvement seen/improved* | by a professor who was respected] | professor/theory |
| Der Kerker | wurde | *verriegelt/Verriegelung* | von einem Wächter den man einstellte | Wächter/einstellen |
| [The prison | is being | *bolted/bolt* | by a watchman who one employed] | watchman/employ |
| Der Kerker | wurde trotz | *Verriegelung bewacht/verriegelt* | von einem Wächter den man einstellte | Kerker/Verriegelung |
| [The prison | is being despite | *bolt guarded/bolted* | by a watchman who one employed] | prison/bolt |

(*appendix continues*)

## Appendix A (*continued*)

### Sentence Material and Probe Words

| Noun phrase | Auxiliary | Critical word | By-phrase | Probe word |
|---|---|---|---|---|
| Die Vorschrift | wurde | *verschärft/Verschärfung* | von einer Partei die wenige verurteilten | verurteilte/Vorschrift |
| [The regulation | is being | *sharpened/sharpening* | by a party who few condemned] | condemned/regulation |
| Die Vorschrift | wurde trotz | *Verschärfung begrüßt/verschärft* | von einer Partei die wenige verurteilten | verschärfe/Partei |
| [The regulation | is being despite | *sharpening welcomed/sharpened* | by a party who few condemned] | sharpen/party |
| Das Vorgehen | wurde | *vereinfacht/Vereinfachung* | von einem Minister den man bestach | Vorgehen/Vereinfachung |
| [The procedure | is being | *uncomplicated/uncomplication* | by a minister who was bribed] | procedure/uncomplication |
| Das Vorgehen | wurde als | *Vereinfachung deklariert/vereinfacht* | von einem Minister den man bestach | Ministerin/besticht |
| [The procedure | is being as | *uncomplication declared/uncomplicated* | by a minister who was bribed] | minister/bribed |
| Das Lager | wurde | *verschanzt/Verschanzung* | von der Armee die keiner angriff | Verschanzung/Armeen |
| [The camp | is being | *entrenched/entrenchment* | by the army which nobody attacked] | entrenchment/armies |
| Das Lager | wurde trotz | *Verschanzung aufgegeben/verschanzt* | von der Armee die keiner angriff | angriff/Lager |
| [The camp | is being despite | *entrenchment given up/entrenched* | by the army which nobody attacked] | attack/camp |
| Das Ergebnis | wurde | *verallgemeinert/Verallgemeinerung* | von der Journalistin die man einlud | Journalist/einlud |
| [The result | is being | *generalized/generalization* | by the journalist who was invited] | journalist/invited |
| Das Ergebnis | wurde als | *Verallgemeinerung/verallgemeinert* | von der Journalistin die man einlud | Ergebnis/verallgemeinere |
| [The result | is being as | *generalization described/generalized* | by the journalist who was invited] | result/generalize |
| Das Projekt | wurde | *unterstützt/Unterstützung* | von einem Bischof den alle kontrollierten | kontrollierten/Projektes |
| [The project | is being | *supported/support* | by a bishop who all controlled] | controlled/projects |
| Das Projekt | wurde trotz | *Unterstützung aufgegeben/unterstützt* | von einem Bischof den alle kontrollierten | unterstützt/Bischof |
| [The project | is being despite | *support given up/supported* | by a bishop who all controlled] | supported/bishop |

*Note.* Translations are in brackets.

## Appendix B

## Items Used in the Grammaticality Judgment Test

Die Sauce wurde Bestandteil des Gerichts.
[The sauce became part of the dish.]

Der Computer wurde Standard.
[The computer became standard.]

Die Note wurde Ziel für viele.
[The note became goal for many.]

Das Inventar wurde Besitz der Firma.
[The inventory became ownership of the firm.]

Die Instruktion wurde Vorschrift.
[The instruction became prescription.]

Der Strauch wurde Teil der Bepflanzung.
[The bush became part of the planting.]

Die Summe wurde Teil der Gesamtrechnung.
[The sum became part of the grand total.]

Die Stadtmauer wurde Touristenattraktion
[The town wall became tourist attraction.]

Der Müll wurde Zeichen der Industriegesellschaft.
[The rubbish became symbol of the industrial society.]

Die Wunde wurde Hauptproblem der Versorgung.
[The wound became main problem of the medical care.]

Das Material wurde Testsubsanz.
[The material became test substance.]

Das Werkzeug wurde Bestandteil der Ausrüstung.
[The tool became part of the equipment.]

Die Diskussion wurde Bestandteil des Fernsehprogramms.
[The discussion became part of the TV program.]

Das Metall wurde Bestandteil der Legierung.
[The metal became part of the alloying.]

Die Milch wurde Bestandteil des Getränks.
[The milk became part of the drink.]

Der Termin wurde Teil der Vereinbarung.
[The appointment became part of the arrangement.]

Das Gesetz wurde Europanorm.
[The law became Europe-norm.]

Die Verletzung wurde Versorgungszone Nummer eins.
[The injury became maintenance region number one.]

Die Spende wurde Ziel der Aktion.
[The donation became goal of the action.]

Das Ziel wurde Bestandteil des Vertrags.
[The finish became part of the contract.]

Der Unterschied wurde Zeichen der sozialen Ungerechtigkeit.
[The difference became symbol of the social injustice.]

Der Vorschlag wurde Gesetz.
[The proposition became law.]

Das Denkmal wurde Nationalmonument.
[The memorial became national monument.]

Der Plan wurde Teil der Gesamtplanung.
[The conception became part of the whole blueprint, planning.]

Das Bild wurde Titelbild.
[The picture became title page.]

Das Beet wurde Teil der Gartenplanung.
[The patch of land became part of the garden planning.]

Der Name wurde Firmenbezeichnung.
[The name became firm description.]

Der Auftrag wurde Grundlage der Zusammenarbeit.
[The order became foundation of the collaboration.]

Das Zeugnis wurde Vorbild.
[The testimony became prototype.]

Der Artikel wurde Leitartikel.
[The article became leading article.]

Das Gemälde wurde Touristenattraktion.
[The painting became tourist attraction.]

Das Fenster wurde Ziel des Angriffs.
[The window became target of the attack.]

Die Rechnung wurde Teil der Kostenaufstellung.
[The bill became part of the cost account.]

Der Auftrag wurde Problempunkt Nummer eins der Verhandlung.
[The order became problem number one in the negotiation.]

Das Problem wurde Tagespunkt Nummer eins.
[The problem became agenda point number one.]

Der Hinweis wurde Ausgangspunkt für weitere Verhandlungen.
[The indication became starting point for forthcoming negotiations.]

Der Kaffee wurde Nationalgetränk.
[The coffee became national drink.]

Das Dorf wurde Großstadt.
[The village became large town.]

Die Quote wurde Ziel für die nachfolgende Generation.
[The quota became aim for the following generation.]

Das Resultat wurde Vorbild für alle weiteren Aktionen.
[The result became prototype for all following actions.]

Das Medikament wurde Teil der Tropenausrüstung.
[The medicine became part of the tropical kit.]

Die Idee wurde Leitgedanke der gesamen Bewegung.
[The idea became main idea of the whole movement.]

Die Aussage wurde Thema für viele Anhörungen.
[The statement became theme of many hearings.]

Der Vorbau wurde Eingangsbereich des Bürohauses.
[The front became entrance area of the office-block.]

(*Appendix continues on next page*)

Das Modell wurde Diskussionsstoff für viele.
[The model became topic of discussion for many.]

Das Gas wurde Mittel der Insektenvernichtung.
[The gas became means of the insect destruction.]

Das Datum wurde Nationalfeiertag.
[The date became national holiday.]

Das Verfahren wurde Standard.
[The proceeding became standard.]

Die Statue wurde Nationalmonument.
[The statue became national monument.]

Die Berechnung wurde Standard.
[The calculation became standard.]

Der Urlaub wurde Bestandteil der Abmachung.
[The holiday became part of the arrangement.]

Die Urkunde wurde Vorlage für die Nachfolger.
[The document became submission for the successors.]

Der Aufsatz wurde Teil der Gesamtveröffentlichung.
[The essay became part of the whole publication.]

Die Theorie wurde Vorbild.
[The theory became model.]

Der Kerker wurde Touristenattraktion.
[The prison became tourist attraction.]

Die Vorschrift wurde Gesetz.
[The regulation became law.]

Das Vorgehen wurde Modell für„ähnliche Projekte.
[The procedure became model for similar projects.]

Das Lager wurde Zentrallager.
[The camp became master camp.]

Das Ergebnis wurde Vorbild für weitere Aktionen.
[The result became model for following actions.]

Das Projekt wurde Modellprojekt.
[The project became prototype project.]

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