Wh-movement vs. Scrambling:
The brain makes a difference

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1. Theoretical background

1.1 INTRODUCTION

Within theoretical linguistics, there is an ongoing debate as to whether wh-movement and scrambling are two sides of the same coin or whether they are distinct phenomena[1]. Consider the following sentences, which illustrate scrambling in German.

(1) a. Vielleicht will der Peter den Physiker überlisten.
perhaps wants the$_{(NOM)}$ Peter the$_{(ACC)}$ physicist outwit
'Perhaps Peter wants to outwit the physicist.'
b. Vielleicht will den Physiker der Peter überlisten
perhaps wants the$_{(ACC)}$ physicist the$_{(NOM)}$ Peter outwit

(2) a. Der Onkel wollte dem Neffen das Auto schenken.
the uncle wanted the$_{(DAT)}$ nephew the$_{(AMB)}$ car to give
'The uncle wanted to give the car to the nephew
b. Der Onkel wollte das Auto dem Neffen schenken.
the uncle wanted the$_{(AMB)}$ car the$_{(DAT)}$ nephew give

Whereas some authors assume that scrambling differs from wh-movement in that it does not involve a movement operation (Haider, 1997; Fanselow, 2000), other authors describe scrambling as an instance of movement (Fanselow, 1990; Müller, 1995, chapter 3 for an overview). Given that the sentences in (1b) and (2b) are the result of a movement operation, we must ask how this operation is related to other types of movement such as wh- or NP-movement. Not unexpectedly, we can find arguments for the perspective that scrambling is an instance of A-movement (Fanselow, 1990; Frey & Tappe, 1991) as well as for the position that scrambling can be analyzed as A-bar movement (e.g. Müller, 1995). Additional problems arise in ditransitive structures such as (2). Whereas it seems uncontroversial that the subject precedes the object, it has been subject to debate whether or not there is a default order for object arguments in German (Haider, 1997; Lenerz, 1977; Müller, 1995). Thus, assuming the existence of a scrambling operation, it is not entirely clear how scrambled sentences can be distinguished from their non-scrambled counterparts.

To aggravate the situation, the argument order in German seems to be a consequence of various factors such as animacy, definiteness, case, focus and thematic role (Uszkoreit, 1986; Lenerz, 1977; Hoberg, 1981; Primus, 1991). Furthermore, pronouns appear to behave somewhat differently to full NPs with respect to word order (Lenerz, 1977; Hoberg, 1981; Müller, 1995). Example (3) shows that pronouns may be scrambled in front of the subject without difficulty, whereas the same construction seems to be unacceptable with full DPs.

(3) a. Vielleicht hatte es ihm der Präsident überreicht.
perhaps had it$_{(ACC)}$ him$_{(DAT)}$ the$_{(NOM)}$ president presented
'Perhaps the president had presented him with it.'
b. ??Vielleicht hatte den Pokal dem Sportler der Präsident überreicht.
perhaps had the$_{(ACC)}$ trophy the$_{(DAT)}$ sportsman the$_{(NOM)}$ president presented
'Perhaps the president had presented the sportsman with the trophy.'

With respect to scrambling amongst objects, however, acceptability patterns are reversed, i.e. sentences involving pronouns appear to be more restrictive with respect to word order than those involving full DPs. This is illustrated in (4).

(4) a. Wollte Peter es ihm nicht heute schenken ?
wanted Peter it$_{(ACC)}$ him$_{(DAT)}$ not today give
'Didn't Peter want to give it to him today?'

[1] It is, of course, also controversial whether movement is only a metaphor (Wunderlich, 1997; Bresnan, 1982) or rather describes a truly syntactic operation (e.g. Chomsky, 1981). On the basis of theoretical arguments (e.g. Mahajan, 1990; Saito, 1985; Mahajan, 2000) as well as psycholinguistic findings (e.g. Clifton & Frazier, 1989; DeVincenzi, 1991; Mc Elree & Bever, 1989; Swinney, Ford, Frauenfelder, & Bresnan , 1988 and Nicol, Fodor, & Swinney, 1994) we will assume in this paper that movement is indeed a component of the syntax and, moreover, a psychologically real concept.

b.?*Wollte Peter ihm es nicht heute schenken ?
wanted Peter him$_{(DAT)}$ it$_{(ACC)}$ not today give

c. Wollte Peter das Buch dem Richter nicht heute schenken ?
wanted Peter the$_{(ACC)}$ book the$_{(DAT)}$ judge not today give
'Didn't Peter want to give the book to the judge today?'

d. Wollte Peter dem Richter das Buch nicht heute schenken ?
wanted Peter the$_{(DAT)}$ judge the$_{(ACC)}$ book not today give

In view of the numerous conclusions reached theoretically and of the subtle judgments that these are based on, the question of how scrambling in German is best described may be a fruitful one to examine using psycholinguistic techniques. Thus, in this paper, we will bring together a number of experimental results bearing on the issue at hand. The first section discusses some behavioral results with respect to possible differences between wh-movement and scrambling. In the second section we present a number of studies using event-related brain potentials (ERPs) which show that wh-movement and scrambling elicit different brain responses. Finally, we discuss the results presented and conclude that scrambling in German, while not being an illegitimate syntactic operation, induces a local syntactic violation, whereas wh-movement does not.

1.2 PREVIOUS STUDIES ON WH-MOVEMENT AND SCRAMBLING IN GERMAN

In the last five years, there have been a number of behavioral studies examining the nature of wh-movement and scrambling in German. Let us firstly consider wh-movement. In a series of self paced reading studies, Meng (1997), Schlesewsky, Fanselow, Kliegel, & Krems (2000), Fanselow, Kliegl, & Schlesewsky (1999) and Schriefers, Friederici, & Kühn (1995) found a subject preference in initially ambiguous wh-sentences and relative clauses (5) as well as a processing advantage for initially unambiguous nominative-first clauses (6).

(5) a. Welche Botschafterin besuchte der Jäger ?
which ambassador$_{(AMB)}$ visited the$_{(NOM)}$ hunter
'Which ambassador did the hunter visit?'

b. Das ist die Botschafterin, die die Jäger besucht haben
this is the ambassador, that the hunters visited have
'This is the ambassador that the hunters visited.'

(6) a. Welcher Lehrer bewunderte den Steuerberater ?
which$_{(NOM)}$ teacher admired the$_{(ACC)}$ accountant
'Which teacher admired the accountant?'

b. Welchen Lehrer bewunderte der Steuerberater ?
which$_{(ACC)}$ teacher admired the$_{(NOM)}$ accountant
'Which teacher did the accountant admire?'

While the ambiguous sentences only allow one to observe a subject-preference, which may be due to some sort of cognitive advantage for subject-initiality, the initial reading time advantage for unambiguous subject-first sentences (as in 6a) can be directly linked to theories which assume a cognitive cost of movement (Clifton & Frazier 1989, Gibson 1998 for an overview)[2].
With regard to scrambling, Clahsen and Featherston (1998) reported two cross modal priming studies, in which they presented sentences (such as (7)), in which the direct object was moved out of the base position and scrambled before the indirect object.

[2] The assumption that the preference for subject-initial structures results from memory effects or the like is not uncontroversial. While Frazier (1987) assumes that in object-initial clauses the moved item (i.e., the wh-phrase) must be "held in a special memory buffer [...] for longer than is necessary" in the subject-initial case, Pickering and Barry (1991) argue for a syntactic dependency between the displaced argument and its subcategorizer. Under the latter view, only the properties of the direct linking (association) between the elements in question causes processing effects and induces preferences. A specific recursion to "memory buffer" or traces is not necessary.

(7) Nach zwei Tagen Streit sprach der Richter das Geschäft dem ziemlich überraschten Andreas # zu.
after two days of dispute awarded the judge the business the rather surprised Andreas to.

The authors found a reactivation at the supposed base position (#) and argue that this result reflects the existence of scrambling as a movement operation as well as the psychological reality of the trace position. Furthermore, they believe the data to show that there is a default word order of arguments (subject > indirect object > direct object) in German.
Another interesting experiment on the acceptability of scrambling in German was conducted by Pechman, Uszkoreit, Engelkamp, and Zerbst (1994), who compared five different variations of argument order against an ungrammatical word order. One of the permutations of subject, direct object and indirect object and the ungrammatical control are illustrated in (8).

(8) a. Bald wird dem Nachbarn den Schuppen der Maler streichen.
soon will the neighbour the shed the painter paint
'Soon the painter will paint the shed for the neighbour.'
b. *Bald wird den Schuppen streichen dem Nachbarn der Maler.
soon will the shed paint the neighbour the painter

In a paper and pencil test, subjects were asked to judge sentences on a 5-point scale with respect to acceptability. Table 1 shows the mean rating values for the experimental conditions.

- Table 1 here -

As we can see, there is a clear acceptability range as, for example, predicted by Uszkoreit (1986). Interestingly, we can observe a gradual increase in the acceptability but are unable to find a break point that indicates a transition from a grammatical sentence to an ungrammatical one.

Finally, in a recent paper, Bader and Meng (1999) compare different types of movement, as illustrated in (9), in a speeded grammaticality task.

(9) a. wh -sentences
... $[\text{welche NP}]_{\text{AMB, sg}}$ $[\text{die NP}]_{\text{AMB, pl}}$ $V_{\text{sg / pl}}$
b. relative clauses
... $\text{die}_{\text{AMB.sg}}$ $[\text{die NP}]_{\text{AMB, pl}}$ V $\text{Aux}_{\text{sg / pl}}$
c. complement clauses (NP)
... dass $[\text{die NP}]_{\text{AMB.sg}}$ $[\text{die NP}]_{\text{AMB.pl}}$ $V_{\text{sg / pl}}$
d. complement clauses (pronoun)
... dass $[\text{sie}]_{\text{AMB.sg}}$ $[\text{die NP}]_{\text{AMB.pl}}$ $V_{\text{sg / pl}}$

Given that the parser assigns the subject role to a sentence-initial ambiguous element on the basis of language specific grammatical requirements or a general cognitive strategy that is independent of the particular structural configuration (Clifton & Frazier 1989; Fanselow, Schlesewsky, Cavar & Kliegl 1999), a sentence must be reanalyzed if the final auxiliary requires a plural marked subject whereas the first NP is marked for singular. In this study, the authors found that regardless of the sentence type, the forced revision of the initial subject preference induces a garden-path effect which is reflected in lower accuracies (cf. Table 2).

- Table 2 here -

These results support the assumption stated above that, regardless of the structural configuration, the subject role will be associated with the first possible argument that is able to fulfill the requirements of this grammatical function. In addition, the data of this experiment show that sentences containing scrambled non-pronominal elements were judged with a significantly lower accuracy than all other conditions. This suggests that there are construction specific requirements which are independent of a general subject first preference and which inhibit or facilitate the garden-path effect and therefore the cost of reanalysis. Furthermore, whereas in sentences including a wh-moved element (wh-clauses, relative clauses) the movement operation seems to be unaffected by construction specific requirements, in complement clauses illustrating different types of scrambling (pronoun vs. nonpronominal full DP), a difference with respect to the strength of reanalysis can be observed. This could be taken to indicate that scrambling is analogous to wh-movement with regard to the movement

operation, while the two differ with regard to the landing position of the dislocated element (Müller, 1995). The nature of the landing position of pronominal scrambling is difficult to decide on, seeing that one might assume either that scrambling of pronouns is licensed by the availability of a specific position or that pronouns dislocated by scrambling target the same position as fronted wh-elements. Both alternatives yield the prediction that the strength of a reanalysis induced by pronominal scrambling is akin to that induced by wh-movement. By contrast, non-pronominal DPs are scrambled to a position that must be created by adjunction and that is therefore both structurally distinguishable from the other landing positions and not incrementally predictable during online parsing. Thus, this operation should lead to a locally illegitimate processing step, since an object must be integrated into a subject position that is, in principle, not open to it due to grammatical constraints. On the other hand, and this is simple speculative but also not unlikely, the contrast between wh-movement and non-pronominal scrambling may be attributable to frequency differences, i.e. a quantitative modulation only.

Unfortunately, on the basis of Pechmann et al.'s findings and Bader and Meng's results we can decide neither whether scrambling could lead to an illegitimate utterance nor whether scrambling and wh-movement are qualitatively different. As mentioned above, the gradience in the acceptability ratings themselves only shows us a quantitative difference between different types of movement operations. However, we are unable to decide about possible qualitative differences, because even if a break point dissociating between different processes exists, there is no way to render it visible. In order to do so, it is necessary to employ a method yielding more fine-grained results. In the following we will present a number of studies which provide electrophysiological evidence for the view that wh-movement and scrambling differ.

2. Syntax-related brain potentials

Classical behavioral measurements used in psycholinguistics, such as grammaticality judgment or reading time measures, only enable us to observe a higher processing load for sentences with a moved element. As scrambling and Wh-movement both involve moved elements, these measures do not allow us to detect a possible difference between the two. Event-related brain potential measures provide a more fine grained pattern and, thereby, the chance to observe possible underlying differences.

Event-related potentials (ERPs) are small brain potentials within the spontaneous electrical activity of the brain, which are time-locked to the occurrence of concrete events (e.g., to words in sentences). ERP components are characterized in terms of polarity (positive or negative), latency (i.e., temporal relationship to stimulus), scalp distribution (i.e., particular ERP deflections are typically large at some locations and small or non-existent at others) and in terms of the experimental manipulations they are elicited by. The ERP technique is potentially powerful in psycholinguistic research because ERPs are continuous, on-line and have a temporal resolution in the range of milliseconds (e.g., see Garnsey, 1993; Kutas & Van Petten, 1994). Moreover, the multidimensional nature of ERPs (i.e., polarity, latency, and scalp distribution) makes them suitable for differentiating between qualitatively different processes. ERPs have been used in the last decade more and more systematically to investigate language processing, both in the domain of semantics and of syntax. The particular ERP effects that have been identified to correlate with syntactic processes are two transient ERP components and a sustained frontal negativity. The two transient components are short-living, i.e. they are only present until about 1000 ms after the critical element. The sustained frontal negativity, in contrast, spans several elements within a sentence.

We will first consider the two transient ERP components. The first component is a left anterior negativity, called LAN. Sofar it has been shown to be evoked by outright syntactic violations, such as phrase structure violations or morphosyntactic violations. It usually appears about 300-500 ms after the onset of the critical word when the stimulus material is presented visually in a word-by-word manner (Neville, Nicol, Barss, Forster & Garrett, 1991; Roesler, Friederici, Puetz, & Hahne, 1993; Münte, Szentkuti, Wieringa, Matzke, & Johannes, 1997; Gunter, Friederici, & Hahne, 1999).

- Figure 1 here -

Figure 1 presents this left anterior negativity (note that negativity is plotted up) exemplified with a German sentence containing a phrase structure violation (Gunter et al., 1999). The critical element that turns the sentence into an incorrect one is the sentence final verb which is preceded by a preposition. The preposition obligatorily requires a noun phrase to follow, therefore, a verb in this position is an outright syntactic violation.

The other transient syntax-related ERP component is a late centro-parietal positivity present about 600 ms and beyond, called P600, which is observed in garden-path sentences at the critical disambiguating element (Osterhout & Holcomb, 1992; Osterhout, Holcomb, & Swinney, 1994).

- Figure 2 here -

Figure 2 exemplifies the P600 at the critical element of a garden-path sentence. The example is taken from Osterhout and Holcomb (1992) in which the critical element is the word "*to*". Note that a late positivity is not only seen in correlation with syntactic anomalies as in garden-path sentences, but also with outright syntactic violations following the LAN (Münte et al., 1997; Coulson, King & Kutas, 1998; Hahne & Friederici, 1999; or alone Hagoort, Brown & Groothusen, 1993).
On the basis of the available data we have proposed the following functional interpretation for these two components: the LAN reflects first-pass parsing processes, whereas the late positivity reflects secondary processes of syntactic reanalysis in garden-path sentences and repair in incorrect sentences (Friederici, 1995; Friederici, Hahne, & Mecklinger, 1996). Thus these two components are taken to indicate different stages of syntactic parsing.
In addition to these two transient ERP components at the sentence's critical word there is another ERP effect that has been correlated with the processing of syntactically complex sentences. Sustained frontal negativities (e.g. Figure 3) have mainly been observed in embedded relative clause sentences (King & Kutas, 1995; Müller, King, & Kutas, 1997). They were interpreted as reflecting increased working memory load in syntactically complex sentences.

- Figure 3 here -

The three syntax related ERP effects, thus, seem to reflect different aspects of syntactic processing.

3. Three ERP studies in German

In the following we will discuss three ERP studies on German sentence processing that speak to the issue laid out above.

3.1 WH-SENTENCES

The first study investigated the processing of wh-sentences. This study varied two factors systematically: first, the wh-element was unambiguously marked either for subject or for object, and second the distance between the wh-element (filler) and its trace position (gap) was either long or short. Examples of the stimulus sentences are given in (1) to (4).

Long wh-sentences

S-wh:	Thomas fragt sich,	wer	am Dienstag	nachmittag	nach dem Unfall den Doktor verständigt hat.
	Thomas asks himself,	*who* $_{(NOM)}$	*on Tuesday*	*afternoon*	*after the accident the doctor*$_{(ACC)}$ *called has.*
O-wh:	Thomas fragt sich,	wen$_i$	am Dienstag	nachmittag	nach dem Unfall der Doktor ___$_i$ verständigt hat.
	Thomas asks himself,	*who* $_{(ACC)}$	*on Tuesday*	*afternoon*	*after the accident the doctor* $_{(NOM)}$ *called has.*

Short wh-sentences

S-wh:	Thomas fragt sich,	wer	am Dienstag	den Doktor	verständigt hat.
	Thomas asks himself,	*who* $_{(NOM)}$	*on Tuesday*	*the doctor* $_{(ACC)}$	*called has.*
O-wh:	Thomas fragt sich,	wen$_i$	am Dienstag	der Doktor ____$_i$	verständigt hat.
	Thomas asks himself,	*who* $_{(ACC)}$	*on Tuesday*	*the doctor* $_{(NOM)}$	*called has.*

If object-marked wh-elements in clause initial position are considered by the parser as a grammatical sentence, we should not observe a local LAN indicating the detection of a syntactic error. If the object-marked wh-element rather is identified immediately as a filler whose original position (trace/gap) is further down in the sentence, we expect to find an ERP correlate signaling that this element is held in

working memory until its original position is encountered. That is, we expect a sustained frontal negativity spanning the distance between the filler and the gap.
Twenty-two German native speakers (12 females) participated in the experiment. All participants were students of the University of Leipzig, right handed and had normal or corrected-to-normal vision. Sentences were presented visually in a chunk-by-chunk fashion with the wh-element and each of the NPs and PPs as well as the verb presented as separate chunks. The presentation rate of each chunk was either 600 ms for single words or 700 ms for phrases (i.e., NPs and PPs) and the verb. After each sentence a comprehension question was presented visually. Participants were required to read the sentences attentively and to answer the 'yes/no' question following each sentence by button press.
A total of 160 wh-sentences was presented. In half of them the wh-element was unambiguously marked as subject, and in the other half as object. In half of the object wh-questions the distance between the filler and the gap was long (8 words) and in half it was short (4 words). Thus, each of the four conditions contained 40 sentences. For details of the procedure and the ERP analysis see Fiebach, Schlesewsky, and Friederici (in preparation).
Although ERPs were recorded from 51 electrodes, we will restrict the following presentations to one representative electrode from the left frontal area (F3). The distribution of observed activity is displayed with difference maps indicating the difference in the brain's activity between the subject-wh-sentences and the object-wh-sentences.

- Figure 4 here -

Figure 4 displays the waveforms for the subject-wh-sentences (solid line) and the object-wh-sentences (broken line) overlaid for the long distance conditions beginning with the wh-element until the verb. At the first PP following the case marked wh-element, we observed a more negative going wave form (note that following the conventions of electrophysiological research negativity is plotted up) for the object-wh-sentences than for the subject-wh-sentences. The negativity is sustained and spans over the entire filler-gap range. The difference map in the right panel of Figure 4 was calculated over the time range of the sustained negativity, i.e., from 1,000 to 4,000 ms after the onset of the wh-filler. It clearly indicates that the maximum of this sustained negativity is in the left frontal area over the scalp.
In line with an earlier ERP study on the processing of subject and object relatives in English (King & Kutas, 1995), we interpret the sustained left frontal activity as brain activity reflecting working memory processes that seem necessary for holding the filler in memory until the gap is encountered.

- Figure 5 here -

Figure 5 gives the average ERP results for the short conditions. Again, subject-wh-sentences (solid line) and object-wh-sentences (broken line) are overlaid, and the difference map for the analogous time window (i.e., 1,000 to 2,100 ms) is presented in the right panel. There is no reliable difference between subject- and objectwh-sentences, suggesting that the linkage of the filler with its gap is effortless in sentences with short filler-gap distance.
The combined data from the short and the long condition suggest that the parser processes the object-marked wh-element as being grammatical, immediately assigning it an object filler that has to be stored in memory until its original position out of which it has been moved (trace or gap) is encountered.

3.2 RELATIVE CLAUSES AND COMPLEMENT CLAUSES

A second study investigated the processing of subject relative (SR) and object relative (OR) clause sentences and compared these to the processing of subject-first complement clauses (SC) and to object-first complement (OC) clauses. The critical difference between the two sentence types is that object as well as subject relative clauses contain moved elements, whereas only object complements but not subject complements contain elements moved from their original position. Object complements are considered to be scrambled, whereas object relatives are not. The study was conducted to look at processes of reanalysis. Therefore, subject and object NPs contained ambiguous case markings not allowing an immediate ultimate interpretation. Sentences were disambiguated only at the sentence final auxiliary which was marked for number indicating either a subject-first or an object-first interpretation.

Relative clauses

SR Das sind die Professorinnen, die die Studentin gesucht *haben*.
These are the professors that the student sought have.

OR Das sind die Professorinnen, die die Studentin gesucht *hat*.
These are the professors that the student sought has.

Verb complement clauses

SC Er wusste, dass die Professorinnen die Studentin gesucht *haben*.
He knew that the professors the student sought have.

OC Er wusste, dass die Professorinnen die Studentin gesucht *hat*.
He knew that the professors the student sought has.

According to a well established psycholinguistic theory (Frazier, 1978, 1987) it is assumed and supported by a number of sentence processing studies (Bader & Meng, 1999; DeVincenzi, 1991; Frazier & Flores d'Arcais, 1989; Friederici & Mecklinger, 1996; Gorrell, 1995, 2000; Schlesewsky, Fanselow, Kliegl, & Krems, 2000; Schriefers, Friederici, & Kühn, 1995) that the parser when confronted with a temporary syntactic ambiguity applies as an initial structure the simplest analysis that is compatible with the input. In case of subject/object-first ambiguous sentences, the simplest structure is the subject-first. Thus we predicted to observe an ERP effect signaling reanalysis, that is we predicted a late positivity at the sentence final auxiliary.
Moreover, as the reanalysis from a subject- to an object-relative clause only requires a recoindexation, whereas the reanalysis from a subject-first to an object-first complement requires the installation of a new structure containing a filler-gap relation, we predicted to see a reflection of this difference in the difficulty of reanalysis in the late positivity.

Twenty German native speakers (12 females) participated in the experiment. All participants were students of the Free University of Berlin. They all were right handed and had normal or corrected-to-normal vision.

Sentences were presented to them in a chunk-by-chunk manner of either one or two words, with the NPs being presented as one chunk. Chunks and interstimulus intervals ranged from 300 to 550 ms depending on the length of the chunks. After each sentence a comprehension question concerning the content of the sentence was presented visually and participants were instructed to answer the yes/no question by pressing a response key.
Thirty-two sentences of each type (SR, OR, SC, OC) were presented visually. ERPs were recorded from 11 electrodes. Here, only two representative electrodes from the frontal (F3) and the parietal area are (Pz) presented.

- Figure 6 here -

Figure 6 displays the average ERP for the critical disambiguating auxiliary in the relative clauses. ERPs for the subject relatives (solid line) and object relatives (broken line) are overlaid. As expected, we observed a late positivity for the object relatives compared to the subject relatives. This positivity was shown to start early and to peak at 600 ms. For details of the analysis see Friederici and colleagues (Friederici, 1998; Friederici, Mecklinger, Spencer, Steinhauer, & Donchin, submitted).

- Figure 7 here -

Figure 7 displays the average ERP for the critical disambiguating element, i.e. the auxiliary, in the complement clause. ERPs for the subject-first (solid line) and the object-first (broken line) complements are overlaid. As expected, we observed a late positivity for the object-first as compared to the subject-first complements. This late positivity differs from that observed for the relative clauses in that it has a later peak.
In an additional analysis performed on the ERP data, we have identified the late positivity to consist of two factors: one reflecting the diagnosis that a reanalysis is required, and one reflecting the actual recomputation necessary. For details of this analysis see Friederici and colleagues (Friederici, Mecklinger, Spencer, Steinhauer, & Donchin, submitted). For the relatives, these two factors are active in the same time domain indicating that reanalysis can be performed immediately. For the complement sentences the diagnosis that a revision is necessary, as reflected by one of the two factors, appears to take place early (as this factor is active in an early time window). However, that factor reflecting the actual reanalysis is only active in a late time window, indicating that recomputation is performed late. Thus, it appears that the two positivities observed for the relatives and for the complements directly reflect the different types of recomputation necessary for each of these structures, immediate recoindexation for the relatives and actual restructuring for the complements. This difference in the

ERPs may be taken as a reflection of the different structures underlying object relative clauses and object complement clauses, that is wh-movement and scrambling, respectively.

3.3 SCRAMBLED SENTENCES

The processing of scrambled case marked NPs in German was investigated by Roesler and colleagues (Roesler, Pechmann, Streb, Röder, & Hennighausen, 1998). We will present this study as a third ERP study relevant for the issue under discussion.
The authors set out to study case marked double object sentences (*The father gave the pacifier to the baby.*) Each NP appeared in each possible position, resulting in six different conditions. Each condition contained 50 sentences.

S-IO-DO	Dann hat	der Vater	dem Sohn	den Schnuller	gegeben.
	Then has	*the father*	*to the son*	*the pacifier*	*given.*
S-DO-IO	Dann hat	der Vater	den Schnuller	dem Sohn	gegeben.
	Then has	*the father*	*the pacifier*	*to the son*	*given.*
IO-S-DO	Dann hat	dem Sohn	der Vater	den Schnuller	gegeben.
	Then has	*to the son*	*the father*	*the pacifier*	*given.*
DO-S-IO	Dann hat	den Schnuller	der Vater	dem Sohn	gegeben.
	Then has	*the pacifier*	*the father*	*to the son*	*given.*
IO-DO-S	Dann hat	dem Sohn	den Schnuller	der Vater	gegeben.
	Then has	*to the son*	*the pacifier*	*the father*	*given.*
DO-IO-S	Dann hat	den Schnuller	dem Sohn	der Vater	gegeben.
	Then has	*the pacifier*	*to the son*	*the father*	*given.*

Seventeen German native speakers (8 females) participated in the experiment. All participants were students of the University of Marburg. They all were right handed and had normal or corrected-to-normal vision.
Stimulus sentences were presented to them visually in a word-by-word fashion with a presentation rate of 250 ms and an interstimulus interval of 250 ms. For further methodological details see Roesler et al. (1998).

Given the sentence material, several different ERPs can be expected dependent on whether the parser treats the sentences in which one of the objects is fronted as grammatically correct or not. If the parser considers these object-first sentences as grammatically correct, than we would expect a sustained frontal negativity starting after the unambiguously case marked direct or indirect object, as this case marking signals that the first NP is not a subject-NP and must therefore be stored in memory until its original position is encountered.

If, however, the parser treats these sentences in which full object NPs are fronted as grammatically incorrect than we expect a local, transient LAN at clause initial object marked elements, i.e. the case marked determiner.
The data Roesler et al. (1998) present in their paper fulfill the latter expectations.

- Figure 8 here -

The left column of Figure 8 displays ERP averages at the clause initial determiner for the three different sentence types that can be identified at this point, namely subject-first (i.e., an average of S-IO-DO and S-DO-IO), indirect object-first (i.e., IO-S-DO and IO-DO-S) and direct object-first (i.e., DO-S-IO and DO-IO-S). Data presented are from three left hemisphere electrodes (F3, Bl and C3) and the parietal electrode Pz for the determiner and the following noun. We can identify a difference between these three conditions at the left frontal electrode with a more negative going wave for the two object-first conditions compared to the subject-first condition. The distribution of this difference is plotted in Figure 9. Figure 8 (right column), furthermore, shows that this difference is no longer present at the noun following the determiner. Thus the observed left anterior negativity is very local suggesting that readers process the fronted object NP as a grammatical violation. Roesler et al., however, interpret the observed effect nonetheless as a memory effect.

- Figure 9 here -

"*However , considering the fact that the LAN is temporally restricted to the case marker in our study and that it resolves before the to-be-stored noun is read at all, it seems unlikely that the LAN-effect indicates storage as such. If this type of LAN effect is related to working memory activity at all, it seems more likely that it is a manifestation of some preparatory processing step which enables storage of the forthcoming noun*." (Roesler et al., 1998, p. 171)

We do, however, think that the observed local LAN in the Roesler et al. study can be interpreted differently. As the object-first word order is not licensed by the German grammar (at least not when full NPs are fronted in a sentence which is presented out of context) the LAN may well be an indication of grammatical violation detected by the parser.

4. Conclusions

In a first step let us consider a summary of the results in Table 3.

-Table 3 -

Firstly, in ambiguous sentences we can observe that there is no difference between wh-movement and scrambling. In both types of structures, a late positivity is elicited when a subject interpretation of an initial argument must be revised during processing of the finite information. In unambiguous sentences, by contrast, the two types of structures elicit different components. Whereas sentences including wh-movement elicit a sustained left frontal negativity that reflects maintenance of the critical (dislocated) argument in working memory, sentences involving scrambled arguments induce a left anterior negativity.

In order to interpret these findings, we must consider how sentences are parsed incrementally. During online parsing, the parser predicts what the next structural position will be on the basis of the current element and the structure built so far (Stabler, 1994). When the next word is encountered, there are two possibilities: this element may fulfill the requirements of the predicted structural position or it may not. If the latter is the case, a local structural violation is induced, thus giving rise to a LAN. The finding of such an effect in sentences allowing a possible grammatical continuation shows that the LAN need not reflect a global ungrammaticality (from a representational point of view), but can also be induced by a local syntactic mismatch. This provides further evidence for the assumption that the LAN is an effect of early syntactic integration (as predicted by Friederici, 1995). From such a perspective, the differences found for the unambiguous structures may be explained.
Consider wh-sentences. The position (Spec,CP), which the wh-element targets, is both predictable and a multi-purpose-position (Gärtner & Steinbach, 2000), into which different elements can be moved. Thus, subjects as well as objects can fulfill the structural requirements of this position and the sustained left frontal negativity on the following positions reflects only the memory load induced by differences with respect to filler-gap-dependencies. This is illustrated in *structure 1*.

- Structure 1 -

By contrast, in scrambled sentences, the parser predicts a special purpose position (Spec,IP) that follows the finite auxiliary. A scrambled object argument, however, cannot fulfill the structural requirements of this position. The consequence is a local syntactic violation that finds its expression in a LAN[3] (see *structure 2*).

- Structure 2 -

In ambiguous sentences, there is no difference with respect to component (P600), but only with respect to the latency of the component. As mentioned above this latency difference reflects the difference between reindexation (wh-movement) and restructuring (scrambling). Whereas the former entails removing the trace from the subject position to which it was initially assigned and placing it in

[3] Such a line of argumentation avoids the problem of assuming that the LAN is linked to storage/or prediction cost, as stipulated by Roesler et al. (1998; see also section 3.3) For theoretical problems with such view see Gibson's SPLT-approach (Gibson, 1998).

the object position, in the latter the reindexation of the initial ambiguous element is combined with a restructuring of the current tree. In this case an additional adjoined position must be posited over the subject position in the middlefield.
An open question, however, is why the ambiguous scrambled sentences do not induce a LAN, while their unambiguous counterparts do. We have argued that the LAN in scrambled constructions reflects a temporary syntactic violation caused by a local syntactic mismatch between a special purpose position and an element that does not fulfill the properties of this position. However, the absence of a LAN in ambiguous constructions shows that the scrambling operation in itself does not render an expression ungrammatical. Rather, it is the point of recognizing that such an operation has applied that is crucial. When the parser encounters a scrambled element clause-medially, the resulting local syntactic mismatch gives rise to a LAN. By contrast, in sentences in which a scrambled word-order may only be recognized upon reaching the last word, there is no longer any reason for such a mismatch to occur, seeing that the parser has all information that is necessary for a restructuring operation available. In this way, we take the P600 in the initially ambiguous scrambled constructions to reflect such processes of restructuring.

In sum we can conclude that wh-movement and scrambling differ with respect to the underlying structural requirements during structure building.

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Table 1
Mean rating values for the six sentence formats (cited from Pechman et al. 1994)

S-IO-DO	S-DO-IO	IO-S-DO	DO-S-IO	IO-DO-S	*DO-V-IO-S
4.71	3.64	2.85	2.26	1.81	1.66

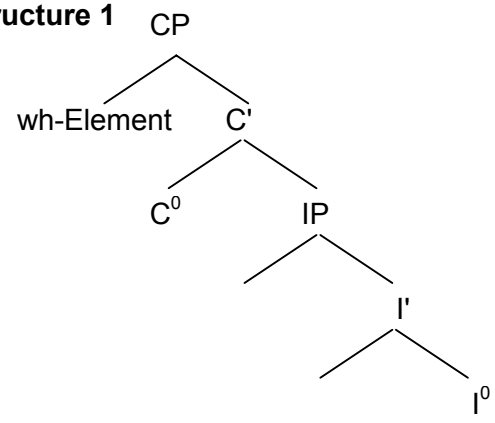
Table 2
Percent correct responses for different types of subject-object-asymmetries (cited from Bader & Meng 1999)

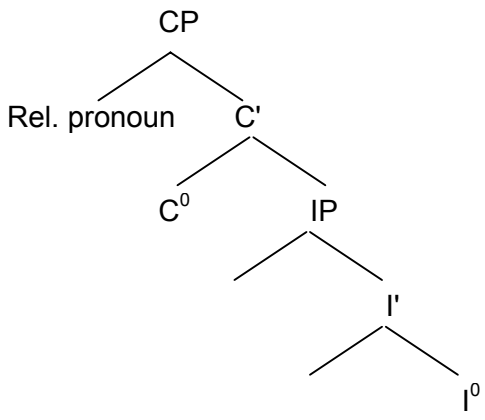
word order / type	relative clause	indirect question	complement (pronoun)	complement (NP)
subject-object	81	78	89	91
object-subject	53	54	55	34

Table 3

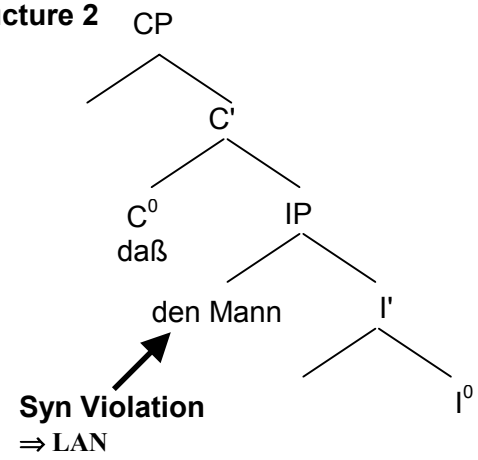
	wh-movement	scrambling
unambiguous (clause-medially)	sustained left frontal negativity	left anterior negativity
ambiguous (sentence final)	late positivity	late positivity

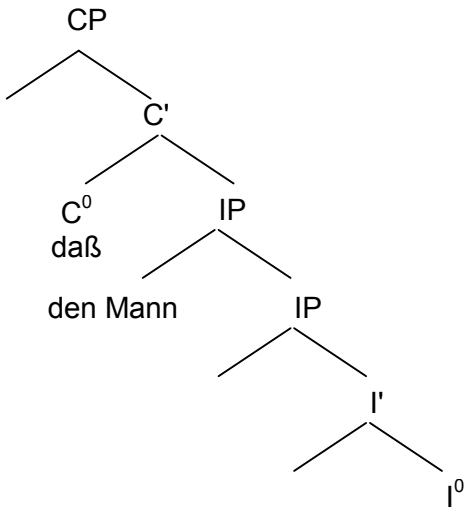
Structure 1





Structure 2





Legends of Figures

Fig. 1:
Grand averages of event-related brain potentials (ERPs) for the critical sentence final word (*gegessen/ eaten*) superimposed for the correct (solid line) and the incorrect (broken line) condition. The figure displays a left frontal electrode (F3). Negativity is plotted up. The arrow indicates the early left anterior negativity, ELAN for the incorrect condition.

Fig. 2:
Grand averages of the ERPs for the critical word to superimposed for the preferred (solid line) and the non-preferred (broken line) condition. The figure displays the central electrode (Cz). Negativity is plotted up. The arrow indicates the early positivity for the non-preferred structure.

Fig. 3:
Grand averages of the ERPs for relative sentences. Superimposed are subject relative (solid line) and object relative (broken line) sentences. The figure displays a left frontal and a right frontal electrode. Negativity is plotted up.

Fig. 4:
Multi-word ERPs to long Wh-questions. Left: One left anterior electrode (F3) ERPs to long object (dotted line) as compared to long subject Wh-questions (solid line). Right: Potential map displaying the difference between long object and subject Wh-questions in the time range from 1,000 to 4,000 ms after the onset of the filler.

Fig. 5:
Multi-word ERPs to short Wh-questions. Left: One left anterior electrode (F3) ERPs to short object (dotted line) as compared to short subject Wh-questions (solid line). Right: Potential map displaying the difference between short object and subject Wh-questions in the time range from 1,000 to 2,100 ms after the onset of the filler.

Fig. 6:
Grand averages for critical sentence final auxiliary superimposed for subject relative (solid line) and object relative (broken line) sentences. The figure displays the central electrode (Cz). Negativity is plotted up. The arrow indicates the early positivity for the object relatives.

Fig. 7:
Grand averages of the ERPs for critical sentence final auxiliary superimposed for subject-first complement (solid line) and object-first complement (broken line) sentences. The figure displays the central electrodes (Cz). Negativity is plotted up. the arrow indicates the late positivity for the object-first complement.

Fig. 8:
Grand averages of the ERPs for determiner (left colum) and noun (right colum) in the different sentence types (for further explanation see text). Superimposed are the critical words for subject-first, indirect object-first and direct object-first conditions (Adapted from Rösler et al., 1998)

Fig. 9:
Difference maps for indirect object-first minus subject-first sentences (left colum), direct object-first minus subject-first (middle colum) and subject-first/ direct object-second minus subject-first/ indirect object-second (right colum). Dark shading indicates negativity.

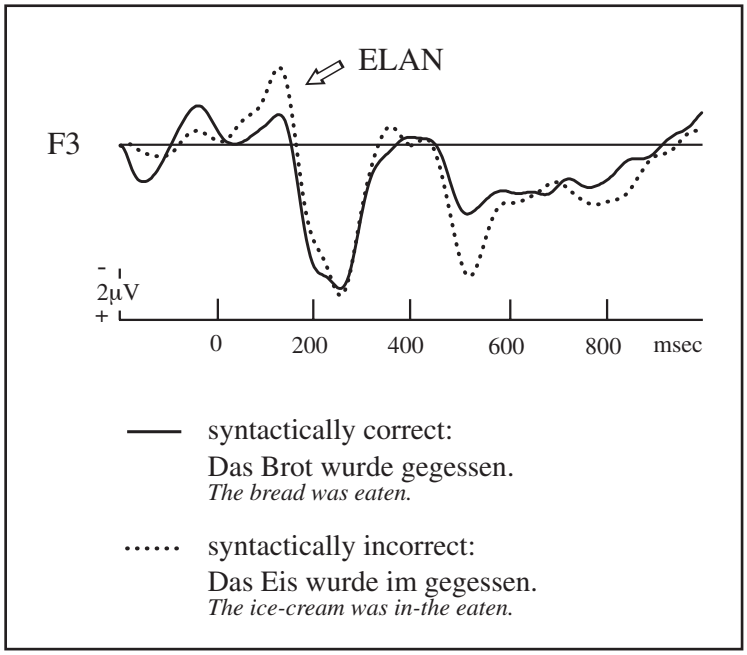

ELAN
F3
-
2μV
+
0
200
400
600
800
msec
syntactically correct:
Das Brot wurde gegessen.
The bread was eaten.
syntactically incorrect:
Das Eis wurde im gegessen.
The ice-cream was in-the eaten.

Figure 1

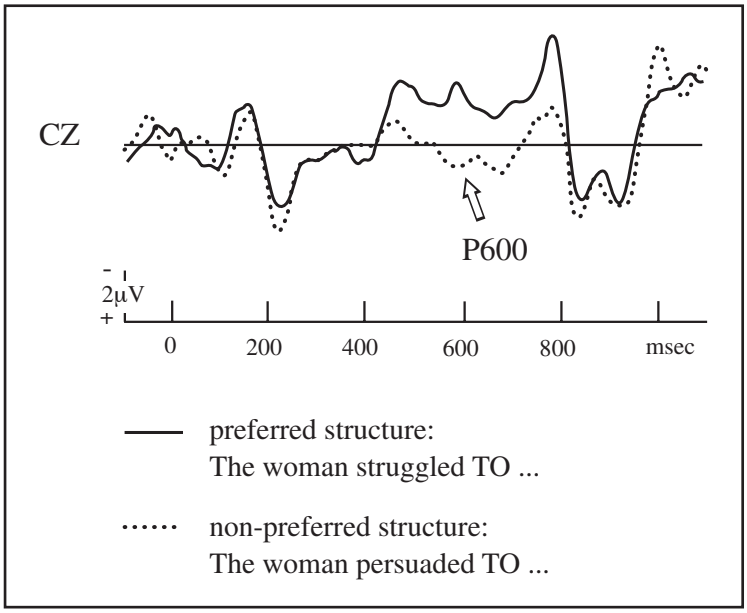

CZ
P600
-
2μV
+
0
200
400
600
800
msec
preferred structure:
The woman struggled TO ...
non-preferred structure:
The woman persuaded TO ...

Figure 2

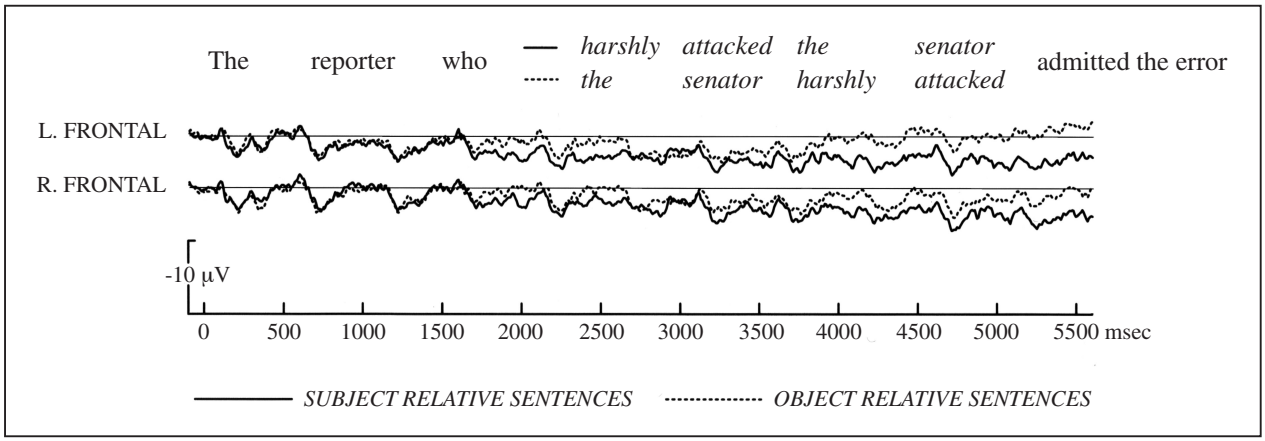

The reporter who harshly attacked the senator admitted the error
the senator harshly attacked
L. FRONTAL
R. FRONTAL
-10 μV
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 msec
SUBJECT RELATIVE SENTENCES
OBJECT RELATIVE SENTENCES

Figure 3

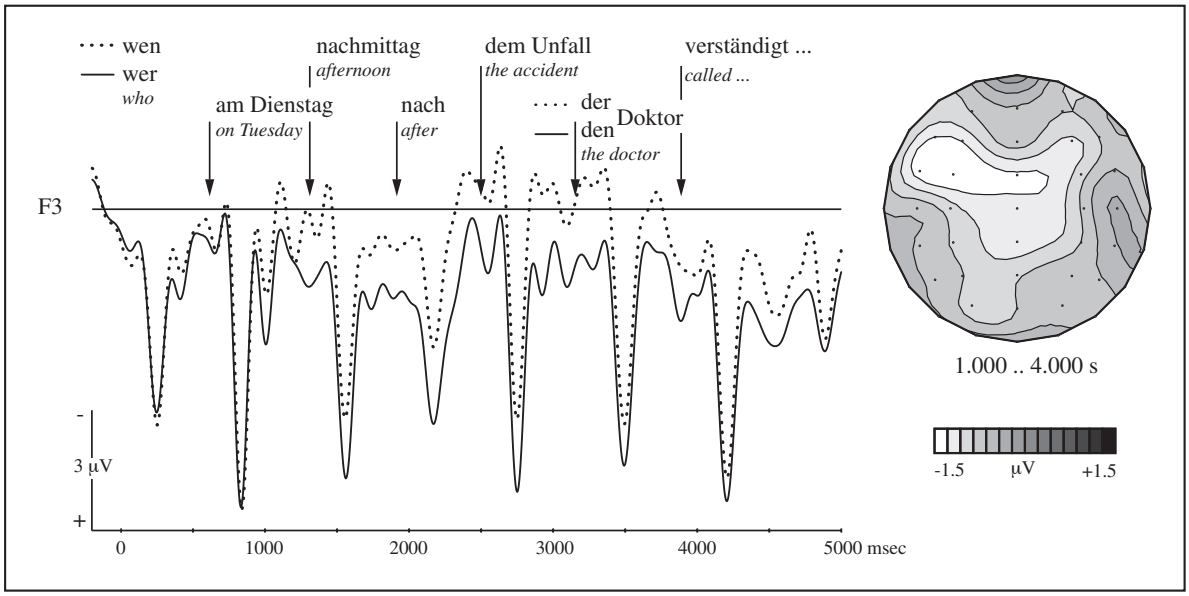

wen
wer
who
nachmittag
afternoon
dem Unfall
the accident
verständigt ...
called ...
am Dienstag
on Tuesday
nach
after
der
den
Doktor
the doctor
F3
3 µV
-
+
0
1000
2000
3000
4000
5000 msec
1.000 .. 4.000 s
-1.5
µV
+1.5

Figure 4

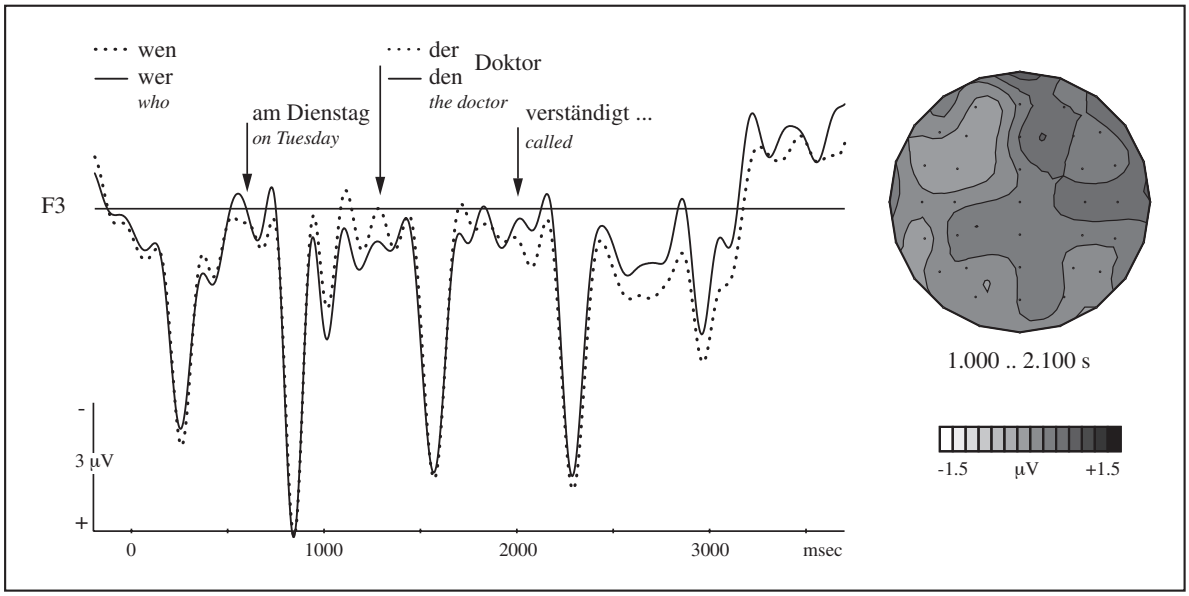

wen
wer
who
der
den
the doctor
Doktor
am Dienstag
on Tuesday
verständigt ...
called
F3
-
3 µV
+
0
1000
2000
3000
msec
1.000 .. 2.100 s
-1.5
µV
+1.5

Figure 5

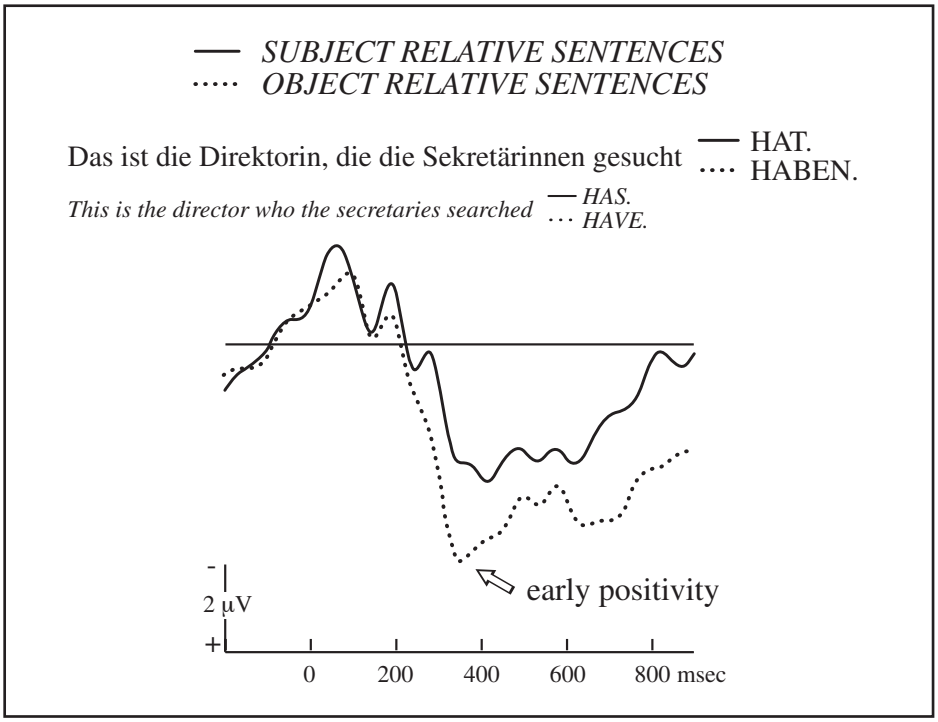

SUBJECT RELATIVE SENTENCES
OBJECT RELATIVE SENTENCES
Das ist die Direktorin, die die Sekretärinnen gesucht
HAT.
HABEN.
This is the director who the secretaries searched
HAS.
HAVE.
early positivity
2 μV
-
+
0
200
400
600
800 msec

Figure 6

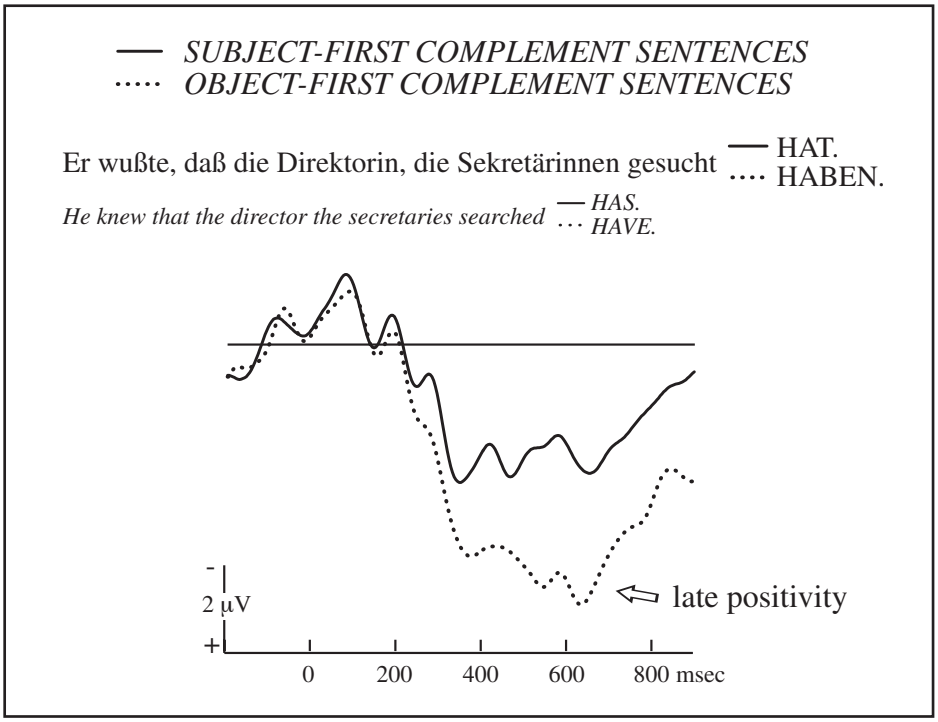

SUBJECT-FIRST COMPLEMENT SENTENCES
OBJECT-FIRST COMPLEMENT SENTENCES
Er wußte, daß die Direktorin, die Sekretärinnen gesucht
HAT.
HABEN.
He knew that the director the secretaries searched
HAS.
HAVE.
late positivity
2 µV
-
+
0
200
400
600
800 msec

Figure 7

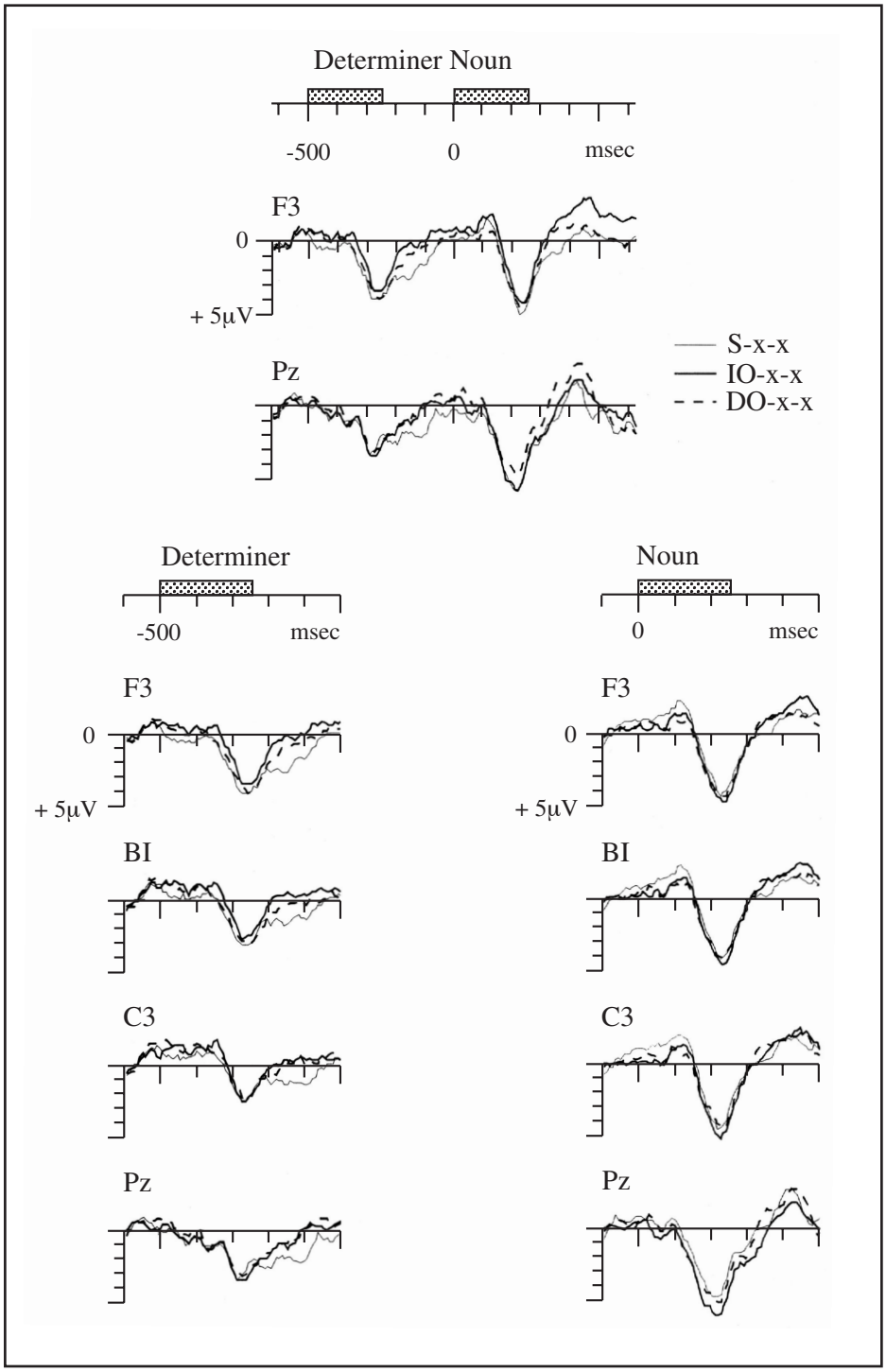
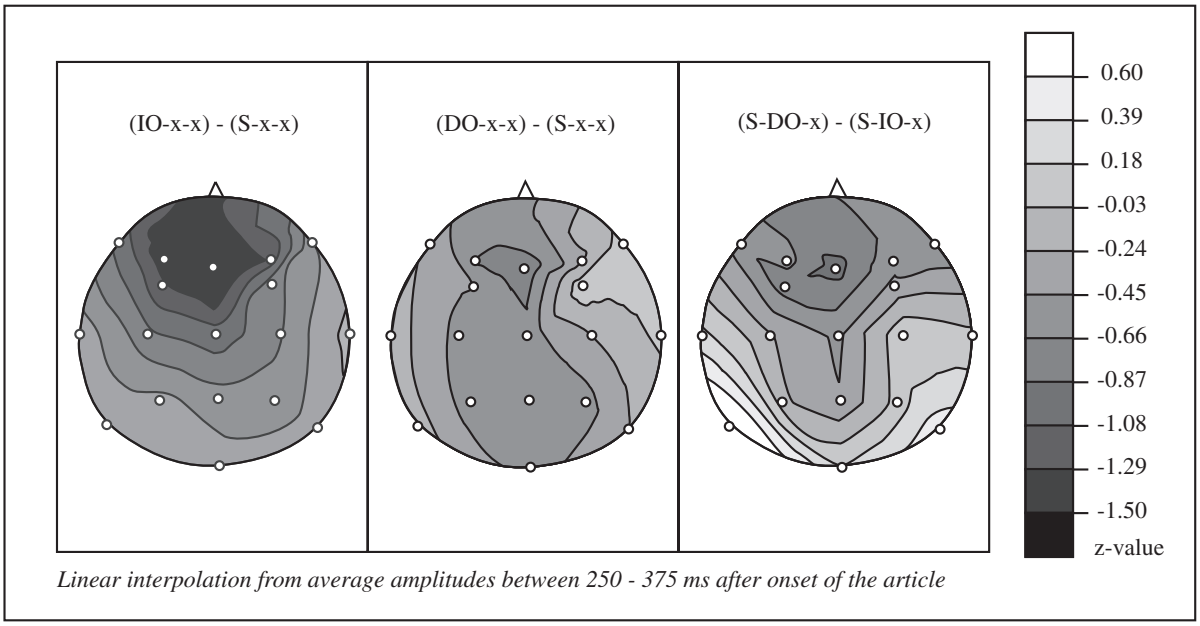

Determiner Noun
-500
0
msec
F3
0
+ 5μV
Pz
S-x-x
IO-x-x
DO-x-x
Determiner
-500
msec
Noun
0
msec
F3
0
+ 5μV
BI
C3
Pz

Figure 8



Linear interpolation from average amplitudes between 250 - 375 ms after onset of the article

Figure 9